

Ag. Ento. 3.1 Fundamentals of Entomology
Credit ours: (2+1=3)

THEORY

Part – I

1. History of Entomology in India.
2. Factors for insect's abundance. Major points related to dominance of Insecta in Animal kingdom.
3. Classification of phylum Arthropoda up to classes. Relationship of class Insecta with other classes of Arthropoda. Harmful and useful insects.

Part – II

4. Morphology: Structure and functions of insect cuticle, moulting and body segmentation.
5. Structure of Head, thorax and abdomen.
6. Structure and modifications of insect antennae
7. Structure and modifications of insect mouth parts
8. Structure and modifications of insect legs, wing venation, modifications and wing coupling apparatus.
9. Metamorphosis and diapause in insects. Types of larvae and pupae.

Part – III

10. Structure of male and female genital organs
11. Structure and functions of digestive system
12. Excretory system
13. Circulatory system
14. Respiratory system
15. Nervous system, secretary (Endocrine) and Major sensory organs
16. Reproductive systems in insects. Types of reproduction in insects.

MID TERM EXAMINATION

Part – IV

17. Systematics: Taxonomy –importance, history and development and binomial nomenclature.
18. Definitions of Biotype, Sub-species, Species, Genus, Family and Order.
Classification of class Insecta up to Orders.

Major characteristics of orders. Basic groups of present day insects with special emphasis to orders and families of Agricultural importance like

19. Orthoptera: Acrididae, Tettigonidae, Gryllidae, Gryllotalpidae;
20. Dictyoptera: Mantidae, Blattidae; Odonata; Neuroptera: Chrysopidae;
21. Isoptera: Termitidae; Thysanoptera: Thripidae;
22. Hemiptera: Pentatomidae, Coreidae, Cimicidae, Pyrrhocoridae, Lygaeidae, Cicadellidae, Delphacidae, Aphididae, Coccidae, Lophophidae, Aleurodidae, Pseudococcidae;
23. Lepidoptera: Pieridae, Papilionidae, Noctuidae, Sphingidae, Pyralidae, Gelechiidae, Arctiidae, Saturnidae, Bombycidae;
24. Coleoptera: Coccinellidae, Chrysomelidae, Cerambycidae, Curculionidae, Bruchidae, Scarabaeidae;
25. Hymenoptera: Tenthredinidae, Apidae. Trichogrammatidae, Ichneumonidae, Braconidae, Chalcididae;
26. Diptera: Cecidomyiidae, Tachinidae, Agromyziidae, Culicidae, Muscidae, Tephritidae.

PRACTICAL

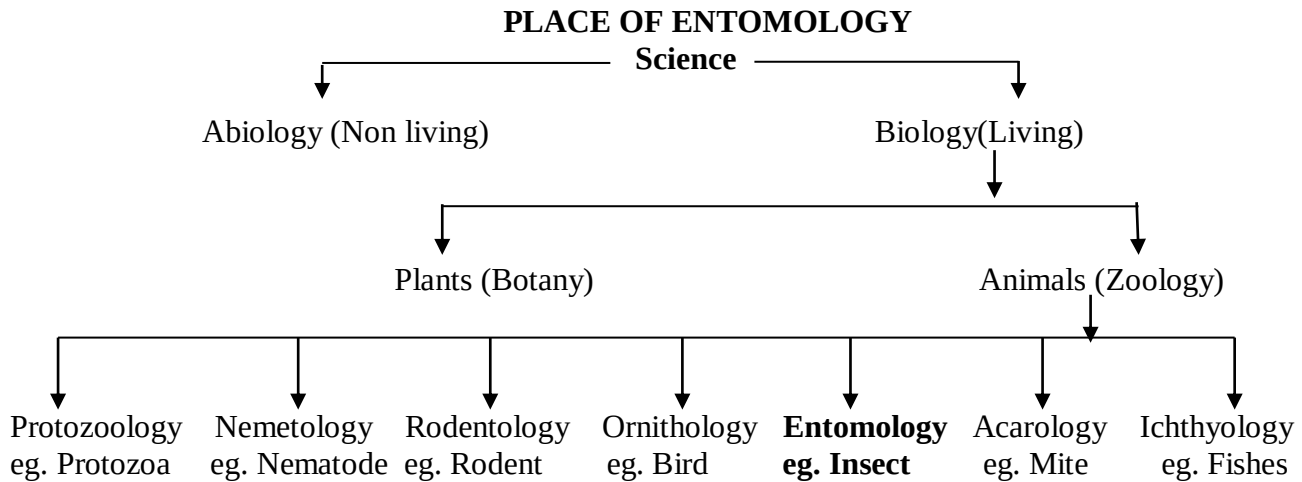
1. Methods of collection and preservation of insects including immature stages;
2. External features of Grasshopper/Blister beetle/Cockroach;
3. Types of insect antennae,
4. mouthparts and legs;
5. Wing venation, types of wings and wing coupling apparatus.
6. Metamorphosis and diapause, types of insect larvae and pupae;
7. Dissection of digestive system in insects (Grasshopper/Cockroach);
8. Dissection of male and female reproductive systems in insects (Grasshopper/Cockroach);
9. Major characteristics of orders. Study of characters of orders Orthoptera, Dictyoptera, Odonata, Isoptera, Thysanoptera, Hemiptera,
10. Lepidoptera, Neuroptera, Coleoptera, Hymenoptera, Diptera and their families of agricultural importance.

Reference Books

1. General and Applied Entomology By: Nayar K.K., Ananthakrishnan T.N. and David B.V.
2. Imm's General Text Book of Entomology By: O.W. Rechar & R.G.Davies
3. Insect Physiology and Anatomy By: Pant, N.C. and Ghai, S.
4. Insects: Structure & Function By: R. F.Chapman
5. Principles of Insect Morphology By: Snodgrass R. E.
6. An Introduction to Study of Insects By: Borer & Delong
7. A Text Book of Entomology By: Mathur & Upadhyay
8. The Insects: An Outline of Entomology By: P. J. Gullan and P. S. Cranston
9. A Manual of Practical Entomology By: M. M. Trigunayat
10. An Outline of Entomology By: G. S. Dhaliwal
11. Entomology and Pest Management By: Larry P. Pedigo
12. Modern Entomology By: D. B. Tembhare
13. Agricultural entomology and pest control By S. Pradhan
14. Introduction to General and Applied Entomology By: V. B. Awasthi
15. Principles of Entomology: Basic and Applied By: N. Kachhawaha
16. Insecta- An Introduction By: K. N. Ragumoorthi, V. Balasubramani,
M. R Srinivasan and N. Natrajan

LECTURE 1

History of Entomology in India



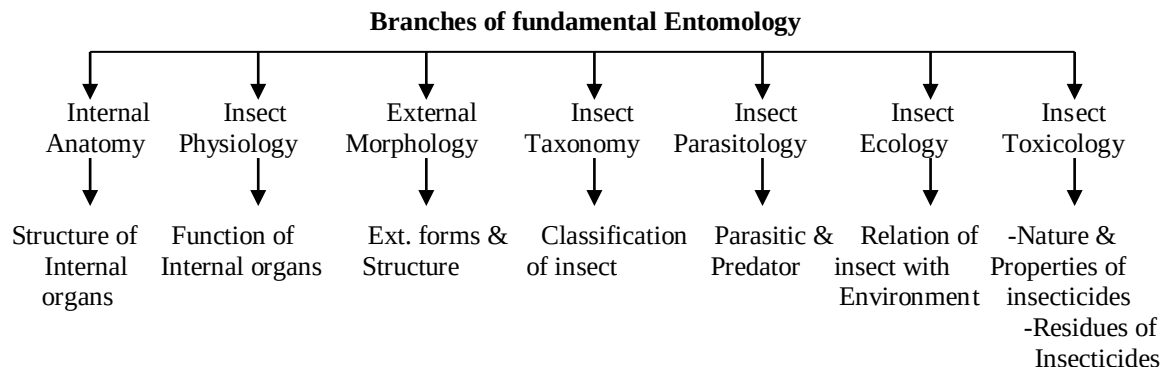
What is Entomology?

The word '**Entomology**' has been derived from the two Greek words,

Entomon = Insects and **Logos** = Science

- It is a branch of zoology & deals with various aspects of insects.
- It is simply defined as **the science deals with the study of insects.**

Entomologist: The people who study, observe, collect, rear and experiment with insects.



Branches of Applied Entomology

Applied Entomology has its aim the manipulation of insects (both harmful and beneficial) to man's advantage.

- Study of insects related to agriculture (eg. field crops) is known as **Agricultural Entomology.**
- Study of insects related to horticulture (eg. fruits and vegetable crops) is known as **Horticultural Entomology.**
- Study of insects related to forest (eg. forest trees) is known as **Forest Entomology.**
- Study of insects related to live stock and veterinary animals (eg. mosquitoes, house fly, lice etc.) is known as **Veterinary Entomology**

- Study of insects in relation to Human beings is known as **Medical Entomology** (eg. mosquitoes, house fly, head lice, flea etc.)
- Study and use of insects in crime investigations is known as **Forensic Entomology** (eg. dipteran fly).

HISTORY OF ENTOMOLOGY

In ancient scripts like Ramayana and Mahabharata, some of the terms used were related to insects appeared in the ancient Sanskrit writings. They are -

▪ Pipilika – Ant	▪ Pathanga – Grasshopper
▪ Madhumakshika – Honey Bees	▪ Umbakapalika - Termite queen
▪ Bharamara – Wasp	▪ Laksha - Lac Insect
▪ Makshika - Fly	

The references to insects were found in Sanskrit dictionary, '**Amarakosa**' and in books like **Arthashastra**, **Chanakya sutra**, **Sakuntala** etc.

- 3870 BC: Indian king sent silken stuff to a Persian ruler.
- 0-100 AD : The first detailed classification of insects was done by Umaswati.
- 100-200 AD : Classification of ants, flies and mosquitoes by the surgeon *Sushruta*.
- 1200-1000 BC : Classification of bees by the Indian physician *Charaka*.
- 384-322 BC: **Aristotle** made investigations about flies, honey bees and ants, and also known as **Father of Biological Classification**
- **1758**: The beginning of the modern Indian entomology with the publication of **10th** edition of '**Systema Naturae**' by '**Carolus Linnaeus**' where only 12 Indian insects were included and it forms the first record.
- 1745- 1808: "**J. C. Fabricius**" made an extensive study of Indian insects for the first time and classified insects into 13 orders based on the type of mouth parts.
- 1767-1779: "**J. G. Koenig**", a medical officer from Denmark, initiated the first regular scientific work on Indian insects and supplied the insect specimens to systematists like **Linnaeus**, **Fabricius**, **Cramer** and **Dury**. Fabricius, made Koenig's name remembered forever by naming the well known and destructive red cotton bug of this country as *Dysdercus koenigi*.
- 1782: "**Dr. Kerr**" published an account of Lac insects
- 1791: **Dr. J. Anderson** – Physical General to East India Company published about **cochineal scale insect**.
- **1800** : **Edward Denovan** published an illustrated book entitled "An epitome of the natural history of insects of India and the Islands in the Indian seas" which was the

first pictorial documentation on the insects of Asia and was revised in 1842 by West Wood.

- **1875:** Establishment of Indian Museum in Calcutta.
- **1893: “Dr. Rothney”** published the book ‘Indian ants’ (Earliest record of biological pest control in India i.e. white ants attack on stationery items kept free by red ants.)
- **1897 :** On August 20, 1897, Sir Ronald Ross discovered the link between malaria transmission and mosquitoes. Ross was awarded the Nobel Prize for medicine in 1902, the second person to receive it. Sir Ronald Ross was a British physician born in Almora, India. He had the breakthrough discovery during the dissection of a specific species of mosquito, the Anopheles, previously fed on a malaria patient. Malaria parasite was found on the mosquito and on its salivary glands.
- **1901: Lionel de Niceville** was appointed as **first entomologist to Govt. of India.**
- **1901: E. P. Stebbing**, the first Imperial Forest Entomologist initiated work in Forest Entomology
- **1903: Maxwell Lefroy** succeeded as the **second entomologist to Govt of India.**
- **1905:** Imperial Agricultural Research Institute (IARI) established at **Pusa** (Bihar) **Maxwell Lefroy** was made the first Imperial Entomologist.
- **1906** publication of '**Indian Insect Pests**' by **Maxwell Lefroy**
- **1906 :** Imperial Forest Research Institute (IARI) established at **Dehradun. E. P. Stebbing** was appointed as the first imperial forest entomologist
- **1909** publication of '**Indian Insect Life**' by **Maxwell Lefroy**
- **1910:** The Central Bureau of Malaria was established and research work on mosquitoes and malaria were carried out.
- **1911 :** Agricultural Research Institute renamed as Imperial Agricultural Research Institute. Later on Imperial Agricultural Research Institute was shifted to New Delhi in 1936. In 1947, Imperial Agricultural Research Institute was renamed as Indian Agricultural Research Institute.
- **1912:** Plant Quarantine Act was enforced
- **1912: T. B. Fletcher**, appointed as the **first Government Entomologist** of Madras
- **1914: E. P. Stebbing**, the first imperial forest entomologist published "Indian Forest Insects of Economic Importance : coleoptera"
- **1914:** Destructive Insect Pests Act was enforced
- **1916 :** Zoological Survey of India (**ZSI**) was established at **Kolkata.**
- **1925:** Indian Lac Research Institute started at Ranchi
- **1934: Hemsingh Pruthi** succeeded Fletcher as Imperial Entomologist.

- **1936:** IARI shifted from PUSA, Bihar to New Delhi.
- **1937:** Entomology division was started in IARI, New Delhi
- **1937:** A laboratory for storage pests was started at Hapur, U.P.
- **1938:** Entomological Society of India was established with **Mian Afzal Hussain** as the founder president.
- **1939:** Establishment of **Locust Warning Organization** after the locust plague during 1926-32.
- **1939:** First issue of "**Indian Journal of Entomology**" was published. Hemsingh Pruthi an Indian Scientist as Chief Editor of the first official publication of the Entomological Society of India, Calcutta, the '**Indian Journal of Entomology**'.
- **1944:** The first time master degree in Agriculture in Entomology was started and first batch from the Agriculture College, Kanpur Dr. N. C. Pant, Head of Division of Entomology, IARI.
- **1945:** The first beekeeping center was established at **Nagrota**
- **1953 :** National malaria eradication programme was launched
- **1962:** Successful introduction of *A. mellifera*, honeybee species **at Nagrota, India** was made by **Dr A.S. Atwal**.

Establishment of Entomological Institutes

Sr.	Year	Institute	Location
1	1905	Establishment of "Agricultural Research Institute" by Lord Curzon. The land was donated by Mr. Phiffs of USA after whom the place was named as Pusa	Pusa, Bihar
2	1906	Forest Research Institute	Dehradun
3	1916	Establishment of Zoological Survey of India	Kolkata
4	1925	Establishment of Indian Lac Research Institute	Numkam, Ranchi
5	1929	Imperial (now Indian) Council of Agricultural Research	New Delhi
6	1937	Establishment of Entomology Division at IARI after shifting of IARI in 1936	New Delhi
7	1939	Establishment of Locust Warning and Control Organization under ICAR. Dr. Hem Singh Pruthi was the in charge of this organization.	Jodhpur
8	1943	Central Sericulture Research and Training Institute	Berhampore (W.B)
9	1946	Directorate of Plant Protection Quarantine and Storage (DPPQS)	Faridabad, UP
10	1946	National Institute Of Plant Health Management (formerly known as Central Plant Protection Training	Hyderabad

		Institute, later National Plant Protection Training Institute	
11	1947	Imperial Agricultural Research Institute, renamed as Indian Agricultural Research Institute	New Delhi
12	1948	Constituted Central Silk Board	Bangalore
13	1957	Establishment of Commonwealth Institute of Biological Control (CIBC)	Bangalore
14	1958	Post Graduate School of the IARI was established at IARI, Pusa Institute	New Delhi
15	1962	Central Bee Research and Training Institute	Pune
16	1966	National Plant Protection Training Institute (NPPTI)	Hyderabad
17	1968	Central Insecticides Board & Registration Committee	Faridabad
18	1988	National Centre for Integrated Pest Management (NCIPM) of Indian Council of Agricultural Research (ICAR), India	New Delhi
19	1993	Formerly CIBC was renamed as Project Directorate of Biological Control (PDBC)	Bangalore
20	1996	Indian Grain Storage Management and Research Institute (IGMRI). Formerly, Grain Storage Research and Training Centre (GSRTI) was established in 1958.	Hapur
21	2000	National Bee Board	New Delhi
22	2007	The name changed as Indian Institute of Natural Resins and Gums(IINRG) on 20 Sept., 2007 formerly known as Indian Lac Research Institute.	Numkam, Ranchi
23	2008	National Institute of Plant Health Management (NIPHM) (formerly NPPTI) established with a mandate for Human Resource Development in Plant Protection by way of generating Master Trainers/Subject Matter Specialists in the field of Plant Protection for various States/Union territories.	Rajendranagar, Hyderabad
24	2014	Formerly NBAII, 2009 (National Bureau of Agricultural Important Insects) upgraded to NBAIR – National Bureau of Agricultural Insect Resources (initially known as Project Directorate on Biological Control, 1993)	Bangalore

LECTURE 2

Factors for Insect's Dominance

Major Points Related to Dominance of Insecta in Animal Kingdom

Reasons of Insect Dominance

Insects occupy around 70 per cent of all known species of animal kingdom. The most diverse order of insects is **Coleoptera** followed by **Lepidoptera**, **Hymenoptera** and **Diptera**. The structural, developmental and protective characters acquired by insects made them dominant in the animal kingdom.

Factors responsible for dominance of insects

I. Structural perfections

1. Exoskeleton: Insect body is covered with an outer cuticle called exoskeleton which is made up of a cuticular protein called **Chitin**. This is light in weight and gives **strength**, **rigidity** and **flexibility** to the insect body. It is responsible for protection from -

- Desiccation or water loss from the body
- Physical or mechanical injuries and to maintain shape and size of the body
- The attack of other micro-organisms
- Various environmental conditions.
- Giving strength to the body appendages which may be useful for digging, preying and oviposition.
- It provides area for muscle attachment.
- Exoskeleton turned into good tools for digging, preying & oviposition etc.
- Maintain the shape of body.

2. Small size: Majority of insects are small conferring various advantages like...

- Require little food, less space (for shelter), and energy for their survival.
- It can easily escape from their natural enemies.
- Small quantity of food can sustain large number of small individuals.
- Increase migration efficiency
- Escape from adverse effect of weather & biotic environments.
- Muscular strength is better in smaller animals. e.g. Flea length 1/20" but can jump horizontally (long) 13" & vertically (height) 8"

3. Hexapod locomotion: Insects use three legs at a time during locomotion, while the remaining three legs are static, which gives greater stability. If a pair of legs is lost, the insect will take locomotion.

4. Functional wings

- Two pairs of wings helpful for taking flight from one place to another -
 - in search of food and shelter
 - to find a mate
 - to oviposit

- to get protection from their natural enemies.
- Functional wings increase chances of - feeding and breeding range, avoiding bad climate/weather.
- If in a particular locality, their food plant is not available or fully eaten up they may fly to other places to look for their host plants.
- The power of flight greatly increased chances of survival and dispersal.

Capacity for flight The Desert Locust (*Schistocerca gregaria*) flies at an average air speed of 33 km/h. The migratory locust (*Locusta migratoria*) ranges from Europe to China, and even small swarms may cover several square miles, flying at night with the wind, may cover about 500 km without rest.

5. **Compound eyes:** Most of the adult insects and nymphs consist of compound eyes as visual organs which possess number of hexagonal units known as **ommatidia**. Because of presence of number of ommatidia (facets) in the compound eyes, even if some or few ommatidia get damaged, the insect does not lose the power of vision because each ommatidia acting as an eye.
 - Ants possess → 50 – 400 facets
 - House fly → 4000 facets
 - Butterfly → 17000 facets
 - Dragonfly → 50000 facets
6. **Quicker speciation:** Changes that occur during the process of evolution through variation in their habitat or habits will be maintained or continued to several generations resulting in the development of more species from a genus.
7. **Scattered sense organs:** The sense organs viz., visual organs, gustatory organs, organs of touch etc. are distributed on different parts of the body such as antennae, eyes, mouth parts in the head, legs with claws on thorax, tympanum, cerci in the abdomen etc. This scatteredness on all parts of the body prevents the chance of all being damaged.
8. **Decentralized nervous system:** The nervous system is so decentralized that insects can be artificially stimulated to walk, fly, feed, mate or oviposit even if some parts of the body are removed or damaged.
9. **Direct tracheal respiration:** Insects respire by means of thin elastic air tubes known as trachea which open outside, on the body surface through spiracles. Presence of this trachea ensures direct transfer of adequate oxygen to actively breathing tissues of the insect and makes it to be an efficient terrestrial or aerial arthropod.
10. **Enteronephric excretion or Presence of Malpighian tubules:** In insects, excretion is mainly by means of Malpighian tubules which open in between midgut and hindgut. This arrangement is well suited for water conservation as well as for the absorption of unwanted waste metabolites at a quicker rate.

II. Developmental characters

1. **Higher reproductive potential:** - helps to increase the population at faster rate.
eg. Egg laying capacity (fecundity) of termite queen is 6000 - 7000 eggs per day for 15 long years.
2. **Controlled reproduction:** Though insects possess high fecundity, there is also high degree of control over reproduction by reducing the number of females that can lay eggs.
eg. Honey bees and termites.
3. **Method of reproduction:** Insects can reproduce both sexually as well as parthenogenetically.
4. **Short life cycle:** Most of insects have very short life cycle i.e. 2 to 4 weeks which help insects to complete more number of generations in a definite period of time.
5. **Specificity of food and polyphagous feeding habits:** The diversity in food habits among different species of insects reduces food competition among them. Less competition for food increases their chances of survival and further multiplication. Even food for immature and adult is also differing.
6. **Zenith of evolution:** During the process of evolution, insects have shown a high degree of specialization to the extent that there is division of labour, polymorphism etc. that make them to be efficient in their struggle for existence.

III. Protective adaptations and devices

For protecting themselves from adverse environmental conditions or natural enemies, insects have developed or attained some adaptations as given below.

1. **Morphological adaptations:** The body colour and shape of some insects make them look like part of the plant, thereby protecting themselves from natural enemies eg. **Stick insects** and **leaf insects**
2. **Physiological adaptations:** Some insects produce or release poisonous or unpleasant odors from their body or possess warning colouration by imitating certain distasteful insects. eg. **Stink bugs** produce foul smelling substance. Some **blister beetles** (Meloidae) produce **cantharidin**, a strong irritant and blistering agent.
3. **Behavioural adaptations:** It is a defense strategy adopted by some insects through feigning death or imitating the voice of dangerous insects or mimicry.
eg. Larvae of mustard sawflies when disturbed draw their legs beneath and drop to the ground and act as if dead. Alarm pheromone, Aggregation pheromone
4. **Construction of protective structures:** Some insects construct shelter with the available plant material for protecting themselves from adverse conditions, natural enemies and to store food material for use during the period of scarcity.
eg. Cases / Bags in case of **case worms/bag worms**, Termatoria in case of **termites**, Honey comb in case of **honey bees**.
5. **Presence of complete metamorphosis**
 - More than 82 per cent of insects undergo complete metamorphosis (holometabolous insects) with four stages.
 - Food sources for the larval and adult stage are different so competition for food is less.
 - Ecological niches for egg, larva, pupa and adult is varying that may save them.

6. More number of species

- Live in varying habitat (terrestrial, aquatic, amphibian).
- Different species / stages can live on various foods.
- Greater chances of survival under abnormal weather.
- Can survive in varying climate.
- Long geological history

7. Large number of individuals in a single species: e.g. Locust swarm comprising of 10^9 numbers of individual, occupying large area. The largest known swarm covered $1,036 \text{ km}^2$, comprising approximately 40 billion insects.

8. Resistance to desiccation: Insects minimize the water loss from their body surface through prevention of water loss (wax layer of epicuticle, closable spiracles, egg shell), conservation of water (capable of utilizing metabolic water, use less quantity of water to remove the nitrogenous waste), resorption of water from fecal matter.

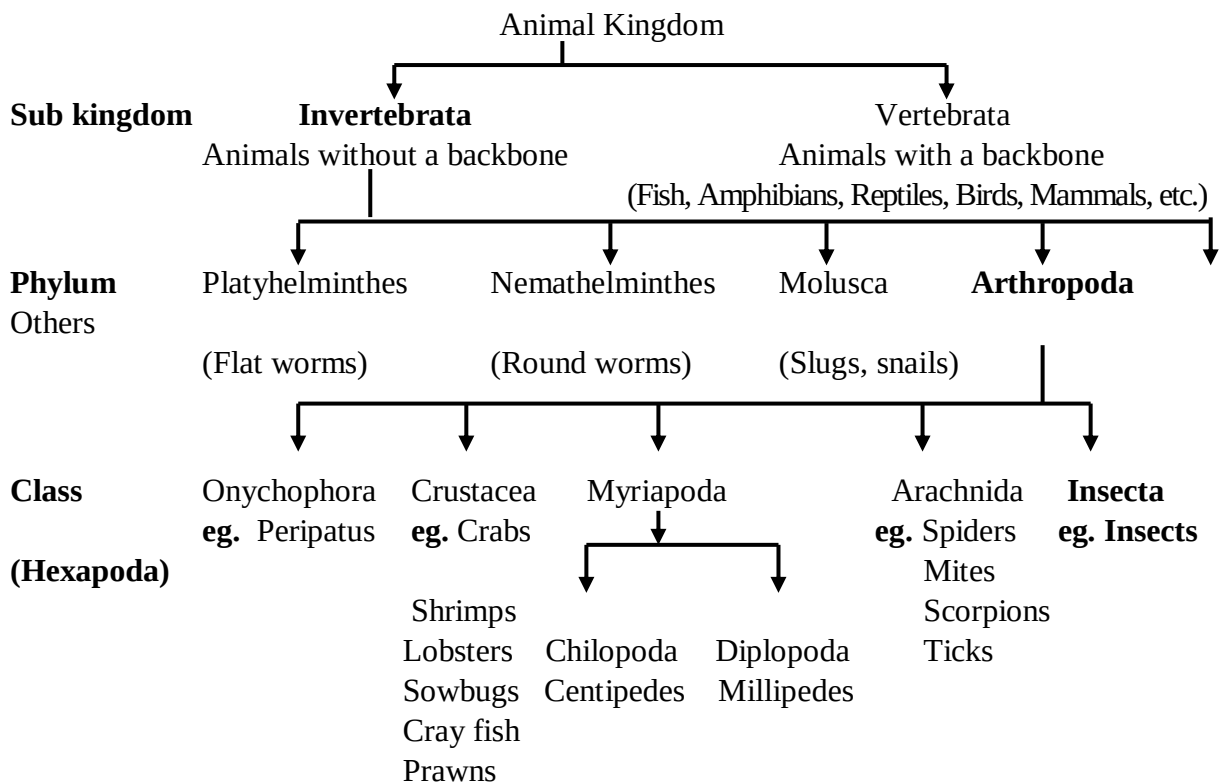
LECTURE 3

Classification of phylum Arthropoda up to classes
Relationship of class Insecta with other classes of Arthropoda
Harmful and useful insects

Characteristics of Arthropoda

The word '**arthropoda**' is of Greek origin (**Arthros = joint; podas = foot**). Thus arthropods are joint footed animals - a character common to all members of the phylum.

- i. Bilateral symmetry
- ii. Jointed appendages
- iii. Well developed exoskeleton
- iv. Presence of tagma (segmented body region)
- v. Presence of haemocoel (haema = blood; coelom = cavity)
- vi. Presence of dorsal heart and ventral nerve cord
- vii. Presence of striated muscles
- viii. Tracheal system for respiration
- ix. Arthropoda moults at regular intervals

The relationship between insects and other major groups in the animal kingdom

RELATIONSHIP OF CLASS INSECTA WITH OTHER CLASSES OF ARTHROPODA

I **Class: Onychophora** (Greek *Onychos* for "claws" and *Phoros* for "bearer")

eg. Peripatus

1. Soft integument contains chitin
2. Bilaterally symmetrical and vermiform.
3. Body possesses 14 to 43 pairs of unjointed legs.
4. Body cavity a true coelom.
5. Most possesses a through straight gut with an anus.
6. Possesses serial sac-like excretory organs (Nephridia) like annelida.
7. Terminal claws to the appendages like arthropoda.
8. Nervous system includes a brain and a pair of ventral nerve chords.
9. Possesses a simple respiratory system in the form of tracheae and spiracles.
10. Possesses open circulatory system with a heart and haemocoelic body cavity.
11. Reproduction normally sexual and gonochoristic.
12. All are terrestrial.

II **Class: Crustacea**

eg. Crabs, Lobster, Cyclops, Shrimps

1. Possess at least five pair of jointed legs.
2. Possess two pairs of antennae.
3. Body divided into cephalothorax (fused head and thorax) and abdomen.
4. Their body composed of distinct segments covered by a chitinous exoskeleton.
5. Majority or nearly all are aquatic.
6. Respiration through gills in majority members, in some small forms they breathe through the body wall.
7. Development through metamorphosis.
8. Possesses open circulatory system.
9. Compound eyes present.
10. The sexes are separate and the genital openings are generally in pairs.

III **Class: Myriapoda**

1. One pair of antenna
2. Body divided into (head and trunk = tubular)
3. Each segment of trunk with either 1 pair (centipede) or 2 pairs of legs (Millipedes).

i. Chilopoda eg. Centipedes

1. They are flattened worm like creatures.
2. The body segments are distinctively jointed.
3. They have a distinct head bearing two antennae.
4. They have one pair of legs on each segment of the body.
5. The first pair, just behind head, has poison glands whose secretion has the property of paralyzing the prey on which it feeds.
6. Some may give painful bite to human being.
7. They feed on insects and other small animals.

ii. Diplopoda eg. Millipedes

1. They are elongated worm like creatures with cylindrical body.
2. The segments are internally fused in twos.
3. They have two pairs of leg on each segment (leaving first three on which one pair of leg) of the body.
4. They have no poison glands.
5. They feed on organic matter.

IV Class: Arachnida eg. Spiders, Mites, Ticks, Scorpions etc.

1. Body divided into cephalothorax and abdomen.
2. Possess four pair of legs.
3. Respiration through air tubes, lung books or trachea.
4. They do not have antennae but possess chelicerae instead of antennae.
5. They do not have compound eyes but have simple eyes.
6. Some of the species have poison glands and a sting, with which they inject poison and cause severe pain.
7. They are terrestrial animals.

V Class: Hexapoda (Insecta)

1. Possesses three pairs of legs.
2. Body divided into head, thorax and abdomen.
3. One pair of sensory antenna.
4. Two pairs of wings on thorax.
5. One pair of compound eyes.
6. Post-embryonic development through metamorphosis.
7. Circulatory system open.
8. Respiration through spiracles and tracheae.
9. Excretion through Malpighian tubules.
10. Decentralized Nervous system.

HARMFUL AND USEFUL INSECTS

Relationship of Insects with mankind

- Enemy → Grass hopper, Fruit flies etc.
- Productive → Honeybees, lac insect, Silkworm.
- Helpful in pollination → Bees, Wasps, Butterflies etc.
- Beneficial → Parasites & Predators.

I How insects are harmful (Enemy)?

Insects as destroyer of crop

A) Field crops

1. Biting & chewing plant parts → Grass hopper, Locusts, Beetles & Caterpillar
2. Piercing Sucking cell sap → Aphid, Jassids, Whitefly, Scales, Mealy bugs etc.
3. Boring stem → Sugarcane borers, Paddy borers
4. Spreading harmful insects (mutualism) → Red ants spread the aphids, mealy bugs & scales
5. Transmit pathogens → Whitefly – YMV of okra and leaf curl
6. Producing toxic substances → BPH
7. Egg laying (Oviposition) injury → Mango hopper
8. Rolling/folding the leaves and scraping epidermis → Leaf roller, Leaf Webber, Rice hispa
9. Making cases out of plant parts → Rice caseworms, Rose bagworm
10. Making galls → gall midges
11. Contamination /spoilage → mango mealy bugs and scale, fruit flies, cardamom thrips etc.
12. Damaging stored grains → pulse beetles, grain weevil, flour beetle, lesser grain borer, rice moth, Angoumois grain moth etc.

(B) Injury & nuisance to human being and its pet animals

(a) Nuisance

- Hiding in houses and make noise → Cricket
- Mixing excreta in food → Cockroach
- Disturb sleep → Cricket, Mosquito
- Biting & walking on body → Fleas & Bed bug
- Irritation → Fleas & Bed bugs
- Biting & sucking blood → Mosquito
- Cause mycosis (enter in Eyes, Nose, Ear) → House fly

(b) Insect poisoning

- Stinging → Honey bees, Wasps
- Nettling Hairs (swelling, irritation, reaction, low BP) → Caterpillar of Saddle back moth
- Acidic excretion (Cantharidin) → Blister beetle

(c) Spread & Transmit plant diseases

- Leaf curl virus disease: by whitefly, aphid, leaf hopper, thrips etc.
- Mycoplasma like organisms (Little leaf of brinjal) → Jassids

(d) Spread & Transmit human & animal diseases

- Spread diseases causing agents like bacteria, fungi & virus.
 - Body louse → Skin diseases, Typhoid
 - Flea → plague
 - Mosquito → Malaria (*Anopheles*), Filariasis (*Culex*) caused by *Plasmodium*

- House fly → Cholera, dysentery,
- Tse-tse fly → Sleeping sickness caused by *Trypanosomias*
- Sand fly → Kala-azar in man caused by *Leishmania*; Anthrax in sheep and goat

(e) Damaging stored products

- Clothes → carpet beetle, cloth moth
- Household things & wooden furniture and → Termite, carpenter ant etc.
- Books → book lice, silverfish
- Cigarette → cigarette beetle

(f) Pests of farm and wild animals eg. Sand fly, horse fly, stable fly, horn fly, bot fly, warble fly, sucking lice, biting lice, fleas etc.

(g) Injecting toxin in plants → hopper burn due to brown plant hopper in paddy

(h) Excretion /secretion of honey dew → Aphids, mango hopper, mealy bugs and scales.

(i) Making harvest /processing difficult → Dusky cotton bugs, red cotton bug, aphids etc.

II. How insects are our friends?

(A) Productive insects

- Silkworm → Silk & Non edible fat
- Bees → Honey, Wax, Propolis, Royal jelly, Bee venom
- Lac insects → Shellac
- Cochineal insects → Natural colour dye /pigments

(B) Contain useful substances

- Cactus scale → Cochineal & Crimson dyes (For Printing & ink)
- Dobson fly → Fish food
- European blister beetle → Cantheridin (Used in medicine)
- Dipteran maggots → Allantoin, a substance used in wound healing.
- Gall insects → Tannic acid

(C) Produce useful galls on plants

- Some galls → Tannic acid → Processing hides & fur
- Some galls → To make quality ink & colour

(D) Helps in pollination in fruit & vegetable crops

Honey bees, Stingless bees, Bumble bees, Wasps, Butterfly etc.

eg. Sweet fig → Cross pollination – 100% depend on fig wasps

(E) Useful as a food of pet animals

- Fish → Feed on aquatic insects
- Game & song birds → Feed on insects
- Poultry birds & ducks → Feed on insects
- Primitive man → Feed on insects like Crickets, Locusts, Honey bees, Termite queen, Grub of beetles etc.

(F) Natural enemies

- i) Parasites:** *Trichogramma spp.* – Borers
Bracon spp. – Sugarcane borers
Epiricania – Sugarcane pyrilla
Cotesia – Plutella & Spodoptera
Diaeretiella rapae – Mustard aphid

ii) Predators: (Catch & devour the insects)

- Lady bird beetle
- *Chrysoperla*
- Ant lion, Dragonfly
- Mantid, Predatory bug (*Geocoris*)
- Wasps, Tiger beetle, Giant water bug

(G) Pests on weeds

- Useful to farmers → biocontrol of weeds

Dactylopius tomentosus (Scale insects) → on prickly pear (Cactus)

Neochetina eichhorniae (Weevil) → Water hyacinth

Zygogramma bicolorata (beetle) → Congress grass (*Parthanium* spp.)

(H) As scavengers → Dung roller, Carrion beetle, Dipteran flies, Termites etc.

(I) Improving fertility and physical condition of soil → by burrowing and aerating, producing humus and degradation of their own dead bodies; and as food for men (locust, grass hopper, termites, grubs of beetle and weevils) and animals (fishes and birds).

(J) Scientific studies in forensic investigation → Blow flies, flesh flies etc.

(K) Useful in pollution study → Aquatic insects such as mayflies

(L) Recreation agents

- Song of some insects → Pleasant eg. Soil cricket, Tree crickets, Cicadas
- Beautiful butterflies → inspiration to artists

STRUCTURE AND FUNCTIONS OF INSECT CUTICLE, MOULTING

Insect body wall is called as Integument or Exoskeleton. It is the external covering of the body which is ectodermal in origin. It is rigid, flexible, lighter, stronger and variously modified in different body parts to suit different modes of life.

Functions of Body wall

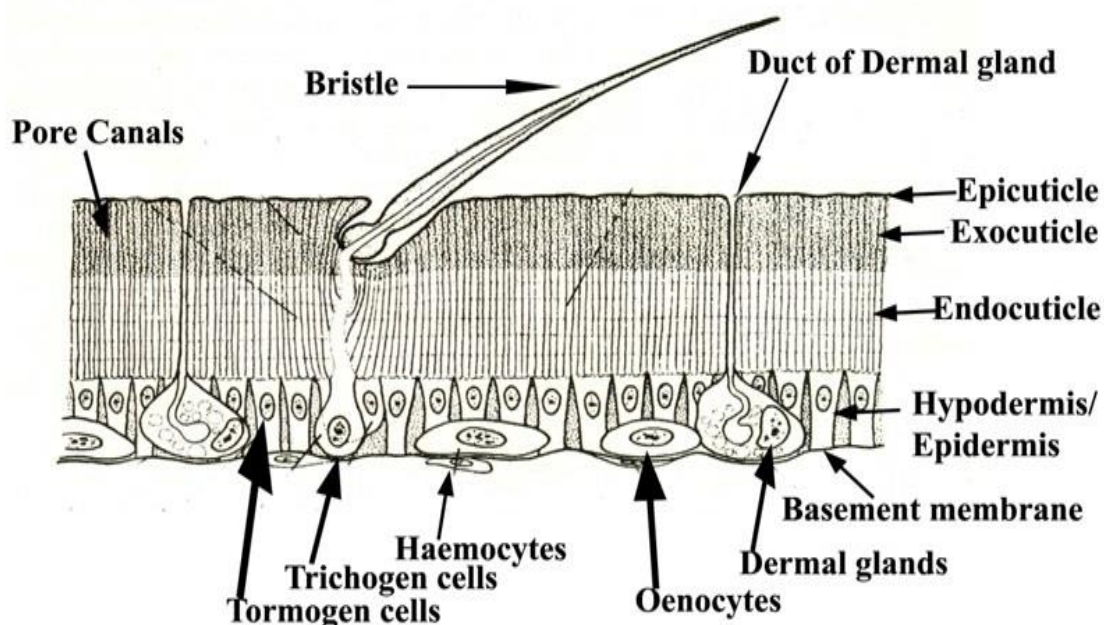
- Serves as chief exoskeleton of insect body
- Acts as external armor and strengthen external organs like jaws and ovipositor
- Provide firm basis for the attachment of muscles.
- Determine shape of body
- To act as agent of locomotory system, because muscles of legs, wings & movable sclerites are attached to exoskeleton.
- Support & protect vital internal organs like foregut, hindgut and trachea.
- To protect the organism from outside forces (mechanical abrasion, physical injuries and biological (parasites, predators and pathogen)).
- Protect from bad effect of chemicals.
- Receive external stimuli through sensory hairs
- Prevents water loss from the body.
- Keeps water, ion and thermal balance
- It is impermeable so protect the insect from desiccation.
- Perform the function like absorption , secretion, excretion & sensory reception
- Cuticular pigments give colour.

Structure of insect body wall

Integument consists of three layers viz.,

- A. Cuticle
- B. Epidermis/ hypodermis
- C. Basement membrane

SECTION OF CUTICLE



I. Cuticle

It is outermost non cellular and complex thick layer of integument secreted by epidermis / hypodermal cells.

It is non – living. It also forms the inner layer of trachea / tracheoles, glands, foregut, hindgut & some parts of reproductive system. The cuticle undergoes the process of sclerotization & greater part of cuticle become hard & dark. It is divided in to two regions

A. Epicuticle (Upper) B. Procuticle (Inner)

1. Epicuticle

Outer most non-chitinous, unpigmented layer which is very thin (1-4 μ). Pore canals present in the exocuticle helps in the deposition of epicuticle. It consists of the following 4 layers.

- i. **Cement layer:** Outer most layer formed by lipid and tanned protein. It bears hairs, spine or microtrichia. It is secreted by dermal glands and is composed of lipoprotein. It protects wax layer.
- ii. **Wax/ lipid layer:** Thin layer of wax beneath the cement layer. It contains closely packed wax molecules hence impermeable to water so conserve the water and prevents desiccation too. Consists long chain hydrocarbons, esters of fatty acids and alcohols (wax).

- iii. **Polyphenol layer:** Beneath the wax layer, rich in polyphenols. Transported from the pore canals and accumulates on outer surface of the cuticulin. Resistant to acids and organic solvents.
- iv. **Cuticulin layer:** Non chitinous polymerized lipoprotein layer. Highly resistant to acids & organic solvents. Elaborated by oenocytes. It serves the purpose of permeability and also acts as growth barrier.

2. Procuticle: It is further divided into exocuticle and endocuticle.

i. **Exocuticle**

- Outer layer of procuticle.
- Consists of chitin & hard proteins (sclerotin)
- Provides rigidity & toughness to the cuticle.
- It is pigmented by hard, brown material and referred to as “ Tanned” dark in colour and rigid.
- Shaded off at the time of moulting.

ii. **Endocuticle**

- It is the inner and thickest layer.
- This layer is made up of Chitin and arthropodin.
- This layer is colourless, soft and flexible.
- Pore canals passes through endocuticle.

Pore Canals

- In the procuticle, there are large no of ducts running from epidermis to inner epicuticular layer is known as pore canals.

Functions of Pore Canals

- Act as transport the materials during formation stage of cuticle.
- Carry oxidizing enzymes used in sclerotization to exocuticle
- Transport the materials used in repair of wounds
- They carry moulting fluid, protein, polyphenols & wax

What is Sclerotization ?

It is the process of hardening of body wall, where the exocuticle become hard, tough & inelastic.

II. Epidermis/ hypodermis

- It is an inner unicellular layer resting on basement membrane.

- It is a middle layer of body wall
- Continuous single layer of living cells
- Some specialized gland cells are scattered among the normal epidermal cells.
- The cells forming cuticular sensilla are also found in this layer
- Oenocytes which originates from the epidermal cells

Function of epidermis/hypodermis

- i. Cuticle secretion
- ii. Secretion of moulting fluid
- iii. Digestion and absorption of old cuticle (endocuticle)
- iv. Wound repairing
- v. Determine the surface pattern of insects (Gives surface look)

III. Basement membrane

- It is the inner most layer of body wall below the epidermis.
- Continuous layer, adjacent to internal organ below the epidermis secreted by the blood cells (haemocytes).
- It is the basal part of the body wall formed from degenerated epidermal cells (haemocytes)
- It is amorphous granulated layer (0.5 μ or less in thickness) providing attachment to muscles & chordotonal organs, tympanal organs, tracheoles & nerves passed through basement membrane

Functions

- It provides base for the attachment of the muscle.
- Chorodotonal organs, tympanal organ and tracheae passes through it.

Composition of cuticle

1. **Chitin:** It is the main constituent of cuticle, which is Nitrogenous polysaccharide and polymer of N-acetylglucosamine. It is water insoluble but soluble in dilute acids, alkalies and organic solvents.
2. **Arthropodin:** An untanned cuticular protein, which is water soluble.
3. **Sclerotin:** Tanned cuticular protein, which is water insoluble.
4. **Resilin:** An elastic cuticular protein responsible for the flexibility of sclerites, e.g., wing articulatory sclerites.

ENDOSKELETON

Cuticular in growth of body wall providing space for muscle attachment is known as endoskeleton. There are two types:

1. **Apodeme:** Hollow invagination of body wall.
2. **Apophysis:** Solid invagination of body wall.

CUTICULAR APPENDAGES

1. **Non-cellular:** Non-cellular appendages have no epidermal association, but rigidly attached. e.g. minute hairs and thorns.
2. **Cellular:** Cellular appendages have epidermal association.
 - i. **Unicellular**
 - a. **Clothing hairs**, plumose hairs. e.g. Honey bee, Bristles
 - b. **Scales** - flattened out growth of body wall e.g. Moths and butterflies
 - c. **Glandular seta**. e.g. caterpillar
 - d. Sensory setae - They respond to the external stimuli. These are present on antennae, legs, mouth parts and various region of body in all groups of insects.

Seta/Macrotrichia - hair like out growth (Epidermal cell generating seta is known as **Trichogen**, while the socket forming cell housing trichogen is known as **Tormogen**).

Setae are hollow structures developed as extension of exocuticle and are produced by a single enlarged hypodermal cell called '**trichogen cell**'. Articular membrane is usually produced by a second hypodermal cell called '**tormogen cell**'.

Study of arrangement of seta is known as **Chaetotaxy**).

- ii. **Multicellular**
 - e.g. Spur - Movable structure
 - Spine- Immovable structure

GLANDS

Cuticular glands are either unicellular or multicellular. Following are some of the examples.

- i. Wax gland - e.g. Honey bee and mealy bug
- ii. Lac gland - e.g. Lac insect
- iii. Moulting gland secreting moulting fluid.
- iv. Androconia or scent scale - e.g. moth
- v. Poison gland - e.g. slug caterpillar

MOULTING

DEFINITION: The process of casting off old cuticle and deposition of new cuticle at certain time interval is known as **moulting** or **ecdysis**.

The cuticular parts discarded during moulting is known as **Exuvia**. Moulting occurs many times in an insect during the immature stages before attaining the adult-hood. The time interval between the two subsequent moulting is called as **Stadium** and the form assumed by the insect in any stadium is called as **Instar**. In some insects the old cuticle remains on insect body is called **pharate instar**.

❖ Why do insect moults?

- The insect body is covered by hard and non-elastic cuticle layer so body cannot grow in size continuously.
- To accommodate the growing internal parts, insect has to cast off its cuticle periodically.
- To provide enough space for the growing organs, the body wall or integument ruptures at certain time interval.
- The part of old cuticle is casted off after the deposition of new cuticle beneath it.
- The new cuticle is soft and elastic when deposited. Thus, it facilitates the expansion of the internal organs resulting in increased in size of the body.
- Later on, the new cuticle undergoes the process of sclerotization as a result of which it becomes hard and dark.
- This whole process of casting off old cuticle and deposition of new cuticle at certain time interval is known as moulting.

There are two phases of moulting

1. **Apolysis:** Separation of old cuticle from epidermis
2. **Ecdysis:** Process of casting or shedding the old cuticle.

❖ Control of moulting

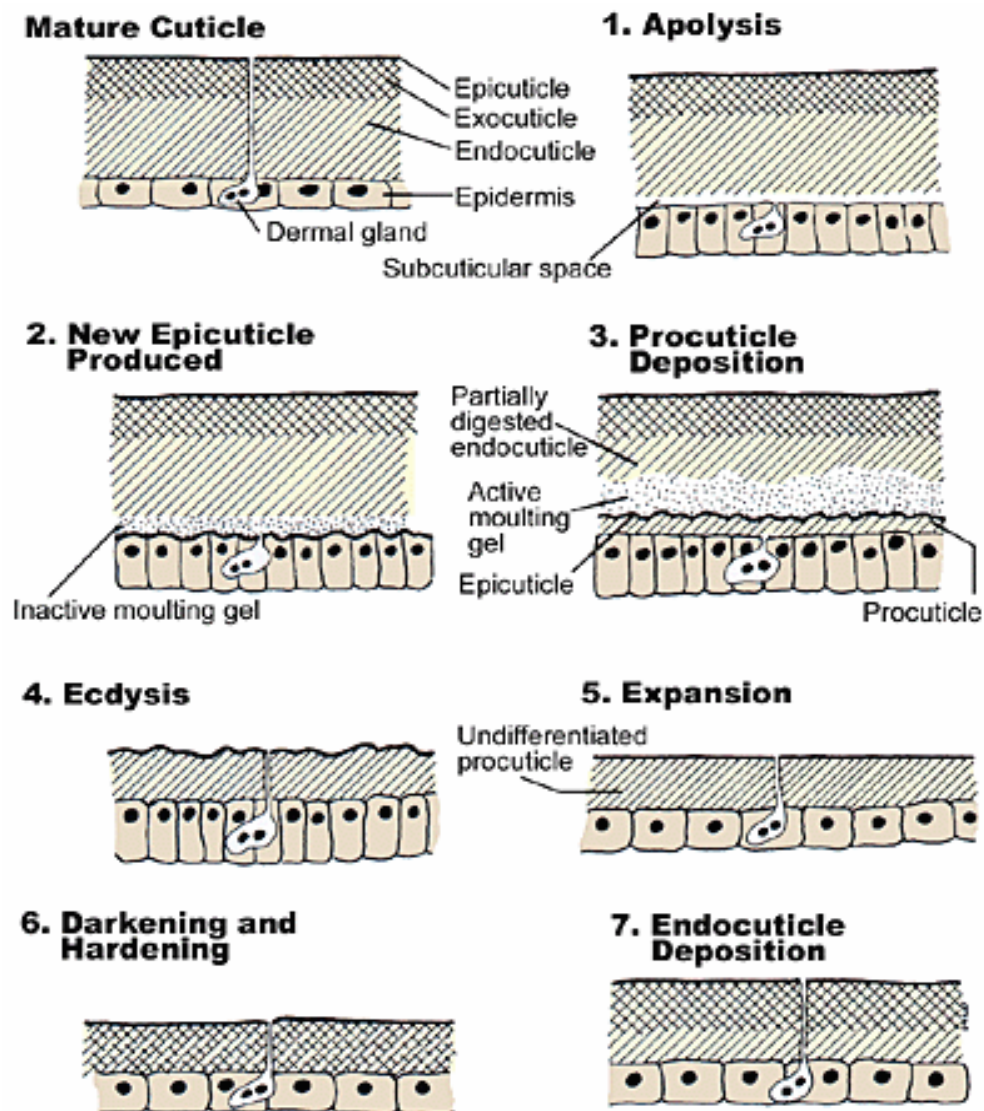
- It is controlled by endocrine glands like prothoracic glands secrete ecdysone hormone. This hormone induces the insects to moult.
- Prothoracic glands are activated by **prothoracic-tropic hormones** produced by neuro-secretory cells of brain. The hormone bursicon is responsible for the sclerotization.

STEPS IN MOULTING (Ecdysis), SCLEROTOZATION AND MELANIZATION

Steps in moulting

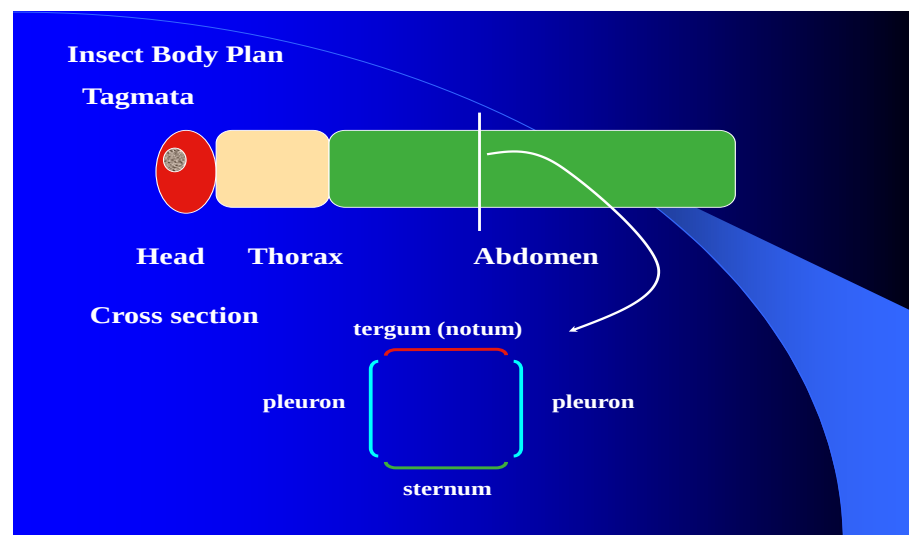
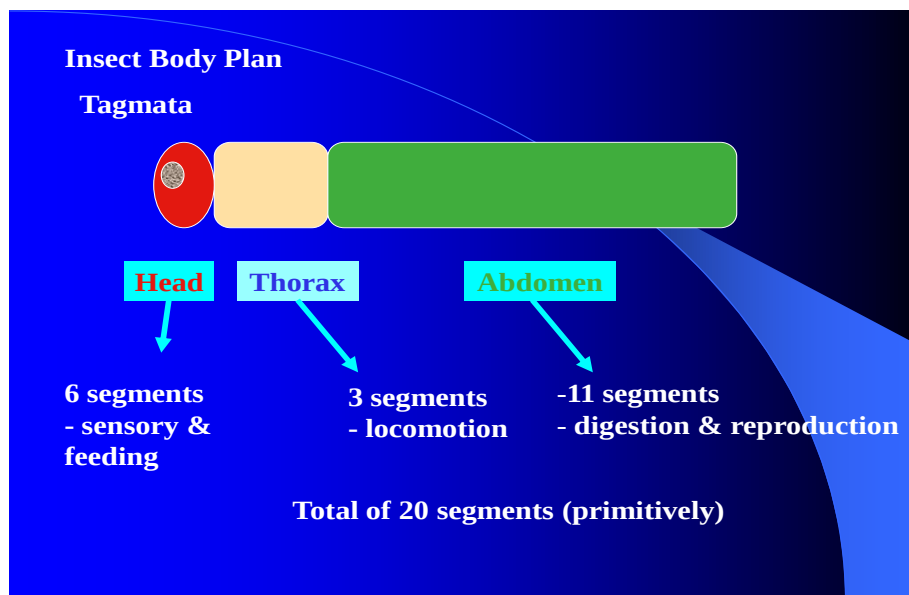
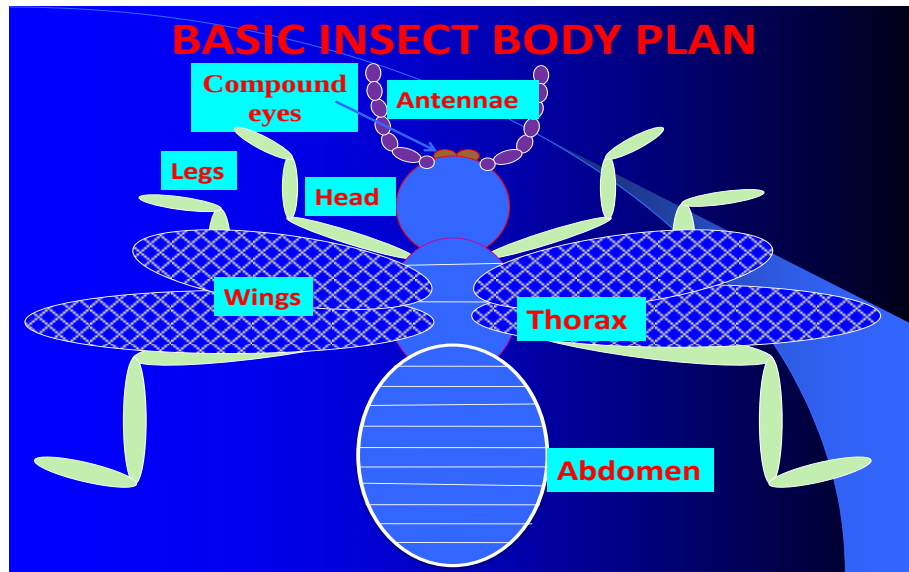
1. Behavioural changes: Insect stops feeding and become inactive.
 2. First, the old cuticle is loosened to form a small space between cuticle & epidermal cells.
 3. The epidermal cells become active & undergoes mitosis and increases the tension, under influence of brain hormones & change in size & shape.
 4. Due to this process they generate tension & pushing the cuticle off (Apolysis: detachment of cuticle from epidermis).
 5. Formation of **Sub cuticular space**
 6. Secretion of **moulting gel** in the sub cuticular space which is rich with **chitinase** and **protease**.
 7. These enzymes dissolve endocuticle & dissolved fluids are absorbed by epidermis.
 8. **New epicuticle formation:** Lipoprotein layer (cuticulin) is laid over the epidermis.
 9. **Procuticle formation:** Procuticle is formed below the epicuticle.
 10. **Activation of moulting gel:** Moulting gel is converted into moulting fluid rich in enzymes. This activates endocuticle digestion and absorption.
 11. **Wax layer formation:** Wax threads of pore canals secrete wax layer.
 12. **Cement layer formation :** Dermal glands secrete cement layer (Tectocuticle).
 13. **Moulting/Ecdysis:** This involves
 - a. The old cuticle burst at the ecdysial cleavage line.
 - b. The rupture is caused by pressure of blood.
 - c. Insect contract the abdomen & forcing the blood into thorax until the cuticle breaks.
 - d. Insect may swallow air (water if aquatic) for this process.
 - e. Insect pulls out its body from the old skin.
 - f. The head comes first followed by thorax, abdomen and appendages leaving behind the exuvae.
 - g. Some insects hang themselves on some support & pull out their body.
- Removal of old cuticle:** Peristaltic movement of body and lubricant action of moulting fluid helps in the removal of old cuticle. During each moulting the cuticular coverings discarded are the cuticular of legs, internal linings of foregut and hindgut and trachea.

14. **Formation of exocuticle:** The upper layer of procuticle develops as exocuticle through addition of protein and tanning by phenolic substance.
15. **Formation of endocuticle:** The lower layer of procuticle develops as endocuticle through addition of chitin and protein. This layer increases in thickness.
- ✓ **Control of Moulting:** It is controlled by endocrine gland like prothoracic gland which secrete moulting hormone. Endocrine glands are activated by prothoracico-tropic hormones produced by neurosecretory cells of brain.



STRUCTURE AND FUNCTIONS OF INSECT BODY SEGMENTATION

INSECT BODY SEGMENTATION



GENERAL BODY SEGMENTATION

Insect body is Segmented and divide in to small ring like structure known as **somite** or **metameres**.

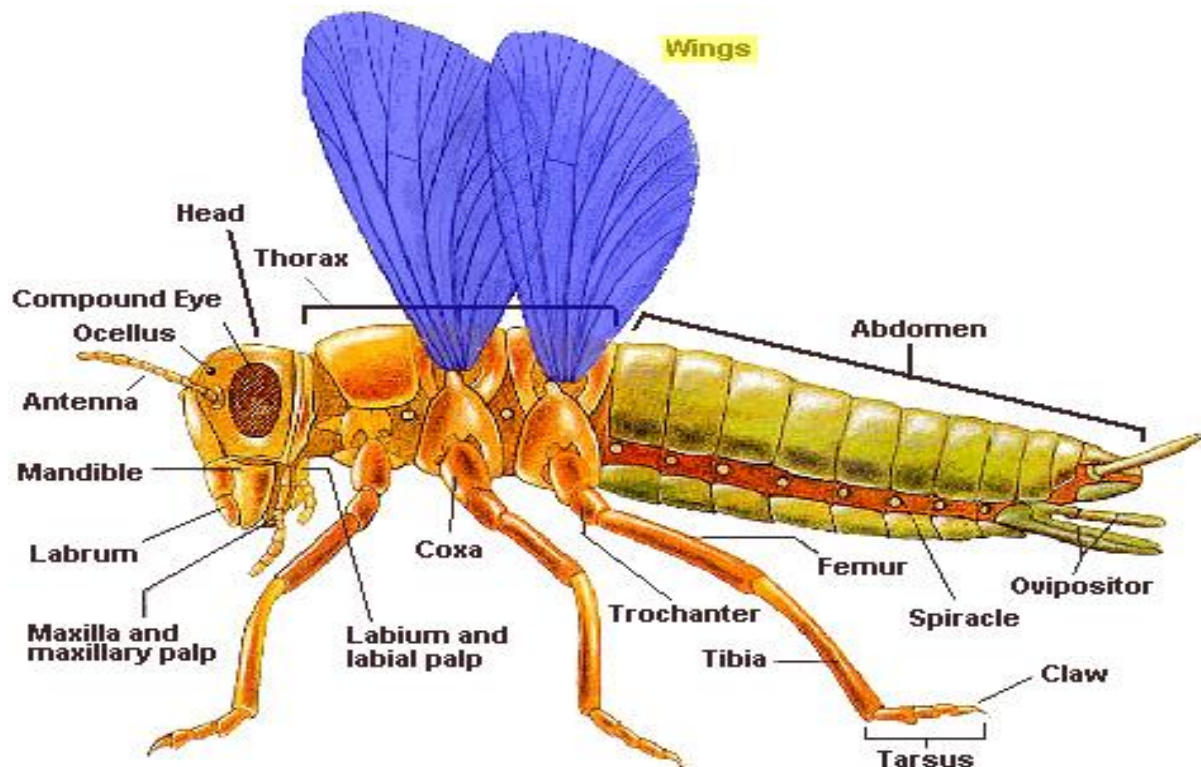
Insect body is divided in to three regions or tagmata namely **head, thorax** and **abdomen**. This grouping of body segments in to regions is known as **tagmosis**.

Insect body is divided into three distinct regions called as head, thorax and abdomen. The head is a compact front division followed by the middle strong division called as thorax. The last and posterior division is long, tubular which is known as abdomen. Body wall of insect is divisible into three regions known as dorsal (upper side of the body), lateral (both sides) and ventral (lower side).

- **Segmentation:** It is the process in which the body of an insect consequently presents in jointed structure called segmentation.
- **Segment:** The body of an insect successively divides into a series of rings like structure known as segment or somites or metameres.
- **Sclerites:** Hardened body wall /plate bounded by suture /membranous area.
- **Suture /Inter-segmental membrane:** The flexible portion of the cuticle between two adjacent segments is known as inter-segmental membrane. Which allows free movement of body.

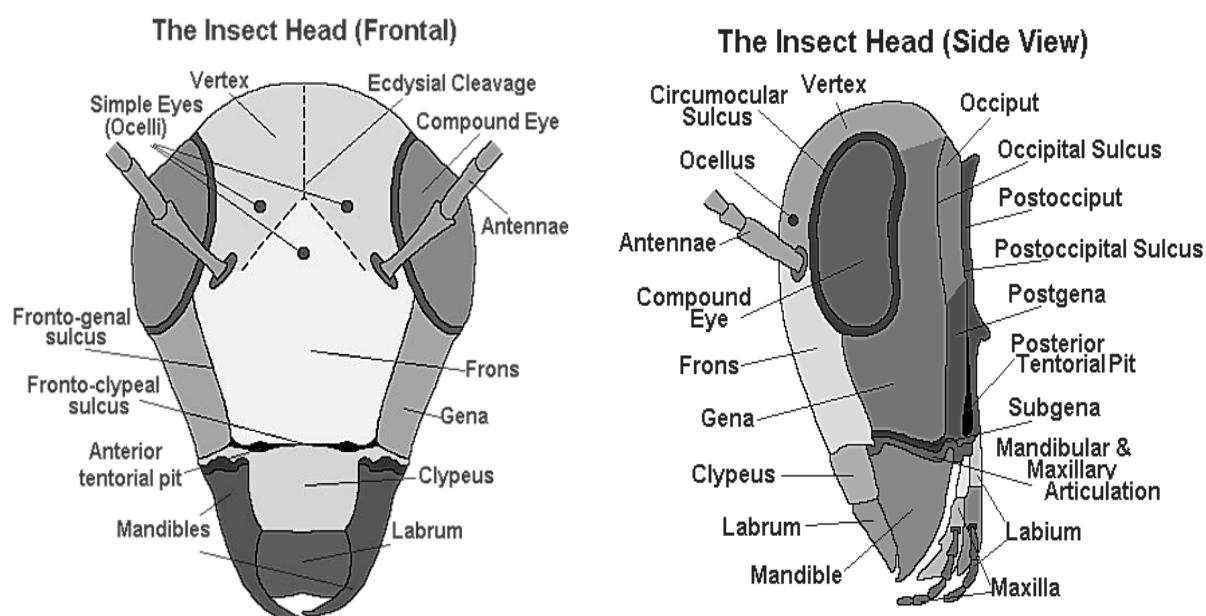
Insect body divided in 3 divisions

- 1.Head
- 2.Thorax
- 3.Abdomen



1. Insect Head

- First anterior tagma is formed by six different segments viz., 1. Antennae, 2. Compound eyes, 3. Labrum (Upper lip), 4. Mandible, 5. Maxillae and 6. Labium (Lower lip).
- They are fused together and form a single head capsule termed as **head**.
- Each segment is paired or single and located on different regions of the head. Head is attached /articulated with the thorax through neck /**cervix**.
- Insect head is made up of five different sclerites i.e, vertex, frons, clypeus, gena and occiput.
- The head capsule excluding appendages formed by the fusion of several sclerites is known as **Cranium**.
- To facilitate the movement of different sclerites, different sutures are present on insect head i.e., epicranial /ecdysial cleavage line, fronto-clypeal, clypeolabral and post-occipital suture.



Brief information about appendages /organs presents on insect head

A. Different parts of head

Sr. No.	Appendages of head	Numbers	Actual position	Function
1.	Antenna	Two	Between two compound eye on 1 st segment of head	Sensory
2.	Compound eye	Two	Dorsal-lateral on 2 nd segment of head	Vision
3.	Labrum	One	Attached with clypeus on 3 rd segment of head	Protect mandibles and guide the food
4.	Mandibles	Two	on 4 th segment of head	First pair of jaw and for chewing

5.	Maxillae	Two	on 5 th segment of head	Second pair of jaw and for sensory
6.	Labium	One	on 6 th segment of head	Close the mouth cavity
7.	Ocelli	Three	2 on vertex and 1 on frons	Vision

B. Different sclerites of head

Sr. No.	Sclerites of head	Actual position on head
1.	Vertex	Area between two compound eyes on the upper part of head.
2.	Frons	Facial area below the vertex and above clypeus.
3.	Clypeus	Cranial area below the frons to which labrum is attached.
4.	Gena	Lateral cranial area behind the compound eyes.
5.	Occiput	Cranial area between occipital and post occipital suture.

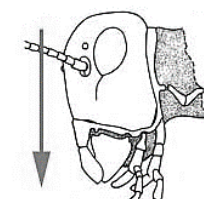
C. Different sutures of Head

No.	Sutures of head	Actual position on head
1.	Epicranial /ecdysial	The dorsal position of the head is known as epicranium. "Y" shaped suture /line runs from the dorsal region of the head between the eyes and branches into a fork on face.
2.	Fronto-clypeal	Found between frons and clypeus.
3.	Clypeolabral	Found between clypeus and labrum.
4.	Post-occipital	Groove bordering occipital foramen. Line indicating the fusion of maxillary and labial segment.

Head inclinations: According to the orientation of head with respect to insect body, it is divided into three types i.e., hypognathous, prognathous and opisthognathous.

A. Hypognathous Type

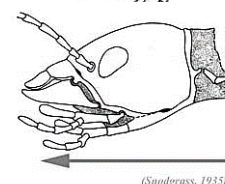
- Long axis of head is vertical and mouth parts are ventral in position projecting downwards. Median line of head forms right angle with median line of body. e.g. Grasshopper, cockroach, mantids etc.



B. Prognathous Type

- Long axis of head is horizontal and mouth parts are projecting in forward directions. Mouthparts are in parallel to the body region.

e.g. Workers of termites, weevils, *Chrysoperla* larva etc.

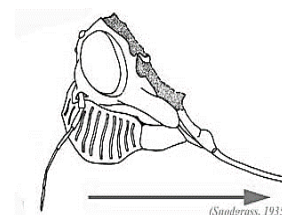


(Snodgrass, 1935)

C. Opisthognathous Type

- The head is directed backwards and mouthparts are post-ventral in position. Mouthparts are beak like and resting between first pair of legs.

e.g. Red cotton bug, plant hoppers etc.



(Snodgrass, 1935)

2. **Thorax:** The second /intermediate region divided into three distinct parts viz., prothorax, mesothorax and metathorax. Thoracic segments having locomotor organs i.e., three pairs of legs (each on pro, meso and metathorax) and two pairs of wings (each on meso and metathorax [collectively known as pterothorax]).

Thoracic sclerites

Thoracic segments are made up of three sclerites viz., dorsal body plate tergum or nota, ventral body plate sternum and lateral plate pleuron.

1. **Pronotum:** This sclerite is undivided and saddle shaped in grasshopper and shield like in cockroach.
3. **Pterothoracic notum:** It has three transverse sutures (antecostal, prescutal and scuto-scutellar) and five tergites (acrotergite, prescutum, scutum, scutellum and post-scutellum).
4. **Thoracic sterna:** Ventral body plate of each thoracic segment is called as prosternum, mesosternum and metasternum. Thoracic sterna are made up of a segmental plate called eusternum and an intersternite called spinasternum. Eusternum is made up of three sternites viz., presternum, basisternum and sternellum.
5. **Thoracic pleura:** Lateral body wall of thoracic segment between notum and sternum. Sclerites of pleuron is called as pleurite and they fuse to form pleural plate. Pleural plate is divided into anterior episternum and posterior epimeron by pleural suture. Pterothoracic pleuron provides space for articulation of wings and legs.
6. **Thoracic appendages:** They are three pairs of legs and two pairs of wings. Two pairs of spiracles are also present in the mesopleuron and metapleuron.

3. Abdomen

- In general, having **11 segments**
- Last region is segment like known as **telson** (Not true segment)
- The abdominal segment is known as **Uromere**.
- Abdomen possess **8 pairs of spiracles**
- External genitalia and gills present in aquatic insects.
- Body cavity filled with **blood (haemocoel)**
- In Hymenoptera (wasps, bees, ants), the **first abdominal segment** is transferred to thorax and closely attached/fused to metathorax to form mesosoma, hence the thorax looks like four segmented.
- The **1st abdominal segment** thus transferred is referred as **propodeum**.
- The **2nd abdominal segment** is long called **petiole** or **pedicel**, where as the other abdominal segments are enlarged, collectively called **gaster**.

Abdominal appendages

1. **Reproductive appendages:** The reproductive organ of female is located on 8th and 9th segments and in male on 9th segment of abdomen. Reproductive structures are located on **the 9th segment in males** (including the aedeagus, or penis, and often a pair of claspers).

(A) Female genitalia

- ✓ It consists of three pairs of valves and known as **ovipositor**. In human louse and flea, it is absent. In bees, wasps and ants the ovipositor is modified in to stinging organ.
- ✓ In mayflies and earwig female genital opening (Gonopore) is just behind the 7th abdominal segment.
- ✓ In dragonfly and damselfly have the gonopore on the ninth abdominal segment, the copulatory organ on ventral side of the second and third abdominal segments.

(B) Male genitalia

- Completely developed male genitalia consist of one pair of clasper, one pair of aedeagus and one pair of paramere.
- Clasper: It helps to grip the female during copulation.
- Aedeagus: It is used in sperm injecting and sperm transference to the female.

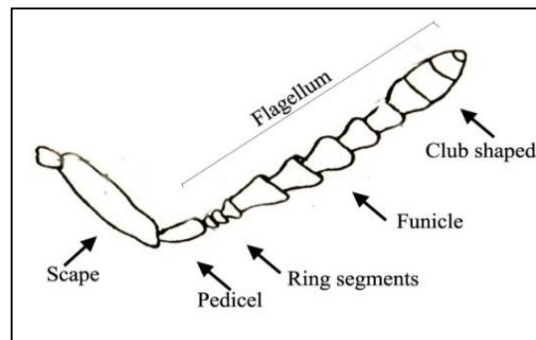
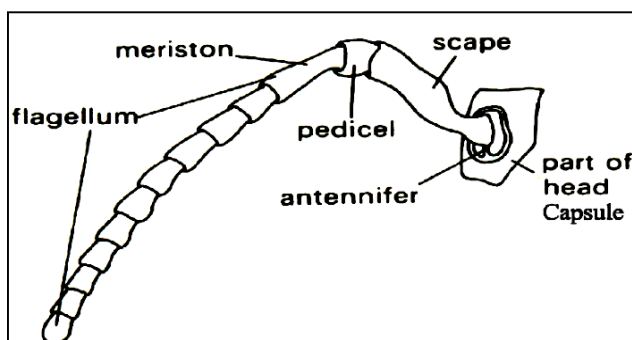
2. Non- Reproductive appendages

- **Cerci /cercus:** Paired cercus is present in Diplura, Zygentoma, Ephemeroptera, Zygoptera (a suborder of the Odonata), Plecoptera, the orthoptera and blattoids and Mecoptera. The cerci are the true appendages of the 11th segment. Typically, they are elongate multi-segmented structures that function as sense organs. In more advanced insect sterna become reduced or lost or transform in to forceps (earwig). In male Embioptera, the basal segment of the left cercus forms a hook with which the insect can clasp its mate.
- **Styli:** It is present on most abdominal segments of Microcoryphia, Zygentoma and Diplura, and on the ninth sternum of some male orthoptera. In bristletails, at least, the styli serve to raise the abdomen off the ground during locomotion.
- **Prolegs:** Segmentally arranged, leg-like structures are present on the abdomen of many endopterygotes larvae. They are known as prolegs (pseudopods or larvapods).

- **Spiracles:** Thorax: 2 pairs and Abdomen: 8 pairs (lateral side of first to eight segment). Spiracles open on plural region of the abdomen.
- **Gills:** A large number of aquatic larvae possess segmentally arranged gills on a varied number of abdominal segments. These are respiratory organs. Aquatic larvae and nymphs may have gills laterally on some to most abdominal segments. Some of these may be serially homologous with thoracic wings (e.g. the plate gills of mayfly nymphs).
- **Tenaculum:** A minute structure located on the ventral side of the third abdominal segment, which serve as hook for the furcula.
- **Furcula:** The forked springing organ on the ventral side of 4th abdominal segment is known as furcula which is useful to help in jump.
- **Telson:** A segment like structure after 11th segment. It is not a true segment.
- **Tympanum:** (vibrating membrane): An organ lies on first abdominal tergum e.g. Grass hopper (pit like structure)
- **Epiproct /paraproct:** The 11th segment is present in the adults of the lower orders where its tergum is represented by the epiproct above the anus (often fused with the 10th tergum), while vestiges of its sternum seen in the paraprocts which lie on either side of the anus.
- **Cornicles:** Aphids have a pair of short tubules known as cornicles or siphunculi. It is projecting from dorsum of fifth or sixth abdominal segment.

6. STRUCTURE AND MODIFICATIONS OF INSECT ANTENNAE

Insect antennae are important non-visual sensory organs. Antennae are a pair of sensory **preoral** mobile jointed appendages arising from the 2nd or antennal segment of the head possessing nerves coming from **deutocerebrum** of the brain. They are well developed in adults and poorly developed in immature stages. Antennae are absent in order **Protura** and class **Arachnida** where as 2 pairs of antenna (antennules) are present in class **Crustacea**. These are said to be **uniramous** (unbranched), segmented and mobile structures which are basally fixed in to deep antennal socket (**antennifer**). Antennal socket is provided with an antennal suture. The base of socket is connected to the edge of the socket by an articular membrane. This permits free movement of antennae.



It is articulated with head in front or between the eyes and divide into 3 regions.

1. **Scape** : It is the first (basal) segment of antenna, which articulates with the head capsule through antennifer that provides movement for the scape.
2. **Pedicel** : It is the 2nd or middle segment of antenna that forms a joint between scape and flagellum. It consists of the special auditory organ known as “**Jhonston’s organ**”. **Jhonston’s organ is absent in Collembola & Diplura.**
3. **Flagellum** : It is the **last antennal segment** which consists of many segments that varies in shape and size.

In the family Chalcidoidea, the flagellar segments are divided in to the basal ring segments funicle and terminal club. In general, there are no muscles in the flagellum and hence the antennae are called annulated type. In collembola and Diplura, the flagellar segments are muscular in nature and regarded as true segments and the antennae are known as segmented type.

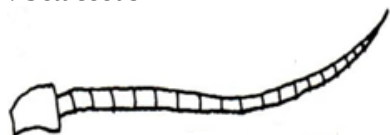
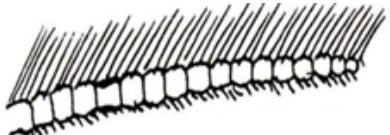
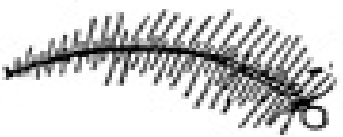
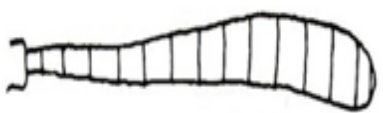
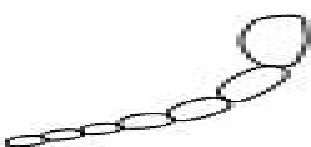
Functions of antenna

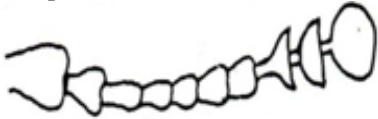
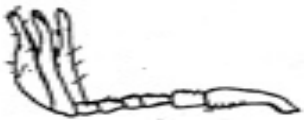
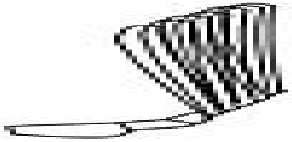
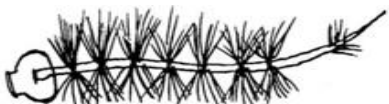
Numerous sensory organs or sensilla in the form of hairs, pegs, pits, cones occurs on antenna.

1. Mainly serve as the sense organ responding to touch, smell & odour (olfactory/chemoreceptors (eg. House fly).
2. It detect humidity (hygroreceptors) (eg. Ants)
3. It detects temperature (thermoreceptors) as well as air currents or wind speed (mechanoreceptors) (Honeybees).
4. Jhonston’s organ on pedicel functions as an auditory organ responding to sound and also helpful for measuring the speed of air currents.
5. Help the mandibles for holding prey (eg. Mantid) and for mastication of food material.
6. Helps in sexual dimorphism (eg. mosquito and Lepidoptera)

7. Useful for clasping the female during copulation
8. Aid in respiration by forming an air funnel in aquatic insects.
9. To find its way
10. To find the food
11. To find the opposite sex (mating partner).
12. To communicate with each other (eg. Ants).
13. It detects danger, and protect against NEs.

Types of Antennae

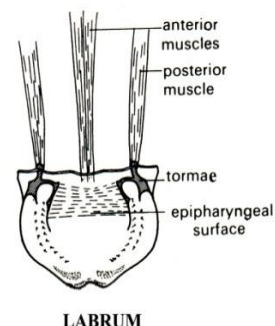
Type of antennae	Shape of antennae	Example	Nature of modification
1. Filliform 	Thread like	Grasshopper, crickets, tiger beetle, true bugs, lice, ground beetle, mantids, earwigs	Segments are more or less uniform throughout from base to apex and never end with bristle.
2. Setaceous 	Whip/bristle like	Cockroach	Segments gradually decrease in size from base to apex presenting a whip or bristle like structure.
3. Moniliform 	Like string of beads	Termite worker, rove beetle	Segments are round or oval with well developed constriction between segments, appearing like string of beads.
4. Pectinate 	Comb like	Sugarcane root borer, firefly beetle, Female arctid moth	Segments possess lateral processes on one side giving comb like appearance.
5. Bipectinate 	Double comb	Mulberry silk moth, Male Lymantrid moth	Segments bear lateral processes on either side, giving double comb like appearance.
6. Serrate 	Saw like	Pulse beetle, Mango stem borer	Segments of flagellum are triangular with projecting points on one side giving saw like appearance.
7. Clavate 	Clubbed	Butterflies	Segments gradually increase in diameter from base to tip ending in a club like apical part.
8. Clavate with hook 	Clubbed antennae with hook	Skipper butterfly	Segments gradually increase in diameter from base to tip and the terminal 3-5 segments suddenly enlarge to form a knob like structure.

9. Capitate		Clubbed with knob	Lemon butterfly, Red flour beetle, Khapra beetle (Trogoderma)	Segments gradually increase in diameter from base to apex and the terminal 3-5 segments suddenly enlarge to form a knob like structure.
10. Genuiculate		(Elbowed)	Ants, honey bees	The first segment (scape) is greatly elongated and flagellum always makes an angle with it
11. Lamellate		Plate like	Dung rollers, Rhinoceros beetles, Chaffer beetles	The terminal segments expand to one side and form broad plate or leaf like structure.
12. Flabellate		Fan shaped Feather like	Stylopids, Male strepsiptera, Rhipiphoridae	Projections of some terminal segments become long and extend laterally and form a feather like structure called flabella that lie against one another like the folds of a fan.
13. Plumose		Brush like with dense hairs	Male mosquito	Whorls of hairs arise from each joint of the segment. Each whorl contains number of hairs.
14. Pilose/Whorled		Brush like with sparse hairs	Female mosquito	Looks like a plumose but each whorl contains less number of hairs.
15. Aristate		Antennae with arista	House fly	Antennae are small, microscopic 3 segmented. 3 rd segment enlarged and bears a bristle called arista on its dorsal side.
16. Stylete		Spine like Antennae with Style	Robber fly, Snipe fly	Antennae small with 3-4 segment. Terminal segment elongate into a bristle like structure called style.
17. Ensiform		Sword like	Green Grasshopper	The segments of flagellum are thin and gradually taper towards the apex and form a leaf-blade-like structure.

TYPES /MODIFICATIONS OF INSECT MOUTH PARTS

These are organs concerned with feeding. The insect mouth parts mainly consist of 5 parts i.e., Labrum (upper lip), mandibles (first pair /anterior jaws), maxillae (second pair /accessory jaws), labium (lower lip) and hypopharynx

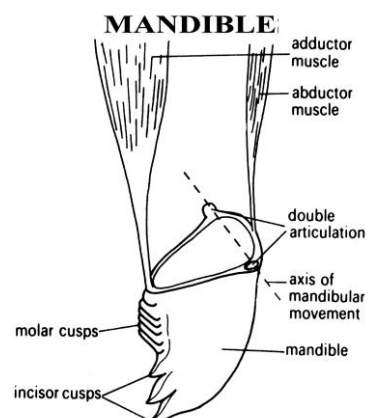
Labrum (upper lip): It is third segment of head appendages. It is a small sclerite that forms the upper lip of mouth and closes the mouth cavity from front. It is flap like structure attached to the clypeus by an articular membrane. It is frequently membranous and continuous with the dorsal wall of pharynx. It is movable and act as upper lip. In chewing type mouth parts (cockroach and grass hopper) the inner surface of the labrum is referred to as labrum-epipharynx which is well developed in Hymenoptera. It is an organ of taste (sense organ).



Functions:

- It holds the food in position so that mandibles can act on it.
- It helps to pull the food into the mouth.
- It forms the roof of the pre oral food cavity and closes the mouth cavity.
- Its inner surface is usually provided with chemoreceptors and is produced into small lobe-like epipharynx in Hymenoptera.

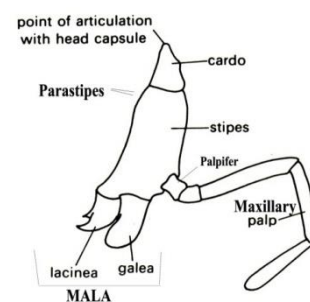
Mandibles (true jaws): It is fourth segment of head appendages also known as 1st pair of jaws. It is a second part of mouth parts and located directly behind the labrum. These are the paired, unsegmented and strongest sclerotized structures called jaws. They have sclerotized teeth like structure on their inner border among which the distal structures are sharply pointed and called as incisors /cutting teeth while proximal structure called as molar /grinding teeth. Each mandible is moved by powerful **Abductor** and **adductor muscles**.



Functions:

- For chewing and grinding of the food.
- Carry the things.
- As a defensive part to fight with natural enemies e.g. termites
- To mould the wax (e.g. honey bees) and mud (Mud wasp and dung roller).

Maxillae (accessory jaws): It is fifth segment of head appendages also known as 2nd pair of jaws. The third part of mouth is lying behind the mandibles. These are paired homologous structures. Each maxilla has five well defined parts i.e., cardo, stipes, maxillary palps, galea and lacinia. The basal triangular segment of the maxilla is the **cardo** and the second rectangular segment is **stipes**. The palpus is borne on the lobe of



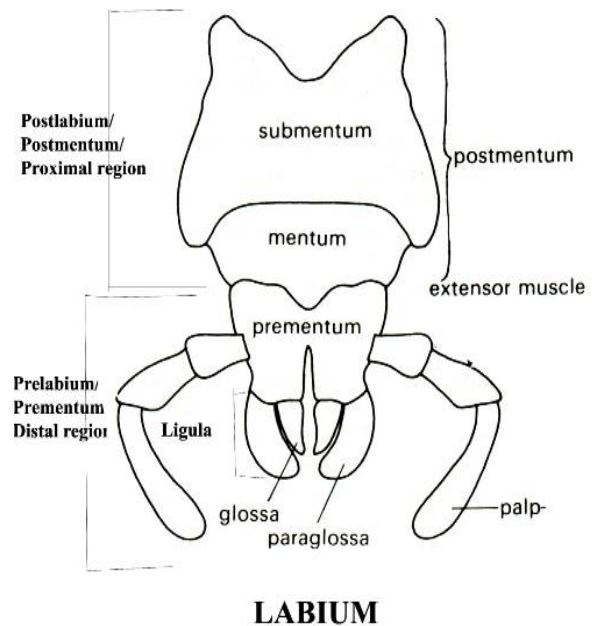
MAXILLA

stipes is called the palpifer (**maxillary palpi**). The stipes bears at its inner apex two lobe like structures called as **lacinia** (an elongate jaw like structure) and outer lobe like structure called as **galea**. Lacinia is spined or toothed on its inner border. Maxillary palps possess **olfactory** and **gustatory** sense receptors and function as **sensory** organs. These Galea and lacinia helps in holding the food material along with the mandibles.

Functions:

- They are used for holding and sending food into mouth.
- Useful to know the quality and taste of food.
- Maxillary palp and galea acts as a sense organ (smell and taste).
- In some insects, lacinia is modified for cutting, grinding and grasping the food.

Labium (lower lip): It is sixth segment of head appendages. It is the lower lip of mouth and closes the mouth cavity from behind or below. It is divided into proximal **prementum** and a basal *post-mentum* usually divides into basal *sub-mentum* (Large basal sclerite) and distal *mentum* (middle sclerite). Near the base of pre mentum, on either side lobe like ‘**palpiger**’ is present which bears labial palps. Prementum has four terminal lobes. The median pair is ‘**glossae**’ and outer ‘**paraglossae**’ together called **ligula** that function mainly as **gustatory** sense organs. The ligula consists of a pair of small lobes in the middle called as *glossae* and one pair of larger lobes laterally called as *paraglossae*.



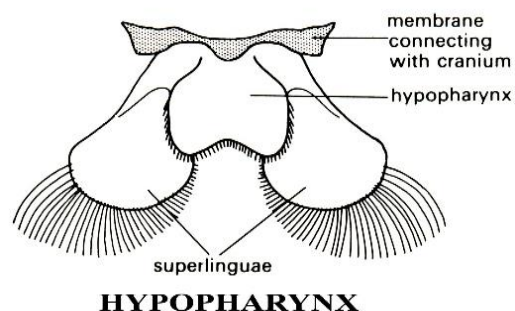
Functions:

- It closes the mouth cavity. It also helps to holding the food during masticating.
- Labial palpi functions as sense organs.

Hypopharynx: It is a tongue like organ attached with anterior wall of labium, through which the salivary glands open. It is located centrally between labrum and labium in the floor of mouth or preoral cavity. Ducts of salivary glands open on or near its base.

Functions:

- Secretion of enzymes is the function of hypopharynx.



Classification of Insect Mouthparts OR Types of Insect Mouthparts

Sr. No	Type of Mouth parts	Examples
I	Mandibulate	
1	Cutting and chewing type	
i	Grinding/Masticating subtype	Grasshoppers, Beetles
ii	Grasping/Predaceous	White ants
iii	Grasping-sucking/ Mandibulate suctorial	Larvae of Chrysoperla
iv	Brushing/Spatulate/Scrapping	Blister beetle, Dung roller
2	Chewing and lapping type	Honey bees
II	Haustellate	
A	With stylets	
1	Piercing and sucking type	
i	The bug or hemipterous sub type	Red cotton bug
ii	Anoplurous/Louse sub type	Human lice
iii	Dipterous/Common biting sub type	Female Mosquitoes
iv	Muscid sub type	Stable fly
v	Siphonopterous/Flea	Flea
vi	Anchoring sub type	Tick
vii	Chelate sub type	Mite
2	Rasping and sucking type	Thrips
B	Without stylets	
1	Siphoning type	Butterflies and moth
2	Sponging type	Adult Houseflies
III	Other types	
1	Degenerate type	Maggots of Diptera
2	Mask type	Nails of Dragonflies

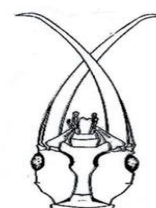
TYPES OF INSECT MOUTHPARTS:

Mouthparts vary greatly among insects of different orders, but basically the mouth parts may be divided into two groups:

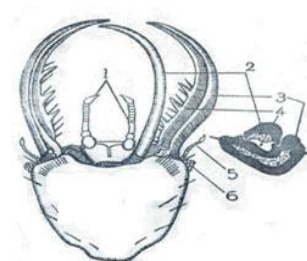
I. Chewing and Biting type (mandibulate)

1. Grinding/masticatory type: Mandibles are provided with grinding teeth for grinding plants and animal tissues. It masticate the solid food particles. Eg. Cockroach, grasshopper, locust, beetles, weevils, Lepidopteran caterpillar, cricket, earwigs etc.

2. Grasping type or predacious: Mandibles are elongate, curved with sharp points for eating and holding the prey. Teeth are absent. Eg. Soldier ants and predatory beetles



3. Grasping-sucking type or Mandibulo-suctorial: Mandibles are long, sickle shaped for grasping and piercing the prey. A channel or groove from the tip to base forming

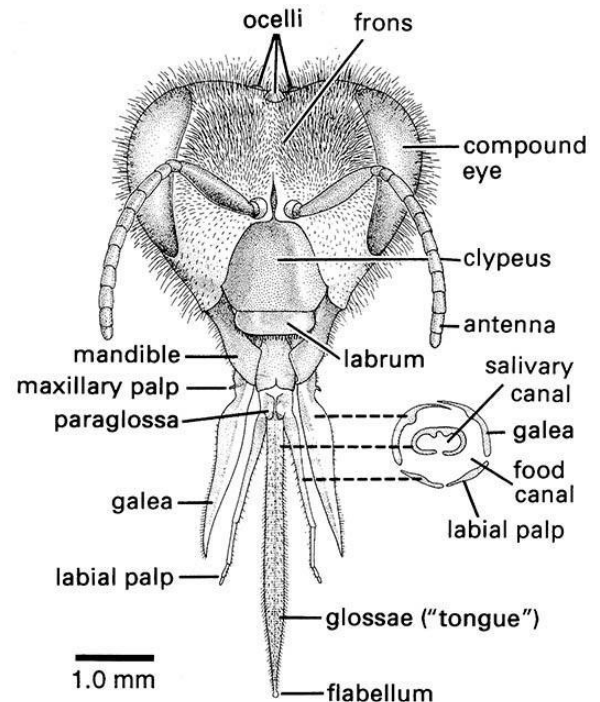


a close cavity through which insect suck the blood from prey. Maxillae act as blade. Eg. Larva of chrysopa, antlion and fire beetles.

- 4. Brushing type or scrapping:** Mandibles are without cutting teeth. They are densely covered with hairs and flat spatula like. These mandibles are used for molding the wax, mud and dung. Eg. Pollen feeder and dung beetle.



II. Chewing and Lapping Type: The labrum and mandibles are **biting type**, whereas maxillae, labium and hypopharynx combine together to form a sucking **proboscis**. Mandibles are smooth and are situated on either side of the labrum which is used in moulding wax and making the honey comb. The labium has sub-mentum, mentum, paraglossa and glossa or tongue, with a long labial palp on each side. The glossa is long and at its tips is a small “*Flabellum or labellum*”. The glossa is used for gathering honey. It is an organ of taste and smell. The maxillae and labial palps form a tube enclosing the glossa which moves up and down to collect nectar. At rest, mouth parts are folded beneath the head against stipes and mentum. During feeding they are straightened with labial palpi closely applied to glossa and partly embraced by the ensheathing of galea and lacinia. Glossa is very active while food is being imbibed retracting and protruding from the base of mentum. The liquid food (nectar) ascends by means of capillary action in to the central channel of glossae and enters in to the space between paraglossae and in to the mouth cavity. Eg. Honey Bees and wasp

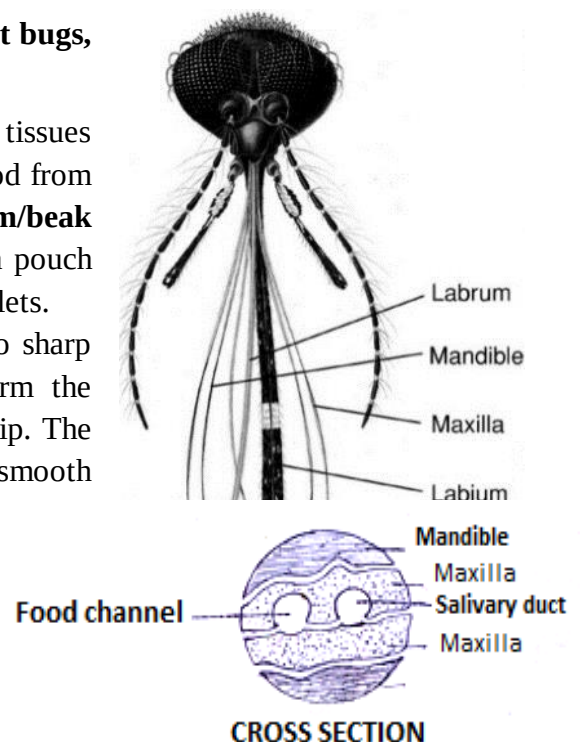


Sucking type (haustellate)

1. Piercing and Sucking Type: e.g.: Aphids, plant bugs, mosquitoes

They are mainly adopted for piercing the tissues and sucking either plant sap or the nectar or blood from the host. Mouth parts are represented by **rostrum/beak** which is a modification of **Labium**. It acts as a pouch for protecting the **mandibular** and **maxillary** stylets.

Mandibles and maxillae are modified in to sharp needle like stylets. The mandibular stylets form the outer pair and possess serrated margins at their tip. The maxillary stylets forms the inner pair having smooth curved tips and combine together enclosing a



food channel. The food channel is divided into an upper **cibarium** and lower **salivarium** with the help of the grooves present inside the maxillary stylets. Salivarium is used for **releasing the saliva** and cibarium is used for **sucking the sap**. The hypopharynx is modified into a **pharyngeal pump** and is situated at the tip of the food channel. Labrum is modified into a small **flap like** structure at the base of rostrum. Insects with these types of mouthparts pierce the tissues with the mandibular stylets and suck the contents (sap/ blood / nectar) through cibarium with the action of pharyngeal and cibarial muscles.

'Saliva' may be pumped down one of the tubes. This saliva makes the food into a liquid. The stylets themselves are enclosed in a sheath formed almost entirely by the labium which is dorsally grooved for their reception. At its base however the labial groove is wanting and in this region the sheath is roofed over the labrum. Usually labium is four segmented. Labial palps are wanting. Labrum forms the cover over the grooved labium. The hypopharynx is highly specialized and reduced either to form the floor of the cibarial sucking pump or to form mandibular plates. The stylets are pierced inside the plant tissues and generally they suck plant sap from phloem vessels. Eg. bugs, mosquito, aphids etc.

Sub type

(i) The bug or Hemipterous subtype

- Maxillary palps absent.
- Mandibles (2 Stylets) & Maxilla (2 Stylets) modified into stylets.
- Mandibles puncture alternately & maxilla suck up the sap from the plant.

(ii) Louse or Anopleurous sub type

- Maxillary palp absent.
- Two stylets – formed by maxilla.

Eg. Human louse, Other blood sucking louse

(iii) Mosquito sub type

- Maxillary palps present.
- Modified for blood sucking purpose.
- Six stylets

Maxilla	- 2	} Forming food channel
Mandible	- 2	
Labrum epipharynx	- 1	
Hypopharynx	- 1	

Stylets move upward & downward for making wounds.

(IV) Muscid sub type : (Biting fly)

- Leabella consist cutting teeth.
- Labium enters in the wounds.
- Food channel formed by labrum epipharynx & hypopharynx.
- Mandibles are wanting.

Eg. Stable fly, Horn fly, Tse Tse fly

(V) Siphonopterous sub type

- Two mandibles.
- Maxillary palps absent.

- Three stylets (Mandibles– 2 and Epipharynx –1)
- Mandible Pierce the skin & suck the blood.

Eg. Flea

(VI) Tick or Anchoring sub type

Eg : Cattle tick

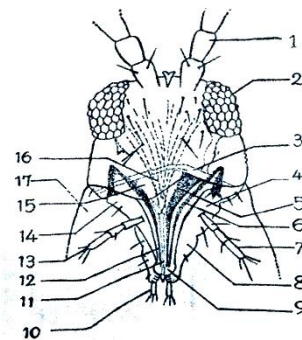
(VII) The Chelate or Mite sub type

Eg. Mites (Poultry mite, Red mite, Scab mite, Mango mite)

2. Rasping and Sucking Type or Lacerating and Sucking Type

These are asymmetrical type mouth parts, as **right mandible** is rudimentary. They are in between the biting – chewing type; and piercing - sucking type. The labrum, labium, bases of maxillae are modified to form a small tubular cone called mouth cone. The maxillae are modified into stylets. The right mandible is absent and the left mandible is modified as stylet. All these three stylets are repeatedly inserted into the plant tissues and the oozing out cell sap is sucked by applying mouth cone. Hypopharynx is reduced and small. Eg. Thrips

Mouthparts of thrips
Rasping – sucking type



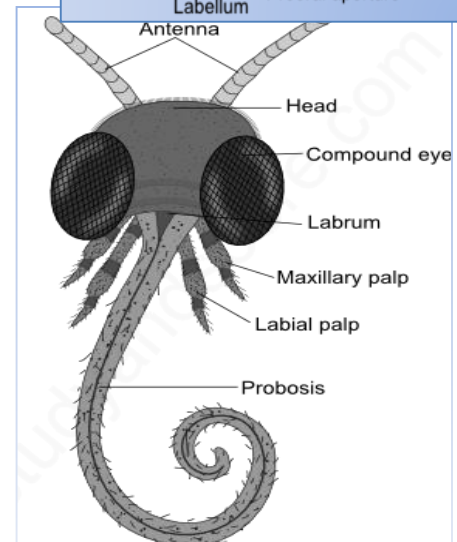
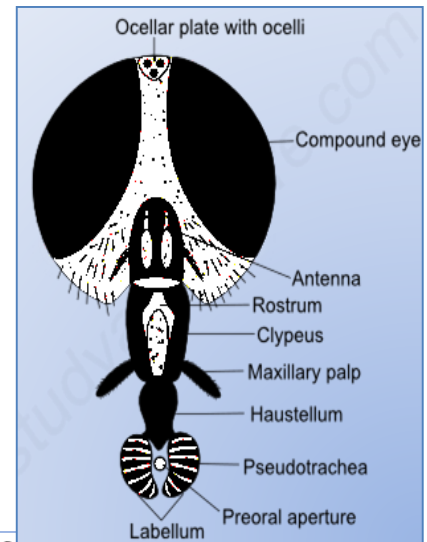
1. Antennae	9. Labrum
2. Compound eye	10. Labial palp
3. Chitinous band	11. Hypopharynx
4. Maxillary sclerite	12,14. Right maxillae
5. Left mandible	15. Clypeus
6. Maxillary sclerite	16. Fat bodies of hypopharynx
7,13. Maxillary palp	17. Prothorax
8. Labium	

3. Sponging or Lapping and Sucking Type

The proboscis consists of labium which is grooved on its anterior surface. Within this groove consists labrum-epipharynx (enclosing the food canal) and slender hypopharynx (containing the salivary canal). The proboscis is fleshy, elbowed, retractile and projects downwards from head. The proboscis can be differentiated into basal **rostrum**, middle **haustellum** and distal region of the proboscis is enlarged, sponge like and two lobed which acts as suction pads called oral discs or **labellum**. Labella have two sponge like structure and covered with capillary canals called pseudotrachea, which collect the liquid food and convey it to the canal. Labella function as

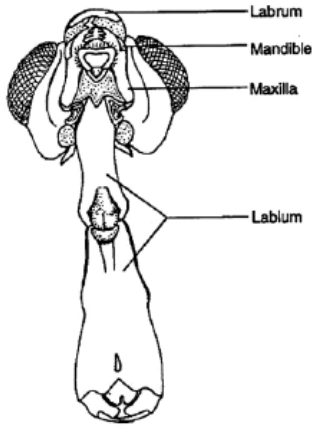
sponging organs and are capable of taking exposed fluids. These insects often spit enzyme containing saliva onto solid foods to liquidities them. Labrum epipharynx & Hypopharynx unite to form a food channel. Salivary duct open in Hypopharynx. Eg. House fly

4. **Siphoning Type:** In these Siphoning types of mouth parts, mandibles are absent. All mouth organs are



highly reduced except the galea of maxillae. Each galea of maxilla elongated into tube like hollow structure and semicircular. When both galea come close together they enclose, a sucking proboscis. Thus both the galea together forms the sucking proboscis coiled and kept below the head during non-feeding. E.g. Butterflies, Moths etc.

- III. **Mask Type:** These mouth parts are modified for biting and chewing type. Labium is modified into a mask. Prementum and postmentum and the suture between them form a hinge. The labial palpi are represented as teeth like structures / spines at the tip of the labium that are helpful for catching the prey. All other parts remain rudimentary (reduced). During resting period, when the insect is not feeding, the mouthparts cover a part of the head. Hence it is called mask type. Labial palps and help in catching the prey. When prey is sighted it is stretched with great rapidity. When at rest the mask is kept in a position the labium covers a portion of the head. Eg. Naiads of Dragonfly

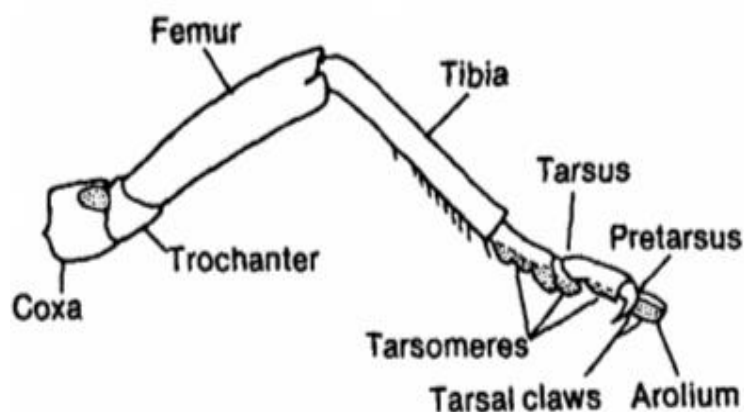


- IV. **Degenerate Type:** Typical example of the mouth parts is found in larva of higher diptera. The maggots of housefly and certain flower fly mouth are entirely wanting. The mouthparts are working vertically instead of laterally. A pair of hooks represents the mouthparts. Eg. Maggot of house fly.

STRUCTURE AND MODIFICATIONS OF INSECT LEGS

Every insect have three pairs of legs which are articulated on ventro-lateral region of thorax. The fore-legs are located on the prothorax, the mid-legs on the mesothorax, and the hind legs on the metathorax. All the three thoracic segments of an insect possess a pair of legs as locomotory organs giving the name hexapods and the class insecta as **hexapoda**. Insect leg mainly consists of 5 parts viz., **Coxa**, **Trochanter**, **Femur**, **Tibia** and **Tarsus**.

In primitive insects, a small sclerite known as **subcoxa** occur before the coxa which form the true basal segment. In the process of evolution, this sub coxa is reduced or modified.



Structure of leg

1. Coxa: It is the functional basal segment and it is rigidly fixed to thorax or weakly articulated.

2. Trochanter : It is very small and the **second** segment. It is articulated with coxa and more or

less fixed to femur.

3. Femur : It is 3rd segment of insect leg. It is the largest, strongest segment and is articulated with the tibia.

4. Tibia : It is 4th segment of insect leg. It is equal or more than the length of the femur, articulated with tarsus.

5. Tarsus : It is usually divided into sub segments tarsomeres. The number of tarsomeres vary from 1-5 and are movable one on the other. Among the 5 segments, 1st segment is large, big or broad in size known as **basitarsus**.

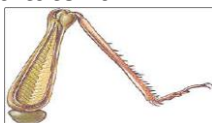
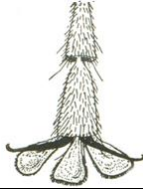
The tarsus at it's end consists of pretarsus which is in the form of a pair of claws and cushion like **pulvilli**. In between the claws, if there is lobe like structure, it is known as "**aroleum**" as in Orthoptera (grass hopper) and if it is bristle like structure, it is called "**embodium**" as in Diptera. In some insects, the ventral surface of pretarsus consist of a median circular plate between the claws known as **unguitractor** where as the claws are known as **ungues**.

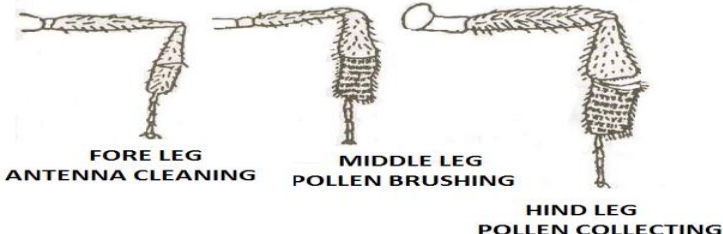
Types or modifications of legs

Legs are modified into several types based on the habitat and food habit of insect and used for a wide variety of functions.

Function of insect leg

- The hexapod condition facilitates the insect in maintaining balance during locomotion in terrestrial and aquatic habitat.
- The leg is modified to perform the functions like; walking, running, jumping, digging, swimming, grasping, clinging, sound producing and pollen collection.
- To hold the female during mating.

No.	Type of legs	Special function	Example	Nature of modification
1	Ambulatorial 	Walking	Cockroach	Femur flat and tibia are long. Pretarsus is provided with claw and flattened arolium. It can move perfectly on smooth and rough surface
2	Cursorial 	Running	Black ant	Femur flat, coxa highly muscular Tibia and tarsi slender and elongated. Tarsal segment much larger and touches to ground while running.
3	Saltatorial 	Jumping	Hind leg of grasshopper.	In some of the insects the femur of hind leg enlarged to accommodate muscles and this types of legs used for jumping. Trochanter is most modified
4	Fossorial 	Digging; Burrowing leg	Fore legs of mole cricket	Fore tibia are broad, highly sclerotized. Terminal digital processes used for digging and excavation. Tarsi and pre tarsi reduced
5	Scansorial 	Climbing; or clinging leg	All the three pairs of legs of head louse.	Single segmented tarsus bears a hook like curved claw with ventral pad. In ectoparasitic insects the holding capacity is important characters & they possess well-developed claw present at terminal end of tarsus and apex end of tibia and claw which pickup the thin hair. This type of legs is thin and stout.
6	Raptorial 	Grasping Preying	Forelegs of preying mantis.	Coxa long. Femur and tibia possess the spur like structure Tibia can be accommodated into groove of femur and tarsus can be inserted into the apical hook of the femur. Reduced preapical tarsus.
7	Natatorial 	Swimming	Hind legs of water bug and water beetle.	In aquatic insects, the legs are used for swimming and such types of legs bears a row of swimming hairs on mid and hind legs.
8	Pulvillus type 	Sticking	All the three pairs of legs of house fly	Pulvilli – Ped like Empodium – Pointed Pulvilli and empodium having tubular hair and moistened by glandular secretion. So, adhesion occurs and can walk on smooth surface.
9	Stridulatorial	Sound producing	Insects of Acrididae family	A row of pegs situated on the inner side of each hind femur which would work against the outer surface of each tegmen.
10	Bladder-Footed 		Onion thrips	The distal tarsomeres bear vesicle to provide a firm hold on to the surface on which the insects feed.

11		Basket like leg	Dragonflies Damselfly	The long legs having rows of stiff bristles along the inner margins
12		Web spinning	Fore leg of Embioptera	Metatarsus of forelegs is swollen to accommodate the silk gland.
13	Foragial leg (Forage = to collect food material) e.g. Legs of honey bee  FORE LEG ANTENNA CLEANING MIDDLE LEG POLLEN BRUSHING HIND LEG POLLEN COLLECTING			

i. **Forelegs** : The foreleg has three important structures

a. Eye brush b. Antenna cleaner or strigillis c. Pollen brush

ii. **Middle legs**: It has two important structures.

a. **Pollen brush**: Stiff hairs on basitarsus form pollen brush which is useful to collect pollen from middle part of their body.

b. **Tibial spur**: At the distal end of the tibia, a movable spur is present which is useful to loosen the pellets of pollen from the pollen basket of hind legs and to clean wings and spiracles.

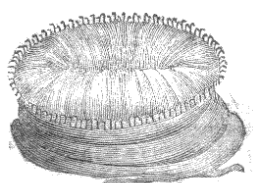
iii. **Hind legs**: It has three important structures viz., pollen basket, pollen packer and pollen comb.

a. **Pollen basket**: It is also called corbicula. The outer surface of the hind tibia contains a shallow cavity. The edges of the cavity are fringed with long hairs. The pollen basket enables the bee to carry a larger load of pollen and propolis from the field to the hive.

b. **Pollen packer**: It is also called pollen press. It consists of pecten and auricle. Pecten is a row of stout bristles at the distal end of tibia. Auricle is a small plat fringed with hairs at the basal end of basitarsus. Pollen packer is useful to load pollen in corbicula.

c. **Pollen comb**: About ten rows of stiff spines are present on the inner side of hind basitarsus. The pollen comb is used to collect pollen from middle legs and from posterior part of the body.

Prolegs or **False legs** or **Pseudolegs**: e.g. abdominal legs of caterpillar. There are two to five



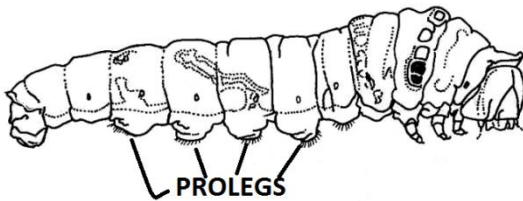
pairs of abdominal legs termed prolegs in caterpillar. Prolegs are thick, fleshy and not segmented. They are shed with last larval moult. One pair of prolegs on the last abdominal segment are called anal prolegs or

claspers. The tip of proleg is called planta upon which are borne hooks or claws known as crochets which are useful in crawling or clinging to surface.

Fig. Prolegs

Legs of immature stages

The immature stage of **exopterygotes** i.e. nymph consist of only thoracic legs similar to its adult where as that of **endopterygote** i.e. larva possess two types of legs.



i. Thoracic legs or **true legs**: Jointed, present on all the 3 thoracic segments.

ii. Abdominal legs or **prolegs**: Unjointed sucker like legs, having flat, fleshy surface at its tip known as **planta**. The planta consists of hook like structures

known as **crochets** which are used for clinging to the substrate. The number of prolegs varies from 1-5 pairs which are distributed on 3rd, 4th, 5th, 6th and 10th abdominal segments. For example, sawfly larva has 6-8 pairs of abdominal prolegs. In some insects leg are degenerated e.g.: Coccidae; Endoparasitic hymenopterans.

STRUCTURE AND MODIFICATIONS OF INSECT WING AND WING COUPLING APPARATUS

- Among the invertebrate animals, only insects possess wings.
- Wings are present only in adult stage.
- Number of wings varies from two pairs to none.
- Certain primitive insects like **silver fish** and **spring tail** have **no wings (apterous)**.
- Ecto parasites like head louse, poultry louse and flea are secondarily wingless.
- Wings are deciduous (being discarded after flight) in ants and termites.
- There is only one pair of wings in the true flies.
- Normally two pairs of wings are present in insects and they are borne on pterothoracic segments viz., mesothorax and metathorax.
- Wings are moved by thoracic flight muscles attached to their bases.

Wing: It is a flattened double layered expansion of body wall which has same structure as the body wall /integument. It bears many longitudinal veins and cross veins.

Wing Margins: The anterior margin is known as costal margin while the lateral /posterior and hind/outer margins are called as anal and apical margins, respectively.

Wing angles: The angle through which the wing is attached to the thorax is called as humeral angle. The angles formed between costal and apical margins and apical and anal margins are known as apical and anal angle, respectively.

Based on the presence or absence of wings, class insecta is divided into two subclasses.

1. Apterygota and 2. Pterygota.

- The primitive **apterygotes** are **wingless**. e.g.: Silver fish and Spring tails
- Among the pterygotes, wings arise from meso- and meta- thoracic segments.
- Front pair of wings is known as forewings and back pair of wings is known as hind wings.
- Sometimes wings may be reduced among pterygotes e.g. Mallophaga and Siphunculata.
- In coccids, only males are winged; and aphids may or may not have the wings.

The arrangement of veins on the wings is called **venation** which is extensively used in insect classification. The principal longitudinal veins arranged in order from the anterior margin are costa (C), sub costa (Sc), radius (R), median (M), cubitus (Cu) and anal veins (A). Small veins often found inter connecting the longitudinal veins are called cross veins.

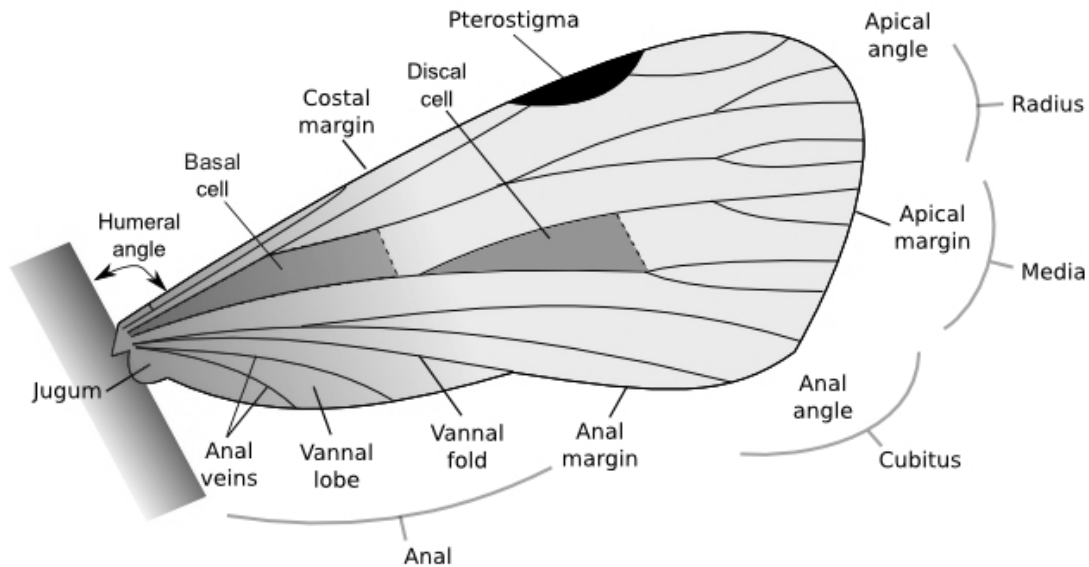
Three margins are

1. costal or anterior
2. Apical or outer and
3. Anal or inner

Three angles are

1. Humeral angle : between body wall and costal margin
2. Apical angle : between costal and apical margin
3. Anal angle : between apical and anal margin

In insects like dragonfly and damselfly, there is an opaque spot near the coastal margin of the wing called **pterostigma**.



TYPICAL WING OF INSECT

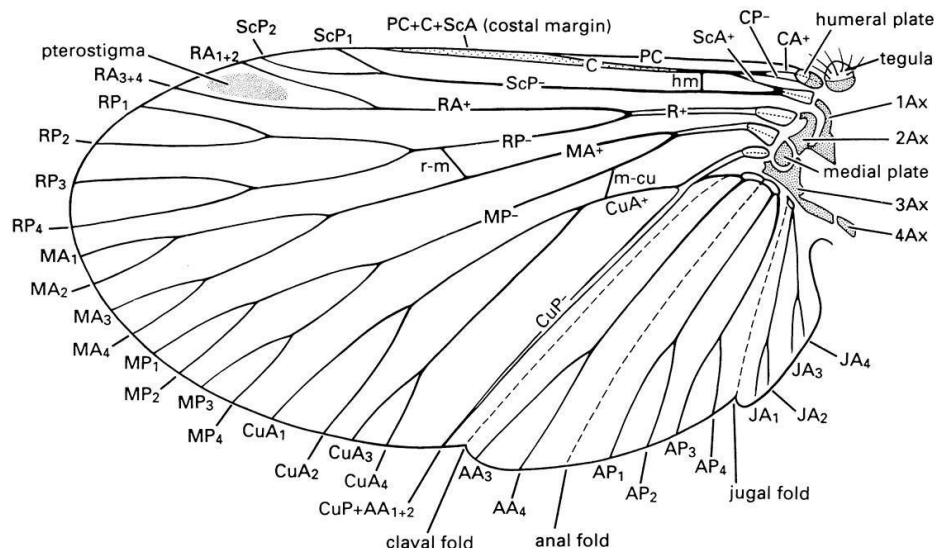
Functions of insect wings

- Flying or locomotion to search habitat, food and mate as well as escape from attack of natural enemies and adverse conditions.
- Balancing as well as protection for the insect body
- To study the systematics of insects.

Wing venation: The arrangement of longitudinal and cross veins in wing is known as wing venation. Wing venation differs in different insects. With the help of veinal arrangements, insects can be classified into different families or orders.

Types of veins:

1. **Longitudinal veins:** The principal veins arranged in order from the anterior to posterior margin.
2. **Cross veins:** Small veins often found inter connecting the longitudinal veins are called cross veins.



Description of longitudinal veins

Costa (C): It is the first anterior marginal vein hence the area of wing called costal margin.

At the leading edge of the wing, strong and marginal, extends to the apex of the wing, it is unbranched and convex (+). Sometimes it bears stigma or pterostigma on fore and hindwings of Odonata and only on forewings of Hymenoptera, Psocoptera and Mecoptera.

Subcosta (Sc): It is the second longitudinal vein and is divided distally into two branches, the outer and inner designated as Sc₁ and Sc₂, respectively. Sc is reduced or fused with R in most Hemiptera. It is concave (-).

Radius (R): It is the third vein; usually the strongest vein on the wing, with branches usually covers the largest area of wing apex. The first outer branch (R₁) runs directly towards outer margin. The second branch is often referred as radial sector (Rs) which is concave and gives branches as R₂, R₃, R₄ and R₅.

Media (M): It is the fourth longitudinal vein. It is divided into two branches viz., anterior media (MA) which is convex and divided into MA₁ and MA₂ and posterior media (MP) usually with 4 branches MP₁, MP₂, MP₃ and MP₄ and are concave.

Cubitus (Cu): It is fifth longitudinal vein; it is divided into convex anterior CuA and concave posterior CuP branches. CuA is branched into two branches and CuP is unbranched.

Anal veins (A): These are veins behind the cubitus, AA and AP are usually separated by the anal fold. They are unbranched and convex.

Jugal (J): Small veins in the jugal area which is found only in Neoptera.

Description of cross veins

Names of cross veins based on their position relative to longitudinal veins:

- c-sc cross veins run between the costa and subcosta
- r (radial) cross veins run between adjacent branches of the radius
- r-s cross vein connecting subcosta and radius
- r-m (radio-medial) cross veins run between the radius and media
- m (medial) cross vein connecting adjacent branches of the media
- m-cu (medio-cubital) cross veins run between the media and cubitus
- cu-a (cubito-anal) cross veins connecting the cubitus and first anal vein
- h (Humeral) cross veins connects the costa and subcosta near base of wing
- s (Sectorial) cross veins that either connects the radius (R₁) to the branch R₄ to R₅ or connects R₃ to R₄.

MODIFICATIONS /TYPES OF INSECT WINGS

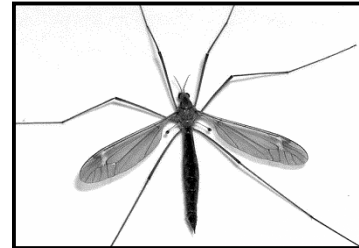
Insect wings are modified in different insects according to their habitats and use. It exhibits various shape and color patterns due to presence of scales. Some insects are primarily wingless e.g. silverfish, springtail etc., while others are secondarily wingless e.g. bed bug, louse etc. In some insects only males are winged e.g. mealy bugs, scale insects. In social insects, only reproductive forms are winged for a short time e.g. termites, ants etc. However some insects have only one pair of wings e.g. flies. The wings are smallest in the

parasitic Hymenoptera (wasps) and largest in moths and butterflies (wing expanse of atlas moth is 14'').

1. Halteres

- Only one pair of wings is present. Forewings are well developed while, hindwings are lacking and represents only by a pair of knob or thread like structures which act as balancing organ which is modified into halteres.

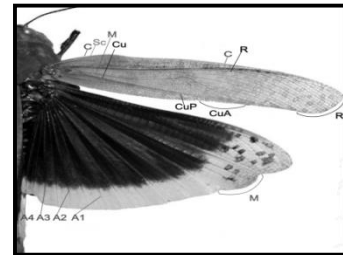
Eg. House fly, mosquito and male mealy bug



2. Tegmina

- The forewings are hardened/thickened that are completely leathery in texture while hindwings are membranous.

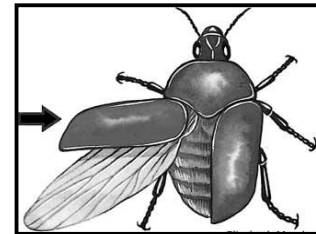
Eg. Grasshopper, cockroach, dragonflies, damselflies (orthoptera, blattodea, phasmida and dictyoptera)



3. Elytra

- Forewings are much hardened to form a hard sheath is known as elytra which serve as protective cover of membranous hindwings.

Eg. beetles (coleoptera) and earwig (dermeptera)



4. Hemelytra

- Base of the forewings are thickened, elytra like and remaining part of forewing is soft /membranous is called as hemelytra.

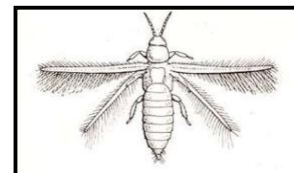
Eg. Water bug and red cotton bug (heteroptera)



5. Fringed /Feather wings

- The margins of both front and hindwings have long fringes of hair (like a feather of bird).

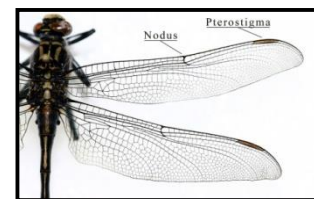
Eg. Thrips (thysanoptera)



6. Membranous:

- Both pairs of wings are thin, equal, membranous and transparent with dense network of wing venation.

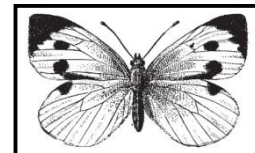
Eg. Termite, Dragonflies and Antlion (odonata, neuroptera)



7. Scaly wings

- Scales are flattened outgrowth of body wall.

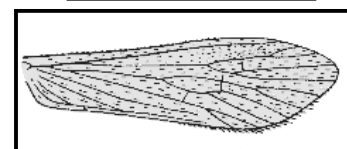
Eg. Butterfly and moth (lepidoptera)



8. Hairy wings

- Front and hind wings clothed with setae

Eg. Trichoptera



MODIFICATION /TYPES OF WING COUPLING APPARATUS

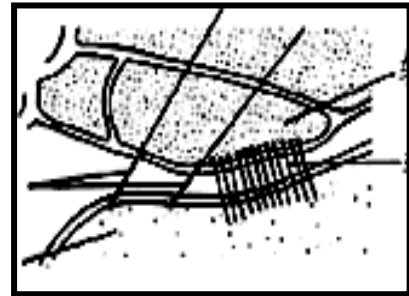
The two wings of a side usually move together during flight. The two wings are kept together by means of a structure known as wing coupling. Its structure differs in different species and sometimes among two sexes of same species.

- **Jugal lobe (Retinaculum):** Present on posterior margin of the forewing which ensure fly simply before wing overlapping.
- **Humeral lobe (Frenulum):** Present on anterior margin of the hindwings.

1. Primitive type

- Jugal lobes present at posterior margin of forewing, while humeral lobe on anterior margin of hindwing. Both lobes bear few long bristles. During flight, jugal bristle lying on top of hindwing and frenulum press the forewings from underside.

Eg. Scorpion fly (Mecopteran)



2. Jugate wing coupling

- Jugal area produced lobe like fibula or more elongated jugam. It lies on top of hindwing during flight and is folded beneath the forewing at rest.

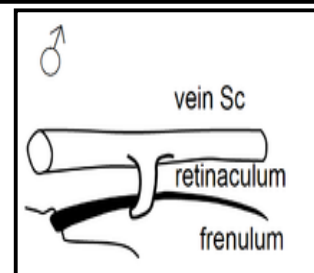
E.g. Ant lion, Chrysopa (Neuroptera)



3. Frenate wing coupling (Male)

- Forewing possess flap like hook known as retinaculum which arises from sub-costal vein of wing. Hindwing have bristle like projection known as frenulum which held into frenulum during flight. Frenular bristles are fused together and formed single stout structure.

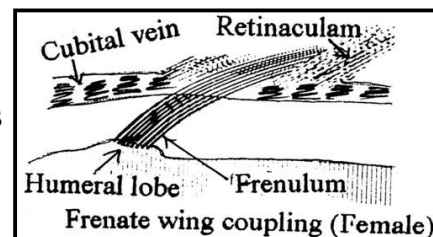
Eg. Fruit sucking moth



4. Frenate wing coupling (Female)

- Frenulum consist group of stout bristles
- Frenulum lies beneath the extended forewing and joints with retinaculum (patches of hairs)

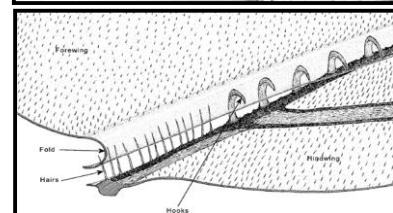
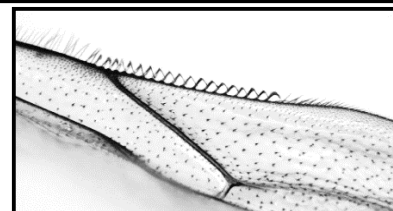
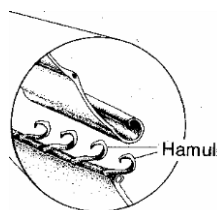
Eg. Cabbage butterfly



5. Hamuli

- Costal margin of hindwings bears row of small hooks (hamuli) which catch the sclerotized ridge of hindmargins of forewings and both wings move together during flight

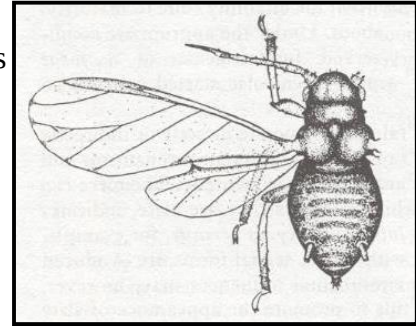
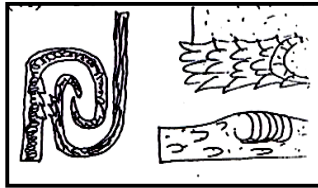
Eg. Honeybee (Hymenoptera)



6. Fold or Hook

- Wings held together in flight due to small hooks/ folds along the wing margin.

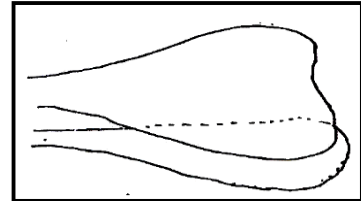
Eg. Hemiptera (aphid)



7. Amplexiform wing coupling

- It is the simplest form of wing coupling in which a linking structure is absent. Wings are coupled simply by overlapping basally.

Eg. Silkworm moth



1. DIGESTIVE SYSTEM IN INSECTS

The digestive system (alimentary canal) of insects is a long, muscular and tubular structure extending from mouth to anus which includes the parts/organs associated with ingestion (intake of food), trituration (chewing), digestion, absorption into haemolymph and egestion (elimination of undigested materials). It is divided into three regions viz., Foregut (Stomodeum), midgut (Mesenteron) and hindgut (Proctodaeum).

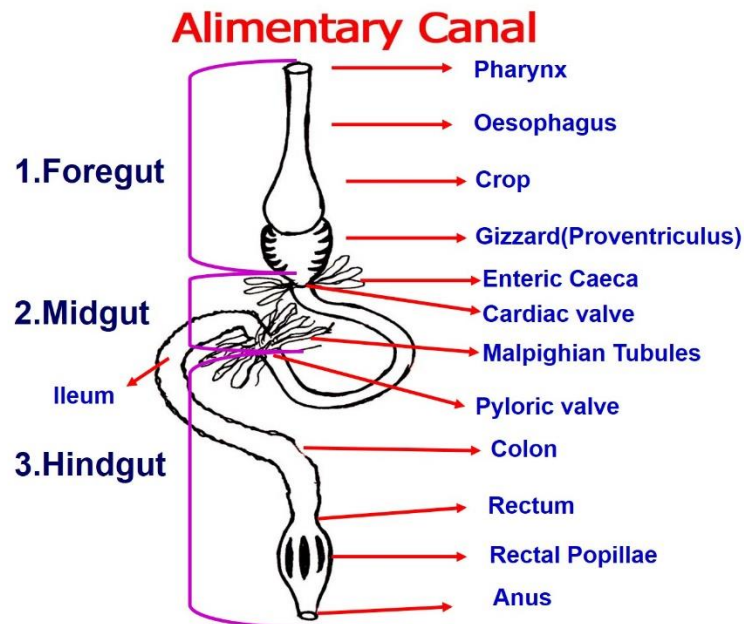


Fig. Digestive system in insects

Foregut (Stomodeum):

It is ectodermal in origin. Anterior invagination of ectoderm forms foregut (Stomodeum). The main function of foregut is ingestion and storage of the food. Internal cuticular lining is present. It includes pre oral food cavity, pharynx, oesophagus, crop and gizzard (Pro-ventriculus). Terminal mouthparts lead into a pre-oral cavity. Pre-oral cavity between epipharynx and hypopharynx is called as Cibarium. Pre-oral cavity between hypopharynx and salivary duct is Salivarium. Cibarium is a small pouch for the temporary storage of food or modified into sucking pump in hemiptera. Salivarium undergoes modification to form the salivary syringe in hemiptera and silk regulator in lepidoptera larvae.

- Pharynx** : It is the moist anterior portion of the foregut and varies greatly among different insects. It is situated between pre-oral cavity and oesophagus. In insect with biting and chewing mouth parts, the primary function of the pharynx is to receive the food ingested by the insects and to pass it on to oesophagus. Pharynx acts as a sucking pump in sucking insects (sap feeders).
- Oesophagus** : It is located between pharynx and crop. It is a narrow tube which passes the food into crop.
- Crop** : It is the dilated distal part of oesophagus acting as food reservoir and located between oesophagus and gizzard. In bees, crop is called as honey stomach where nectar conversion occurs. It collapses when empty.

- d) **Gizzard** :Proventriculus or Gizzard is the posterior (last) part of foregut and is highly sclerotized part of alimentary canal. It is found in solid feeders and absent in fluid feeders or sap feeders. The internal cuticle of gizzard is variously modified as follows.
- i. Teeth like in cockroach, grasshopper and cricket to grind and strain food.
 - ii. Plate like in honey bee to separate pollen grains from nectar
 - iii. Spine like in flea to break the blood corpuscles

Food flow from foregut to midgut is regulated through cardiac or oesophageal valve. Cardiac valve prevents the regurgitation of food from midgut to foregut.

Midgut (Mesenteron):

It is the middle part of alimentary canal. It is endodermal in origin and also called as mesenteron/ventriculus. This part contains no cuticular lining. Midgut is mainly concerned with secretion of enzymes, digestion and absorption of digested food. Midgut possess blind pouches/diverticula varying in length and number. These are two types.

- i. Gastric caecae (Enteric caecae or Hepatic caecae): Finger like outgrowths found in anterior ends of midgut. In cockroach and mantids, it is eight in number. In case of locust, grasshopper and cricket two caecae are present, whereas it is absent in collembola and lepidoptera.

Functions of caecae :It increases the surface area for secretion of digestive enzyme and absorption of water, minerals, amino acid, glucose etc.

- ii. Caecal diverticulae/Mycetomal caecae : Usually present in posterior region of ventriculus - especially in heteroptera. It possess mycetocytes, cells housing symbiotic bacteria. The bacteria present in the mycetome kills the foreign bacteria present in alimentary canal and thus provide a safe place for the multiplication of normal bacteria in the digestive track.

Filter chamber: It is found in many sap sucking homopterans and some heteropteran insects, which take large quantities of fluid to obtain adequate nourishment. Midgut is structurally and functionally modified for rapid elimination of excess water from the food. In this case, the two ends of midgut and the beginning of hind gut are enclosed in a sac known as filter chamber.

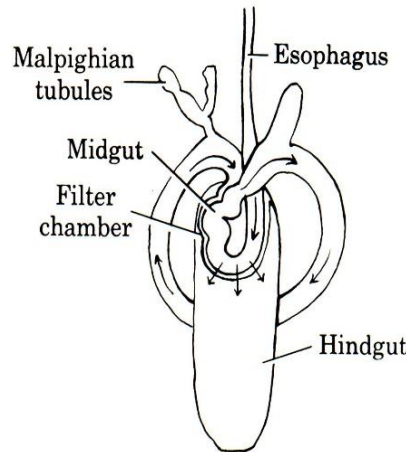


Fig. Filter chamber

Function : Rapid elimination of excess water from the food. This process avoids dilution of digestive enzymes and concentrates food for efficient digestion. Also helps in osmoregulation by preventing dilution of haemolymph. Excess water and soluble carbohydrates of food pass directly from anterior cardiac region to posterior intestine by diffusion while protein and fat are retained for digestion and absorption in ventriculus.

Important structures present in midgut are as follows:

- a) **Peritrophic membrane:** It is the internal lining of midgut, semipermeable in nature, secreted by anterior or entire layer of midgut epithelial cells. Present in solid feeders and absent in sap feeders.

Functions

- It lubricates and facilitates movement of food.
 - Envelops the food and protects the midgut epithelial cells against harder food particles.
 - Acts as barrier to microflora and prevents the infection
 - Facilitates the absorption in fluid feeders
- b) **Midgut epithelium:** It is the functional stomach where maximum amount of digestion and absorption take place. It is made up of three types of epithelial cells. (i) Secretory cells (Columnar cells): Involved in secretion of digestive enzymes and absorption of digested food (ii) Goblet cells (aged secretory cells): Involved in active transportation of potassium ion (K⁺) across the gut wall. (iii) Regenerative cells: Regenerate the new epithelial cells and replace the cells damaged by digestive enzyme.
 - c) **Pyloric valve (Proctodeal valve):** It is located between the junction of midgut and hindgut. Midgut opens into hindgut through pyloric valve, which regulate food flow.
 - d) **Malpighian tubules:** It was first discovered by Marcello Malpighi in 1669. They are located at the junction of midgut and hindgut. These are small, long, slender tubules, yellowish in colour, lying in haemocoel.

Hindgut (Proctodeum):

It is ectodermal in origin and produced by the posterior invagination of ectoderm. It extends from posterior end of midgut to anus. Internal cuticular lining is present, which is permeable to salts, ions, amino acids and water. The main function of hindgut is the absorption of water, salt and other useful substances from the faeces and urine. Hindgut is differentiated into three regions viz., ileum, colon and rectum. In the larva of scarabaeids and termites, ileum is pouch like for housing protozoan/ bacterial symbionts and acts as fermentation chamber. Ileum follows into an undifferentiated region: colon which is slender tube. Rectum is globular or pyriform and thin wall chamber. It contains rectal pads helping in dehydration of faeces and undigested material thrown out by anus as excreta.

Cryptonephridial condition:

- This is a structural modification in which the ends of malpighian tubules come into close contact with hindgut or rectum and enclosed with it under the membrane in a perinephric space. This condition is found in Adult Coleoptera, larval Lepidoptera and larval Symphyta.
- Helps in absorption of water and ions from the faeces and passes them into lumen of malpighian tubules.
- Aggregation pheromone released by female bark beetle from the secretory cells present near the junction of ileum and rectum.
- Male fruit fly, *Dacstryoni* have rectal pouches that produce sex attractant.

Digestion: Process where the food materials ingested by insect, broken down into smaller molecules such as monosaccharides and amino acids which are absorbed through gut wall.

Digestive glands:

Salivary glands: They are associated with labial segments, paired structure, lie ventral to foregut in head and thorax, occasionally extends up to abdomen. In Cockroach, a pair of labial glands acts as salivary glands where the salivary ducts open into salivarium. They are found in majority of insects but absent in most coleopteran. In caterpillars, mandibular glands are modified to secrete saliva, where the salivary glands are modified for silk production.

Functions of saliva:

- 1) To moisten and to dissolve food
- 2) To lubricate mouthparts
- 3) To add flavour to gustatory receptors
- 4) In cockroach, the saliva contains amylase for the digestion of starch.
- 5) In honey bee, saliva contains invertase for sucrose digestion
- 6) In Jassid, saliva contains lipase and protease for lipids and protein digestion. Jassid saliva also contains toxins which produce tissue necrosis and phytotoxemia on the plant parts.
- 7) In plant bug, saliva contains pectinase which helps in stylet penetration and extra intestinal digestion.

- 8) In mosquito, saliva contains anticoagulant which prevents blood clotting.
- 9) In gall midges, saliva contains Indole Acetic Acid (IAA).
- 10) In disease transmitting vectors, the saliva paves way for the entry of pathogens.

Digestive enzymes

Insect Group	Enzyme	Substrate
Phytophagous larvae	Amylase	Starch
	Maltase	Maltose
	Invertase	Sucrose
Omnivorous insects	Protease	Protein
	Lipase	Lipid
Nectar feeders	Invertase	Sucrose
Wood boring insects and Termites	Cellulase	Cellulose
Meat eating maggots	Collagenase	Collagen and elastin
Bird lice	Keratinase	Keratin

Digestion of unusual food materials

Wood

- Most of phytophagous insect cannot digest lignin, cellulose and hemicellulose
- Some insects break down cellulose by cellulase enzymes (Cerambycid larvae)
- Some insects break down cellulose through symbiotic bacteria present in hind gut (Scarabaeid larvae).
- Some insects break down cellulose through protozoans present in gut (Termite).

Wax

- Wax moth larvae feed on wax
- Bacteria plays role in digestion of wax
- The enzymes lipase, lecithinase and cholinesterase also helps in digestion.

These microbes were transmitted between individuals through food exchange (mouth to mouth feeding) called trophallaxis and through egg called as transovarial transmission.

In plant bug and ant lion grub, partial digestion occurs in the host body prior to food ingestion called as extra intestinal digestion. In most of the insects digestion occurs in mid gut.

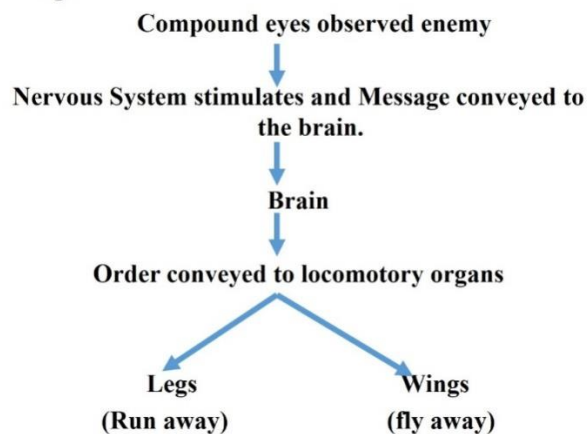
Absorption: In many insects, absorption of nutrients occurs through microvilli of midgut epithelial cells by diffusion. Absorption of water and ions occur through rectum. In cockroach, lipid absorption occurs through crop. In termites and scarabaeids (white grubs), absorption occurs through ileum. In solid feeders, resorption of water from the faeces occurs in the rectum and the faeces is expelled as pellets. In sap feeders (liquid feeders), the faeces is liquid like. The liquid faeces of homopteran bugs (aphids, mealy bugs, scales and psyllids) with soluble sugars and amino acids is known as honey dew, which attracts ants for feeding.

2. NERVOUS SYSTEM IN INSECTS

The nervous system is an information processing and conducting system, transmits electro-chemical impulses and functions as a connecting link between sense organs and effectors / responding organs.

Sense organs	Effector organs
Respond to the external as well as internal stimuli e.g. Compound eyes Antenna, Ocelli, Tympanum, Johnston organ	Respond according to instruction from the brain or ganglia e.g. Legs Muscles Wings Mouth parts Ovipositor

• e.g.:



Nervous system is composed of neurological cells and neurons.

Neurological cells: Provide support and nutrition to neurons.

Neurons: The basic component in the nervous system is the nerve cell or neuron. It is composed of a cell body, two projections (the dendrites) and the axon. Dendrites receive the stimuli and axon transmits information, either to another neuron or to an effector organs. Axon may have lateral branches called collateral or terminal arborization and synapse.

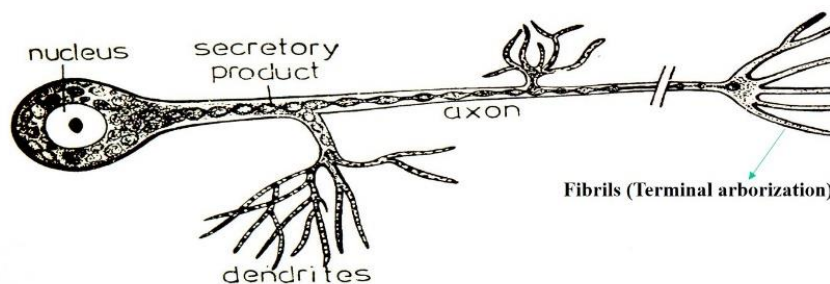
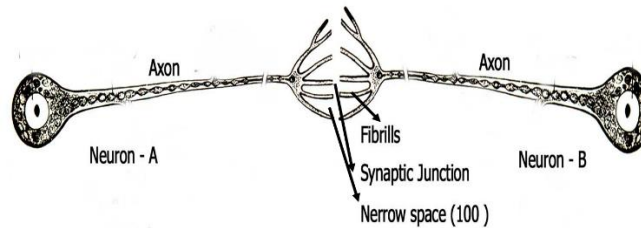


Fig. Structure of insect neuron

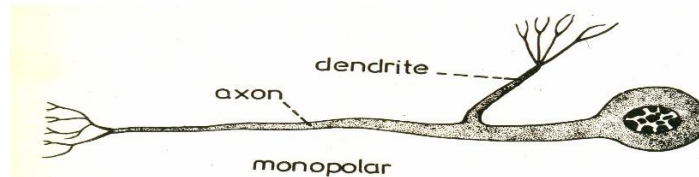
Synapse: Two adjacent axons are connected by terminal arborization or fibrils known as Synapse or Synaptic junction.



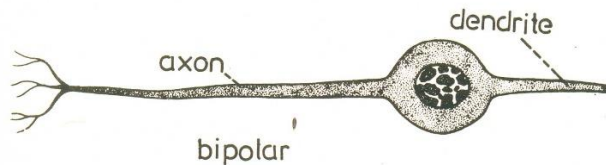
Types of neurons: Neurons are of following types based on structure and function.

A. Structural basis

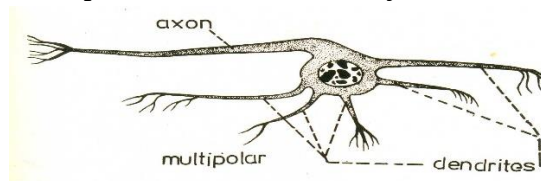
- i. Monopolar neuron: Neuron with a single axon



- ii. Bipolar neuron: with a proximal axon and a long distal dendrite.



- iii. Multipolar neuron: with a proximal axon and many distal dendrites.



B. Functional basis

- i. Sensory neuron (Afferent neuron): It conducts impulse from sense organs to central nervous system (CNS). e.g. compound eyes to brain/ganglia.
- ii. Motor neuron (Efferent neuron): It conducts impulse from CNS to effector organs e.g. brain/ganglia to legs.
- iii. Inter neuron (association neuron): It inter-links sensory and motor neurons. They are situated in brain/ganglia.

Ganglia: The cell bodies of inter neurons and motor neurons are aggregated with the fibers, inter-connecting all types of nerve cells and form nerve centers called as ganglia.

Classification of Nervous system: Nervous system can be divided in to three major sub-systems as

- i. Central nervous system (CNS)
 - ii. Visceral nervous system (VNS)
 - iii. Peripheral nervous system (PNS)
- i. Central nervous system:** It consists of double series of nerve centers (ganglia). These ganglia are connected by longitudinal and transverse tracts of nerve fibers. The longitudinal tracts of nerve fibers are termed as connectives and transverse tracts are called as commissures. Each body segment possess a pair of ganglia. Sometimes two adjacent ganglia unite to form a ganglionic center (e.g. suboesophageal ganglion). Ganglion in thorax and abdomen form a long ventral nerve cord.

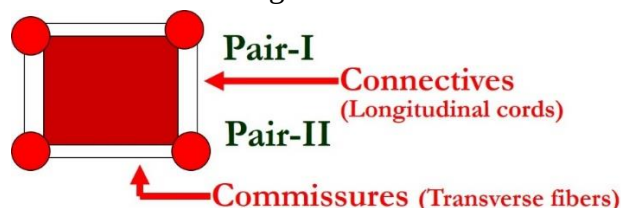


Fig. Connectives and commissures of nerve fibers

Central nervous system includes the following.

- a. Brain/ cerebral ganglion/ supra- oesophageal ganglion
 - b. Sub oesophageal ganglion
 - c. Ventral nerve cord
- a. Brain/ cerebral ganglion:** Brain is the main sensory centre controlling insect behaviour. It is situated in the head above the oesophagus, contains inter-neurons, receives message from sense organ (compound eyes, ocelli and antennae). Brain is made up of 3 lobes viz.,
- Protocerebrum: Large, innervate compound eyes and ocelli.
 - Deutocerebrum: Beneath protocerebrum, innervate antennae.
 - Tritocerebrum: Innervate labrum.
- b. Sub oesophageal ganglia:** Formed by the last three cephalic neuromeres which innervate mandible, maxillae and labium. It is connected with gland 'Corpora allata'. It is the ventral ganglionic center of head.
- c. Ventral nerve cord:** Median chain of segmental ganglia lying on the floor of thorax and abdomen. Thoracic ganglia control locomotion activity *i.e.* legs and wings. Abdominal ganglia variable in number e.g. 8 pairs in larvae which innervate spiracles.

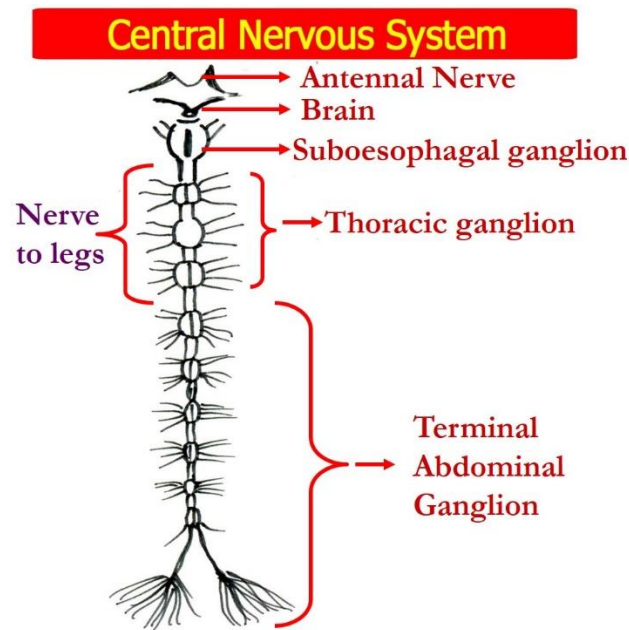


Fig. Central nervous system of insect

ii. Visceral nervous system: The visceral (sympathetic) nervous system consists of three separate systems viz., (a) Oesophageal/ stomodeal/ stomatogastric visceral nervous system (b) Ventral visceral nervous system and (c) Caudal visceral nervous system

- a. **Oesophageal/ Stomodeal/stomatogastric nervous system:** It is directly associated with the brain, situated dorsally and at side of foregut. It controls the activity of foregut, midgut and heart.
- b. **Ventral visceral nervous system:** Associated with the ventral nerve cord, consists of a pair of transverse nerves which control the activity of spiracles
- c. **Caudal visceral nervous system:** Associated with the posterior segments of abdomen, control the activity of reproductive system and hindgut.

iii. Peripheral nervous system: Includes all the nerves radiating from the ganglia of “Central” and “Sympathetic” nervous system. It consists of two types of neurons viz., Bipolar neurons and Multipolar neurons.

3. SENSE ORGANS / RECEPTORS IN INSECTS

The organs associated with sensory perception and developed from epidermal cells are called sense organs. Sense organs transform the internal / external stimulus into nerve impulse and carry to central ganglia which cause changes in behaviour of insects or maintain existing behaviour. The sense organs are classified in six groups:

1. Mechanoreceptors
2. Auditory receptors
3. Chemoreceptors
4. Thermo-receptors
5. Photo-receptors and
6. Hygro-receptors

1. Mechanoreceptors: Detect mechanical forces like gravity, pressure, touch, contact with solid object, current of air/water, mechanical stress on cuticle. These receptors are divided into four types viz.,

- i. Articulated sensory hairs/ trichoformsensilla
- ii. Campaniformsensilla
- iii. Chordotonal organs
- iv. Multipolar stretch receptors
- i. Articulated sensory hairs:** Hair like little sense organ, distributed all over body surface (*i.e.* antenna, tarsi, cerci), comprises of trichogen cell, tormogen cell, bipolar neurons. Stimulated to produce nerve impulses on movement of hairs.
- ii. Campaniformsensilla(Dome sensilla):** Dome shaped cuticular structure. These cells are sensitive to pressure and located in cerci, leg joints and wing bases.
- iii. Chordotonal sensilla (scolopidia):** Subcuticular mechano-receptors which receive vibrations are called chordotonal organ. It is a compound structure composed of number of sensilla. Each sensilla have sensory body located at abdomen, appendages and wing bases. e.g. Johnstons organ present in mosquito (male) is an example of chordotonal sensilla.
- iv. Multipolar stretch receptor:** Multipolar neuron-Associated with connective tissue / muscles.

2. Auditory receptors (detect sound waves): Noise may be transmitted through liquid and solid media but little is known of their reception by insects. Types of auditory organs are

- i. Tympanal organs
- ii. Auditory hairs
- iii. Johnston's organ
- i. Tympanal organs:** Paired organs composed of thin cuticle associated with tracheal air sacs, externally surrounded by cuticular ring. Tympanal membrane (drum like membrane) vibrates due to sound wave and auditory nerve transmit this sense to ganglion. Tympanal organs are located at...
 - the 1st abdominal abdomen of short horned grasshopper, cicada.
 - present on prothoracic tibia in cricket and katydids.
 - between the metathoracic legs of mantids.
 - the metathorax of many noctuid moths.

- the prothoracic legs of many orthopterans.
 - the wings of certain moths and lacewings.
- ii. **Auditory hairs:** Found in lepidopteran larvae. In Orthoptera, hairs on cerci respond to sound vibration frequency *i.e.* 3000 cycle/sec.
- iii. **Johnston's organ:** Highly specialized chordotonal organ, located on 2nd antennal segment (pedicel). Johnston's organ stimulates during movement of flagellum and perceives vibration of water surface and air currents. In mosquito (male), it serves as sound receptor and perceives sound of wing vibration created by female.
- 3. Chemoreceptors** (detect smell and taste): Detect chemical energy. Derived from unspecialized clothing hairs and cuticular parts. Three types of chemoreceptors are i) Common chemical sense, ii) Gustatory sense and iii) Olfactory sense
- i) Common chemical sense: Occurs all over the body and helps in avoiding reactions to high concentration of irritating substances *e.g.* acids and base.
- ii) Gustatory sense (taste): Sensilla with one pore (uniporous) detect chemicals in solid and liquid form by contact are called as gustatory receptor. Located in antenna, wall of pre-oral food cavity, mouth parts and ovipositor.
- iii) Olfactory sense (smell): Sensilla with multiple pores (multiparous) which detect chemicals in vapour/gaseous form by smell are called as olfactory receptor. Located in maxillary palps, labial palps and antennae.
- 4. Thermoreceptors** (detect heat): Sense organs (receptors) which are sensitive to temperature changes are called as thermoreceptors. Occurs on antenna, maxillary palp and tarsi. Insect can orient itself to a place having desirable temperature. *e.g.* Blood sucking insects attracted by the heat of their mammalian host (bed bug).
- 5. Photoreceptors** (Vision and visual organs): Sense organs having ability to perceive light in visible or near visible range of the electro-magnetic spectrum are termed as photoreceptors. Three types of photoreceptive structures found in insects are i) Compound eyes, ii) Lateral ocelli and iii) Dorsal ocelli.
- i) Compound eyes:** Most adult insects has a pair of compound eyes, each lies on the either side of the head capsule. The compound eye is made up of many individual units called ommatidia. Each ommatidium is marked externally by a hexagonal area called facet. Number of ommatidia varies in insects *e.g.* 6-8 ommatidia in ants, 4000 in house fly, 10000-28000 in dragonfly.

Structural parts of ommatidium:

- a) **Cornea:** Outer most part of ommatidium, transparent, biconvex, modified cuticular area often termed as facet or lens.
- b) **Corneagen cells:** Epidermal or hypodermal cells lying behind the cornea. A group of two corneagen cells secrete a single lens.
- c) **Cone or semper cells:** Four distinct cells beneath cornea which secrete crystalline and form a cone are called cone or semper cells.
- d) **Retinula cells:** The crystalline cone is followed by a long retina which is the basal part of an ommatidium. Retinular cells are generally six to ten in number which collectively secrete a light sensitive rod at the centre called rhabdom. Rhabdom contains light sensitive pigments called rhodopsin.

- e) **Pigment or iris cells:** Two groups of iris cells viz., primary and secondary pigment cells.

Types of compound eyes

According to presence and nature of crystalline cone, there are four groups viz., (a) Eucone eyes, (b) Pseudocone eyes, (c) Acone eyes and (d) Exocone eyes

- Eucone eyes: Ommatidium contains hard, refractive corneal body secreted within crystalline cone Cell. e.g. Thysanura, odonata, orthoptera
- Pseudocone eyes: Cone cells are filled with transparent liquid. e.g. Cyclorrhaphan diptera (housefly)
- Acone eyes: Crystalline cone cells – do not secrete refractive material e.g. Dermaptera (earwig), Hemiptera, Coleoptera (Weevil, Lady Bird Beetle)
- Exocone eyes: Crystalline body is replaced by cone shaped extension of inner surface of cornea. e.g. Dermestid beetle.

Types of images:

Compound eyes may form 2 types images viz., (a) Apposition image (b) Superposition image.

- Apposition image:** This type of image is formed during bright day light in Diurnal insects e.g. Butterflies. Pigment cells surrounds each ommatidia. The light rays pass through the central portion of ommatidia and cannot enter in to adjacent cells. Because primary pigment cells surrounding crystalline cone cells absorb the light rays. In this type, mosaic vision is produced. Several fragments of image combine to form whole image of an object.
- Super position image:** Primary pigment cells are absent allowing light to pass through adjacent ommatidia. Image formed in this type are indistinct and blurred. This type is seen in nocturnal and crepuscular insects (e.g. moths, ant lion).

ii) Lateral ocelli (Stemmata): Visual organs of holometabolous larva. Structure is similar to ommatidium. It helps to detect form, colour and movement, and also to scan the environment.

iii) Dorsal ocelli: Visual organs of nymph and it vary from 0-3 in numbers. It contains a single corneal lens with many visual cells individually secreting the rhabdomere. Dorsal ocelli perceive light to maintain diurnal rhythm and is not involved in image perception.

6. Hygroreceptors: Hygroreceptors are the special type of chemoreceptors that perceive moisture in air. e.g. antennae and maxillary palp of some insects.

4. CIRCULATORY SYSTEM IN INSECTS

In animal, blood circulate through special vessels (arteries, veins etc.) is known as closed circulatory system. In insects, blood circulate through body cavity (Haemocoel) irrigating tissues and organs is known as open circulatory system.

Haemocoel: General body cavity filled with blood is called haemocoel. It is divided into three sinuses by two diaphragms viz., Dorsal diaphragm and Ventral diaphragm.

Parts/ organs involved in circulatory system

1. Diaphragms and Sinuses: Two diaphragms viz., Dorsal diaphragm and Ventral diaphragm.

- i. **Dorsal or Pericardial sinus:** The compartment (sinus) above dorsal diaphragm is termed as Dorsal or Pericardial sinus. Heart or dorsal blood vessel is located in this sinus.
- ii. **Visceral or Middle sinus:** The Compartment (Sinus) between dorsal and ventral diaphragms having large cavity is known as Visceral or Middle sinus. This sinus accommodates digestive & reproductive system.
- iii. **Perineural sinus:** The compartment (Sinus) below ventral diaphragm is called as Perineural sinus. This sinus contains ventral nerve cord.

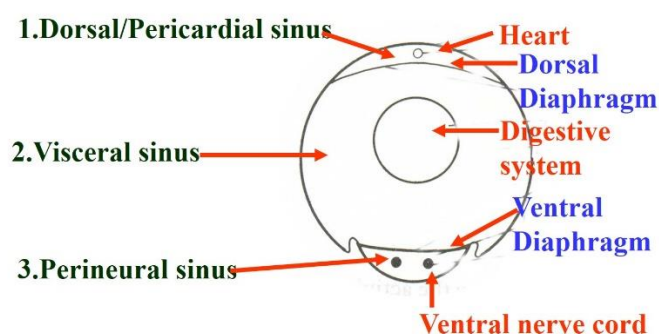
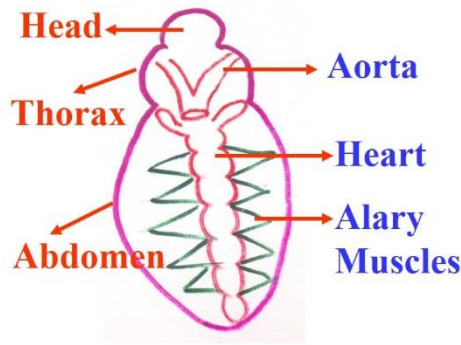


Fig. Diaphragms and Sinuses

2. The Dorsal Blood Vessel: Principal organ responsible for blood circulation is called Dorsal Blood Vessel or Dorsal Vessel. It lies or runs along the dorsal midline, just below the terga/ integument of insect body, extending from the posterior region of the abdomen to just beneath the brain in the head. The dorsal vessel is divided into two regions viz., anterior aorta (conducting vessel) and posterior heart (Pumping organ).



a) **The heart:** The heart is usually confined in abdomen and may be extended up to the prothorax in some insects. It is divided into series of chambers by successive contraction. It consists of 9 parts/ chambers from first to 9th abdominal segment. Each chamber has a pair of lateral opening called ostia by which blood enters in the chamber. The ostia permit the one-way flow of haemolymph (insect blood) into the dorsal vessel due to valves that prevent backflow. There are two types of valves viz., Auricular valve and Ventricular valve.

- i. **Auricular valve:** The wall of heart is reflected inwards and forwards at each ostium which forming auricular valve. It prevents return flow of blood into dorsal sinus.
- ii. **Ventricular valve:** It prevents backward flow of blood into heart itself.

b) **Aorta:** Anterior part of dorsal blood vessel is called Aorta. It is the principal artery of body. It is separated from the heart by aortic valve which prevent the backward flow of blood. It extends from thorax and terminate in head near brain. It has funnel like mouth or divided into two or more cephalic arteries.

3. Accessory Pulsatory Organ: Sac like pulsatile structures located at various regions of body and pulsate independently of the heart. It supplies adequate blood to fast moving appendages. They are present at the base of wings in Odonata, legs in Hemiptera, Mesothorax in Diptera and base of antenna in many insects.

4. Aliform / alary muscles: These are paired muscles with restricted origin on terga. They spread out like fan over the surface of dorsal diaphragm. They function as elastic sheets which bring out contraction and expansion of the heart.

Haemolymph and its functions

The blood of insect is commonly called as haemolymph. It is often clear and colourless but may be variously pigmented or rarely red due to haemoglobin (e.g. Chironomid larva) or green due to Chlorophyll dissolved in plasma. Haemolymph is composed of 15 to 75 % of total volume of insect body. Haemolymph is made up of Plasma and Blood cells (haemocytes).

1. **Plasma:** It is transparent, slightly acidic and contains 85 % water. It also contains Inorganic ions, proteins, amino acids, fats, organic acids, sugars etc.
2. **Blood Cells (Haemocytes):** All insects and all life stages of insect contains haemocytes.

Types of haemocytes:

- i. Prohaemocytes/ proleucocytes: Small spherical cells with large nucleus. The cytoplasm is strongly basophilic and rich in RNA. The prohaemocytes are basic stem cells which divide and give rise to other types of cells.
- ii. Plasmocytes: Most abundant haemocytes and polymorphic (amoeboid, round, oval, spindle or fusiform), have basophilic vacuolated cytoplasm.
- iii. Granulocytes: They are rounded or oval, derived from plasmatocytes. They are phagocytic and contains acidophilic granules in cytoplasm. They are largest of the three haemocytes.
- iv. Oenocytoids: They are derived from oenocytes, not from the prohaemocytes. They are large, rounded or oval in form. The cytoplasm is basophilic and nucleus is eccentric in position. e.g. found in coleopteran, hemipteran, diptera and lepidoptera.
- v. Cystocytes/ coagulocytes: They are known as coagulocytes concerned with the coagulation or clotting of haemolymph. They have a yellowish-hyaline cytoplasm containing scattered granules. The plasma membrane is not easily discernible / visible.
- vi. Spherules: They are spherical, oval or spindle shaped. They have coarse spherules that occupy the whole cell. e.g. found in lepidoptera and diptera.
- vii. Adipohaemocytes: They are characterized by refringent fat droplets and other inclusions, found in lepidoptera, diptera.

Functions of haemolymph

1. Lubricant: Haemolymph keeps the internal cells moist and the movement of internal organs is also made easy.
2. Hydraulic medium: Hydrostatic pressure developed due to blood pumping is useful in the following processes.
 - a) Ecdysis (moulting)
 - b) Wing expansion in adults
 - c) Eclosion in diptera (adult emergence from the puparium using ptilinum)
 - d) Eversion of penis in male insects
 - e) Eversion of osmeteria in papilionid larvae
 - f) Eversion of mask in naiad of dragonfly
 - g) Maintenance of body shape in soft bodied caterpillars.
3. Transport and storage of food materials and hormones
4. Protection: It helps in phagocytosis, encapsulation, detoxification, coagulation and wound healing. Non cellular component like lysozymes also kill the invading bacteria.
5. Heat transfer: Haemolymph through its movement in the circulatory system regulate the body heat (Thermoregulation).
6. Maintenance of osmotic pressure: Ions, amino acids and organic acids present in the haemolymph helps in maintaining osmotic pressure required for normal physiological functions.
7. Helps in gaseous exchange of O₂ and CO₂

Circulation of blood (haemolymph) in insect

Heart is principal pulsatory organ. The circulation of blood is maintained by the rhythmical contractions of the heart. The alary muscles helps in pulsation of heart by contraction and expansion. Contraction of heart (systole) starts from posterior end and runs forward like a wave. During diastole (expansion), the blood from pericardial sinus is drawn in the heart chamber through the incurrent ostia and during systole (contraction) the expanded lips of these ostia get closed and act as a valve so that the blood is prevented from returning through these into the pericardial sinus and is propelled forward. The blood propelled in such a manner in the aorta is discharged into the cephalic haemocoel. From the head and thoracic haemocoel the blood flows backward into the perivisceral sinus or abdominal haemocoel. The backward flow of blood is probably assisted by the undulatory movements of the ventral diaphragm.

Some blood pumped into antenna, wings and legs by accessory pulsatory organs. Finally, the blood is returned to the pericardial sinus from the perivisceral sinus.

Heart beat:

Diastole: Relaxation phase results from the relaxation of the muscles assisted by the elastic filaments supporting the heart and in some cases by the contraction of the alary muscles.

Systole: Contraction phase of heart beat results from the contraction of the muscles in the heart wall which starts posteriorly and spread forward as a wave.

Diastasis: This is the third phase in the heart circle in which heart rests in the expanded condition. Increase in the frequency of heart beat results from reduction in the period of diastasis.

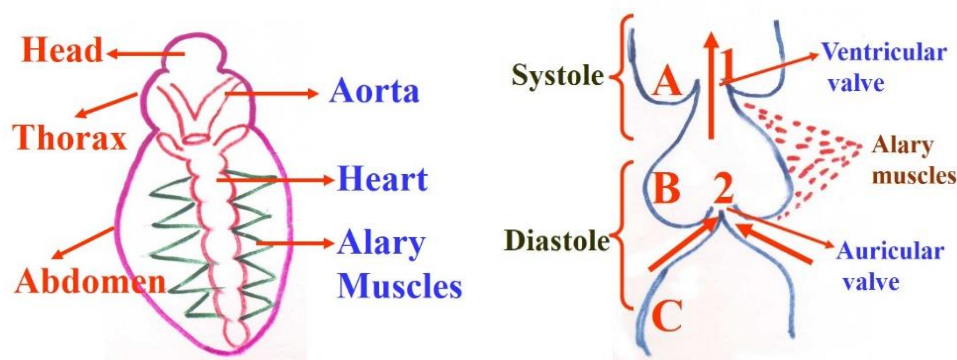


Fig. Circulation of blood (haemolymph) in insect

5. RESPIRATORY SYSTEM IN INSECTS

It is the process of gaseous exchange where in the insects takes fresh air and give out CO₂& water vapour.

OR

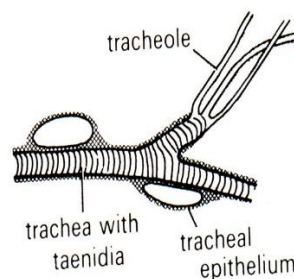
The process by which a living organism or cell takes O₂, distributes and utilizes it in oxidation and gives out the products, especially CO₂ and H₂O.

This process involves interchange of gases between the environment and the blood or cellular tissues of the organism.

There are three types ventilator system or respiration viz., 1) Tracheal respiration, 2) Integument respiration, 3) Gill or branchial respiration.

- 1) **Tracheal respiration:** It is a system of branching tubules called trachea permitting direct contact of air with the tissues through a number of openings (spiracle). External opening of tracheal system is called spiracle. Organs involved in this are tracheae, tracheoles, spiracles and air sacs.

Trachea: It is a simple elastic tube which when filled with air, present a silvery appearance through which insect breathe. It is invagination of the epidermis and thus their lining is continuous with the body cuticle. The cuticular linings of the tracheae are shed during moulting.



Taenidia: Inner layer of trachea is thickened forming visible helix like structure known as taenidia.

Function of taenidia:

- Keeps the trachea distended and thereby allow free passage of air
- Allow the tracheae to be flexible but resist compression (collapsing)
- Permits exchange of O₂& CO₂.
- Removes excess moisture in form of vapour *i.e.* outlet for loss of excess water

Tracheoles: The trachea is divided and re-divided, becoming smaller and finally each ends in a cluster of minute branches. The ultimate branches of trachea are known as tracheoles.

- It is 0.2 to 0.3 μ diameter

- It may contain air or liquid
- It may end blindly
- Its wall is freely permeable to water
- Tracheoles penetrate the cells of tissue, muscle and end intercellularly

Trachea

1. Elastic tube runs from spiracle
2. Extracellular
3. Shed off their cuticle at each moulting
4. Possess taenidia

Tracheole

1. Ultimate branching of trachea
2. Intracellular
3. Do not shed
4. Do not possess taenidia

Spiracle: The paired lateral openings located on thorax and abdomen of insect to regulate air passage and minimise water loss are termed as spiracles.

- It is ectodermal invagination.
- There are 10 pairs of spiracles, located on pleura of thoracic (2 pairs) and abdominal (8 pairs) segments.

Peritreme: The annular sclerite surrounded the external opening of spiracle is called a peritreme.

Atrium (vestibule): Spiracles have a chamber or atrium with opening and closing mechanism called atrial valve. Atrium is situated below peritreme and working as air filter. It has hairs and cuticular outgrowths, however do not possess taenidia.

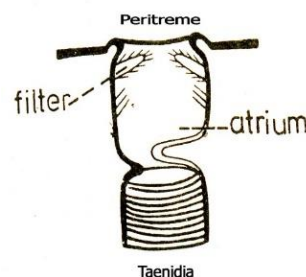


Fig. Structure of Spiracle

Classification of respiratory system based on spiracle

Based on the number and arrangement of functional spiracles, respiratory system is classified into three viz., Holopneustic, Hemipneustic and Apneustic.

1. **Holopneustic** (Open ventilator system): This is most primitive arrangement found in living insects, 10 pairs of spiracles are present (1 pro or meso-thoracic + 1 meta-thoracic + 8 in abdominal). e.g. grasshopper, Diptera (Bibionid) and some hymenoptera.

2. **Hemipneustic:** Out of 10 pairs, one or more than one pairs are non-functional. It has following **five** sub-divisions...

- i. **Peripneustic:** Metathoracic spiracles being non-functional, 9 pairs (1 prothoracic + 8 abdominal) of spiracles are functional. e.g. larvae of neuroptera (antlion), mecoptera, lepidoptera, many hymenoptera and coleoptera.
- ii. **Amphipneustic:** Only 2 pairs (1 prothoracic + 1 last abdominal) of spiracles are functional. e.g. dipteran larvae (maggot).
- iii. **Propneustic:** Only 1 pair (prothoracic) of spiracles are functional. e.g. Dipteran Pupae
- iv. **Metapneustic:** 1 pair (last abdominal) of spiracles are functional. e.g. some Dipteran larvae and aquatic larvae of Coleoptera.
- v. **Hypopneustic:** 7 functional (1 thorax + 6 abdominal), 3 non-functional. e.g. head louse

3. **Apneustic:** In this type of respiration, all spiracles are closed or non-functional and hence it is known as Apneustic(closed tracheal system) e.g. naiad of may fly and endoparasitic insects. Air enters by diffusion through the general body surface or specialized extension known as gill or branchiae e.g. Collembola, Protura, parasitic Diptera, immature stages of endoparasitic Hymenoptera.

Air sacs: In pterygote insects, tracheae are dilated in various parts of body to form thin walled vesicles or air sacs where taenidia is absent. It is easily differentiated due to glistening white vesicles. It is well developed in honey bee, house fly & scarabaeid beetles.

Functions of Air sacs:

- Assist flight by reducing specific gravity.
 - Increase volume of tidal air.
 - Act as oxygen reservoir.
 - Provide buoyancy to flying and aquatic insects.
 - Thoracic air sacs supply extra air to fast respiring muscles, wings and legs.
 - Provide extra space for growing organs (ovaries in female).
 - Allow free vibration of tympanic membrane of tympanum (auditory organ).
 - Act as heat insulators.
- 2) **Integument Respiration:** In insects that do not have tracheae or any other device for respiration, the exchange of gases takes place directly through integument e.g. Collembola, Protura, Parasitic insect larvae.
- 3) **Gill or branchial respiration:** Respiration in aquatic insects takes place through Gills or branchiae which are tracheated thin outgrowth of body wall. There are 3 types of gills found in aquatic insects viz., Tracheal gills, Spiracular gills and Blood gills.

Tracheal gills:

- Found in larvae of *Nymphulaspp*
- Filiform or lamellate structure well supplied with tracheae and tracheoles.
- Located on abdomen of many aquatic larvae and pupa.
 - Lamellate gills –found in mayfly naiad
 - Filamentous gills - found in damselfly naiad
 - Rectal gills - found in dragonfly naiad



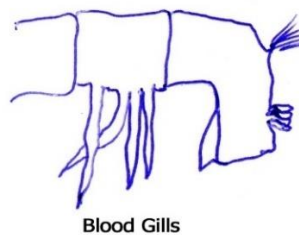
Spiracular gills:

- Found in pupae of some beetles and flies, Maggots of Tipulid and Simuliid fly.
- Spiracles drawn out to form a long process.
- One or more pairs of spiracles usually forms spiracular gills.
- Insects have spiracular gills adopted for aquatic and aerial respiration.



Blood gills:

- Well developed in wire worms or Blood worm, ChironomidDiptera
- These are tubular structures and are sometimes eversible.
- Help in absorption of water and inorganic ions rather than respiration.
- Blood of Chironomid larva contains haemoglobin dissolved in plasma which permits to take up O_2 to body tissues under low O_2 tension.
- Permit the insects to remain submerged into water for longer time.



6. EXCRETORY SYSTEM IN INSECTS

The process of elimination of waste products is known as excretion and the organs involved in this process constitutes excretory system. The excretion process helps the insect to maintain salt water balance, remove the nitrogenous waste materials and thereby maintaining pH and osmotic pressure in insect body. The eliminated substances of insects are solid, liquid or gaseous in form.

Gas - Carbon dioxide

Liquid - Water

Solid -Nitrogenous and non-nitrogenous salts.

Following are the excretory organs.

1. **Malpighian tubules:** Thin, blind-ending tubules, yellowish in colour originating near the junction of mid and hindgut, predominantly involved in regulation of salt, water and nitrogenous waste excretion. This structure was first discovered by Marcello Malpighi in 1669.

The distal ends of malpighian tubules come into close contact with hindgut. This condition is known as cryptonephridial condition or hidden kidney. The main function is to conserve water by withdrawing moisture from the faeces. The primitive number of malpighian tubules is six. They are absent in Collembola, some Thysanura and aphids, 2 in scale insects, 4 in bugs, 5 in mosquitoes, 6 in moths and butterflies, 60 in cockroach and more than 200 in locusts.

Secondary functions:

- Secrete sticky substances for covering of egg (in Chrysomelidae).
 - Produces silk to form pupal cocoon (in immature Neuroptera).
 - Light production (In some Dipteran larvae).
 - Spit production (in spit bug).
2. **Integument:** Nitrogenous wastes products are excreted while moulting of insects. During each moult, insect loses large amount of nitrogen and other substances deposited in exuviae. Ectoderm acts as excretory tissue for elimination of carbon dioxide and water.
 3. **Tracheal system:** The insect respiratory system, comprising of tracheae and tracheoles, excrete carbon dioxide and water.
 4. **Alimentary canal:**
 - In collembola, thysanura and aphid (malpighian tubules are absent), epithelial cells of midgut containing excretory substances are casted off with each moults.
 - Salts of calcium and uric acid are accumulated in midgut walls in the form of crystalline bodies. Insects make little use of calcium absorbed from food and remaining substance directly eliminated through wall of hindgut.

5. Accessory organs

- i. **Nephrocytes:** They are the group of cells found in localized regions of the body. They are divided into two groups viz., Dorsal or pericardial nephrocytes (linear series at one or either side of heart in pericardial sinus) and Ventral nephrocytes (chain of cells suspended in haemocoel below intestine and attached to salivary glands). Nephrocytes are able to absorb colloidal particles from blood, Proteins, chlorophyll etc.
- ii. **Fat bodies:** A loose or compact aggregation of rounded or polyhedral cells, mostly trophocytes, suspended in the haemocoel. They absorb and accumulate the uric acid or urates and calcium salts (storage excretion).
- iii. **Oenocytes:** Large cells found in body cavity or epidermis, associated with fat bodies and arranged in groups or scattered and working as excretory organ.
- iv. **Labial Glands:** In collembola and thysanura where malpighian tubules are absent, the labial glands are excretory in function. These are tubular structures situated at the head and open by a common duct above the base of labium.

Excretory products: Main excretory products are nitrogenous substances like Ammonia (NH_3), Urea, Uric Acid, Amino acid & Allantoin.

- Ammonia – nitrogenous excretory product in urine of aquatic insects (Ammonotelic)
- Uric acid – important in terrestrial insects (Uricotelic)
- Amino acid and Allantoin – Rarely excreted

Ammonia: Urea is broken down into Ammonia (NH_3) and CO_2 by enzymatic action. In aquatic insects ammonia is the excretory product, which is freely soluble in water and requires more amount of water for waste product removal. This type of excretion is known as Ammonotelism.

Urea: Present in small quantity in insect.

Uric Acid: It is the main excretory product of terrestrial insects, reptiles and birds. It is insoluble in water, however its Na and K salts are readily soluble. Hence, it is excreted from the body in the form of Na and K urates which requires less amount of water for waste product removal. This type of excretion is known as Uricotelism.

Allantoin: In blowfly larvae and red cotton bug, the haemolymph is quite rich in uric acid, also chiefly consists of allantoin. In these insects, uric acid is broken down by enzyme called uricase into allantoin which is soluble in water and therefore be readily excreted from the body.

Honey dew: In homopteran insects (aphid, whitefly), excrete out honey dew which contain amino compounds, fructose, glucose and glucose-1-phosphate. These insects have highly modified alimentary canal to cope with large amount of cell sap imbibed while feeding.

7. REPRODUCTIVE SYSTEM IN INSECTS

Sexual dimorphism is the condition where the two sexes of the same species exhibit different characteristics beyond the differences in their sexual organs. In insects, male and female sexes are mostly separate and this condition is seen in bees, mosquito and cockroach. In some cases, male and female reproductive system is similar in embryonic condition but in adult stage it is differentiated. In thrips, male and female R.S. look similar in adult stage. The other types are:

Gynandromorph (Sexual mosaic): Abnormal individual with secondary sexual characters of both male and female. e.g. mutant *Drosophila*.

Hermaphrodite: Male and female gonads are present in one organism. e.g. Cottony cushion scale, *Icerya purchasi*.

Male reproductive organs	Female reproductive organs
Paired testes composed of follicles (testicular tubes)	Paired ovaries composed of ovarioles (ovarian tubes)
Paired vasa deferentia	Paired oviducts
Median ejaculatory duct	Common oviduct and vagina
Accessory glands are (i) Mesadenia (ii) Ectadenia	Accessory glands are (i) Collateral glands
Seminal vesicle	Spermatheca , Bursa copulatrix
External genitalia (Aedeagus)	External genitalia: Ovipositor

Male reproductive system: The main functions of the male reproductive system are the production and storage of spermatozoa and their transport in a viable state to the reproductive tract of the female. Morphologically, the male tract consists of

1. A pair of testes
2. A pair of sperm duct or vas deferens
3. A pair of seminal vesicle
4. A median ejaculatory duct
5. A pair of accessory glands
6. An intromittent organ/ aedeagus

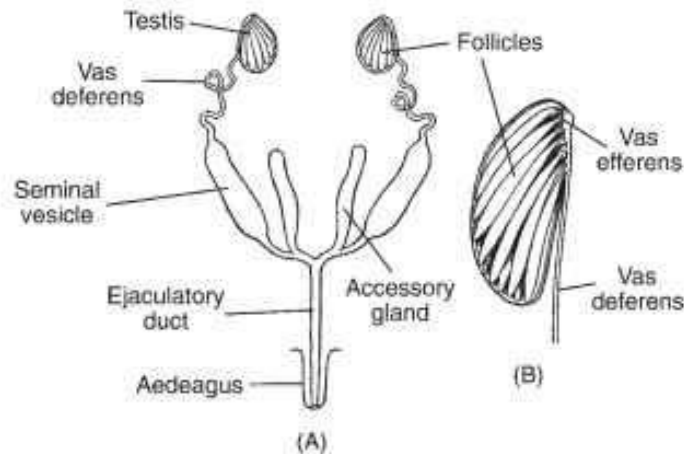


Fig. Male reproductive system

Testes: They are bilateral paired structure, which may line above or below the gut and are often close to the midline. They are smaller than ovaries and maintained in position by tracheas and fat body. Each testes are made up of several lobes or follicles. Initially, each follicle consists of a layer of epithelium resting on a basement membrane. The epithelium absorbs nutrients from haemolymph and makes them available to germ cells. Each follicles divided into 4 zones viz., 1. Germarium, 2. Zone of growth, 3. Zone of division and reduction and 4. Zone of transformation.

1. Germarium: It contains the primordial germ cells or spermatogonia which undergo multiplication.

2. Zone of growth: In this zone, spermatogonia increases in size by mitosis and develops into spermatocytes.

3. Zone of division and reduction: In this zone, spermatocytes undergo meiosis and give rise to spermatids.

4. Zone of transformation: The spermatids transformed into spermatozoa in this zone. Adult have only spermatids and spermatozoa.

Vasa deferentia or male genital ducts: They are paired canals leading from testes and mesodermal in origin. In some insects e.g. locust and grasshopper, the posterior part of vasa deferentia enlarges and forms a sac like structure called seminal vesicle in which spermatozoa stores. Frequently, a part of each duct is much convoluted forming coils for storing the sperms is termed as epididymis. Function of vasa deferentia is to receive sperms or spermatophores from testes and transport them to median ejaculatory duct.

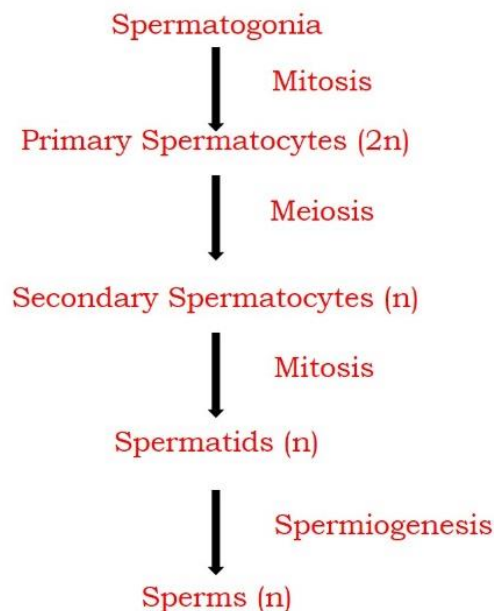
Median ejaculatory duct: The vasa deferentia unite to form short common canal which meets the median ejaculatory duct. It is ectodermal in origin.

The aedeagus: Terminal part of ejaculatory duct is often enclosed in an invagination of the body wall to finger like outgrowth called as intromittent organ or aedeagus.

The male accessory glands: The glandular structures associated with the male reproductive organs usually perform the function of secreting of mucous or viscid fluid are called male accessory glands. The fluid may be discharged as liquid form (seminal fluid) with the sperms or also may hardens to form a covering or capsule (spermatophores/ sperm bundles). Generally, number of male accessory glands are 1-3 pairs. Two types of male accessory glands are:

- i. Mesadenia: Derived from mesoderm and formed as outgrowth of the vasa deferentia.
- ii. Ectadenia: Derived from ectoderm and formed as outgrowth of the ejaculatory duct.

Spermatogenesis (occurs inside sperm tube): The production or development of mature spermatozoa is called spermatogenesis.



Female reproductive system: The main functions of female reproductive system are egg production, receiving spermatozoa from male and storage of spermatozoa until the eggs are ready to be fertilized. Morphologically female reproductive system consists of

1. A pair of ovaries
2. A paired oviduct (lateral oviduct)
3. A median oviduct
4. Accessory glands or collateral glands
5. Spermatheca (sperm pouch)
6. Bursa copulatrix (copulatory pouch)
7. Vagina (genital chamber) and gonopore

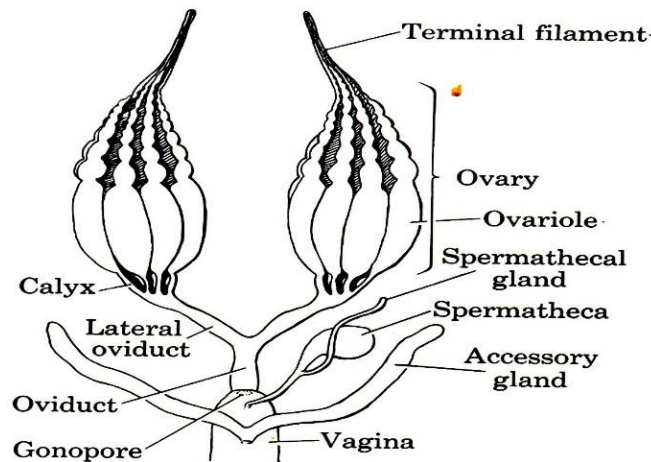


Fig. Female reproductive system

Ovaries: Compact bodies lying in body cavity of abdomen on either side of alimentary canal. Each ovary is composed of a variable number of separate egg tubes or ovarioles which opens in to the lateral oviduct. Each ovariole / egg tube is differentiated internally into four zones viz., i) Terminal filaments, ii) Germarium, iii) Vitellarium/ zone of growth and iv) Pedicel.

- i) **Terminal filaments:** Slender thread like apical prolongation of peritoneal membrane is known as terminal filament. Filaments of ovarioles of one ovary combine to form a common thread which unite with the ovary of opposite sides and form a median ligament which helps developing ovaries to remain suspended in haemocoel.
- ii) **The germarium:** Apex of ovariole and located below terminal filaments. It contains cells that differentiate to form the primordial germ cells.
- iii) **The vitellarium:** Major portion of an ovariole. It contains the developing eggs and nutritive cells (Nurse cells or trophocytes).
- iv) **Pedicel/ stalk:** A short duct connecting the egg tube with lateral oviduct is pedicel. It is mesodermal in origin.

Lateral oviduct: Proximal ends of ovarioles from each ovary unite to form lateral oviduct on each side. It is mesodermal in origin.

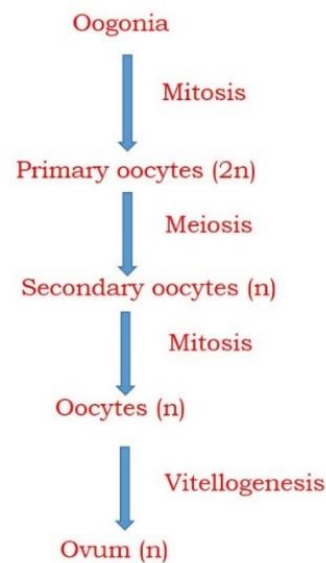
Female genital duct / common oviduct: Oviducts are paired canals leading from ovaries and two ducts unite forming a common oviduct. In Glossina (Tsetse fly), the vagina is enlarged and form a chamber 'Uterus'.

Accessory glands / collateral glands/ cement glands: These are one or two pairs of glands often produce substance for attaching the eggs to the substratum during oviposition. e.g. egg case production in mantid, ootheca formation in cockroach, venom production in bees.

Spermatheca: Pouch or sac like structure, ectodermal in origin. Function of spermatheca is to receive and store spermatozoa. The spermatheca opens on dorsal wall of genital duct.

Bursa copulatrix: Pouch / chamber like development of vaginal region opens through 9th abdominal segment by genital aperture. This chamber serves as a copulatory pouch during mating and thus it is known as bursa copulatrix. Its external opening is called as vulva. In many insects, the vulva is narrow and the bursa copulatrix becomes an enclosed pouch or tube referred to as vagina.

Oogenesis (occurs inside egg tube): The production or development of egg or ovum is called oogenesis.



Types of reproduction

Reproduction: Production of young ones or off spring is referred to reproduction. Reproduction is done in various ways.

1. **Oviparity:** Majority of female insects, are oviparous, lay eggs. Embryonic development occurs after oviposition by utilizing the yolk, e.g. Head louse, moths.
2. **Viviparity:** Unlike oviparous, here initiation of egg development takes place within the mother. The life cycle is shortened by retention of eggs and even developing young within the mother. Four main types of viviparity are observed in different insect groups.
 - i. **Ovo-viviparity:** Fertilized eggs containing yolk are incubated inside the reproductive tract of the female and hatching of egg occur just prior to or soon after oviposition e.g. thrips, some cockroaches, few beetles, and flesh fly. Fecundity of this group is low.
 - ii. **Pseudo-placental viviparity:** This occurs when a yolk deficient egg develops in the genital tract of the female. The mother provides a special placenta-like tissue, through which nutrients are transferred to developing embryos. There is no oral feeding and larvae are laid upon hatching. e.g. aphids, some earwigs, psocids and polytenid bugs.

- iii. **Haemocoelousviviparity:** This involves embryos developing free in the female's haemolymph with nutrients taken up by osmosis. This form of internal parasitism occurs only in strepsiptera and some gall midges.
- iv. **Adenotrophicviviparity:** This occurs when a poorly developed larva hatches and feeds orally from accessory gland (milk gland) secretion within the uterus of the mother. The full grown larva is deposited and pupates immediately (e.g.) Tsetse flies, louse, ked, bat flies.

3. **Parthenogenesis:** Reproduction without fertilization is parthenogenesis. Different types of parthenogenesis are as follows:

a. **Based on occurrence**

- Facultative (not compulsory) e.g. bee.
- Obligatory or constant (compulsory) e.g. stick insect
- Cyclic/ sporadic: alternation of gamic and agamic population e.g. aphid.

b. **Based on sex produced:**

- Arrhenotoky: Produce male e.g. bee
- Thelytoky: produce female e.g. aphids
- Amphitoky / deuterotoky: produce both male and female e.g. Cynipid wasp.

c. **Based on meiosis:**

- Apomictic : no meiosis occurs
- Automictic : meiosis occurs, but diploidy is maintained

4. **Polyembryony:** This form of asexual reproduction involves the production of two or more embryos from one egg by subdivision. Mostly observed in parasitic insects (e.g. *Platygaster*). Nutrition for a large number of developing embryo cannot be supplied by the original egg and is acquired from the host's haemolymph through a specialized enveloping membrane called **trophamnion**.

5. **Paedogenesis:** Some insects cut short their life cycles by loss of adult and pupal stages. In this precocious stage gonads develop and give birth to young one by parthenogenesis *i.e.* reproduction by immature insects.

- Larval paedogenesis –seen in Gall midges
- Pupal paedogenesis – seen in Blister beetle

Male and female genital organs

In most insects, the 8th and 9th abdominal segments are greatly modified to form reproductive appendages or external genitalia. The 9th abdominal segment in male insects and 8th and 9th abdominal segments in the female insects form the genital apparatus (gonopod).

Male genital organs:

The male genitalia are placed on posterior side of 9th abdominal sternum to form copulatory organ. In a typical male pterygote insect, the complete external genitalia are composed of anaedeagus (penis), two pairs of parameres or inner processes and a pair of claspers that serves to grasp the female while mating.

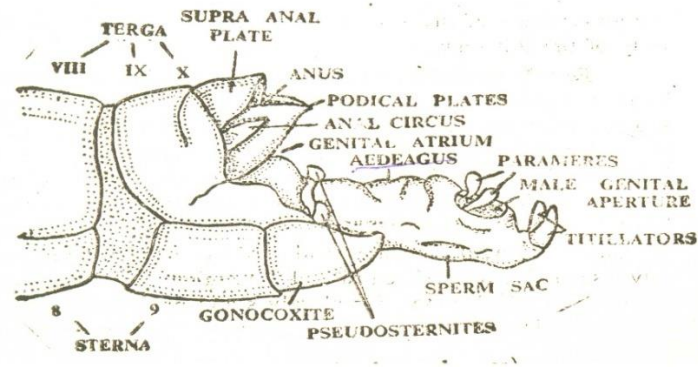


Fig. Male genital organs

Aedeagus (penis): Intromittent (male copulatory organ) structures are present for penetrating the body wall and depositing sperms known as aedeagus. It lies between the claspers. It is composed of penis (usually unpaired but double in mayfly and lobe-like in cockroach) and used for sperm injecting.

Parameres: Usually in 2 pairs. Forceps like structure, which act as a principle genital clasper in adult.

Claspers: one pair, helps in gripping the female during copulation.

Female genital organs:

In all female, genital opening in 9th abdominal segment structurally serving for egg deposition and it is known as ovipositor or external genitalia. Female genitalia consists of 3 pairs of valves viz., dorsal valve, anal valve, ventral valve. In mallophaga (e.g. Bird lice) and siphunculata (e.g. human lice) ovipositor is vestigial, so eggs are dropped. In grasshopper, ovipositor is elongated and powerful to lay eggs in soil. In Hymenoptera, it is not used for egg laying but modified to form poison injecting apparatus called Sting.

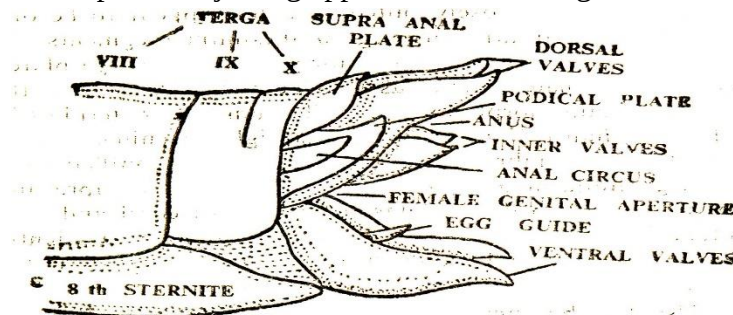


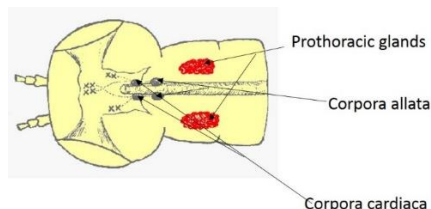
Fig. Female genital organs

8. ENDOCRINE SYSTEM IN INSECTS

Endocrine system helps to maintain homeostasis, coordinate behaviour and regulate growth, development and other physiological activities. The endocrine system in insect is made up of followings:

1. Endocrine glands
2. Neurohemal organs
3. Neurosecretory cells
4. Internal organs

1. **Endocrine glands:** Secretory structures adapted for producing hormones and releasing them into the circulatory system is called endocrine glands. In insects, the largest and most obvious endocrine glands are found in the prothorax, just behind the head and called as prothoracic glands. These prothoracic glands manufacture ecdysteroids which stimulate synthesis of chitin and protein in epidermal cells and trigger physiological events that culminates in moulting. Hence, the ecdysteroids are often called “moulting hormones”. Once the insect reaches the adult stage, its prothoracic glands wither away and stop molting.



2. **Neurohemal organs:** Similar to glands, but they store their secretory product in a special chamber until stimulated to release it by a signal from the nervous system (or another hormone). e.g. corpora cardiaca and corpora allata.

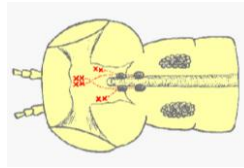
Corpora cardiaca: A pair of neurohemal organs located on the walls of the aorta just behind the brain are called corpora cardiaca. This paired structures secrete peptide hormone called prothoracicotropic hormone (PTTH) only after they receive a signal from neurosecretory cells present in the brain. PTTH acts as a chemical messenger and stimulates the prothoracic glands to produce and release ecdysteroids.

Corpora allata: Another pair of neurohemal organs, lie just behind the corpora cardiaca are called corpora allata. They manufacture juvenile hormone (JH). Juvenile hormone inhibits the development of adult characteristics during the immature stages and promotes sexual

maturity during the adult stage. Neurosecretory cells present in the brain stimulate the activity of corpora allata to produce JH.

3. Neurosecretory cells: Specialized nerve cells (neurons) that respond to stimulation by producing and secreting specific chemical messengers are termed as neurosecretory cells.

The neurosecretory cells are found in clusters, both medially and laterally in the insect's brain. Axons from these cells can be found along with tiny nerves which run to the corpora cardiaca and corpora allata. The cells produce and secrete brain hormone which is very similar to prothoracicotropic hormone (PTTH). Functionally, they serve as a link between the nervous system and the endocrine system and also influence the function of other endocrine glands.



4. Internal organs: Many other tissues and organs of the body also produce hormones. e.g. Ovaries and testes produce gonadal hormones to coordinate courtship and mating behaviours. Ventral ganglia in the nervous system produce eclosion hormone and bursicon. Eclosion hormone helps an insect in moulting and bursicon causes hardening and tanning of the new exoskeleton.

Weismann's ring: Formed by the fusion of corpora cardiaca, corpora allata, prothoracic glands and hypocerebral ganglion to secrete puparium hardening hormone. Present in maggots of Dipteran flies.

PART IV

1. Systematics: Taxonomy –importance, history and development and binomial nomenclature

The study of identification and relationships among living organisms is called **systematics**. The term systematics was used by **Carolus Linnaeus** (1707-1778). The branch of biology dealing with identification, nomenclature and classification of organism is called **taxonomy**. *Taxonomy* is a word used mainly in biology to talk about classifying living organisms, organizing them according to their similarities. The word comes very straight forwardly from Greek words for "arrangement" — *taxis* — and "method" — *nomia*. So any special method for arranging or organizing things can be called **taxonomy**. The term **taxonomy** (Gr., *taxis*= arrangement; *nomos*=law) was coined by **A.P. de Candolle** (1813).

Taxonomy is the branch of biology that names and groups organisms according to their characteristics and evolutionary history.

In short, **Taxonomy is the science of classification**. Taxonomists arrange species into classifications based on the theory and principles of identifying, describing, naming and classifying an organism, using morphological, behavioural and genetical as well as biochemical observations.

Simpson (1961) has defined **taxonomy as the theoretical study of classification including basis, principles, procedures and rules**. According to Simpson, "Systematics is the scientific study of kind and diversity of organisms and any and all relationships among them". Taxonomy includes nomenclature and classification.

Nomenclature: The system or procedure of assigning names to groups of organism as part of a taxonomic classification.

Classification: The arrangement of organisms into groups on the basis of their relationships.

Evolution: The gradual development of living organism. **OR** The process by which different kinds of living organism is believed to have developed from earlier forms during the history of the earth.

Stages of Taxonomy

- (i) **Alpha taxonomy (α) : concerned with naming and characterization of species.**
The level of taxonomic study concerned with characterizing and naming species.
- (ii) **Beta taxonomy (β): Concerned with classification**
The level of taxonomic study dealing with the arrangement of species into lower and higher taxa.
- (iii) **Gama taxonomy (γ) : Concerned with evolutionary relations and phylogeny.**
The level of taxonomic study concerned with biological aspects of taxa, including intraspecific populations, speciation, and evolutionary rates and trends.

IMPORTANCE OF TAXONOMY

1. Provide Taxonomy

- The vertebrate groups can be thoroughly understood
- Describe biodiversity before we lose it

2. Provide Specimen Identification

- Provide identification of beneficial, harmful and diverse species of natural organisms

3. Maintain Collections

- Collections serve as a permanent archive
- Serve as a permanent record of a species
- It allows for the documentation of biotic change
- Provide specimens from extirpated populations
- Allows future workers to verify work

4. Classification

- Provide framework of names that is universal and stable
- Framework provides a means of communicating across languages and cultures
- Classification must reflect phylogeny

5. Phylogeny Estimation

- Understanding of evolutionary novelty
- Study of evolutionary patterns and processes
- Co-speciation e.g. between parasites and their hosts
- Historical biogeography

HISTORY OF TAXONOMY

1. **Aristotle (384-322 B.C.):** The classification system was introduced by the Greek philosopher Aristotle (384-322 B.C.), considered as **father of Zoology**, studied under [Plato](#). He studied the living organisms, viz., plants and animals and gave the statement on classification that “animals may be characterized according to their way of living, their action, their habit and their body parts”. He developed the 1st widely accepted system of biological classification classified the major groups of animals as insects, fishes, birds and whales, hence he is considered as **father of Biological Taxonomy**.
2. **Carolus Linnaeus (1753):** Use of a species name based on looking at physical and structural similarities. The Swedish botanist, Carolus Linnaeus (1707-1778) developed the **modern system of taxonomy**. He published his scheme classification in his famous book “*Systema Naturae*” in 1753. He is considered to be the “**Father of Taxonomy**” (classification).

1758: Binomial nomenclature is the system developed by **Carolus Linnaeus**, who laid the foundations for the modern biological naming scheme of binomial nomenclature in 1758. He gave system of writing the name of organisms in two words. The first word of the name belongs to the **genus**; other word belongs to that

specific animal or plant and is called **species**. e.g. the **house fly** as *Musca domestica* and the Humans are named: *Homo sapiens*

He developed a Hierarchy (a ranking system) for classifying organisms that is the Basis for Modern Taxonomy.

For this reason, he is considered to be “father” of modern taxonomy.

- Linnaeus used an organisms morphology (form and structure), to categorize it.
 - His system is still being used today.
 - His system allowed organisms to be grouped with similar organisms.
 - He first divided all organisms into two Kingdoms, Plantae (Plants) AND Animalia (animals).
 - This was the same as Aristotle’s main categories.
3. **Charles Darwin (1809-1882)**: The English naturalist Charles Darwin (1809-1882) also contributed and shaping up the classification system.

These are three most important men in the history of taxonomy before the twentieth century.

The word species, genus, and family were first used by **John Ray (1627-1705)**. His most important contribution was the establishment of species as the ultimate unit of taxonomy.

The word class and order were used by **Linnaeus** and he published the tenth edition of **Systema Naturae** in 1758 including global fauna.

The term phylum was given by **George Cuvier (1769-1832)**.

Post-Linnaean taxonomy

Modern System a Nested Hierarchy-Seven Levels of Organization

❖ Modern System:

- Each kingdom (plant and animal) was divided into a phylum* (division for plants)
- Each phylum into smaller groups called class.
- Each class was divided into an order.
- Each order was divided into family (families).
- Each family was divided into a genus (plural-genera)
- Each genus was divided into a species. (scientific name)

*Note: Phyla and family were not in Linnaeus’s classification system but were added by modern scientists.

Modern Taxonomy

- Now based on evolutionary relationships
- Taxonomists study:
 - Structural similarities
 - Chromosomal structure (karyotypes)

- Reproductive potential
- Biochemical similarities
 - Comparing DNA and amino acids
- Embryology/development
- Breeding behavior
- Geographic distribution

Changes in the zoological code are decided upon by the International Commission on Zoological Nomenclature, elected by the international society of zoologists. The zoological code differs in many ways from the botanical. Among other things, species do not need to be described in Latin.

The German biologist **Willi Hennig** (1913–1976) founded the cladistic era in 1966, by stating that only similarities grouping species (synapomorphies) should be used in classification, and that taxa should include all descendants from one single ancestor (the rule of monophyly). With the invention of the polymerase chain reaction (PCR), which made it economically possible to amplify DNA-sequences for use in systematics, and the strong development of computer programs that could handle large data sets, cladistics became more or less the rule for systematic work.

Phylocode

Two zoologists from USA, **Kevin de Queiroz and Jacques Gauthier**, started the discussions in the 1990's and laid the theoretical foundation to a new nomenclatural code for all organisms, the PhyloCode. A meeting in Harvard in 1998 drew out the lines for a PhyloCode, and a first draft was published on the web in 2000.

The main idea with the PhyloCode is that only species and clades should have names, and that all ranks above species are excluded from nomenclature. The aim is to change current names as little as possible and to build the stability on clades rather than on ranks.

The PhyloCode is still only a draft, it is controversial, and has led to a worldwide and very interesting debate. Its success will depend on the number of taxonomists that will use it for their taxonomic work.

NOMENCLATURE OF ORGANISMS

When we classify any animal its nomenclature is the first requirement. Therefore, two types of names (1) **Common (Vernacular) names** (2) **Scientific names** of organisms are used. The well known animals and plants are known by different names in different languages and countries of the world. For popular organisms different local names are used in different parts of a country. This causes a main problem in the study of organisms because a person of other place or language cannot understand about that organism. For example, the bird that we know as sparrow (gauraiya) in India and Pakistan is known by different name in other countries, house sparrow, pardal, musch, suzune etc. in England, Spain, Holland, Japan and so on sequentially. The easiest solution to all such problems is only to assign one

scientific name for this animal- *Passer domesticus* Linnaeus, so that it can be studied easily throughout the world.

BINOMIAL NOMENCLATURE

This is the system developed by **Carolus Linnaeus** a Swedish botanist, who laid the foundations for the modern biological naming scheme of binomial nomenclature in 1758. He published his scheme classification in his famous book “***Systema Naturae***” in 1753. He is considered to be the “**Father of Taxonomy**” (classification). He gave system of writing the name of organisms in two words. The first word of the name belongs to the **genus**; other word belongs to that specific animal or plant and is called **species**. e.g. **Humans** are named: ***Homo sapiens***; name of the honey bee as, ***Apis mellifera***; the **house fly** as ***Musca domestica*** and the **lion** as ***Panthera leo***.

TRINOMIAL NOMENCLATURE

To designate a subspecies, a trinomial nomenclature is used wherein the subspecific name also written over and above the generic and specific names.

e.g. Rat- *Rattus rattus frizivorous* Linnaeus, Mustard sawfly - *Athalia lugens proxima* (Klug), *Homo sapience sapience* Linnaeus

THE INTERNATIONAL RULES OF ZOOLOGICAL NOMENCLATURE

In 1898, the **International Congress of Zoology** organised an International Commission on Zoological Nomenclature to formulate a set of rules, which would be binding for all taxonomical publications. The aim of International Code of Nomenclature is to make the stability in naming the taxa, avoiding the use of names which may cause error or confusion. A few commonly followed rules are given below:

- Zoological or botanical names are independent *i.e.* same generic and specific names may be applied to both *i.e.* plants and animals.
- Scientific names must be in **Latin** or Latinized and should be written and underlined or printed in *Italics*.
- Family names are formed by adding **idae** to the stem of the name of the type genus e.g. canis-Canidae
- Generic name consists of a single words and its first letter written in capital. The letters should be set in *italic i.e.* slanting types or underlined. Generic names are noun.
- Second name is specific. It should also be italicized or underlined and written in small letters (no capital). It is usually an adjective.
- The specific name should be followed by the name of the author or taxonomist who described that species for the first time. e.g. Frog - *Rana tigrina* Linnaeus, honey bee- ***Apis mellifera***

Significance of classification (Convenience of study)

- Knowledge of affinities (relationship)
- Knowledge of sequence of evaluation

- Knowledge of connecting links
- Knowledge of adaptation (variation)
- Knowledge of phylogeny

According to **Darwin** (1850), “All natural beings are found to resemble each other in descending degree, so that they can be classed in groups under groups”. All groups of animals can individually be subdivided into smaller and smaller subgroups. Within the invertebrates we can distinguish subgroups as annelida and arthropoda; within the arthropoda, chelicerata and mandibulata; within the chelicerata, crustacea, myriapoda and insecta and so forth. The task of classification then is the delimitation of these groups and their arrangement in an orderly sequence, i.e., hierarchy.

Hierarchy: It is a systematic framework with a sequence of classes (sets) at different levels in which each class, except the lowest, includes one or more subordinate classes. **OR** A ranking system from general to specific.

Linnaeus was the first taxonomist to establish a definite hierarchy of taxonomic categories recognised within the animal kingdom. He has given seven step hierarchy for classification known as Linnaeus hierarchy. These are kingdom, phylum, class, order, family, genus and species. The varieties, used by Linnaeus as an optional category of various types of intraspecific variants, was eventually discarded or replaced by the species. Most are formed by combining the original category names with the prefixes super or sub. Thus, there are super order, super families and subfamilies etc. Some used terms for additional subdivisions, such as infraclass, cohort, infraorder and tribe.

Outline of hierarchy of generally accepted taxonomic categories are **21** given hereunder.

Kingdom

Phylum

Sub-phylum

Super-class

Class

Sub-class

Infraclass

Cohort

Super-order

Order

Sub-order

Infraorder

Super-family

Family

Sub-family

Tribe

Subtribe

Genus

Sub-genus

Species

Sub-species

EXERCISE

1. What are the seven levels of organization that Linnaeus used to categorize organisms?
2. What criterion do modern taxonomists use to classify an organism?
3. What are two reasons that species names are more precise than common names?
4. Explain Linnaeus's system of classification, and identify the main criterion he used to classify organisms.
5. **Fill in the blanks with appropriate word(s)**
 - i. **Linnaeus** was the first taxonomist to establish a definite hierarchy of taxonomic categories recognised within the animal kingdom.
 - ii. **Linnaeus** published the tenth edition of **Systema Naturae** in **1758** including global fauna.
 - iii. The term phylum was given by **George Cuvier**.
 - iv. The classification system was introduced by the Greek philosopher **Aristotle**, considered as **Father of Zoology**.
 - v. The level of taxonomic study concerned with characterizing and naming species is known as **Alpha taxonomy**.
 - vi. The level of taxonomic study dealing with the arrangement of species into lower and higher taxa is known as **Beta taxonomy**.
 - vii. The level of taxonomic study concerned with biological aspects of taxa, including intraspecific populations, speciation, and evolutionary rates and trends is known as **Gama taxonomy**.

6. Match the following

No.	Group A	Group B (Answer)
1	Alpha taxonomy	Concerned with naming and characterization of species
2	Beta taxonomy	Concerned with classification
3	Gama taxonomy	Concerned with evolutionary relations and phylogeny
4	Linnaeus	<i>Systema Naturae</i>
5	Aristotle	Father of Zoology
6	Classification	Arrangement of organisms
7	Evolution	Gradual development of organism
8	Linnaeus	Father of Taxonomy
9	George Cuvier	Coined the Term 'Phylum'

7. Define the following term

i. Taxonomy	ii. Systematics	iii. Classification	iv. Hierarchy
v. Nomenclature	vi. Species	vii. Genus	viii. Family
ix. Order	x. Class		

2. Definitions of Biotype, Sub-species, Species, Genus, Family and Order

BIOTYPE

A group of organisms having the same or nearly the same genotype, such as a particular strain of an insect species. **OR**

A group of genetically identical organisms within a species. Individual or population of any species not separated morphologically.

SUB-SPECIES

A sub-division of a species, usually inhabiting a particular area: visibly different from other populations of the same species but still able to interbreed with them.

A subspecies is further division of a species based on minor but constant differences in structure, appearance or biology. Individuals in different subspecies will be morphologically or genetically different from one another but still capable of interbreeding and producing viable offspring.

SPECIES

The basic unit of living things, consisting of a group of individuals which all look more or less alike and which can all breed with each other to produce another generation of similar creatures. Species is one of the seven taxonomic ranks used to classify living organisms.

A species can be defined as a group of organisms that can breed and produce fertile offspring.

In modern taxonomy scientists now consider a species to be a group of evolving organisms and have moved away from the idea of a historical *Type specimen* representing the form of a species.

GENUS

A taxonomic category ranking used in biological classification that is below a family and above a species level, and includes group(s) of species that are structurally similar or phylogenetically related.

A group of closely related species (plural: genera). The name of the genus is incorporated into the scientific names of all the member species: *Pieris napi* and *Pieris rapae*, for example, both belong to the genus *Pieris*

FAMILY

It is the sub division of order contains a group of related genera. It is classify between order and genera.

A taxonomic subdivision of an order, suborder, or superfamily that contains a group of related subfamilies, tribes and genera. Family names always end in -idae.

ORDER

A subdivision of a class or subclass containing a group of related families.

Order is one of the seven taxonomic ranks used to classify living organisms. Order is positioned after Class and before Family.

1. Kingdom

2. Phylum
3. Class
4. Order
5. Family
6. Genus
7. Species

There are 29 insect Orders (According to A. D. Imms) although, like much of biological classification, this is still being discussed and changed by scientists.

Class: It is the major sub division of phylum which constituting several orders

Phylum: It is the major primary sub division of animal kingdom

EXERCISE

1. Define / Explain

- i. Biotype
- ii. Species
- iii. Genus
- iv. Family
- v. Order
- vi. Class
- vii. Phylum

2. Fill in the gap with most appropriate word

- i. Family is the sub division of order contains a group of related genera.
- ii. According to A. D. Imms insects are classified into 29 orders.
- iii. Class is the major sub division of phylum which constituting several orders
- iv. The basic unit of living things, consisting of a group of individuals which can breed with each other to produce another generation of similar creatures is called species.

3. Classification of class Insecta up to Orders

Insects are the six legged flying arthropods coming under the phylum Arthropoda and class Insecta. The widely accepted classification of insects was proposed by the eminent insect taxonomist **A. D. Imms (29 orders)**.

Characters of class Insecta

1. Body is divided into three regions viz, head, thorax and abdomen
2. Thorax is the centre of locomotion with, 3 pairs of jointed legs and
3. Presence of two or one pair of wings
4. In head, a pair of sensory antenna and
5. A pair of compound eyes is usually present.
6. Excretion is mainly through Malpighian tubules.
7. Tracheal system of respiration well developed.
8. Possesses open circulatory system

9. Decentralized Nervous system. Brain is divided into protocerebrum, deutocerebrum and tritocerebrum.
10. Possess exoskeleton made up of hard cuticle which plays important role for survival.
11. Presence of metamorphosis (incomplete/complete) during development

CLASSIFICATION OF CLASS INSECTA UP TO ORDERS

(IMM'S CLASSIFICATION)

The class Insecta has **two subclasses** viz., Apterygota (Ametabola) and Pterygota (Metabola).

Characteristics of subclasses:

	Apterygota (Ametabola)	Pterygota (Metabola)
1.	Primarily wingless -evolved from wingless ancestors.	Winged or secondarily wingless- evolved from winged ancestors e.g. Flea, head louse, bed bug.
2.	Metamorphosis is absent or slight and simple.	Present and variable
3.	Mandibular articulation in head is monocondylic i.e. single	Dicondylic i.e., double.
4.	Mouth parts are hidden in the head	Mouthparts are exposed
5.	Pleural sulcus in thorax is absent.	Present.
6.	Pregenital abdominal appendages present.	Absent.
7.	Adults moult several times	Adults do not moult

The subclass Apterygota has 4 orders namely

Apterous insects, the wingless condition being primitive, with slight or no metamorphosis. One or more pairs of abdominal appendages present other than genitalia and cerci.

[A] Subclass: Apterygota - (Primitively wingless insects) / Ametabola

1. Protura (Pro = first; oura = tail) – Proturans, *Acerentomon* sp.
2. Diplura (Di = two; oura = tail) – Diplurans, Twintails
3. Collembola (Colla = glue; embolon= boll) – Springtails
4. Thysanura (*Thysanos* = fringe; oura = tail) – Silverfish, Bristletails

[B] Subclass : Pterygota – Winged insects

Winged insects which are sometimes secondarily apterous. Metamorphosis very varied, rarely slight or wanting. No abdominal appendages present other than genitalia and cerci.

Characteristics of subclasses:

	Exopterygota (Hemimetabola)	Endopterygota (Holometabola)
1	Wings develop externally	Wings develop internally
2	Metamorphosis incomplete and simple	Metamorphosis complete and complex
3	Active immature stages (nymphs) resemble adults in structure and habits	Active immature stages (larva) differ adults in structure and habits
4	No pupal instar	Pupal instar present
5	Three stages: Egg – Nymph - Adults	Four stages: Egg – Larva – Pupa – Adults
6	Food habits of both nymph and adults same	Food habits of both nymph and adults different
7.	Habitat of nymph and adults same	Habitat of all stages mostly differing.

[I] Division Exopterygota (incomplete metamorphosis) / Hemimetabola

DIVISION I. EXOPTERYGOTA (=Heterometabola) Insects passing through a simple and sometimes slight metamorphosis, rarely accompanied by a pupal instar. The wings develop externally and the larvae are generalized nymphs.

5. Ephemeroptera (Ephemeros = lasting a day; ptera = wing) – Mayflies
6. Odonata* (Odoun = tooth) – Dragonflies and Damselflies
7. Plecoptera (Plecus = plaited; ptera = wing) – Stonefly
8. Grylloblattodea (Gryllus = a cricket; blatta = a cockroach) – *Grylloblata*
9. Orthoptera* (Orthos = straight; ptera = wing) – Grasshoppers, Katydids, Crickets, Locust, Mole crickets
10. Phasmida* (A specter, an apparition) – Stick insects, Leaf insects
11. Dermaptera* (Derma = skin; ptera = wing) – Earwigs
12. Embioptera (Embio = lively; ptera = wing) – Webspinners
13. Dictyoptera*/** (Dictyon = net; ptera = wing) – Cockroaches, Mantids
14. Isoptera* (Iso = equal/similar; ptera = wing) – Termites
15. Zoroptera (Zoros = purely; ptera = wing) – Zoropterans
16. Psocoptera – Book lice, Psocid
17. Mallophaga** (Mallos = wool; phagein = to eat) – Bird lice (Biting lice)
18. Anoplura/Siphunculata** (Anoplos = unarmed; oura = tail)– Human lice
19. Mantophasmatodea# – Gladiator
20. Hemiptera* (Hemi = half; ptera = wing) – True bugs, Hoppers, Whiteflies, Psyllids, Aphids, Scales, Mealybugs, Ciccadas...
21. Thysanoptera* (Thysanos = fringe; ptera = wing) – Thrips

Division II. ENDOPTERYGOTA (=Holometabola)

Insects passing through a complex metamorphosis always accompanied by a pupal instar. The wings develop internally and the larvae are usually specialized.

[II] Division Endopterygota (complete metamorphosis) / Holometabola

22. Neuroptera* (Neuron = nerves; ptera = wing) – Antlion, Chrysopa, Dobsonfly, Alderfly, Snakefly
23. Mecoptera (Mecos = length; ptera = wing) – Scorpionfly
24. Lepidoptera* (Lepidos = scale; ptera = wing) – Butterfly, Moth
25. Trichoptera (Trichos = hair; ptera = wing) – Caddisfly
26. Diptera*/** (Di = two; ptera = wing) – House fly, Tsetse fly, Fruit fly, Crane fly, Blow fly, Hessian fly, Robber fly, Phorid fly (Mushroom pest), Syrphid fly, Tsetse fly, Tachinid fly, Horse fly
27. Siphonaptera** (Siphon = tube; ptera = wing) – Fleas
28. Hymenoptera*/** (Hymen = membrane; ptera = wing) – Honeybees, Wasps, Sawfly, Ants, Chalcidfly
29. Coleoptera* (Coleos = sheath; ptera = wing) – Mangostem borer, Weevil, Ladybird beetle, White grub
30. Strepsiptera (Strepsis = twisted; ptera = wing) – Stylopids

*** Order of Agriculture importance and ** Order of Veterinary importance**

This is newly reported smallest order of insect, but its acceptance is yet to wait.

EXERCISE

1. Write the classification of class Insecta up to orders with examples (According to A. D. Imms)
2. Classify the division Endopterygota up to order level with proper examples
3. Classify the division Exopterygota up to order level with proper examples
4. Write the characteristics of class Insecta
5. Differentiate the following
 - i. Exopterygota and Endopterygota
 - ii. Hemimetabola and Holometabola
 - iii. Ametabola and Metabola
 - iv. Apterygota and Pterygota

4. Major characteristics of orders. Basic groups of present day insects with special emphasis to orders and families of Agricultural importance

1. Orthoptera: (Orthos = Straight; Ptera = Wing) e. g. Grass hopper, cricket and locust

This is a large order with more than 21000 described species worldwide. The insects of this order are found more in the tropics but some species do occur in the coldest zone.

Generally, they are terrestrial and usually capable of jumping. Some members of this order are strong fliers, all belonging to the family Acrididae. Some of the grass hoppers are important pests of field crops, e.g. paddy grass hopper, surface grass hopper, crickets etc. The locusts which fly gregarious in large numbers invade distant areas causing depletion of green biomass resulting in famine and starvation.

General characters of Orthoptera

- Medium to large sized insects with well developed exoskeleton.
- Head is hypognathous.
- They are winged.
- Fore wings modified into tegmina.
- Hind legs often enlarged for jumping purpose (saltatorial leg).
- Special sound producing and auditory organs often present (Stridulatorial legs in cricket).
- Cerci short and one segmented.
- They have chewing and biting type of mouthparts.
- Female has well developed ovipositor; male genitalia symmetrical.
- They have incomplete metamorphosis.
- Mostly herbivorous (some are predaceous and omnivorous).

A. Sub order: Ensifera e. g. Crickets and long horned grasshoppers

- Antenna longer than their body.
- Tympanal organs present on their fore tibia, tarsi 3 to 4 segmented.
- Ovipositor elongated.

Sr. No.	Name of Family	Characters
1	Tettigonidae	• e. g. Katydid (Long horn grasshopper) <i>Tetigonia</i> sp. • Antennae are very long. • Tegmina modified asymmetrically for stridulation. • Four segmented tarsi • Predominantly green colour. • They have long laterally flattened, blade like ovipositor. • Mainly diurnal
2	Gryllidae	• e. g. House cricket <i>Gryllus domesticus</i>

		• Head large and antennae very long. • Eye large. • Hind legs modified for jumping type. • Tarsal segment not more than three segments • Cerci long and unjointed. • Ovipositor long, slender and needle like or cylindrical. • Most male crickets stridulate by friction of modified tegmina and produce a loud chirping sound. • Mainly nocturnal
3	Gryllotalpidae	• e. g. Mole cricket, <i>Gryllotalpa africana</i> • Antennae short. • Tarsi 2 to 3 segmented. • Forelegs modified for digging (Fossorial). • Tympanum on fore tibia. • Eyes small. • Ovipositor small.

B. Sub order: Caelifera e. g. Short horned grasshoppers and locusts

- Antennae shorter than body.
- Hind legs adapted for leaping.
- Tarsi not more than three segmented.
- Ovipositor short and stout.
- Tympanal organ present at the base of abdomen.

Sr. No.	Name of Family	Characters
1	Acrididae	• e.g. Locusts (<i>Scitocera gragaria</i>), Surface grasshopper (<i>Chrotogonus</i> sp.) and Rice grasshopper (<i>Hieroglyphus banian</i>) • Forewings invariably leathery called tegmina. • Pronotum is collar shaped. • Ovipositor well developed, short and curved. • Hind legs modified as jumping. • Grasshoppers stridulate by rubbing their long hind legs against their wings for producing the buzzing sound. • Mouth parts chewing type, eyes and antennae well developed. • Auditory organs located on each side of the basal segment of abdomen.

2. Dictyoptera: (Dictyon = Net; Ptera = Wing) e. g. Cockroach and Mantids

They are medium or large sized insects. They are terrestrial and occurring in tropical and subtropical region. They are not good flier. The order includes two distinct sub orders.

General characters of Dictyoptera

- Long filiform antennae

- They have two pairs of wings, but the front pair is leathery (tegmina type) and held flat over the body when at rest.
- Biting type of mouth parts
- Pronotum large as in praying mantis and shield shaped as in cockroaches.
- Ovipositor reduced.
- Tarsi 5 segmented.
- Stridulatory and auditory organs absent.
- Cerci (two small appendages sticking out of the rear of the insect) are visible.
- Mainly nocturnal and omnivorous.

A. Sub order: Blattoidea e. g. Cockroaches

- Head nearly or completely cover.
- Pronotum shield shaped.
- Cerci prominent.
- Swift runners with ambulatorial and curssorial type of legs.
- Antennae long filiform.
- Mouthparts are typically mendibulate.
- Compound eyes present.
- They are nocturnal but also seen venturing during day time.
- They are omnivorous.
- They are household pests and spoil kitchen articles and food.

B. Sub order: Mantoidea e. g. Mantid

- Pronotum large elongated.
- Forelegs raptorial, helps in seizing the prey.
- Antennae long filiform.
- Head triangular with vertical head and freely movable hence can see at 360°.
- Generally triangular heads having large compound eyes on both side and generally three ocelli situated in between.
- Elongated prothorax
- They are cryptic as predatory adaptations
- Eggs are deposited in ootheca or capsule formed of frothy quick drying material.
- They are largely arboreal and occur in all warmer parts of the world.
- They are carnivorous and live predaceous life both as young and adult.
- They feed on grasshoppers, flies, caterpillars etc.
- The female usually devours the male after mating.

3. Order: ODONATA (*Odonto* = Strong Teeth) e. g. Dragonfly and damselfly

These conspicuous insects comprise a largely tropical order containing about 5500 described species. These are predatory insects. They catch and devour small flying insects. These are found in large numbers flying nearby stream, river etc. It can fly at a speed of 100 km/hr. They are fastest flying insects. The nymphs are aquatic in habit. Wide range of coloration is found in the adult.

General characters of Odonata

- Minute antennae
- Extremely large eyes
- Strong fliers, with two pairs of transparent membranous wings
- In flight dragonfly can propel itself in six directions
- Long slender abdomen
- Basket like legs, which are important for the capturing of prey
- Highly predaceous with chewing mouth parts
- Hemimetabolous (Incomplete metamorphosis)
- Diurnal habits
- Larval stage (naiads) with posterior tracheal gills for exchange of gases
- Aquatic nymph, territorial/aerial adult

A. Sub order: Anisoptera e. g. Dragonfly

- Predacious insect with biting mouthparts..
- Large insects with two pairs of unequal membranous wings, each with a large number of veins and cross veins and a prominent stigma known as Pterostigma.
- Unequal wings. Hind pair broadened basally.
- Wings held horizontally at rest.
- Antennae setaceous very small and the eyes are very long.
- Abdomen extremely long and slender.
- Metamorphosis hemimetabolous.
- Nymph is aquatic; respiration by means of caudal or rectal gills.
- They are diurnal in habit found in proximity of water.

B. Sub order: Zygoptera e. g. Damselflies

- Fore and hind wings similar and petiolated basally.
- Wings held vertically above the abdomen.
- Eyes projected laterally and separated by a space more than their dorsal diameter.
- Nymphs are slender, elongated abdomen and three caudal gills.
- They are diurnal in habit, found in proximity of water and predaceous in nature.

4. Order: NEUROPTERA (Neuron = Nerve; Ptera = Wing) e.g. Green lacewing (*Chrysoperla carnea*) and Antlions (*Myrmeleon*)

Approximately 5000-6000 species are described.

General characters of Neuroptera

- Two pairs of wing are similar membranous and folded roof like over the body at rest.
- Mandibulosuctorial type mouthparts.
- Prothorax often larger than meso- and metathorax.
- Cerci absent.
- Antennae long well developed and filiform.
- Larvae campodeiform with prognathous head and predaceous in nature.

- Pupae exarate dectious.
- Both larvae and the adults are predaceous on other insects.
- Ant lions are often attracted to light at night. During the day it hides amidst the vegetation.

Economic importance of Neuroptera

- Chrysopa feeds on aphids thus act as biological control agent of aphids.
- The larvae of ant lions feed on ants. The ant lion prepare a tunnel like pits in the soil when the runaway ants slips into the pit, the larvae capture the victim and sucks out the body fluids.

Sr. No.	Name of Family	Characters
1	Chrysopidae	• e. g. Green lacewing (<i>Chrysopa</i> sp.) • Antennae longer than forewings. • Biting mouthparts • Mandibles long and strong. • Wings and body green • Bronze/golden compound eyes. • Eggs stalked. • Larvae with hooked hair on the body for supporting the dead host. • Chrysopa feeds on aphids.
2	Myrmeleontidae	• e. g. Antlion • Antennae longer than forewings. • The adult has two pairs of long, narrow, multi-veined wings in which the apical veins enclose regular oblong spaces. • It has long, slender abdomen. • It has prominent, apical clubbed antennae. • They are highly active in desert regions and are a nuisance. • They will deliver a small, mildly painful bite if given the chance to land on someone.

5. Order: ISOPTERA (Iso = Equal; Pteron = Wings) e.g. Termites

The isoptera is a small order of some 2600 described species of hemimetabolous neopterans. Termites are found throughout the tropics. Termites live in a nest called **termitaria** which are subterranean and which sometimes rise above the soil surface as large mounds. A termite colony has usually royal pair – the king and the queen which are primary reproductive castes; sterile castes consist of soldiers and workers, both are apterous. They feed on wood and are able to digest cellulose with the help of protozoa in their gut. They exhibit symbiosis with intestinal protozoans.

Different castes in a termite colony

- 1) **Queen:** It is reproductive caste that is responsible for maintaining the population of workers and soldiers in the termitaria.

- 2) **King:** It has a function of copulation with queen and accompany the queen for rest life
- 3) **Soldier:** They perform the function of patrolling the termitaria and defend the colony from the enemies. Soldiers have large heads armed with pincer-like mandibles (jaws). Soldiers are wingless
- 4) **Workers:** They are actual workers, who find and collect foods and nourish young one, queen, king and maintain cleanliness of termitaria. Workers are wingless

General characters of Isoptera

- Termites are soft bodied social and polymorphic (Queen, king, soldiers and workers) insects living in large communities.
- Two pairs of similar wings present in sexually mature males and females during breeding season only.
- The wings are deciduous.
- The wings are membranous with restricted venation.
- Mouthparts biting and chewing type.
- Termites feed predominantly on cellulose rich material; wood, rotting timber, paper, books, furniture, many harvest grasses, many crops etc.
- Antennae short moniliform.
- External genitalia are absent or rudimentary in both sexes.
- Incomplete metamorphosis
- Very common in tropical and subtropical climates and less abundant in temperate regions.

Sr. No.	Name of Family	Characters
1	Termitidae	• e. g. <i>Odontotermes obesus</i> and <i>Microtermes obesi</i>. • Ground dwelling with wide range of food habits and colony structure. • Worker castes well developed. • Pest of sandy soils and wood. • Wings very slightly reticulate. • Pronotum of workers and soldiers narrow with raised anterior lobe.

6. Order: THYSANOPTERA (Thysanos = Fringed; Aura = Tail) e.g. Thrips

This is a worldwide order of minute to small insects commonly known as thrips, comprising about 5000 species. They are mostly yellow, yellowish brown or black and may found among all kinds of vegetation, both on reproductive and vegetative parts. When disturbed, some species crawl in a leisurely fashion, other run quickly or leap and large number is flying but do not readily do so. Member of this order cause damage to cotton, onion, castor, groundnut, pulses, rose, tomato, chilly, tobacco etc.

General characters of Thysanoptera

- Their development is intermediate between hemi- and holometabolous; metamorphosis accompanied by two or three inactive pupa-like instars.

- The body is slender and elongate.
- Head hypognathus.
- Short antennae with 6 to 10 segment.
- Mouthparts are asymmetrical stylet like for rasping and sucking type.
- Right mandible is reduced in size.
- Fore and hind wings are similar and narrow with a long fringe.
- Legs do not have claws
- In female the cerci are absent.
- Many species curving the abdominal tip upward and movement.
- Some thrips are beneficial as pollinators and as natural enemies of mites, scales and pest thrips.

Sr. No.	Name of Family	Characters
1	Thripidae	• e. g. <i>Thrips tabaci</i> • Mouthparts not bilaterally symmetrical. Thrips are the only insects that have asymmetrical mouthparts. • The right mandible disappears during embryogenesis. • Tarsus has claw like appendages. • Antennae 4-9 segmented with slender, simple or forked sense cones. • At rest the wings are parallel. • In female the cerci are absent.

7. Order: HEMIPTERA (Hemi = Half; Ptera = Wing) e.g. Aphids, Jassids, Whiteflies, Mealy bugs, Scale insects, Red cotton bug

The hemiptera distributed worldwide and is most diverse of the non endopterygote orders, with more than 90000 described species. The hemiptera or “true bugs” are easily recognized by the form of their mouthparts. Some of them are blood suckers and transmits diseases in vertebrate animals. Several bugs are natural enemies that help to destroy insect pest.

General characters of Hemiptera

- Usually small to large insects.
- Bugs have somewhat flattened body.
- Forewings are hemelytra (i.e. leathery at the base and membranous at the tip) in Heteroptera and uniform wings in Homoptera.
- Mouthparts piercing and sucking type, mandibles and maxillae are modified into needle like stylets.
- Metamorphosis usually gradual (incomplete), rarely complete.

Economic importance of Hemiptera

- Aphid, jassid and whitefly act as vectors of plant viruses.
- They transmit many diseases in plant.
- They suck the cell sap from the plant parts and cause economic damage.

- They attack a wide variety of crops, vegetables crops, fruit crops, garden crops etc and cause heavy loss farmers.

A. Sub-order: Homoptera

- Forewing either leathery or membranous folded roof like.
- Abundant discharge of a sugary waste product of honey dew especially in aphids.
- Pronotum small.
- Eggs lay singly mostly in plant tissues.
- Hemimetabolous.
- No scutellum.
- Body shape is wedged or oval, slender and elongated.

Sr. No.	Name of Family	Characters
1	Cicadellidae	• e.g. Leaf hopper (<i>Amrasca bigutella bigutella</i>), Green leaf hopper (<i>Nephotettix virescens</i>), and Mango planthopper (<i>Ideocerus atkinsoni</i>) • This is the largest family of homoptera • Comb-like rows of large spines along tibia of hind legs. • Wedge shaped or slender in form. • Ocelli absent. • Antenna 8 segmented when disturbed they often leap several feet and always ready for flight. • An adult walks diagonally. • Leafhoppers are important carriers of plant diseases -- especially mycoplasmas.
2	Delphacidae	• e.g. brown planthopper, <i>Nilaparvata lugens</i> • Median ocellus absent. • Thumblike antenna • Hind tibia large. • Movable spur on the hind tarsus. • Large aedeagus.
3	Aphididae	• e.g. Mustard aphid (<i>Lipaphis erysimi</i>), Cotton aphid (<i>Aphis gossypii</i>), Peach aphid (<i>Myzus persicae</i>) and Black bean aphid (<i>Aphis craccivora</i>) • Winged or wingless adults. • Ocelli absent and cornicles present on abdomen. • Antennae 2-3 segmented. • Tarsi 2 segmented having pair of claws. • Parthenogenetic reproduction.
4	Aleurodidae	• e.g. Cotton whitefly (<i>Bemisia tabaci</i>), Citrus whitefly (<i>Dialeurodes citri</i>) and Sugarcane whitefly (<i>Aleurolobus barodensis</i>) • Nymphs attach to the undersides of leaves and become immobile, resembling scale insects. • Wings powdery with white waxy material. • Wing venation reduced.

		• Excrete honeydews. • Incomplete metamorphosis.
5	Lophopidae	• e.g Palm planthopper • The face being longer than wide with at least two lateral ridges (the median ridge/carina may be absent). • The hind tibia can bear two to three spines. • Lateral ocelli are present below the compound eye. • The wings are broad and held somewhat flat.
6	Coccidae	• e.g., Green scale insect, <i>Coccus viridis</i>; tortoise scale, <i>Toumeyella parvicornis</i> • Most species are sedentary during most of their life cycle and secrete a protective covering over their bodies. • Males harmless without mouthparts. • Females smooth with smooth integument. • Body small inconspicuous, soft covered with wax, scale like or gall like structures or powdery exudates. • Antennae much reduced or absent. • They secrete honeydew. • Rostrum small and double segmented.

B. Sub-order: Heteroptera

- Two pairs of wing present which are different to each other folded flat over the abdomen.
- Mouthparts typically piercing and sucking type.
- Flat body.
- Antennae 4-5 segmented.
- Large pronotum, trapezoidal or rounded in shape.
- Formation of shield like scutellum.
- Forewings basally sclerotized and apically membranous called hemelytra and hind wings are transparent and membranous.
- Habitats -- terrestrial, aquatic and semi-aquatic.
- Members of heteroptera are known as true bugs

Sr. No.	Name of Family	Characters
1	Pentatomidae	• e. g. Painted bug (<i>Bagrada hilaris</i>), Stink bugs. • Moderate to large insects often brightly coloured. • Scutellum large that cover half abdomen. • Rostrum 4 segmented. Tarsi 2-3 segmented. • Ocelli always present. • Well developed hemelytra. • Triangular bugs with five segmented antennae.
2	Coreidae	• e.g. Rice gundhi bug (<i>Leptocoris acuta</i>), Leaf footed bug • Head narrower than thorax • Medium to large sized, elongated or oval polyphagous insects.

		• Both antennae and rostrum 4 segmented. • Many parallel veins in membranes of front wings • Ocelli present. • Scutellum small. • Legs strong with pulvelli. • Scent glands opening conspicuous that produce disagreeable odour.
3	Cimicidae	• e. g. Bed bug (<i>Cimex lectularius</i>) • Ectoparasites of man and other animals • Ocelli absent • Contrasting to other insects, male bedbugs don't place their sperm directly in the female's reproductive tract but they puncture female's abdomen and inject the sperm into female's body cavity. The sperm swim to the ovaries and fertilize the eggs.
4	Pyrrhocoridae	• e. g. Red cotton bug (<i>Dysdercus koenigii</i>). • Insect contrasting red and black colouration. • More veins in the forewing membrane • Both antennae and rostrum 4 segmented. • Ocelli absent. • Polyphagous insects and gregarious in habit. • Primarily granivorous or fructivorous
5	Lygaeidae	• e. g. Dusky cotton bug (<i>Oxycarenus hyalinipennis</i>); <i>Geocoris bullatis</i>, a beneficial predator • Ocelli present. • Small, dark or brightly coloured insects. • Antennae inserted below the head. • Veins in the hemelytra never more than five. • Mostly seed feeders, a few are predatory(<i>Geocoris</i>) .
6	Pseudococcidae	• e. g. Citrus mealy bug <i>Planococcus citri</i>; Cotton mealy bug, <i>Phenacoccus solenopsis</i> • Sexually dimorphic • Female wingless, male are winged • Males are short lived, do not feed only live to fertilize the female.

8. LEPIDOPTERA (*Lepidos* = Scale; *Pteron* = Wings) e. g. Butterfly and moth

The Lepidoptera is one of the major insect orders, both in terms of size with some 180000 described species. Both moth and butterfly live on nectar of flowers; over ripen fruits, honey dew and other substances are members of this order.

General characters of lepidoptera

- Small to large insects with two pairs of membranous wings covered with overlapping flat scales.
- Forewings are larger than hind wings its shape is different from hind wings.

- Antennae pectinate, bipectinate or club shaped.
- Mouthparts siphoning type spirally coiled suctorial proboscis.
- Larvae phytophagous, polypod and having biting type of mouthparts.
- Pupae adecticous and obtect type typically form the cocoon or earthen cell.
- Head hypognathus.
- Butterflies are diurnal and moths are nocturnal.
- Holometabolus insects.

Economic importance of lepidoptera

- The larvae cause damage to the crop and commodities of human interest.
- Some of the lepidopteran acts as parasites of crop insect pest e. g. *Epericanea melanoleuca* on sugarcane pyrilla.
- Many of them play important role in pollination of flowers.
- Silkworm moth yields silk which is of high commercial value.
- It increases the aesthetic values of nature.

Sr. No.	Name of Family	Characters
A. Families of moth		
1	Noctuidae	• e. g. Gram cutworm (<i>Agrotis ypsilon</i>), Gram pod borer (<i>Helicoverpa armigera</i>), Tobacco leaf eating caterpillar (<i>Spodoptera litura</i>), Spotted boll worm, (<i>Earias vittella</i>) and Green semilooper (<i>Trichoplusia ni</i>, <i>Chrysodexis</i> spp.). • Eminently nocturnal moths attracted to light. • Frenulum present as wing coupling apparatus. • Maxillary palp vestigial. • Proboscis stout or flexible. • Forewings coloured and cryptic or dull. • Larvae have setae and prolegs. • Food for adult pollen and nectar; larva fruiting body of plants
2	Sphingidae	• e. g. Spinx moth (<i>Acherontia styx</i>) and hawk moth (<i>Agrius convolvuli</i>). • Moderate to large sized moth. • Antennae gradually thickened and in male they are ciliated with partial whorls. • Apex of antennae are pointed or hooked. • Tympanal organs absent. • Moths have exceptionally powerful flight, crepuscular or nocturnal of diurnal in habit. • Food for adult pollen and nectar; larva foliage
3	Pyralididae	• e. g. Sugarcane shoot borer (<i>Chilo infuscetellus</i>), Sugarcane top borer (<i>Scirpophaga</i> sp.), Rice moth (<i>Corcyra cephalonica</i>), Almond moth (<i>Ephestia cautella</i>), Brinjal fruit and shoot borer (<i>Leucinodes orbonalis</i>), Cotton leaf roller (<i>Sylepta derogeta</i>), Sorghum stem borer (<i>Chilo partellus</i>).

		• Large family varying greatly in shape and size. • Maxillary palp always present. • Legs long and slender. • Forewings usually narrow and hind wings broad. • Moths have abdominal tympanal organs.
4	Gelechiidae	• e. g. Pink bollworm (<i>Pectinophora gossypiella</i>), Angoumois grain moth (<i>Sitotroga cerealella</i>) and Potato tuber moth (<i>Gnorimoschema operculella</i>). • Usually small and delicate moth. • The hind tibia possesses hard hairs. • Maxillary palp either absent or very small. • Fore wings trapezoidal and stalk at the base narrower than hind wings.
5	Arctiidae (previous)/ Erebidae (New)	• e. g. Bihar hairy caterpillar (<i>Spilosoma obliqua</i>), Gujarat hairy caterpillar (<i>Amsacta moorei</i>) and Sunhemp caterpillar (<i>Utetheisa pulchella</i>). • Moths with stout body. • Broad brightly coloured wings with spots or bands on them. • Generally nocturnal. • Larvae densely clothed with long hairs and fed on herbaceous plants.
6	Saturniidae	• e. g. Atlas moth (<i>Attacus atlas</i>). • Large moths (Biggest moth in insect world in terms of total wing surface area). • Antennae bipectinate in both sexes. • Frenulum absent. • Labial palpi very small. • Wings broad with transparent eye spot near center.
7	Bombycidae	• e. g. Silk worm (<i>Bombyx mori</i>). • Generally white moth with several faint brownish lines across the front wings. • Antennae pectinate in both sexes. • Maxillary palpi and tympanal organs absent. • Proboscis rarely developed. • Adults don't feed and they rarely fly. • Larvae glabrous elongated and form dense silken cocoons before pupation.

B. Families of butterfly

1	Pieridae	• e. g. Cabbage butterfly (<i>Pieris brassicae</i>). • Medium sized butterflies usually white, yellow or orange marked with black colour. • Legs well developed and claw toothed. • Larvae green and covered with fine short hairs. • Pupae with single median projection or spine.

2	Papilionidae	• e. g. Lemon butterfly (<i>Papilio demoleus</i>). • Large and conspicuously coloured butterflies with tail like prolongations on hind wings. • Wings generally glossy black with shades of green, red, blue, orange or yellow. • Setae usually absent on the body. • Pupa with two lateral projections.

9. COLEOPTERA (*Coleos* = Sheath; *Ptera* = Wing) e.g. Beetles and Weevils

The coleoptera is the **largest order** in the animal kingdom, with about **350000** described species of holometabolous.

12.5.1 General characters of Coleoptera

- Minute to large insects with hard exoskeleton.
- Forewings are modified into horny shell like elytra (vein less sheath).
- Elytra covering the folded hind wing at rest.
- Mouthparts biting and chewing type.
- Prothorax large.
- Antenna lamellate, serrate or clubbed type.
- In weevil, antennae carried forward; the frons and vertex prolonged anteriorly to form rostrum or snout.
- Ocelli are usually absent.
- Metamorphosis complete.
- Larvae types are apodous, campodeiform, euryciform or scarabaeiform.
- Pupation in a specially constructed cell or chamber.
- Most of the beetles are ground-dwellers, some are aquatic.

12.5.2 Sub-order: Adepaga: The second-largest suborder of the order Coleoptera.

- Grub has a single tarsus and one or two claws.
- No molar area in mandibles. Four malpighian tubules.
- Cervical sclerites absent
- Hind coxae fused to metasternum
- Major transverse wing fold crosses MP/CU observed

12.5.3 Sub-order: Polyphaga: Polyphaga is the largest and most diverse suborder of beetles. It comprises 144 families, and displays an enormous variety of specialization and adaptation, with approximately 90% of the beetle species so far discovered.

- Elytra shorter than abdomen hence not fully covered with elytra.
- Fore tibia toothed or with spines.
- Antennae filiform or club shaped or serrate type.
- Cervical sclerites present
- Hind coxae movable.
- No major transverse wing fold crosses MP/CU

Sr. No.	Name of Family	Characters
1	Coccinellidae	- e.g. Ladybird beetle (<i>Coccinella septumpunctata</i>): beneficial and Hadda beetles (<i>Epilachna vigintioctopunctata</i>): harmful - Small or medium sized oval or round convex brightly coloured and black spotted adults. - Predaceous or phytophagous insects. - Head almost concealed under the pronotum. - Antennae small, clavate type with 11 segmented. - Tarsi 4 segmented.
2	Chrysomelidae	e. g. Red pumpkin beetle (<i>Rhapidopalpa foveicollis</i>) and Rice hispa (<i>Dicladispa armigera</i>) - Orange or bright or elongated metallic colour or leathery or shield like or flattened tortoise adults. - Elongated body. - Sunken needle spots on elytra. - Hispa usually covered with long stout upright spines.
3	Cerambycidae	e. g. Mango stem borer (<i>Batocera rufomaculata</i>) and Long horned beetles (<i>Saperia populanea</i>) - Big beetles, very long antennae like dried twigs usually $2/3^{\text{rd}}$ as long as body and fixed backwardly. - Cryptic colouration of the body. - Tibia has two spurs. - Six malpighian tubules.
4	Curculionidae	e. g. Rice weevil (<i>Sitophilus oryzae</i>), Coconut palm weevil (<i>Rhynchophorus ferrugineus</i>) - Head produced into pronounced rostrum or snout or beak like - Geniculate or clubbed antennae. - Trochantur elongated. - Reduced rigid palps.
5	Bruchidae	e. g. Pulse beetle (<i>Callosobruchus chinensis</i>) - Small, short, stout, dull grayish to brownish body covered setae or scales. - Antennae clavate, serrate or pectinate type. - Head prolonged, prognathous type. - Femora swollen and tarsi 5 segmented ending into claws. - Wings short keeping the abdominal tip exposed.
6	Scarabaeidae	- e.g. White grub (<i>Holotrichia consanguinea</i>) and chaffer beetle (<i>Melolontha</i> sp.) - Forelegs with spines or toothed. - Hind tibiae with a single terminal spur. - Antennae 10 segmented.

		• The larvae live in decomposing organic matter, the larvae attacks roots of plants. • Hypognathous mouthparts. • Grubs scarabaeiform living in soil. • Pupation in earthen cocoons.

10. HYMENOPTERA (Hymen = Membrane; Ptera = Wing)

e.g. Wasps, Ants, Sawflies and Honey bees

The hymenoptera is an order of about 100000 described species of holometabolous neopterans. Most of the species of the sub order symphyta are phytophagous, while most of the insects of the sub order apocrita are useful in one or the other way in agriculture.

General characters of hymenoptera

- Small to medium sized insects.
- Head extremely mobile hypognathous or prognathous.
- Mouthparts biting, lapping or sucking type.
- Antennae geniculate or variable.
- Compound eyes are usually large.
- Wings membranous, hind wings are smaller than the fore wings, hind and fore wings interlocked with hooklets, the 'hamuli'.
- Abdomen basally constricted.
- Ovipositor modified for sawing or piercing or stinging.
- Larvae generally apodous or may be polypod, rarely eruciform with locomotory appendages.
- Tracheal system holopneustic or peripneustic.
- Pupae adecticous and exarate (rarely obtect) generally in cocoon.
- Metamorphosis usually complete.
- They are diurnal who love sunshine and warmth.
- They are free living or phytophagous or entomophagous parasitic or social insects

Economic importance of hymenoptera

- They are act as biological control agents of many crop pests.
- Many are crop pests.
- They are helpful in pollination of various crop plants.
- Honey bees are very beneficial as it provide honey and bees wax.

A. Sub-order: Symphyta

- Abdomen broadly attached with thorax.
- No constriction between 1st and 2nd abdominal segment.
- Slender waist or petiole absent.
- Legs with 2 segmented trochanter.
- Ovipositor used for sawing and boring.
- Prolegs without crochets.

Sr. No.	Name of Family	Characters
1	Tenthredinidae	e. g. Mustard sawfly (<i>Athalia proxima lugens</i>). - Medium sized brightly coloured insects. - Antennae serrate and clubbed type. - Scutellum with defined post scutellum. - Ovipositor is modified into saw like structure. - Prolegs without crochets. - Tarsi 5 segmented.

B. Sub-order: Apocrita

- Abdomen deeply constricted or petiolated between 1st and 2nd segments.
- No constriction between 1st and 2nd abdominal segment.
- Trochanter with 1 or 2 segments.
- Ovipositor well developed.
- Prolegs without crochets.

Sr. No.	Name of Family	Characters
1	Apidae	e. g. Honey bees (<i>Apis dorsata</i>, <i>A. Indica</i>, <i>A. Florea</i> and <i>A. mellifera</i>), stingless bees & bumble bees (Subfamily: Apinae), carpenter bee (Subfamily: Xylocopinae) etc. - Apidae is the largest family within the superfamily Apoidea, containing at least 5700 species of bees. - Social insect living in colony – Queen, king (Drone), Soldiers and workers. - Mouthparts chewing and lapping type. - Solitary, parasitic honey bees. - Antennae geniculate. - Hind legs pollen collecting. - Ovipositor modified for stinging.
2	Trichogrammatidae	e. g. <i>Trichogramma chilonis</i>. - Very small insects. - Egg parasites of lepidopterous insects. - Forewings broad. - Pubescence in line. - Tarsi 3 segmented. - Marginal and stigma veins in curve.
3	Ichneuminidae	e. g. Ichneumon wasp. - The largest family of hymenoptera order. - Forewings with cross veins (2m-cu) present. - Propodium elongated. - Parasites of many Lepidoptera and Coleoptera etc.

4	Braconidae	e. g. Parasitic wasps <i>Bracon chinensis</i>, <i>Apanteles</i> spp., <i>Chelonus</i> spp., <i>Microplitis</i> spp. - Braconidae is the second largest family of hymenoptera order. - Body small and stout. - Abdomen sessile and petiolated. - Thick hind femur. - Forewings with cross veins (2m-cu) absent. - Vein 1r-m of the hind wing is in 95% of Braconidae basal to the separation of R1 and Rs. (it is opposite in Ichneumonidae) - Long ovipositor
5	Chalcididae	e. g. Chalcidfly - Parasites of Lepidoptera and Coleopteran etc. - Hind femur with short teeth. - Wings not folded while resting, wing venation reduced. - Ovipositor short and straight.

11. DIPTERA (Di = Two; Ptera= Wings)

e.g. House fly, Mosquitoes, Fruit fly, Tachinid fly, Tsetse fly, Syrphid fly, Robber fly, Tur pod fly, Drosophila etc.

The diptera is one of the large insect orders, includes over 125000 described species. The adults of most species are diurnal in habit but many mosquito species are nocturnal. Majority are either flower lovers which feed upon nectar or frequently decaying organic matter of various kinds. Some are predacious and live on various insects. Some suck blood of vertebrate animals including men. A few are phytophagous. The pathogens of most virulent diseases such as malaria, sleeping sickness, elephantiasis and yellow fever are transmitted to man through blood sucking diptera.

General characters of Diptera

- Small to medium sized insects.
- Forewings are membranous and hind wings modified into halteres or balancers.
- Antennae aristate, stylet or plumose.
- Mouthparts sponging type forming proboscis or sucking and piercing type.
- Larvae apodous (maggot).
- Pupae adecticous, obtect or exarate type.
- Prothorax and metathorax are reduced and fused with the well developed mesothorax.
- Holometabolus insects. Metamorphosis complete.
- They can hover, fly backwards, turn in place, and even fly upside down to land on a ceiling.

Economic importance of Diptera

- Blood sucking insects are capable of transmitting disease causing microorganisms from one host to other.
- They cause great annoyance.

- Some of the dipterans are pests of agricultural as well as horticultural crops eg. Pigeonpea pod fly, fruit fly, stem fly etc.
- On the other hand, many flies are beneficial
 - Pollinate flowering plants,
 - Decomposition of organic matter.
 - Some flies serve as biocontrol agents of insect pests.

A. Sub-order: Nematocera (*nematos* = head and *ceras* = horn)

- Antenna many segmented, elongated and generally plumose type.
- Antenna usually longer than the head.
- Piercing-sucking mouth parts
- Larvae have well developed head.
- Mostly aquatic larvae
- Eg. Mosquitoes, crane flies, black flies and midges.

Sr. No.	Name of Family	Characters
1	Cecidomyiidae	• e.g. Gall midges, Sorghum midge (<i>Contarinia sorghicola</i>) • Minute and delicate fly • Antennae moniliform with whorl of hairs • Wings with few longitudinal veins • Larvae peripneustic with reduced head responsible for producing galls on leaves, stem and other plants.
2	Culicidae	• e.g. Mosquitoes • They are slender, long-legged insects. • Possess a long piercing sucking proboscis. • They have humped back thorax. • Larvae are distinguished from other aquatic insects by the absence of legs, the presence of a distinct head bearing mouth brushes and antennae.

B. Sub-order: Brachycera (*Brachys* = short; *ceras* = horn)

- More compact, robust flies with short stylet antennae.
- Antenna usually shorter than the head
- Slashing-sponging mouth parts
- Tracheal system amphineustic.
- Prothoracic respiratory organs sessile.
- Abdominal segments with girdles of spines.
- Terminal segment armed with pointed process.
- Larva with incomplete head with vertically biting mandibles.
- Simple obtect pupa.

Sr. No.	Name of Family	Characters
Extra materials for JRF purpose only		
1	Asilidae	e. g. Robber flies (<i>Laphria</i> spp.) - Proboscis/stylate adapted for piercing - Pulvilli large and empodium bristle like - Concave depression on top of head between compound eyes. - Long and powerful legs - Body elongated with numerous bristle.
2	Bombyliidae	e. g. Bee flies (<i>Bombylius major</i>) - Proboscis very long - Empodium rudimentary - Body stout and densely covered with hairs

C. Sub-order: Cyclorrhapha

- Three segmented aristate antenna; flagellum bears spiny projection (arista).
- Sponging mouth parts
- Larva has vestigial head.
- A pupa enclosed in a hardened puparium.
- Circular-seamed flies.
- Coarctate pupa

Sr. No.	Name of Family	Characters
1	Tachinidae	- e.g. Tachinid fly (<i>Sturmiopsis inferens</i>) - Antenna has an unbranched arista, hence stylet antennae - Arista bared. - Abdomen elongated with numerous bristles. - Postscutellum little developed. - Parasites of the lepidopterous larvae.
2	Agromyzidae	e. g. Tur pod fly (<i>Melanagromyza obtusa</i>), Pea leaf miner (<i>Phytomyza horticola</i>) and Seprpentine leaf miner, <i>Liriomyza</i> spp. - Small sized black with bluish, shiny coloured insects. - Larvae mostly mine in leaves, less frequently as stem miners or stem borers. - Larva is apodous - The tracheal system is metapneustic in the first instar early age and amphipneustic in the subsequent stages.
3	Muscidae	e. g. House fly - Antennae three segmented and aristate type - Frontal suture is present - Adults can be predatory, hematophagous, saprophagous, or feed on a number of types of plant and animal exudates. - Larvae occur in various habitats like; decaying vegetation, dry and wet

		soil, nests of insects and birds, fresh water, and carrion.
4	Tephritidae	• e. g. Cucurbits fruit fly (<i>Bactrocera cucurbitae</i>), Ber fruit fly (<i>Carpomyia vesuviana</i>, <i>Dacus dorsalis</i>) • Fore wings either with brownish spots or strips. • Abdomen oval in shape. • The wings usually have yellow, brown, or black markings or are dark-coloured with lighter markings. • Male with long, flexible, coiled aedeagus. • Larvae occur mostly in fleshy fruits.

EXERCISE

Write the characteristics of the following insect order

4. Orthoptera	2. Dictyoptera	3. Odonata	4. Neuroptera
5. Isoptera	6. Thysanoptera	7. Hemiptera	8. Lepidoptera
9. Coleoptera	10. Hymenoptera	11. Diptera	

Write the families of following order with examples

1. Orthoptera	2. Hemiptera	3. Lepidoptera	4. Coleoptera
5. Hymenoptera	6. Diptera		

Differentiate the following

1. Ensifera	and	Caelifera
2. Cricket	and	Grasshopper
3. Anisoptera	and	Zygoptera
4. Dragonfly	and	Damselfly
5. Dragonfly	and	Antlion
6. Butterfly	and	Moth
7. Weevil	and	Beetle
8. Symphyta	and	Apocrita

Theory Notes

Ag. Ento. 4.2

Principles of Integrated Pest Management

Credit hours (1+1=2)

Fourth Semester

B.Sc. (Hons.) Agriculture

Ag. Ento. 4.2 Principles of Integrated Pest Management Credit hours (1+1=2)

Theory

Part I

1. Insect Ecology: Introduction, Environment and its Components. Effect of abiotic factors—temperature, moisture, humidity, rainfall, light, atmospheric pressure and air currents. Effect of biotic factors – food competition, natural and environmental resistance.
2. Concepts of Balance of life in nature, biotic potential and environmental resistance and causes for outbreak of pests in agro-ecosystem

Part-II

3. Categories of insect pests, IPM: Introduction, history, importance, concepts, principles and tools of IPM
4. Host plant resistance, cultural control
5. Mechanical, physical, legislative control
6. Biological (parasites, predators & transgenic plant, pathogens such as bacteria, fungi and viruses) control
7. Chemical control (Importance, hazards and limitations)]
8. Classification of insecticides, toxicity of insecticides and formulations of insecticides
9. Insecticides Act 1968-Important provisions.
10. Application techniques of spray fluids.
11. Phytotoxicity of insecticides. Symptoms of poisoning, first aid and antidotes.
12. Introduction to conventional pesticides for the insect pest management.
13. Implementation and impact of IPM (IPM module for Insect pests).
14. Safety issues in pesticide uses. Political, social and legal implication of IPM.
15. Case histories of important IPM programmes.

Part III

1. Recent methods of pest control, repellents, antifeedants, hormones, attractants, gamma radiation, transgenic, nano technology as well as genetic control.
2. Practices, scope and limitations of IPM.

Part IV

1. Economic importance of insect pests.
2. Methods of detection and diagnosis of insect pest.
3. Importance of Economic threshold level.
4. Ecological management of crop environment.
5. Pest surveillance and pest forecasting.

Practical

- Methods of diagnosis and detection of various insect pests.
- Methods of insect pests sampling.
- Assessment of crop yield losses.
- Calculations based on economics of IPM (ICBR/ NICBR/ CBR).
- Identification of biocontrol agents,
- Crop (agro-ecosystem) dynamics of selected insect pests.
- Plan & assess preventive strategies (IPM module) and decision making.
- Crop monitoring attacked by insect pests.
- Awareness campaign at farmers' fields.
- Pesticide formulations and calculation of spray fluid and doses.

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9. Pesticides Application Equipments - O. S. Bindra and Harcharan Singh
10. Principles and Procedures of Plant Protection - S. B. Chatopadhyay
11. General and Applied Entomology - K. K. Nair, B. V. David and T. N. Ananthkrishnan
12. A glimpses on "Terminology of Agricultural Entomology"- S. K. Ghosh
13. Plant protection: Part 1 (Gujarati) – R. C. Patel
14. Krushi Kit Vidya: Part 1 (Gujarati)- G. A. Patel and H. K. Patel

CHAPTER 1

- **Insect Ecology: Introduction, Environment and its Components**
- **Effect of abiotic factors—temperature, moisture, humidity, rainfall, light, atmospheric pressure and air currents.**
- **Effect of biotic factors – food competition, natural and environmental resistance.**

Ecology

Ecology is ‘the science of inter-relations between living organisms and their environment.

Ernst Haeckel (1869), defined ecology is the study of total relation of the animal both to its inorganic and organic environment, including above all, its favourable and unfavorable relation with those animals and plants with which it comes directly or indirectly in contact.

➤ **Ernst Haeckel - Father of Ecology**

E. P. Odum (1953) defined ecology as ‘the study of the structure and functions of nature (or Environmental biology)’.

Ecology is divided mainly into ‘Autecology’ and ‘Synecology’.

Autecology is the study of individual organisms or an individual species in relation to the environment.

Synecology is the study of the group or groups of organisms associated in a community in the same environment i.e., in relation to various other species living in the same environment.

Population: Population can be defined as ‘a group of individuals or a species occurring in a given area or locality at a specific time’.

Community: Populations of different species live together and form a ‘**Community**’, meaning ‘all populations in the area at a specific time’.

Ecosystem: The complex system of biotic and abiotic factors constitutes an ‘**Ecosystem**’. An ecosystem is a community of living organisms in conjunction with the nonliving components of their environment, interacting as a system.

Agro-ecosystem: The crops, insects, other animals and the physical abiotic factors together constitute an ‘**Agro-ecosystem**’.

Environment denotes the sum total of physical and biological factors that directly influence the survival, growth, development and reproduction of organisms.

Components of environment

In nature the living organism and the non-living substances of environment interact to form ecosystem. The environmental complex constitute

(1) Biotic factors known as ‘Density dependent factors’ include

(a) Food and (b) Other organism and

(2) Abiotic factors known as ‘Density independent factors’ comprise

(a) Temperature (b) Humidity (c) Rainfall (d) Light (e) Air (f) Water (g) Soil etc.

EFFECT OF ABIOTIC AND BIOTIC FACTORS ON POPULATION GROWTH

Factors influencing population growth

I. Abiotic factors or density independent factors.

II. Biotic factors or density dependent factors.

[I] ABIOTIC FACTORS ON INSECT POPULATION

A. Physical factors

B. Nutritional factors

C. Host associated factors

PHYSICAL FACTORS

- Temperature, light, wind, soil conditions influence development, longevity, reproduction and fecundity of insects
- Population density fluctuates depending on weather
- Extreme weather causes mortality of pests

1. TEMPERATURE

- Insects are poikilothermic - do not have mechanism to regulate body temperature
- Upper lethal limit : 40-50 °C (even up to 60 °C survival in some stored product insects). Lower lethal limit : Below freezing point e.g. snow fleas.
- The total heat required for completion of physiological processes in life - history is a constant - **thermal constant**.
- At low temperature (winter) insect takes more days to complete a stage.
- At high temperature (summer) it takes less time to complete a stage.
- Some insects when exposed to extremes of temperature Undergo - **Aestivation** (during summer) or **Hibernation** (during winter). During this period, metabolic activities suspended. When temperature is favourable, they resume activity.

2. MOISTURE/HUMIDITY

- Moisture scarcity leads to dehydration and death of insects.
- Exposure to excessive moisture can be harmful to insect population by -
 - i. Adversely affecting normal development and feeding activity of insects.
 - ii. Encouraging disease causing pathogens on insects and thereby causing insect's mortality.
 - iii. Adverse effect on its cold hardiness (capability to withstand exposure to low temp)

Examples: 1. High RH induces BPH in rice,

2. Low RH in rainfed groundnut crop induces leaf miner incidence

3. RAINFALL

- Rainfall is essential for adult emergence of cutworms and RHC
- Heavy rain reduces population of aphids, diamond back moth (DBM)
- Intermittent low rain increases BPH and thrips

4. LIGHT

Light is essential factor for orientation or rhythmic behaviour of insects, bioluminescence, periodicities of occurrence and periods of inactivity.

The following properties of light influence insect life

- i. Intensity or illumination
- ii. Quality or wavelength
- iii. Duration of light hours / Photoperiod

Photoperiodism: The response of organisms to environmental rhythms of light and darkness. It influences the motor activity rhythms of insects such as locomotion, feeding, adult emergence, mating and oviposition and also moulting and growth in some species.

Photoperiod

Each daily cycle inclusive of a period of illumination followed by a period of darkness.

- Photoperiod influences induction of diapause (a resting stage) in most of the insects e.g. Long day during embryonic development causes adult to lay diapausing eggs in *Bombyx mori*.
- Some insects are active during night - **Nocturnal**
- Some are active during the day - **Diurnal**

- Some active during dawn and dusk - **Crepuscular**

5. Atmospheric pressure

- A rise in atmospheric pressure generally associated with clear weather and moderately strong winds, while drop in atmospheric pressure associated with bad weather, including high winds and possible rainstorms that can result in high mortality.
- Rapid barometric changes significantly reduced the flight initiation of females.

6. AIR CURRENT/WIND

- Interferes with feeding, mating, oviposition
- Wind aids in dispersal of insects e.g. aphids, mites (Eriophyid mites also) disperse through wind.
- Air currents may be directly responsible for the death of insects.

7. TOPOGRAPHY

- Mountains, valley, lakes, seas, steepness of the slope etc. act as physical barrier for spread of insects.
- Topography also affects climate of an area, thus influencing the distribution of certain insects.

8. ADAPHIC FACTORS / SOIL TYPE

- Wireworm, multiplies in wet clay soil with poor drainage
- White grubs and cut worm - multiply in loose soil with good drainage.
- Soil with high organic compound reduces BPH, stem borer in paddy
- In acid soils, in burrows opening at the soil surface and in surface or subterranean nests of termites tends to decrease.

9. WATER CURRENT

- Standing water aids in multiplication of mosquitoes
- Running water is preferred by dragonfly and caddisflies.

10. Oxygen and CO₂

- An excess of CO₂ in atmosphere causes growth retardation in many insects.

[I] BIOTIC FACTORS

1) Competition: Competition operates whenever population is increasing and the resources like food, mates and suitable site for oviposition or pupation are limited.

a) Intraspecific competition: Population of the same species competes for a resource is called intraspecific competition.

- e.g. Cannibalism in American bollworm larvae (*Helicoverpa armigera*).
- Crowding in honeybees leads to swarming

b) Interspecific competition. The competition occurring between members of two or more species. e.g. when flour beetles *Tribolium castaneum* and *Tribolium confusum* were grown in the same jar of flour, one species eliminates the other. Under high temperature and RH conditions *T. castaneum* eliminates *T. confusum* and vice versa under low temperature and RH conditions.

2) Natural and environmental resistance

Environmental resistance factors include factors that are **biotic (living)** and abiotic (non-living). Biotic factors are things like predation, parasitism, lack of food, competition with other organisms and disease.

a) Predators and Parasites

Predators: Predators are free living organisms that feed on other insects, their prey, devouring them completely and rapidly. More than one individual of prey required for predator to reach maturity. e.g. lady beetle, *Chrysoperla*, birds, amphibians, reptiles etc.

Parasites: An organism that is dependent on another organism throughout its all life stages. A parasite weakens or kills the host while feeding. Many parasites on a single host require only one part of one host to reach maturity. e.g. Mosquitoes, *Trichogramma spp.*

b) Food: Insect depends directly or indirectly on plants for food. The quantity and quality of food play an important role in insects' survival, longevity, fecundity, distribution, reproduction, speed of development etc.

i. QUANTITY OF FOOD

- Short supply of food causes intraspecific and interspecific competition

ii. QUALITY OF FOOD

- This depends on nutritional availability of plants

c) Competition with other organisms

Population may not increase due to competition with other organisms.

d) Disease: Disease due to microorganisms may cause the death of organisms, hence population may reduce.

CONCEPT OF BALANCE OF LIFE IN NATURE, BIOTIC POTENTIAL AND ENVIRONMENTAL RESISTANCE CAUSES FOR OUTBREAK OF PESTS IN AGRO-ECOSYSTEM

Concept of balance of life in nature / Law of population growth

Balance of Life

In nature there are two sets of tendencies namely the biotic potential tending to increase the population and the environmental resistance tending to reduce the population. As such there is a constant interaction between these two opposing forces and then maintains a dynamic equilibrium known as '**Balance of life**'.

The population size of any organism can change only by four processes; **Birth, Death, Immigration or emigration.**

Biotic potential: Innate capacity of an organism to reproduce and survive i.e. increase in numbers under optimal environmental conditions. It is also known as '**Maximum reproductive power**'. The biotic potential is depends on -

- 1) **Initial population:** The more the initial population of an organism the more will be its progeny.
- 2) **Fecundity:** The more the fecundity the more will be the resultant population.
- 3) **Sex ratio:** Up to a limit the more the proportion of females, the more the multiplication capacity.
- 4) **Number of generations in a unit time / year:** Obviously the greater the number of generations in a unit time the larger will be the resultant population.

Environmental resistance refers to the sum total of environmental limiting factors that prevent the biotic potential from being realized.

CAUSES FOR OUTBREAK OF PESTS IN AGRO-ECOSYSTEM

Pest outbreak: The increase in number of a particular pest species is termed as pest outbreak. The ecological outbreak operates through:

- Increase in rate of birth
- Decrease in rate of death
- Increase in immigration
- Decrease in emigration

Activity of human beings, which upsets the biotic balance of ecosystem, is the prime cause for pest outbreak. The following are some human interventions –

Reasons for outbreak:

i. Deforestation and bringing forest area under cultivation

- This will affect the weather conditions in that locality and thus set favourable conditions for some insects to assume pest status.
- Pest feeding on forest trees is forced to feed on cropped area.

ii. Destruction of natural enemies

- ⇒ Due to excess use of insecticides, natural enemies are killed that affects the natural control mechanism and pest outbreak occurs.
- ⇒ e.g. Synthetic pyrethroid insecticides kill natural enemies. Thus, encouraged certain sucking pests to multiply to enormous proportions.

iii. Intensive (Monoculture) and Extensive cultivation

- ☞ When one or more related crops are raised over extensive area, limitations of food is nullify. Monoculture leads to multiplication of pests.
- ☞ If the different crops in rotation are closely related to each other or they are alternative hosts for concerned pests, pest population is likely to increase. e.g. cotton-okra: *Erias*; cotton-brinjal: whitefly.
- ☞ Extensive cultivation of susceptible crops in large area increases multiplication of insect due to no food competition. e.g. Stem borers in paddy, *Leucinodes* in brinjal, Thrips in chillies, DBM in cabbage/cauliflower in Prantij.

iv. Introduction of new crops and high yielding improved varieties

- Introduction of HYVs of *Hirsutum* cotton species causes pest outbreaks.
- Introduction of soyabean in Dahod district with its extensive cultivation causes the outbreak of *Prodenia* and green semilooper during *kahrif*-2008.

v. Improved agronomic practices

Good tilth of soil, timely irrigation, application of fertilizers improve the growth of the crop and reduce competition of food that leads build up of pest population.

- **Closer planting** - BPH, gall midge and leaf folder increases in paddy.
- **Irrigation** – With increase in irrigation facilities pest problems in many crops increased. Multiplication of brown plant hopper and gall midge increased as the level of the water in rice fields increased. Water logging enhances the multiplication of stalk borer, internode borer and whitefly in sugarcane crop.
- **Pesticides** – Large scale indiscriminate use of synthetic insecticides created problems of resurgence and pest outbreak.
- **Crop rotation** – Paddy-wheat (stem borer), Green gram – Chickpea (*Helicoverpa*), Sunflower-cotton (*Helicoverpa*) rotation cause pest outbreak.
- **Ratoon crop** favours population build up of pest. Eg. Scale, mealy bugs, whiteflies, stem borer in sugarcane. Mites in pigeonpea.
- Modification in other practices like time and manner of planting, intercropping, detrashing, harvesting time and practices etc. also aggravates insect pest problems in agriculture.

vi. Introduction of new pest in new environment

- A pest becomes more abundant when it is introduced into a new area. eg. FAW in maize, Apple wooly aphid *Eriosoma lanigerum* multiplied fast due to absence of specific parasitoids, *Aphelinus mali* in Nilgiri region.

vii. Accidental introduction of pests from foreign countries (through air/sea ports)

The speedier travel has increased the chances of introduction of foreign pests into areas where they are not present earlier. e.g.

- a. Diamondback moth on cauliflower (*Plutella xylostella*)
- b. Potato tuber moth *Phthorimaea operculella*
- c. Cottony cushion scale *Icerya purchasi* on wattle tree
- d. Wooly aphid - *Eriosoma lanigerum* on apple
- e. Coffee green scale, *Coccus viridis*
- f. San Jose scale, *Quadraspidiotus perniciosus* on fruit trees on the hills.
- g. Psyllid - *Heteropsylla cubana* on subabul
- h. Spiralling whitefly - *Adeyrodichus dispersus* on most of horticultural crops
- i. Fall armyworm – *Spodoptera frugiperda* in maize

viii. Large scale storage of food grains/ agril. produce

- Large scale storage of food grains serve as reservoir for stored grain pests
- Large scale of storage of potato- potato tuber moth, *Phthorimaea operculella*

ix. Resurgence of sucking pests

“Tremendous increase in pest population brought about by insecticides despite good initial reduction in pest population at the time of treatment is called **resurgence**”.

Sometimes application of insecticides give initial protection against sucking pests that offer physiologically favourable conditions for heavy build up of such pests. e.g.

- Deltamethrin, Quinalphos, Phorate - Resurgence of BPH in rice
- Synthetic pyrethroids- Whitefly in cotton
- Carbofuran- Leaf folder in rice

x. Biotypes of pest species

- Development of biotypes of pest species that are able to attack resistant cultivars. e.g. Biotypes of BPH on paddy

xi. Climatic factors of a particular locality

The environmental factors, when they are favourable, cause pest outbreak.

CHAPTER 3

CATEGORIES OF INSECT PESTS & IPM: INTRODUCTION, HISTORY, IMPORTANCE, CONCEPTS, PRINCIPLES AND TOOLS OF IPM

Pest

"Any living organism which can cause significant and economic damage to man or man's properties" OR "Any organism that is detrimental to man and his properties"

It may be insect pest, disease producing pathogens like fungi, bacteria, viruses, mycoplasma etc., mites, rodents, bats, birds, slug & snails, weeds etc.

INSECT PESTS

"Insects that cause economic loss to plant and plant produces and attack livestock or man".

CATEGORIES OF PESTS

I. Based on occurrence and locality

Based on association with the crop

- a. **Regular pests:** Pests that occur more frequently on a crop having close association with particular crop. e.g. Rice stem borer, Mustard aphid, Chilli thrips
- b. **Occasional pests:** Pests that occur rather infrequently and have close association with a particular crop. e.g. Rice horn caterpillar, Rice case worm

Based on the seasonality

- c. **Seasonal pests:** Pests that occur on a crop during a particular season of the year. e.g. Red hairy caterpillar in groundnut in Saurashtra and maize in Dahod in June - July.
- d. **Persistent pests:** Pests, which occur persistently on a crop almost throughout the year. e.g. Thrips on chillies
- e. **Sporadic pests:** Pests, which occur in a few isolated localities during some period. Occasionally causing serious damage. e.g. Rice ear head bug, Mango shoot borer

Based on intensity of infestations

- a. **Epidemic pests:** Pests, which occur in severe form in a region or locality at a particular season. e.g. RHC in maize in Dahod in monsoon.
- b. **Endemic pests:** Pests, which occur regularly and confined to a particular area of locality. e.g. Mustard aphids in North Gujarat, Rice Gall midge in Madurai district
- c. **Migrant pests:** These pests are highly mobile and can infest crops for short periods of time through movement. e.g. Locust

Others

- a. **Exotic Pests:** Non-Native or Non-Indigenous Pests not known to occur in the state or country.

II. Based on damage potential

General Equilibrium Position (GEP): The average population density of insect over a long period of time, around which the pest population tends to fluctuate due to biotic and abiotic factors and in the absence of permanent environmental changes. It is unaffected by temporary interventions of pest control.

Damage Boundary (DB): The lowest level of damage which can be measured.

Economic Injury Level (EIL): The lowest pest population density that will cause economic damage. It is the level before which the control measures are initiated.

Economic Threshold Level (ETL): The population density at which control measure should be initiated against an increasing pest population to prevent economic damage. ETL is always a pest density lower than that of the EIL.

- a. **Key pests:** These are the most severe damaging pests. The damage is always above the DB & EIL. GEP lies always above EIL. Human intervention may bring the population temporarily below the EIL, but it rises back rapidly and repeated sprays may be required to minimize damage. e.g. cabbage diamond back moth.
- b. **Major pests:** These are pests with the population crosses EIL quite frequently and require repeated control measures to avoid economic damage. (Damage >10%). GEP lies very close to EIL or coincides with EIL e.g. Cotton jassid, Rice stem borer.
- c. **Minor pests:** These are pests with population rarely crosses EIL and fluctuates around ETL. But these pests are easily control by available control measures and a single application of insecticides. (5-10% damage). GEP is usually below the EIL. These are occasional pests. e.g. Cotton stainers, Rice hispa
- d. **Negligible Pest:** Population never increases high enough to cause economic injury. That cause less than 5% loss in yield, are said to be negligible pests.
- e. **Potential pests:** These pests normally do not cause any economic damage. Hence, they are not pests at present but any change in the ecosystem may make them to cause economic damage (Damage > 5%). GEP always less than EIL
- f. **Sporadic pests:** GEP generally below EIL Sometimes it crosses EIL and cause severe loss in some places/periods e.g. Sugarcane pyrilla, White grub, Hairy caterpillar.
- g. **Secondary pests:** These pests are usually kept under adequate control by natural enemies, but can increase and produce economic losses if the natural enemies are disrupted by agricultural practices.
- h. **Severe pest:** They have EIL below the GEP. Regular and constant interventions with insecticides are required to produce marketable crops. EIL decreases as the value of crop increases. It also depends on the stage of the crop, stage of the pest etc.

IPM: Introduction, history, importance, concepts, principles and tools of IPM

After World War II the use of pesticides mushroomed, but with all the benefits of the use pesticides, it has adverse side effects on humans and in animals. During the massive use of pesticides, **Rachel Carson**, published a book ***Silent Spring*** through which she warned the people about the side effects of the use of pesticides.

An over-reliance on chemical pesticides led to

- Development of pesticide resistance
- Development of multiple resistance
- Emergence of secondary pest as major pests
- Resurgence of pests
- Elimination of natural enemies of pests
- Hazards to nontarget species
- Hazards to agricultural workmen
- Deleterious effects on the environment (ecotoxicity)
- Increase of production costs, etc.
- Presence of residues in foods, feed and organisms caused widespread concern about contamination of environment.

The importance of integrated approaches to pest control was then felt and the concept of IPM evolved.

In integrated control, it is aimed to give the control measures to the optimum and not to the maximum. Pest management concept is followed to avoid crisis and disaster phases by

- a) Combination of the resources
- b) Analysis of eco- factors
- c) Optimization of techniques
- d) Recognizing or restoring the pest at manageable level

WHAT IS INTEGRATED PEST MANAGEMENT (IPM)?

What is IPM?

‘**Integration**’ means the harmonious use of multiple methods to control single pests as well as the impacts of multiple pests.

‘**Pests**’ are any organism detrimental to humans, including invertebrate and vertebrate animals, pathogens and weeds.

‘**Management**’ refers to a set of decision rules based on ecological principles and economic and social considerations. The backbone for the management of pests in an agricultural system is the concept of economic injury level (EIL).

Therefore, 'IPM' is a multidisciplinary endeavour.

According to FAO (1967), IPM was defined as "a pest management system in the context of associated environment and population dynamics in pest species, utilizes all suitable techniques and methods in as compatible manner as possible and maintains the pest population at levels below those cause economic injury".

According to Kogan (1998) "IPM is a decision support system for the selection and use of pest control tactics, singly or harmoniously coordinated into a management strategy, based on cost/benefit analysis that take into account the interests of and impacts on producers, society and the environment".

History of IPM

- Stern et al. (1959) systematized the integration of chemical and biological control methods. He coined the term IPM for the first time.
- Geier and Clarke (1961): The term pest management was advocated by them.
- 1976: The concept of IPM came of at the XV International Congress of Entomology.
- Metcalf (1994): He advocated judicious use of insecticides as an essential component of IPM systems based on their convenience, simplicity, effectiveness, flexibility and economy.

Concepts of IPM

IPM seeks to minimize the disadvantages associated with use of pesticides and maximizing socio, economic and ecological advantages. These are achieved through consideration of following points.

1. **Understanding the agricultural ecosystem:** An agro ecosystem is intensively manipulated by man. Agro ecosystem is a complex of food chains and food webs that interact together to produce a stable unit.
2. **Planning of agricultural ecosystem:** In IPM programme the agricultural system can be planned in terms of anticipating pest problem and also the ways to reduce them.
3. **Cost benefit ratio:** Based on the possibility of pest damage by predicting the pest problem and by defining ETL, emphasis should be given to cost benefit ratio.
4. **Tolerance of pest damage:** The pest free crop is neither necessary in most cases for high yields nor appropriate for insect pest management. Exceptions occur in case of plant disease transmission by vectors. The relationship between density of pest population and profitability of control measures is expressed through threshold values.
5. **Leaving a pest residue:** It is an important concept of pest management, to leave a permanent pest residue below economic threshold level, so that natural enemies will survive.

6. **Timing of treatments:** Treatment in terms of pesticide spray should be need based, with minimum number of sprays, timely scheduled, combined with improved techniques of pest monitoring and crop development.
7. **Public understanding and acceptance:** In order to deal with various pest problems special effort should be made for effective communication to the people for better understanding and acceptance of pest management practices. The IPM practices followed should be economical and sustainable.

Principles of IPM

1. **Cropping system level management:** Modern IPM emphasizes the management of agricultural systems, rather than individual pests, to prevent or reduce the number and severity of pest outbreaks.
2. **Monitoring, warning and forecasting systems**
3. **Identification of pest and natural enemy:** The ability to accurately identify pests or pest damage is central to IPM, as is the ability to recognize and accurately identify a pest's important natural enemies.
4. **Life history of pest and natural enemy:** An understanding of the life history of pests and their natural enemies, as well as an understanding of the environmental conditions affecting their growth and reproduction, provide valuable information for pest management.
5. **Economic injury levels and economic (action) thresholds:** In most situations it is not necessary, desirable or even possible to eradicate a pest from an area. In IPM, acceptable pest levels are defined in terms of economic injury levels (EILs).
6. **The decision-making process:** can integrate cropping system factors to develop longer-term strategies.
7. **The combination of non-chemical methods:** that may be individually less efficient than pesticides can generate valuable synergies.
8. **Development of new biological agents and products:** offer options for the selection of products minimizing impact on health, the environment and biological regulation of pests.
9. **Reduction of pesticide use**
10. **Pesticide resistance:** Addressing the root causes of pesticide resistance is the best way to find sustainable crop protection solutions.
11. **Development of sustainable solution:** Integration of multi-season effects and trade-offs in evaluation criteria will help in development of sustainable solutions.

Different components or tools of IPM

- 1) Pest surveillance 2) Cultural methods 3) Mechanical methods 4) Physical methods
- 5) Biological methods (Use of parasites, predators & host plant resistance)
- 6) Regulatory / Legislative methods and 7) Chemical methods 8) Behavioural methods
- 9) Genetic / Biotechnology methods

Why Integrated Pest Management?

1. Development of resistance in insects against insecticides e.g. OP and synthetic pyrethroid resistance in *Helicoverpa armigera*.
2. Outbreak of secondary pests e.g. Whiteflies emerged as major pest when spraying insecticide against *H. armigera*.
3. Resurgence of target pests e.g. BPH of rice increased when some OP chemicals are applied.
4. When number of application increases, profit decreases.
5. Environmental contamination and reduction in its quality.
6. Killing of non-target animals and natural enemies (parasites, predators & pollinators).
7. Residue in food and feed.
8. Human and animal health hazards.

Basic Requirements for successful pest management programme

Knowledge on following points is required for successful management of pests.

1. Correct identification of insect pests
2. Life history and behaviour of the pest
3. Natural enemies and weather factors affecting pest population
4. Pest surveillance will provide above data
5. Pest forecasting and predicting pest outbreak
6. Finding out ETL for each pest in a crop
7. Need and timing of control measure - Decision
8. Selection of suitable methods of control
9. Analysis of cost/benefit and benefit/risk of each control measure
10. Farmer's awareness and participation
11. Government support
12. Consumer awareness on use of pesticides free products

4. CULTURAL METHODS OF INSECT CONTROL AND HOST PLANT RESISTANCE (HPR)

CULTURAL METHODS OF INSECT CONTROL

Definition: Cultural control is the purposeful manipulation of a cropping environment to reduce rates of pest increases and damage.

Cultural management of pests involves changes -

- ⇒ to make the crop less suitable for the pest
- ⇒ to make it suitable for natural enemies
- ⇒ to enhance the ability of the crop to withstand pest attack.

1. Tillage: Simply tilling a field may disrupt a pest's life cycle.

e.g. Ploughing the soil up to 40 cm depth expose

- ⇒ pupae of bollworms, Gujarat hairy caterpillar and stem borers
- ⇒ adults of white grubs and
- ⇒ eggs of grasshoppers etc. to sun rays and predatory animals.

2. Field Sanitation: Clean cultivation is often recommended as a way to eliminate shelter and/or overwintering sites for pest populations. e.g.

- Removing crop debris from cotton fields through allowing sheep and goats to graze cotton field after harvest, eliminates overwintering populations of pink bollworms (*Pectinophora gossypiella*).
- Destruction of stubbles / crop residues reduces the incidence of stem borer.
- Collection of all fallen and infested fruits of mango reduces mango fruit fly, *Bactocera dorsalis*.

3. Removal / Destruction of alternate host: It reduces buildup of insects in off season. Whiteflies use many broad leaf weeds as alternate host.

4. Use of clean seed: By using pest free healthy seeds and planting materials, possible infestation of pest can be checked. e.g. Scales and mealy bugs in sugarcane, sweet potato weevil, banana rhizome weevil.

5. Selection of variety: Grow pest resistant variety. e.g. Neelashan (Mango) to hoppers, Bt. cotton to *Helicoverpa armigera*, G 4 (Chilli) to thrips and mites, Pusa Purple Long (Brinjal) to FSB etc.

6. Sowing Time: In some crops, it is possible to create discontinuity in the pest's food supply simply by altering the time of planting by producing asynchrony between host plants and the pests. e.g. Avoidance of late sowing of pigeonpea reduces infestation of pigeonpea pod fly. Similarly, there is less infestation of aphids in timely sown mustard compared to late sown crops.

7. Seed rate: Adoption of appropriate seed rate ensures proper spacing and crop canopy that helps in adoption of proper spray. e.g. Use of high seed rate is recommended for shoot fly in sorghum.

8. Plant spacing: Spacing modifies the micro-environment of the crop, duration of crop growth and development that influence the pest population.

- Closer spacing increases the population of BPH and white backed plant hopper in paddy; whitefly in Soybean.
- Closer spacing in cotton results in bushy growth that affects penetration of light, results in vertical growth of the plant, higher RH, hinders spraying operation that favours the higher incidence of sucking pests (leaf hoppers and whitefly).
- Closer spacing decreases the population of thrips, hoppers and leaf miners in groundnut.

9. Fertilizer management: Application of organic manure or fertilizers in balance amount makes plant healthy that helps to minimize the pest incidence. Application of excess nitrogenous fertilizers increases susceptibility of crops against insect pests. However, application of potash reduces the incidence of insect pests.

- Application of potash reduces virus disease transmitted by whitefly
- Fields receiving higher dose of N-fertilizers favours incidence of the pests than crops receiving N at low level. e.g. BPH, yellow stem borer, whorl maggot, leaf folder, rice Hispa, green leaf hopper etc. in paddy; *Pyrilla* in sugarcane; whitefly in cotton.

10. Irrigation management:

- Wireworms are controlled by flooding the field for several days or by allowing field to dry out during summer.
- Flooding of fields –suppress cutworms, armyworms and root grubs
- Sugarcane and wheat crops can be protected from the attack of termites by frequent light irrigations.

11. Plant sanitation / Pruning / Thinning: Plant sanitation is an essential prerequisite to reduce the insect population.

- Removal of deadhearts with larvae in cereals & sugarcane reduces incidence of stem borers.
- Picking and destruction of damaged square & bolls of cotton reduces incidence of *Helicoverpa armigera* and *Earias* spp. in cotton.
- Picking infested shoots & fruits of brinjal reduces infestation of brinjal shoot and fruit borer; a damaged fruit of tomato, chilly reduces infestation of fruit borer.
- Pruning of branches in Dec. -Jan. reduces citrus leaf miner.

12. Canopy Management: It facilitate -Light exposure, Air exposure, Pesticide exposure therefore it is beneficial.

13. Crop rotation: Rotating the field to a botanically different type of crop can break life cycle by starving pests that cannot adapt to a different host plant.

In termite prone area, crops like; wheat, sugarcane, pigeonpea, chilli should be rotated with tobacco or onion.

- Crop rotation of same group of crops i.e. cucurbits, crucifers, graminaceous, solanaceous etc. should be discouraged to reduce population of pumpkin beetles, DBM, stem borers, *Lucinodes*, respectively.

14. Fallowing: Fallow can reduce pest densities by starvation. If alternate host is present fallow cannot work.

15. Trap cropping: Trap crops are plant stands that are grown to attract insects or other organisms so that the principal crop escapes pest attack. Due to trap cropping we can keep main crop free from insecticides and this enhances natural control.

Main crop	Trap crop	Pest
Cabbage, Cauliflower	Bold seeded mustard	DBM
Tomato	African tall marigold	Fruit borer, Leaf miner
Tobacco	Castor	Tobacco leaf eating caterpillar.
Cabbage	Tomato	DBM
Cotton	Okra	Spotted borer

16. Barrier crops

- The barrier can consist of a relatively tall species that is planted around the perimeter of a primary crop.
- Living barriers include graminaceous species, like sorghum (*Sorghum bicolor*), Johnson grass (*Sorghum halepense*), corn (*Zea mays*) and elephant grass (*Pennisetum purpureum*).

17. Mulching

- Reduces the insect's ability to find the crop.

18. Mixed cropping /Intercropping: Intercropping lowers the overall attractiveness of the environment, when host and non-host plants are mixed together in a single planting.

- Tomato intercropped with cabbage reduces egg laying by DBM.
- Intercropping of cowpea in cotton helps in colonization of coccinellids and also enhanced the parasitism of spotted bollworm.
- Intercropping of groundnut in pearl millet reduces thrips, jassids and leaf miners.
- Intercropping of redgram in cotton for cotton grey weevil; sunhemp in cucurbits for fruit fly; okra in cotton for spotted bollworm; soybean in groundnut for leaf miner.

19. Hedge rows and refuge line: Hedgerows provide benefits to enhance natural enemies. Noncropped refugia can be used to harbour beneficial organisms, especially insects and spiders. Refuge line is also useful in resistance management.

20. Strip harvesting: It is similar to trap cropping. Crops can be harvested in alternate strip so that insect may not move in main crop.

21. Modify harvest schedule: By adjusting time of harvesting, a crop can be saved from attack of the pest.

- Timely picking of cotton avoids attack of dusky cotton bug.
- Infestation of Sweet potato weevil reduces in timely harvest of sweet potato.

22. Ratooning: Avoiding rationing of pigeonpea during off season helps in reducing the carryover of pod fly and eriophyiid mite, *Aceria cajani*

23. Border crops

- As trap crop –Life stages
- As Banker crop –Support NE's
- As Ecofeastcrop –Sacrifice crop
- Maize around cotton field (decrease sucking pest and *H. armigera*)
- Castor in Groundnut, cotton (suppress Spodoptera)

Advantages of cultural control

1. No extra skill
2. No costly inputs (in most cases)
3. No special equipments
4. No toxicity or residue problem
5. Minimum effect on non target organisms
6. Ecologically sound
7. Good component in IPM
8. Minimal cost

Limitations/Disadvantages of cultural control

1. No complete control
2. Not always applicable
3. Usually preventive so it requires detailed advance planning (i.e. Prophylactic nature)
4. Timing decides success
5. May interfere with normal cultural operations

HOST PLANT RESISTANCE (HPR)

HOST PLANT RESISTANCE (HPR): Definition “Those characters that enable a plant to avoid, tolerate or recover from attacks of insects under conditions that would cause greater injury to other plants of the same species” (Painter, R.H., 1951).

⇒ **R. H. Painter : Father of Host Plant Resistance**

Mechanisms of Host Plant Resistance

R. H. Painter (1951) has grouped the mechanisms of host plant resistance into three main categories.

1. Non-preference or Antixenosis: The term ‘Non-preference’ refers to the response of the insect to the characteristics of the host plant, which make it unattractive to the insect for feeding, oviposition or shelter.

Kogan and Ortman (1978) proposed the term ‘Antixenosis’, as the term ‘Non-preference’ pertains to the insect and not to the host plant.

Host plant characters responsible for non-preference of the insects for shelter, oviposition, feeding, etc. are presence of morphological or chemical factor which alter

insect behaviour resulting in poor establishment of the insect. e.g. Trichomes in cotton - resistant to whitefly. Wax bloom on crucifers deter diamond back moth *Plutella xylostella*.

2. Antibiosis: Antibiosis refers to the adverse effect of host plant on the biology (survival, development and reproduction) of the insects and their progeny due to the biochemical and biophysical factors present in it.

The adverse effects may be reduced fecundity, decreased size, long life cycle, failure of larva to pupate or failure of adult emergence and increased mortality. Antibiosis may be due to.

- Presence of toxic substances
- Absence of sufficient amount of essential nutrients
- Nutrient imbalance/improper utilization of nutrients

Chemical factors in Antibiosis

Chemicals present in plants	Imparts resistance against
DIMBOA (Dihydroxy methyl benzoxazin) in maize	Against European corn borer, <i>Ostrinia nubilalis</i>
Gossypol (Polyphenol) in cotton	<i>Helicoverpa armigera</i> (American bollworm)
Sinigrin in cabbage	Aphids, <i>Myzus persicae</i>
Cucurbitacin in cucurbits	Cucurbit fruit flies
Salicylic acid in paddy	Rice stem borer

3. Tolerance: Some plants withstand the damage caused by the insect by producing more number of tillers, roots, leaves etc in the place of damaged plant parts such plants are said to be tolerant to that particular pest.

Tolerance usually results from one or more of the following factors

1. General vigour of the plant.
 2. Regrowth of the damaged tissues.
 3. Strength of stems and resistant to lodging.
 4. Production of additive branches.
 5. Efficient utilization of non vital plant parts by the insect and
 6. Compensation by growth of neighbouring plants
- e.g. Early attack by the sorghum shoot fly on main shoot induced the production of a few synchronous tillers that grow rapidly and survive to produce harvestable ear heads.

Advantages of HPR as a component in IPM

- 1. Specificity:** Specific to the target pest. Natural enemies unaffected
- 2. Cumulative effect:** Lasts for many successive generations
- 3. Eco-friendly:** No pollution. No effect on man and animals
- 4. Easily adoptable:** High yielding insect resistant variety easily accepted and adopted by farmers. Less cost.

- 5. Effectiveness:** Res. variety increases efficacy of insecticides and natural enemies
- 6. Compatibility:** HPR can be combined with all other components of IPM
- 7. Decreased pesticide application:** Resistant varieties requires less frequent and low doses of insecticides
- 8. Persistence:** Some varieties have durable resistance for long periods
- 9. Unique situations:** HPR effective where other control measures are less effective e.g.
 - a. When timing of application is critical
 - b. Crop of low economic value
 - c. Pest is continuously present and is a single limiting factor

Disadvantages/Limitations of HPR

- 1. Time consuming:** Requires 3-10 years by traditional breeding programmes to develop a research variety.
- 2. Biotype development:** A biotype is a new population capable of damaging and surviving on plants previously resistant to other population of same species.
- 3. Genetic limitation:** Absence of resistance genes among available germination.

5. MECHANICAL, PHYSICAL & LEGAL METHODS OF INSECT CONTROL

MECHANICAL METHODS OF INSECT CONTROL

Use of mechanical devices or manual forces for destruction or exclusion of pests.

It includes killing or trapping pests by mechanical means or the use of barriers to prevent pests from gaining access to plants, stored products or other materials.

I. Manual Force

- i. **Hand picking of the egg masses, caterpillars etc. :**
 - Egg masses of red hairy caterpillar, *Spodoptera litura* etc.
 - Collection and destruction of damaged square & boll with larvae of *Helicoverpa armigera* and spotted bollworm in cotton.
- ii. **Using hand nets:** Collection of grasshoppers, ear head bugs, fruit sucking moths etc.
- iii. **Beating:**
 - Swatting housefly and mosquito.
 - Killing locusts with thorny bushes.
- iv. **Sieving and winnowing:** Useful for insect pests of stored grains.
 - Red flour beetle, *Tribolium castaneum* (sieving)
 - Rice weevil, *Sitophilus oryzae* (winnowing)
- v. **Shaking the plants :**
 - Shaking neem tree to dislodge white grub's beetles.
 - Passing rope across rice field to dislodge caseworm over standing water that is then drained out to collect the pest and suppress the population.
- vi. **Hooking:** Iron hook is used against adult rhinoceros beetle to pick out of the hole.
- vii. **Crushing and Swatting:** By hitting and crushing the cockroaches, bed bugs and lice like insects can be managed.
- viii. **Combing:** Delousing method for Head louse
- ix. **Shooting:** Shooting is relevant for noninsect pests like; monkey, pig, and bird etc. It is **restricted under prohibitory laws** for certain animals in India.
- x. **Brushing and Sweeping:**
 - Woollen fabrics for clothes moth, carpet beetle.
 - Scale insects/mealy bugs on rose etc. can be reduced by brushing and sweeping techniques.

II Mechanical force

- i. **Entoletter:** Centrifugal force - kill insect stages - useful for storage pests.
- ii. **Hopper dozer:** Kill nymphs of locusts by hording into trenches and filled with soil.
- iii. **Tillage implements:** Soil borne insects, red hairy caterpillar.
- iv. **Erection of bird perches:** Attracts insectivorous birds. e.g. *H. armigera* in gram
- v. **Mechanical traps:**
 - Heaps of plants/grasses/weeds traps red hairy caterpillar in groundnut, *Spodoptera litura* in cotton and collect and kill the trapped pests.

- Rat traps are helpful in trapping different rat species.
- Placing cut piece of banana pseudostem to attract banana pseudo stem weevil.
- vi. **Use of sticky traps:** Yellow sticky trap can be used for whitefly, aphids; blue trap for thrips.
- vii. **Sex Pheromone trap:** Synthetic sex pheromones are placed in traps to attract males. e.g. *Helicoverpa armigera*, *Spodoptera litura*, *Plutella xylostella*, *Leucinodes orbonalis* etc.
- viii. **Air suction traps:** This trap is fixed in Godowns against stored grain pests.

III Mechanical exclusion

- i. **Mechanical barriers:** Mechanical barriers prevent access of pests to hosts.
 - a. **Wrapping the fruits:** Covering fruit with brown paper bag eg. pomegranate fruit borer, *Deudorix isocrates* and citrus fruit sucking moths.
 - b. **Banding:** Banding (15 cm wide) with grease or slippery polythene sheets (alkathene) around trunk of mango eg. Mango mealy bug.
 - c. **Netting:** Putting screens on windows, doors and ventilators of green house provides protection against vector in green house.
 - d. **Trenching:** Digging trenches around the field helps to prevent movement of larvae from one field to another. eg. Red hairy caterpillar, *Amsacta albistriga*; armyworm, *Spodoptera mauritiana*; crawlers of locust, *Schistocera gregaria* and tobacco leaf eating caterpillar, *Spodoptera litura*.
 - e. **Sand barrier:** Protecting stored grains with a layer of sand on the top.
 - f. **Water barrier:** Ant pans for ant control.
 - g. **Tin barrier:** Coconut trees protected with tin band to prevent rat damage.
 - h. **Electric fencing:** Low voltage electric fences against rats and jackals.
 - i. **Paper and collar barriers:** Paper and collars are placed around small plants like tobacco and potato to protect them from cutworm infestation.
 - j. **Packaging:** The polymer films, laminations, and extrusions can protect packages from insect infestations.
 - k. **Wire-gauge screens or nylon meshes/nets:** It is used to cover seedbeds, vine yards, mango trunks to prevent the damage by insects like defoliators and borers.
 - l. Crushed eggshells or hydrated lime spread around plants will discourage slugs.
- ii. **Clipping:**
 - Clipping of leaf tips of rice seedlings containing egg masses of yellow stem borer reduces the carryover of the infestation from seedbed to main field.
- iii. **Burning / Fire / Flaming:** Burning of rat, locust and grasshopper through flame thrower.
- iv. **Use of reflecto-ribbon:** Due to reflection grainvorous birds remains away from field of bajara, sorghum, maize etc.

Appliances in controlling the pests

1. **Light traps:** Ultra Violet light is widely used in light trap. Attraction of insects through light is physical principle but attracted / trapped insects kills through mechanical devices.
2. **Pheromone trap:** Synthetic sex pheromones are placed in traps to attract males.

3. **Yellow sticky trap:** Cotton whitefly, aphids are attracted to yellow colour and trapped on the sticky material.
4. **Bait trap:** e.g. **Fishmeal trap:** This trap is used against sorghum shoot fly.
5. **Pitfall trap:** It helps to trap insects moving on the soil surface, such as ground beetles.
6. **Probe trap:** Probe trap is used to trap stored product insect.

Advantage of mechanical control

1. Home labour utilization
2. Low equipment cost (in most cases)
3. Ecologically safe
4. High technical skill not required.

Limitations/Disadvantages of mechanical control

1. Limited application
2. Rarely highly effective
3. Some mechanism require costlier equipment
4. Labour intensive

PHYSICAL METHODS OF INSECT CONTROL

PHYSICAL CONTROL: It involves modification of some physical features of environment to render it unsuitable to a pest to minimize (or) prevent pest problems.

1. Manipulation of temperature: Extreme of temperature can cause death of any pest.

Application of heat

- ⇒ Sun drying the seeds to kill the eggs of stored product pests.
- ⇒ Stored grain pests can be killed by exposing them to 55 °C for three hours.

Solarization: Solarization can kills dormant stages of different pests.

Application of cold

- ⇒ Low temperature (below 4 °C) makes the insects inactive.
- ⇒ Cold storage (1 - 2°C for 12 - 20 days) of fruits and vegetables kills fruit flies.

2. Manipulation of moisture

Flooding

- ⇒ Alternate drying and wetting rice fields against BPH.
- ⇒ Drying grains (moisture content < 10%) prevents insect damage by stored grain pests.
- ⇒ Flooding the field for the control of cutworms, armyworm, white grubs, termites etc.

Draining: Draining of water from paddy field for 3-5 day is useful to control BPH and paddy case worm, *Paraponyx stagnalis*.

3. Manipulation of light

- ⇒ Light trapping: It is useful for monitoring of insect pests in an area.
- ⇒ The UV lamp is used to attract nocturnal insects.

4. Manipulation of air

- Increasing the CO₂ concentration in controlled atmosphere of stored grains to cause asphyxiation in stored product pests.

5. Use of irradiation

- Gamma irradiation from isotopes like ⁶⁰Co is used to sterilize the insects in laboratory which compete with the fertile males for mating when released in natural condition.

6. Use of Abrasive dusts

- Applying ash over aphid infested plant parts reduce its incidence.
- Drie-Die: This is a porous finely divided silica gel causes abrasion of the insect cuticle and the loss of moisture from its body, resulting into its death. It is used against stored pests.

7. Use of Sound: By producing sound waves some insects/birds/rodents can be influenced.

- Ultrasonic sound waves can be used against nocturnal insects like mosquitoes and cockroaches.
- Birds and rodents that thrive on grains can be scared by producing sounds.

8. Increase concentration of CO₂: stored pests get killed due to asphyxiation.

9. Producing alarming signals: By producing dreadful sounds of bird's enemies, birds may go away from that area.

10. Use of frightening devices: eg. Birds

LEGISLATIVE/LEGAL METHODS OF INSECT CONTROL

Definition: Legislative control involves the enactment of laws to regulate the entry, establishment and spread of foreign plant and animal pest in a country or area and eradication or suppression of the pests established in a limited area.

Pests Accidentally Introduced into India

Sr. No.	Pests	Native Place	Year of introduction
1	San Jose scale of apple (<i>Quadraspidiotus perniciosus</i>)	Italy	1879
2	Wooly aphid of apple (<i>Eriosoma lanigerum</i>)	China	1889
3	Potato tuber moth (<i>Gnorimoschima operculella</i>)	Italy	1900
4	DBM (<i>Plutella xylostella</i>)		1914
5	Cottony cushion scale (<i>Icerya purchasi</i>)	California, USA	1926
6	American serpentine leaf miner (<i>Liriomyza trifolii</i>)	Florida, USA	1990
7	Spiralling whitefly, <i>Aleurodicus dispersus</i>	Srilanka and Maldives	1994
8	Coconut perianth mite, <i>Aceria guerreronis</i> Keifer	Srilanka	1998
9	Cotton mealy bug, (<i>Phenacoccus solenopsis</i> Tinsley)	USA, via -Pakistan	2004-05
10	South American tomato leafminer, <i>Tuta absoluta</i>	South America	2014
11	Rugose spiraling whitefly, <i>Aleyrodicus rugioeperculatus</i>		2016
12	Fall Armyworm, <i>Spodoptera frugiperda</i>	America and South Africa	2018

Foreign Pests from which India is Free

Mediterranean fruit fly - *Ceratitis capitata*

Cotton boll weevil - *Anthonomus grandis*

Codling moth of apple - *Lasperyia pomonella*

Grapevine phylloxera

Quarantine: Isolation to prevent spreading of infection

Plant Quarantine: The legal restriction to prevent the entrance and establishment of a plant disease or insect pest in an area where the disease or pest does not exist. In India, plant quarantine is regulated under the DIPA (Destructive Insects and Pests Act), 1914.

PEST LEGISLATIONS

The first Act was passed in 1906 under the Sea Customs Act of 1878 to stop the entry of Mexican cotton boll weevil.

1914 - 'Destructive Insects and Pests Act' of India (DIPA): 1. Prohibiting or restricting the import of plants and plant materials, insect and fungi into India. 2. Prohibiting or restricting the movement of insect or diseases and their hosts from one state to another in India.

2020- the *Pesticides Management Bill, 2020*, which replaced '**The Insecticides Act' 1968**

DIFFERENT CLASSES OF QUARANTINE

1. Foreign Quarantine (Legislation to prevent the introduction of new pests, diseases and weeds from foreign countries): The imported plant material has to be thoroughly examined at the ports of entry. The Directorate of Plant Protection Quarantine and Storage was established in Faridabad in 1946.

Phytosanitary certificate: The certificate issued to the consignments by the officers of the exporting state or country, as to their being free from pests, disease and weed seed is called phytosanitary certificate.

Institute exempted from phytosanitary restrictions:

- Indian Agricultural Research Institute (IARI), New Delhi
 - Forest Research Institute, Dehra Dun
 - Indian Veterinary Research Institute (IVRI), Mukteshwar
 - Zoological Survey of India (ZSI)
 - National Bureau of Agricultural Insect Resources (ABAIR), Bangalore
2. Domestic quarantine: within different parts of country (Legislation to prevent the spread of already established pests, diseases and weeds from one part of the country to another)
 3. Legislation to take up effective measures to prevent spread of established pests:
 4. Legislation to prevent the adulteration and misbranding of insecticides and to determine the permissible residues in food stuff.
 5. Legislation to regulate the activities of men engaged in pest control operations and the application of hazardous insecticides

NOTE: On 12th February, 2020, the Union Cabinet approved the *Pesticides Management Bill, 2020*, which seeks to replace the Insecticides Act, 1968, for regulating the pesticide sector by fixing prices and setting up an authority.

6. BIOLOGICAL CONTROL (PARASITES, PREDATORS BACTERIA, FUNGI AND VIRUSES) AND CHEMICAL CONTROL (IMPORTANCE, HAZARDS AND LIMITATIONS)

Biological control: Definition

Biological control can be defined as the utilization of natural enemies to reduce the damage caused by noxious organisms to tolerable levels.

History and development of biological control

1888 - First well planned and successful biological control attempt made by Mr. C.V.

Riley - Vedalia beetle (*Rodolia cardinalis*) was introduced from Australia to USA for cottony cushion scale, *Icerya purchasi*.

1981 - *Epidinocarsis lopezi* was used in a biological release programme for cassava mealy bug control under Africa-wide Biological Control Project in Nigeria, headed by **Dr. Hans Rudolf Herren**. **Dr. Herren** was awarded the **1995 World Food Prize, for developing and implementing the world's largest biological control project** for cassava mealy bug which had almost destroyed the entire cassava crop of Africa (Nigeria).

TECHNIQUES OF BIOLOGICAL CONTROL

1. IMPORTATION OR INTRODUCTION

Introduction/Importation.

It is the importation of pest natural enemies from other countries, to a new environment where they do not occur naturally. Foreign exploration is conducted to identify and collect natural enemies in the country from which an exotic pest has been introduced.

1762 - 'Mynah' bird imported from India to Mauritius to control locust.

1898 - First introduction of natural enemy into India. A coccinellid beetle, *Cryptolaemus montrouzieri* was imported into India from Australia and released against **coffee green scale, *Coccus viridis***. Even today it is effective against mealy bugs in South India.

1920 - A parasitoid *Aphelinus mali* introduced from England into at Saharanpur (Uttar Pradesh, India) to control Woolly aphid on Apple, *Eriosoma lanigerum*.

1926 - The coccinellid beetle, *Rodolia cardinalis* (Origin: Australia), for cottony cushion scale, *Icerya purchasi* was introduced to India via USA (California).

Successful Biological control of weeds

1795 - The first successful classical biological control was achieved in India when cochineal insect, *Dactylopius ceylonicus* was introduced from Brazil in the mistaken belief that it was the true carmine dye producing insect, *D. coccus*, controls a weed Prickly pear, *Opuntia vulgaris*.

1921 - The agromyzid seed fly, *Ophiomyia lantanae* was introduced from Hawaii (origin: Mexico) and released in south India for the suppression of *L. camara*.

1982- for *Salvinia molesta*, the weevil (*Cyrtobagous salviniae*), native to Brazil, was imported from Australia.

1983 - A chrysomelid beetle, *Zygogramma bicolorata* was imported from Mexico for the biological suppression of congress grass, *Parthenium hysterophorus*.

For the biological suppression of water hyacinth, *Eichhornia crassipes*, exotic weevils *Neochetina eichhorniae* and *N. bruchi* (introduced from Argentina via USA)

Transfer of parasitoids within the country

Epiricania melanoleuca is an important parasitoid of *Pyrilla perpusilla*. The redistribution of *E. melanoleuca* for the management of sugarcane pyrrilla has proved a notable success. It was introduced into **Gujarat, in 1982**, from Maharashtra and Haryana, for the control of *Pyrilla*

on sugarcane; even after more than 35 years, it effectively suppresses the *Pyrilla* population in south Gujarat region.

2. Augmentation: It is defined as the efforts to increase population of natural enemies either by propagation and release or by environmental manipulation. Two types,

(i) Inoculative release: Control expected from the progeny and subsequent generations only, and not from the release itself. The release made infrequently to reestablish a species of natural enemy which is killed out by unfavourable conditions. Small numbers of a beneficial species are released in several critical locations to suppress local pest outbreaks

(ii) Inundative release: NE mass cultured and released to suppress pest population directly. Larger numbers are released in a single location to flood the pest population with natural enemies. e.g. *Trichogramma* sp. egg parasitoid, *Chrysoperla carnea* predator.

3. Conservation and encouragement of indigenous NE:

Conservation means the avoidance of measures that destroy NEs and the use of the measures that increase their longevity and reproduction or the attractiveness of an area to NEs. It is also defined as the actions that preserve and increase NE by environmental manipulation.

Important conservation measures

- Conservation activities might include reducing or eliminating insecticide applications to avoid killing natural enemies. e.g. Use of selective insecticides.
- Staggering harvest dates in adjacent fields or rows to insure a constant supply of hosts (prey).
- Providing shelter, over-wintering sites, or alternative food sources to improve survival of beneficial species. e.g. provide alternate host and refugia for NE.
- Avoid harmful cultural practices. e.g. avoid burning of sugarcane trashes.
- Cultivation of intercrop/varieties that favour colonization of natural enemies. e.g. sparse maize plants in groundnut/cotton harbour lady beetle.
- Provide food like pollen and nectar for adult stages of natural enemies.
- Maintenance of diversity may provide alternate hosts as a food, over wintering sites, refuges and so on.

Parasite: A parasite is an organism which usually much smaller than its host and a single individual usually does not kill the host.

e.g. *Epiricania melanolenca* on nymph and adults of sugarcane pyrilla.

Trichogramma chilonis egg parasitoid of eggs of several lepidopterans.

Aphelinus on aphids, mealy bugs, scale, Braconids & Ichneumonids. Braconids wasp.

Predator: Organism that prey the insect pests. e.g. Ladybird beetle and *Chrysoperlla* are the well known predators. Spider is the universal predator. Dragonfly, Damselfly, Preying

Differences between predator and a parasite

	Predator		Parasite
1.	Mostly a generalized feeder	1.	Exhibits host specialization
2.	Very active in habits	2.	Usually sluggish
3.	Mouth parts are well develop	3.	Not very well developed
4.	Ovipositor not specialized	4.	Ovipositor well developed and specialized
5.	Stronger and larger than prey	5.	Smaller than prey

6.	Usually more intelligent than prey	6.	Not clearly more intelligent than host
7.	Habitat is in dependent of that of its prey	7.	Habitat and environment is made and determined by that of the host
8.	Life cycle long	8.	Life cycle Short
9.	Attack on the prey is casual and not well planned	9.	Planning is more evident
10.	Devours the prey rapidly	10.	Kills the host slowly.
11.	Attack on prey is for obtaining food for the attacking predator itself, except wasps.	11.	It is for provision of food for the off spring
12.	A single predatory may attack several hosts in a short period	12.	A parasite completes development in a single host in most cases

Microbial Control: Microbial control refers to the exploitation of disease causing organisms to reduce the pest population below the economic damage level.

[I] Bacteria

i. Spore forming (Facultative, Crystalliferous): *Bacillus thuringiensis (B.t.)* – is used to control larvae of many lepidoptera, larvae of Colorado potato beetle and *B.t. 'israelensis'* is used to control mosquito larvae.

Additionally, some crops have been modified to express the insecticidal protein produced by *Bacillus thuringiensis*. They produce spores and also toxin (endotoxin). The endotoxin paralyses gut when ingested e.g. *Bacillus thuringiensis* effective against lepidopteran pests.

Commercial products : **Delfin, Dipel, Thuricide**

ii. Spore-forming (Obligate): e.g. *Paenibacillus popilliae* (Formerly, *Bacillus popilliae*) attacking white grub of beetles, produce ‘milky disease’.

Commercial product : ‘**Doom**’ against ‘white grubs’

iii. Non-spore forming: e.g. *Serratia entomophila* on grubs

[II] Fungus

i. Green muscardine fungus - *Metarhizium anisopliae* attack coconut rhinoceros beetle, cuculionid and chrysomelid. Commercial product : **Metasoft**

ii. White muscardine fungus - *Beauveria bassiana* against lepidopteran larvae. It also controls sucking pests (aphids, whiteflies and mealy bugs) as well as orthopterans (grasshoppers, locusts, and mormon crickets). Commercial product : **Biosoft**

iii. White halo fungus - *Verticillium lecanii* on coffee green scale, aphids.

Commercial product : **Vertisoft**

iv. *Hirsutella thompsonii* - found virulent against citrus rust mite, two spotted red spider mite.

v. *Paecilomyces lilacinus* : It is nematophagous fungus. It controls nematodes

Commercial product : **Yorker**

[III] Viruses

NPV (Nuclear Polyhedrosis Virus) e.g. *HaNPV* for *Helicoverpa armigera*, *SINPV* for *Spodoptera litura* Commercial product : **Elcar, Virin H, Virin S, SPOD X, Virox**

Symptoms

Lepidopteran larva become sluggish, pinkish in colour, lose appetite, body becomes fragile and rupture to release polyhedra (virus occlusion bodies). Dead larva hang from top of plant with prolegs attached (Tree top disease or “Wipfelkrankheit”)

[IV] Protozoa

Nosema locustae -- This microscopic protozoan is used to control grasshoppers.

Nosema apis—Enemy of honey bees

[V] Nematodes

Steinernema carpocapsae - This nematode serve as a vector of bacterium *Xenorhabdus nematophilus* that causes septicemia in the insect body (codling moth, *Cydia pomonella*). It is also effective against *Spodoptera litura*, paddy cutworm, *Mythimna separate* and yellow stem borer of rice, *Scirpophaga incertulas*.

Commercial product : DD-136.

[VI] **Rickettsiae:** *Rickettsiella popillae* infects the Japanese beetle causing **blue disease**.

Biocontrol Organization: Regional Station of Commonwealth Institute of Biological Control (CIBC) established at Bangalore in 1957. Later on it was act as Project Directorate of Biological Control (PDBC). Presently, **National Beaur of Agriculturally Important Insects (NBAII)**, Bangalore looks after Biocontrol in India. Now, **National Bureau of Agricultural Insect Resources (NBAIR)**.

Advantages of biological control in pest management

1. It can be effective for larger area.
2. Initial cost to establish biological control station may be high but in long run it becomes cheaper.
3. Hidden pests are also controlled by the parasites eg. Stem borer are inside the stem even though they are parasitized.
4. The application of biotic agents is easy and possible even in inaccessible areas like dense forest, tall trees, ponds, rivers, lakes etc.
5. It is safe to non-target insect (beneficial).
6. Pest resistance to NE is not known.
7. Useful to reduce the use of chemical insecticides.
8. No residue problems.
9. No harmful effects on humans, livestock and other organisms.
10. Non-hazardous and eco-friendly methods.
11. It is a long lasting control i.e. biological agents will survive as long as the pest is prevalent.
12. It is self propagating and self perpetuating in nature: Once the parasites/ predators are established in the particular area/locality they multiply themselves.
13. Biological control is close to permanent.
14. Waiting period is not required for harvesting a crop after treatment with biocides.
15. The grower does not require any special treatment procedure / application equipment (sprayer, duster etc.) except for microbial preparations.
16. Biocontrol is an economically viable method. If successfully deployed and converted.
17. Biological control method can be integrated well with other methods namely cultural, physical, mechanical, chemical (except use of broad spectrum insecticides) methods and host plant resistance.

Limitations of biological control in pest management

1. Biological controls slow process and the exotic parasite need at least three years for proper establishment. Further farmers does not like to wait for the natural enemies they wants quick results.
2. The work of the natural enemies cannot be restricted to particular crop or area. They may migrate in nearby field.
3. If parasites have other alternative host in a locality, it may not be effective for particular pest.
4. If certain season is not favourable for the normal development of natural enemy. Replacement/changing will become necessary every year (To fill again).
5. Progress of natural enemy becomes slow if hyperparasites are present in locality.
6. Use of chemical pesticides adversely affects the population level of natural enemies.
7. It is specific in control or effective only for one pest; so far the controls of other pest farmers have to adopt other methods of insect control.
8. Not always applicable.
9. Research costs are high.
10. May be difficult or expensive to produce.
11. Level of control may not be sufficient.
12. Small farm holding is limiting factors in adopting the biocontrol programme.
13. Farmers do not easily believe that insects can help in controlling harmful insect pests.
14. The farmers are inclined to use chemical pesticides because of convenience.
15. There has been a strong feeling among the bureaucrats that biocontrol has more academic importance than practical value, hence the projects were poorly financed.

CHEMICAL CONTROL (IMPORTANCE, HAZARDS AND LIMITATIONS)

Chemical control: Management of insect pests using chemical pesticides is termed as chemical control.

Pesticides: Chemicals which are used to kill pests

Insecticides: Chemicals which are used to kill insects.

Importance

Chemical control have played key role in improvement of plant suffering from abnormalities but have a negative perception in public mind because pesticides are intrinsically toxic. In agricultural production, pesticides are a regular component of most systems; their development has given rise to entirely new ways of growing crops. The quantity and quality of our food and fiber production could not be maintained without substantial pesticide inputs. It is difficult to imagine a technology that would produce the amount of food and fiber and maintain the level of public health that we have today without pesticides. But their use presents a problem.

The consumption of insecticides in India is 61%, fungicide 19%, herbicide 17% and others 3%. In India, 243 g/ha pesticide is consumed which is very low as compared to Taiwan (17 kg/ha), Japan (12 kg/ha), Korea (6.6 kg/ha), Europe (3.0 kg/ha), USA (2.5 kg/ha).

The chemical insecticide came in lime light when DDT insecticidal property discovered by **Paul Muller of Switzerland in 1939**. Paul Muller awarded Nobel Prize in 1948 for discovering insecticidal property of DDT

Advantages of Chemical Control

1. It is often the only means of combating pests.
2. It is curative in effect.
3. It is easy to apply/adopt.
4. Farmers can apply when and where required.
5. Large area can be covered in relatively short time.
6. Broad spectrum activity: A single or combination of two insecticides in a single application may control the pest complex.
7. Depending upon crops, pests and nature of damage, a range of insecticides is available to choose from.
8. Highly effective against pests than other methods of insect control.
9. It can be used in human health programme
10. It can protect animals from illness that can be caused by parasites such as fleas.
11. Growers can get high returns on his investment in a short time.
12. It is compatible with many component of IPM.

Limitations of Chemical Control

1. It is non selective: May harm natural enemies (Parasites and predators) and pollinators.
2. Insecticides cause resurgence of insect pests.
3. It leads emergence of secondary pest outbreak.
4. Resistance often develops: Insects tend to become resistant to insecticides after sometime, cannot be killed.
5. It pollutes air, water and land.
6. It may cause phytotoxicity.
7. Insecticides residues in food commodities and other components of the environment affect wide variety of organisms in the food chain.
8. It upset the balance of nature, which may result in unexpected problems
9. Noncompatible with biological control method.
10. Adverse effect on animals and man himself.
11. It is dangerous to consumers, workers during and after use.
12. As it is recurring, a cost increases as control is not permanent.

Hazards: The adverse effect caused by pesticides to human beings during manufacture, formulation, application and also consumption of treated products is termed as the hazard.

HAZARDS CAUSED BY PESTICIDES

Pesticide hazard occurs at the time of **a.** Manufacturing and formulation, **b.** Application of pesticides and **c.** Consumption of treated products.

Examples of hazards caused by pesticides

1. In Kerala, in 1953, 108 people died due to parathion poisoning
2. 'Bhopal Gas Tragedy' in 1984 at Bhopal where the gas called Methyl isocyanate (MIC) (an intermediate involved in manufacture of carbaryl) leaked killing 5000 people and disabling 50,000 people.
3. Cases of Blindness, Cancer, Liver and Nervous system diseases where pesticides are used in high quantity.
4. Psychological symptoms like anxiety sleep disturbance, depression and severe head ache in workers involved in spraying of insecticides regularly.

Impact of Pesticides in Agroecosystem

The following are some problems caused by pesticides in agro-eco system

- 1. Pesticide residues:** The pesticide that remains in the environment after application causes problems to humans and non-target organisms.
- 2. Insecticide resistance:** Insecticide resistance is the development of an ability to tolerate a dose of insecticide, which would prove lethal (kill) to majority of the individuals of the same species.
- 3. Pest Resurgence:** Tremendous increase in pest population brought about by insecticides despite good initial reduction in pest population at the time of treatment.
- 4. Secondary pest outbreak:** Application of a pesticide against a major pest, kills the natural enemies of minor or secondary pest. This causes the outbreak of a secondary pest.
- 5. Toxicity of non-target organisms**

LEGISLATIVE/ LEGAL / REGULATORY METHODS OF PEST CONTROL

In early days there were no restrictions on the transport of plants and animals from one country to another since the danger involved in it is not realized, which resulted in introduction of pests from one country to another. In many countries many of the dangerous pests have frequently been found to be foreign pests and they inflict greater damage than the indigenous ones.

Legal control : Preventing the entry and establishment of foreign plant and animal pest in a country or area and eradication or suppression of the pests established in a limited area through compulsory legislation or enactment

Quarantine : Isolation to prevent spreading of infection

Plant Quarantine : Legal restriction of movement of plant materials between countries and between states within the country to prevent or limit introduction and spread of pests and diseases in areas where they do not exist.

The importance of imposing restrictions on the movement of pest-infested plants or plant materials from one country to another was realized when the grapevine phylloxera got introduced into France from America by about 1860 and the San Jose scale spread into the USA in the later part of the 18th century and caused severe damage.

The first Quarantine Act in USA came into operation in 1905. While Govt. of India passed an Act in 1914 entitled “Destructive Insect and Pests Act of 1914 (DIPA)” to prevent the introduction of any insect, fungus or other pests into our country. This was later supplemented by a more comprehensive act in 1917.

The legislative measures in force now in different countries can be grouped into five classes. They are,

1. Legislation to prevent the introduction of new pests and weeds etc from foreign countries (International quarantine)
2. Legislation to prevent the spread of already established pests, diseases and weeds from one part of the country to another (Domestic quarantine)
3. Legislation to enforce upon the farmers regarding the application of effective control measures to prevent damage by already established pests.
4. Legislation to prevent the adulteration and misbranding of insecticides and determine their permissible residue tolerance levels in food stuffs and
5. Legislation to regulate the activities of men engaged in pest control operations and application of hazardous insecticides

Pests Accidentally Introduced Into India

Pest	Scientific name
Pink bollworm	<i>Pectinophora gossypiella</i>
Cottony cushion scale	<i>Icerya purchasi</i>
Apple Wooly aphid	<i>Aphelinus mali</i>
San Jose scale	<i>Quadraspidiotus perniciosus</i>
Potato tuber moth	<i>Gnorimoschima operculella</i>
Potato Cyst /Golden nematode	<i>Globodera</i> sp.
Giant african snail	<i>Acatina fullica</i>
Subabul psyllid	<i>Heteropsylla cubana</i>
Bunchy top of banana	
Spiralling whitefly	<i>Aleurodicus dispersus</i>

Foreign Pests From Which India Is Free

Mediterranean fruitfly	<i>Ceratitidis capitata</i>
Grapevine phylloxera	
Cotton boll weevil	<i>Anthonomos grandis</i>
Codling moth of apple	<i>Lasperyisia pomonella</i>

PEST LEGISLATIONS

1905- Federal Insect Pest Act - first Quarantine act against San Jose scale

1912 - US Plant Quarantine Act

1914 - Destructive Insects and Pests Act- of India (DIPA)

1919 - Madras Agricultural Pests and Diseases Act

1968 - The Insecticides Act

Phytosanitary certificate is issued by State Entomologist and Pathologists to the effect that the plant or seed material is free from any pest or disease

CHAPTER 4

CHEMICAL CONTROL

Control of insects with chemicals is known as chemical control. The term pesticide is used to those chemicals which kill pests and these pests may include insects, animals, mites, diseases or even weeds. Chemicals which kill insects are called as insecticides.

Importance of chemical control:

Insecticides are the most powerful tools available for use in pest management. They are highly effective, rapid in curative action, adoptable to most situations, flexible in meeting changing agronomic and ecological conditions and economical. Insecticides are the only tool for pest management that is reliable for emergency action when insect pest populations approach or exceed the economic threshold.

Indian pesticide market is the 12th largest in the World, which is 1.6 per cent of the global market. However per hectare consumption of pesticides in India is very low at 0.5 kg when compared to developed countries. In India 217 pesticide molecules (CIB, 2009) are registered for use, and 65 technical grade pesticides are manufactured indigenously. There are around 400 manufacturing units involved in production of technical grade pesticides and their formulations.

Properties of an ideal insecticide or pesticide:

1. It should be freely available in the market under different formulations.
2. It should be toxic and kill the pest required to be controlled.
3. It should not be phytotoxic to the crops on which it is used.
4. It should not be toxic to non target species like animals, natural enemies etc.
5. It should be less harmful to human beings and other animals.
6. It Should not leave residues in crops like vegetables.
7. It should have wide range of compatibility.
8. It should not be toxic to bees and fish and other beneficial organisms.
9. It should have higher tolerance limits.
10. It Should possess quick knock down effect.
11. It Should be stable on application.
12. It Should not possess tainting effects and should be free from offensive odour.
13. It Should be cheaper

Different Classifications of Insecticides

Insecticides are classified in several ways taking into consideration their origin, mode of entry, mode of action and the chemical nature of the toxicant.

I. Based on the origin and source of supply

A. Inorganic insecticides: comprise compounds of mineral origin and elemental sulphur. This group includes arsenate and fluorine compounds as insecticides. Sulphur as acaricides and zinc phosphide as rodenticides.

B. Organic Insecticides:

1. Insecticides of animal origin: Nereistoxin isolated from marine annelids, fish oil rosin soap from fishes etc.
2. Plant Origin insecticides or Botanical insecticides: Nicotinoids, pyrethroids, Rotenoids etc.

3. Synthetic organic insecticides: Organochlorines , Organophosphorous, Carbamate insecticides etc.,
4. Hydrocarbon oils etc.

II. Based on the mode of entry of the insecticides into the body of the insect they are groups as

(a) Stomach poison:- The insecticide applied on the leaves and other parts of plant when ingested act on the digestive system of the insect and bring about kill. This poison is used for chewing insects e.g. DDT, BHC, Aldrin, Toxaphene dusts, Zinc phosphide, paris green synthetic pyrethryium.

(b) Contact poison:- The toxicant which brings about death of the pest species by means of contact with the cuticle. E.g. quinolphos, Monocrotophos, dichlorvos, endrin, systemic pyrethroid.

(c) Fumigant:- The toxicant which in its gaseous state penetrates insect body through the tracheal system and kills the pests. E.g. Alluminium phosphide, ED\CT mixture.

Commonly used Fumigants and their doses:

1. Aluminium phosphide, marketed as **Celphos** tablets used against field rats, groundnut bruchids etc
2. EDB Ethylene dibromide 1 lb/1000ft³ of food grains.
3. SO₂: By burning sulphur in godowns SO₂ fumes are released.

Systemic insecticides: Chemicals that are capable of moving through the vascular systems of plants irrespective of site of application and poisoning insects that feed on the plants. Ex: Methyl-O- demeton, Phosphamidon , Acephate

‘**Non systemic insecticides**’ are not possessing systemic action are called non systemic insecticides. Some nonsystemic insecticides, however, have ability to move from one surface leaf to the other. They are called as ‘trans laminar insecticides’ . Eg. Malathion, Diazinon, spinosad etc.

An ideal systemic insecticide quality are

1. Should have high intrinsic pesticidal activity.
2. The toxicant must be adequately liposoluble for it to be absorbed by the plant system and water soluble for it to be translocated in the plant system.
3. The toxicant or its metabolites should be stable for sufficiently long period to exercise residual effect.
4. Sufficiently soluble in water for translocation through vascular system
5. Should degrade to nontoxic form in reasonable time to avoid toxicity to consumer.

Systemic insecticides are applied as seed dressing, granular formulations, sprays etc. In the leaf, the entry of the toxicant are through stomata and cuticle. On stem the entry is through lenticels and cracks in the cuticle. In the seed it is through seed coat especially through the micropyle. Systemic insecticides are highly useful against sap sucking and vectors such as leafhoppers, whiteflies, thrips, aphids etc.

III. Based on mode of action:

1. **Physical poisons:** Bring about the kill of insects by exerting a physical effect. Eg: Heavy oils, tar oils etc. which cause death by asphyxiation. Inert dusts effect loss of body moisture by their abrasiveness as in aluminium oxide or absorb moisture from the body as in charcoal.

2. **Protoplasmic poisons:** A toxicant responsible for precipitation of cell protein especially destruction of cellular protoplasm of midgut epithelium. Eg. Arsenical compounds.
3. **Respiratory poisons:** A toxicant responsible for precipitation of cell protein is said to be a protoplasmic poison e.g. Formaldehyde, Fatty acid Copper sulphite, Paris green etc.
4. **Respiratory poison:-** A chemical which inhibit cellular respiration by blocking cytochrome oxidase enzyme as with the fumigant like hydrogen cyanide, carbon monoxide EDB, ED\CT etc. is said to be a respiratory poison.
5. **Nerve poisons:** A chemical associated with solubility in tissue lipid and functions activity by blocking acetylcholinesterase enzyme in insects and warm blooded animals is called nerve poison e.g. organophosphate and carbamate insecticides, synthetic pyrethroids.
6. **Chitin inhibitors:** Chitin inhibitors interfere with process of synthesis of chitin due to which normal moulting and development is disrupted. Ex. Novaluron, Diflubenzuran, Lufenuron, Buprofezin
7. **General Poisons:**Compounds which include neurotoxic symptoms after some period and do not belong to the above categories. Eg.Chlordane, Toxaphene, aldrin

IV. Based on toxicity:

Toxicity	Classification	Symbol	Oral LD50	Dermal LD50
Extremely toxic	Skull & Poison	Red 	1-50	1-200
Highly toxic	Poison	Yellow 	51-500	201-2000
Moderately toxic	Danger	Blue 	501-5000	2001-20,000
Less toxic	Caution	Green 	>5000	>20,000

V. Based on stage specificity:

1. Ovicides
2. Larvicides
3. Pupicides
4. Adulticides

VI. Generation wise:

- First generation - Inorganics and Botanicals
- Second generation - Synthetic organics

Third generation	- Recent chemicals for reproductive control, IGRs like MH & JH mimics
Fourth generation	- Synthetic pyrethroids
Fifth generation	- SPs, Neonicotinoids

Toxicological terminology

LD₅₀ :Lethal dose required for killing 50% of insect and it is expressed in terms of mg/kg body weight of insect

LC₅₀ : Lethal concentration required for killing 50% of insect and it is expressed on terms of percentage

LC₉₀ : Lethal concentration required for killing 90% of insect and it is measured in percentage.

Thus higher the LC₅₀ or LD₉₀ vlues lesser the toxicity and vice versa

Group of insecticides

3) Classification based on chemical nature:-

Pesticides are mainly divided into two major divisions

A) Inorganic compounds:- Arsenic compounds, Fluorine compound, sulphar and lime sulphur, Barium carbonate, Thallium sulphite, Zinc phosphide, Aluminium phosphide.

B) Organic compounds:-Hydrocarbon oils e.g. petroleum oils, Tar oil etc.

Animal origin e.g. Nereistoxin etc.

Plant origin e.g. Nicotinoids, Pyrethroids, Rotenoids, Volatile oils from plants like eugenol.

Synthetic organic compounds

Dinitrophenols e.g. DNOC, Binapacryl etc.

Organic thiocynates e.g. Loro, Thanite etc.

Organochlorine compounds e.g. DDT, Dicofol, BHC, Endosulfan, Aldrin, heptachlor etc.

Organophosphorus compounds e.g. Dichlorvos, Quinalphos, Monocrotophos, Dimethoate, Methyl-o-demeton etc.

Carbamates e.g. carbaryl, carbofuran, Aldicarb, carbosulfan etc.

Organic sulphur compounds -Tetradifon, Aramite, chlorobenside

Other miscellaneous organic e.g. warfarin, coumatetallyl.

Fish oil and soaps e.g. rosin fish oil soap

Synthetic pyrethroids- permethrin, cypermethrin, fenvalerate, decamethrin

Newer insecticide:-

Chloronicotinoids - Imidachloprid (gaucho), Acetamiprid (pride)

ORGANIC COMPOUNDS OF PLANT ORIGINE

Toxicants Derived from plant are called plant origin insecticides

	Name of compound	Plant source	Toxicity & other information
1	Nicotine	<i>Nicotiana tabacum</i> leaves	Nerve poison
2	Pyrethrin	<i>Chrysanthemum cinerariaefolium</i> in flowers	Natural pyrethrin
3	Rotenon	<i>Derris elliptica</i> (root)	As a Fish poison
4	Sabadilla	<i>Schoenocaulon otticinale</i>	Contact poison
5	Tephrosin	<i>Tephrosia vogelli</i>	
6	Ryania	In root of <i>Ryania speciosa</i>	

SYNTHETIC CHEMICALS

A. Organochlorine compounds

	Technical name (Insecticide)	Trade name (Formulation)	Mode of Entry Remark
1	DDT	DDT 5 & 10% dust	Stomach & contact
2	BHC or gamma BHC	BHC 10% dust, Lindane 0.65%	Stomach & contact
3	Aldrin	Aldrin 5 & 10% dust, 30% EC	Stomach & contact
4	Endosulfan	Thiodan 35% EC	Stomach & contact

B. Organophosphorus compound

1	Dichlorovos	DDVP 76% EC, Nuvan	Contact, Stomach, fumigation
2	Phosphamidon	Dimecron 85% EC	Contact & Stomach, systemic
3	Monocrotophos	Nuvacron 36% EC	Systemic
4	Methyl parathion	Folidol 2% Dust	Contact & Stomach
5	Fenitrothion	Sumithion, Folithion 50% EC	Contact & Stomach
6	Fenthion	Leybacid 100% EC	Contact & Stomach, systemic
7	Chlorpyrifos	Dursban or Durmet 20% EC	Contact & Stomach
8	Diazinon	Basudin 20% EC	Contact & Stomach
9	Methyl-o- demeton	Metasystox 25% EC	Systemic & contact
10	Quinalphos	Ekalux 25% EC	Contact
11	Phorate	Thimet 10% G	Systemic
12	Thiometon	Ekatin 25% EC	Systemic, Acaricides
13	Dimethoate	Rogor 30% EC	Systemic & contact
14	Formothion	Anthio 25% EC	Systemic & contact
15	Profenofos	Curacron 50EC	contact & stomach.

16	Triazophos	Hostathion 40 EC	contact & stomach
C. Carbamate compound			
1	Carbaryl	Sevin 50% WP, Carbaryl	Contact
2	Carbofuran	Furadan 3% G	Systemic, Nematicides
3	Aldicarb	Temic 10% G	Systemic, Nematicides
4	Indoxacarb	Avaunt 14.5 SC	contact & stomach
5	Thiodicarb	Larvin 75 WP	
6	Carbosulfan	Marshal 25 EC	
7	Methomyl	Lannate, Dunet	
8	Fenobucarb	Mahakill, Knock, Merlin	
D. Synthetic pyrethroid			
1	Permethrin	Permasect 10 & 20% EC	Contact & stomach
2	Cypermethrin	Cyperkill, Cymbush, Ripcord 20EC	Contact
3	Fenvalate	Sumicidin 20% EC	Contact
4	Decamethrin	Decis 2.8% EC	Contact
5	Lamda cyhalothrin	Karate 5EC, Kungfoo 2.5 EC	Contact & Stomach
6	Beta cyfluthrin	Bulldock 0.25 SL	Contact & Stomach
7	Fluvalinate	Mavrik 20EC	Contact & Stomach
8	Fenpropathrin	Meothrin, Danitol and Rody	
9	Bifenthrin	Talstar	
E. Neo - nicotinoids :			
1	Imidacloprid	Confidor, Gaucho , Provado	Systemic
2	Acetamiprid	Pride	Systemic--sucking pests
3	Clothianidin	Dantop	
F Naturalytes			
1	Avermectin	<i>Streptomyces avermetilis</i>	Emamectin benzoate
2	Spinosyns	<i>Saccharopolyspora spinosa</i>	Tracer,
3	Cartap hydrochloride	Padan	Nereistoxins <i>Lumbriconereis heteropoda</i>
G. Chloronicotinyl Compounds			
1	Thiomethoxam	Actara® and Cruiser 70WS	
2	Fipronil	Regent®	

3	Indoxacarb	Avaunt 14.5 SC	
4	Diafenthiuron	Polo 50 WP	
Diamides			
1	Flubendiamide	Takumi 20 WG	
Quinazolines			
1	Fenazaquin	Magister	
Benzoylphenyl ureas (Insect growth regulators, IGRs) Chitin inhibitors			
1	Lufenuron	Match 5% EC	
2	Novaluron	Remon 10% EC	
3	Buprofezin	Applaud25% EC	
4	Diflubenzuron	Dimilin25% WP	
Organosulfurs			
1	Proargite	Omite	
General			
1	Acephate	Asataf 75 % SP	
2	Dicofol	Kelthane, Dicofol 18.5% EC	
3	Thiodicarb	Laravin75%WG	

Technical, trade names and formulators of various pesticides (May be Duplication)

No.	Technical Name	Trade Name	Formulation
1	Abamectin	Avermectin	1.8 % EC
2	Acephate	Asataf	75 % SP
3	Acetamiprid	Pride	20 % SP,
4	Aluminium phosphide	Celphos	3g Tab
5	Betacyfluthrin	Bulldock	25EC
6	Bifentrin	Talstar	10% EC
7	Buprofezin	Applaud	25% EC
8	Butacarboxim	Drawin	50% EC
9	Carbaryl	Sevin	10% D, 50%WP
11	Carbofuran	Furadan	3% G

12	Carbosulfan	Marshal	25% EC, 5%G
13	Cartap hydrochloride	Padan	4% G, 50%SP
14	Chlorpyrifos	Dursaban,	20% EC, 1.5% DP
15	Clothianandin	Dantop	50% WDG
16	Cyfluthrin	Baythroid	10% WSC, 50% WSC
17	Cypermethrin	Cymbush, Cyperkill	10% EC, 25% EC
18	Deltamethrin/ Decamethrin	Decis	2.8 %EC, 2.5% WP
19	Diazinon	Diazinon, Basudin,	5% G, 10% G, 20%EC
20	Dichlorvos (DDVP)	DDVP, Vapona, Nuvan,	76%EC
21	Difenthrun	Polo	50%WP
22	Dicofol	Kelthane	18.5% EC
23	Diflubenzuron	Dimilin	25% WP
24	Dimethoate	Rogor,	30% EC
25	Emamectin	Proclaim	5% WG,10% SG
26	Endosulfan	Thiodan	2% D, 4% DP, 35% EC
27	Ethion	E-Mite, Phosmite	50% EC
28	Fenitrothion	Sumithion,	5% D, 50% EC,
29	Fenprothrin	Meothrin,	30% EC
30	Fenazaquin	Magister	10% EC
31	Fenthion	Lebaycid	1000%EC
32	Fenvalerate	Sumicidin,	0.4%DP, 20%EC
33	Fluvalinate	Mavrik	25% EC
34	Formothion	Anthio	25% EC
35	Fipronil	Regent	5% EC
36	Imidachloprid	Gaucha, Tatamida,Confidor, Imidagold,	70 WS,17.8 SL, 30.5 SL
37	Indoxacarb	Avaunt, Indoxa	14.5% SC
38	Lufenuron	Match	5% EC
40	Lambdacyhalothrin	Karate	5% EC, 2.5% EC
41	Malathion,	Cythion, Malathion,	5% DP, 50%EC
42	Methamidophos	Monitor,	40% SP
43	Milbemectin	Milbeknock	1% EC
44	Mythomyl	Lannate	40% SP

45	Methyl-O-demeton	Metsystox	25% EC
46	Methyl parathion	Folidol	2% DP, 50% EC
47	Monocrotophos	Nuvacron, Monocil,	36% SL
48	Novaluron	Remon	10% EC
49	Permethrin	Ambush, Permasect	25% EC, 50% EC
50	Phorate	Thimate	10 g
51	Phosalone	Zolone	35% EC
52	Phosphamidon	Dimecron	40% SL
54	Profenophos	Curacron	50% EC
55	Proparagite	Omite, Simba	57% EC
56	Quialphos	Ekalux	1.5 DP, 5 G, 25 EC, 20 AF
57	Spinosad	Tracer	45% SC, 2.5%SC
58	Thiodicarb	Larvin	75WG
59	Thiometon (morphothion)	Ekatin	25%EC
60	Thiamethoxam	Cruiser, Actara	70%WS, 25%WG
61	Trizophos	Hostathion	40% EC
62	Flubendiamide	Takumi	20 WG
63	Fenobucarb	Mahakill, Knock, Merlin	

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3	Cartap hydrochloride	Padan	Nereistoxins

			<i>Lumbriconereis heteropoda</i>

Advantages of chemical control:

1. Chemicals are powerful tools for pest management.
2. Highly effective, rapid curative action and adoptable to most situation.
3. Flexible in changing agronomic and ecological conditions.
4. It is economical.
5. Insecticides are only tools available when pest is crossing threshold levels.
6. For many of pest problems chemical control is the only acceptable solution.
7. They are easy to obtain and apply

Limitations of chemical control:

1. Harmful to non target organisms.
2. Many pesticides bring about the secondary infestation of non target pests and resurgence of target pests.
3. Other beneficial insects like pollinators, honeybees, weed killers may also be killed.
4. There is a risk to man and livestock.
5. Some pesticides may cause phytotoxicity.
6. Some insecticides leave residues which cause environmental pollution.
7. Some insects may develop resistance to insecticides.
8. Some insecticides accumulate in body tissue become dangerous even without any prior indications.
9. Some insecticides have a tendency to be passed over from one food source to another food source.

CHITIN SYNTHESIS INHIBITORS Chitin synthesis inhibitors disrupt molting by blocking the formation of chitin, the building block of insect exoskeleton.

No.	Name	Tradename	Formulation
1	Diffubenzuron	Dimilin	25 WP
2	Flufenoxuron	Cascade	10 WDC
3	Chlorfluazuron	Atabron	5 SC
4	Triflumuron	Alsystin, Baycidal Starycide	25 WP
5	Teflubenzuron	Nomolt,Dart, Nemolt	15 SC
6	Novaluron	Rimon	10 EC
7	Buprofezin	Applaud	25 SC, 70 WP
8	Flufenoxuron	Cascade, Casette, Tenope	10%EC, 5%EC

CHAPTER 5

TOXICITY OF INSECTICIDES

Toxicity- is the ability of pesticides to cause harm to the human or plant health.

Human toxicity: can be caused due to the exposure of pesticides in or on the body.

Pesticide exposure means the contact of pesticides with the surface or organisms.

- Oral exposure : when swallow a pesticide
- Inhalation exposure : when breathing in a pesticide
- Ocular exposure : through the eyes
- Dermal exposure: through the skin

Pesticides cause 3 types of symptoms:

- 1) **Acute** : effect or illness or injuries that may appear immediately after exposure to a pesticide (usually within 24 hours). Acute symptoms of pesticides poisoning include-lack of sensation, stinging sensation, Lack of coordination, Headache, Dizziness, Tremor (Shaking), Abdominal cramps, Sweating, unclear vision, Difficulty including or respiratory depression or ,Slow heartbeat etc.
- 2) **Delayed or Chronic** : in chronic poisoning, the person is repeatedly exposed to toxic agent over a long period, but only a low dose enters the body each time. Chronic effects of long term pesticide exposure include: Impaired memory and concentration, Disorientation , Severe depression, Irritability, Confusion, Headache, speech difficulties, delayed reaction time , nightmares, sleep walking, Drowsiness or insomnia
- 3) **Allergic effect** : harmful effects that some people develop in reaction to substance that do not cause the same reaction in most of the people. Allergic effects of pesticide include: Systemic effects, such as asthma or even life-threatening shock, skin irritation, such as rash, blisters or open sores, eyes and nose irritation, such as, itchy, watery eyes and sneezing.

PHYTOTOXICITY

The application of pesticides or insecticides on plants is intended to control the pests without causing adverse or harmful effects to plants. It is common to see some adverse insecticides in fields which is called **phytotoxicity**. It is of two kinds

1. Permanent phytotoxicity leading to the death of the effected part or whole plant

2. Temporary phytotoxicity which allows the plant to recover after showing phytotoxicity

Most insecticides are not phytotoxcity at ordinary/ recommended concentrations but show temporary/permanent phytotoxcity when applied indiscriminately at much higher concentrations.

Symptoms of phytotoxicity :

- Chlorosis or yellowing of leaves
- Bronzing of leaves
- Necrosis of complete plant or parts of it
- Scorching
- Deformation and curling of leaves
- White spots on leaves
- Burning effects on leaves
- Premature falling of leaves
- Mottled leaves

- Poor germination of seeds

Examples :

Organo chlorines	– Curcurbits
Carbaryl	– Soybean & Redgram
Dimethoate and Malathion	– Sorghum
Methyl parathion	– All Cucurbits
Sulphur	– Crcurbits, Apples and Tea

CHAPTER 6

FORMULATIONS OF INSECTICIDES

Formulation is the processing of a compound by such methods that will improve its properties of storage, handling, application, effectiveness and safety to the applicator and environment and profitability. It is the final physical condition in which insecticide is sold. A single insecticide is often sold in several different formulations.

Types of formulations

- I. **Solid formulations**
- II. **Liquid formulations**
- III. **Gaseous formulations**

SOLID FORMULATIONS

1. **Dusts (D):** These are ready to use insecticides in powder form. In a dust formulation the toxicant is diluted either by mixing with or by impregnation on a suitable finely divided carrier which may be an organic flour or pulverized mineral like lime, gypsum, talc etc., or clay like attapulgite bentonite etc. The toxicant in a dust formulation ranges from 0.15 to 25% and the particle size in dust formulations is less than 100 microns and with the decrease in particle size the toxicity of the formulation increases. Dusts are easy to apply, less labour is required and water is not necessary. However if wind is there, loss of chemical occurs due to drift hence dusting should be done in calm weather and also in the early morning hours when the plant is wet with dew.
Eg. HCH 10% dust; Endosulfan 4% D.
2. **Granules or Pelleted insecticides (G):** These are also ready to use granular or pelleted forms of insecticides. In this formulation the particle is composed of a base such as an inert material impregnated or fused with the toxicant which released from the formulation in its intact form or as it disintegrates giving controlled release. It contains 1 to 10% concentration of the toxicant. The granules are applied in water or whorls of plants or in soil. Action may be by vapour or systemic. In application of granules there is very little drift and no undue loss of chemical. Undesirable contamination is prevented. Residue problem is less since granules do not adhere to plant surface. Release of toxicant is achieved over a long period. Easy for application as water is not required for application. Less harmful for natural enemies. Eg: Carbofuran 3G, Phorate 10 G, Cartap hydrochloride 4G
3. **Wettable Powders (WP):** It is a powder formulation which is to be diluted with water and applied. It yields a stable suspension with water. The active ingredient (toxicant) ranges from 15 to 95%. It is formulated by blending the toxicant with a diluent such as attapulgite, a surface active agent and an auxiliary material. Sometimes stickers are added to improve retention on plant surface. Loss of chemical due to run off may be there and water is required for application.
Eg: Carbaryl 50%WP, Thiodicarb 75% WP
4. **Baits:** In baits a.i is mixed with edible substance. These are always stomach poisons and are used for poison baiting which is chiefly made up of 3 components, Poison (Insecticide carbaryl), Carrier or base (Rice bran), and Attractant (Jaggery) at ratio of 1:10:1. Poison should be strong and easily soluble. Base is the filler like rice bran with just enough water.

5. **Water Dispersible Granules (WDG):** This formulation appears as small pellets or granules. It is easier and safer to handle and mix than wettable powders. When the granules are mixed with spray water, they break apart and, with agitation, the active ingredient becomes distributed throughout the spray mixture. Ex: Thiamethoxam 25 WDG.

LIQUID FORMULATIONS

1. **Emulsifiable Concentrates (EC):** Here the formulation contains the toxicant, a solvent for the toxicant and an emulsifying agent. It is a clear solution and it yields an emulsion of oil-in water type, when diluted with water. The active ingredient (toxicant) ranges from 2.5 to 100 %.When sprayed the solvent evaporates quickly leaving a deposit of toxicant from which water also evaporates. The emulsifying agents are alkaline soaps, organic amines alginates, Carbohydrates, gums, lipids, proteins etc. Eg: Profenophos 50EC.
2. **Soluble Powder or Water Soluble Powder (SP or WSP):** It is a powder formulation readily soluble in water. Addition of surfactants improves the wetting power of the spray fluid. Sometimes an anti-caking agent is added which prevents formation of lumps in storage. This formulation usually contains a high concentration of toxicant and therefore convenient to store and transport. Eg: Acephate 75 SP.
3. **Suspension Concentrate (SC):** Active ingredient is absorbed on to a filler which is then suspended in a liquid matrix (water).It is not dusty and easier to disperse in water. Eg: Imidacloprid 50 SC
4. **Flowables (F):** When an active ingredient is insoluble in either water or organic solvents, a flowable formulation is developed. The toxicant is milled with a solid carrier such as inert clay and subsequently dispensed in a small quantity of water. Prior to application it has to be diluted with water. Flowables do not usually clog nozzles and require only moderate agitation. **Ex.** Ethoxyfenozide(Intrepid 2F)
5. **Solutions:** Many of the synthetic organic insecticides are water insoluble but soluble in organic solvents like amyl acetate, kerosene, xylene, pine oil, ethylene dichloride etc., which themselves possesses some insecticidal properties of their own. Some toxicants are dissolved in organic solvents and used directly for the control of household pests. Eg. Baygon
6. **Concentrated insecticide liquids:** The technical grade of the toxicant at highly concentrated level is dissolved in non-volatile solvents. Emulsifier is not added. Generally applied from high altitudes in extremely fine droplets without being diluted with water at ultra volume rates. There is greater residual toxicity and less loss through evaporation. Active ingredient ranges from 80-100% Eg: Malathion, Bifenthrin and Fenitrothion.

GASEOUS FORMULATIONS

1. **Insecticide aerosols:** The toxicant is suspended as minute particles 0.1 to 30 microns in air as fog or mist. The toxicant is dissolved in a liquified gas and if released through a small hole causes the toxicant particles to float in air with rapid evaporation of the released gas. Eg: Allethrin
2. **Fumigants:** A chemical compound which is volatile at ordinary temperature and sufficiently toxic is known as fumigant. Most fumigants are liquids held in cans or tanks and quite often they are mixtures of two or more gases. Advantage of using fumigant is that the places not easily accessible to other chemicals can be easily reached due to penetration and dispersal effect of the gas. Eg; Aluminium phosphide

3. Ultra low volume concentration: these are special formulations almost technical product as such is dissolved in a liquid solvent for micronized droplet applications without dilution. These are applied with the help of special equipment for controlled droplet applicators (CDA). Total volume dispersed dose is not exceed 1 or 2 litres per hectare by area or ground spray equipmentss.

OTHER FORMULATIONS

- **Microencapsulation:** Microencapsulated formulations consist of dry and liquid pesticide particles enclosed in tiny plastic capsules which are mixed in water and sprayed. Ex. Lambda-cyhalothrin
- **Insecticide Mixtures:** Insecticide mixtures involve combinations of two or more insecticides in the right concentration into a single spray solution. Insecticide mixtures are widely used to deal with the array of arthropod pests encountered in greenhouse and field production systems due to the savings in labor costs. Furthermore, the use of pesticide mixtures may result in synergism or potentiation (enhanced efficacy) and the mitigation of resistance. However, antagonism (reduction in efficacy) may also occur due to mixing two (or more) pesticides together. Judicious use of pesticide mixtures or those that may be integrated with biological control agents is especially important because parasitoids and predators (and even microbials such as beneficial bacteria and fungi) can suppress arthropod pest populations irrespective of the arthropod pests' resistance traits or mechanisms.

Ex: Chlorpyrifos 50% + Cypermethrin 5% EC

- Quinolphos 20% + Cypermethrin 3% EC
- Profenofos 40% + Cypermethrin 4% EC
- Profenofos 25% + Cypermethrin 5% EC
- Profenofos10% + Cypermethrin 20% EC

CHAPTER 7

INSECTICIDES ACT 1968

The Insecticides act of India, 1968, is an act to regulate the import, manufacture, sale, transport, distribution and use of insecticides with a view to prevent risk to human beings or animal and for matters connected there with.

The Act was passed by parliament on **September 2, 1968** and was enforced throughout the country with effect from **August 1, 1971**. The rules were framed and brought into **force on October 30 1971**.

The objectives of insecticides act are

- To register only safe and efficacious pesticides.
- To ensure that the farmers users get quality product for controlling the pests.
- To prescribe usage of pesticides both from ground and air, and also important precautions for their handling and use.
- To minimize health hazards from the pesticides Residue through contaminated food, water and air.
- To ensure that the pesticide industry manufacture, transport, distribute, store and sell the pesticides as per the prescribed regulations, for failing which legal action is taken.
- To ensure that the pesticides are properly tag and labelled to avoid any leakage of the hazardous pesticides in transit and to provide enough instructions for their safe handling and use.

Some of the most important functionaries prescribed and the regulatory procedures laid down under this act are as follows:

A. Central bodies and Laboratories

I. Central insecticide Board

This board fixes tolerance limits for insecticides residues, safety period and shelf life based on the data provided by the manufacturers and also based on research findings of the scientists in the country. It also advises Central and state government in all technical matters of insecticides.

II. Registration committee

Before these can be sold in India, all insecticides has to be approved and registered by this committee. Registration is done after scrutinizing and verifying the formula and their efficacy and safety to human beings and animals. In addition, the committee may also specify the precaution to be taken against poisoning by the use and handling of the particular insecticide.

III. Other committees are

- Pesticides environmental pollution advisory Committee, to advise the pod on all hazards emanating from the use of pesticides.
- 6 different expert panels has been constituted to finalize the approved usage of insecticides fungicides herbicides and fumigants the manufacturers of pesticides are obliged to give these usage and bio effective qualities on leaflet.

B. Registration of insecticides

C. Licences for manufacture and sale

D. Central insecticides laboratory

E. State insecticides testing Laboratories

Salient features of the insecticides act (1968)

Compulsory registration with CIB (Central level)

Licence for manufacture, formulation and sale at state level

Inter departmental/Ministerial/Organisational co-ordination achieved by high level Advisory Board "Central Insecticides Board" with 28 members from various fields

RC to look after registration aspects of insecticides

Enforcement by Insecticide inspectors at state/central level

Power to prohibit the import, manufacture and sale of insecticides and also confiscate stocks.

Guilty are punishable.

CHAPTER 8

APPLICATION TECHNIQUES OF SPRAY FLUIDS

The desired effect of a pesticide can be obtained only if it is applied by an appropriate method in appropriate time. The method of application depends on nature of pesticide, formulation, pests to be managed, site of application, availability of water etc.

1. **Dusting:** Dusting is carried out in the morning hours and during very light air stream. It can be done manually or by using dusters. Some times dust can be applied in soil for the control of soil insects. Dusting is cheaper and suited for dry land crop pest control.

2. **Spraying:** Spraying is normally carried out by mixing EC (or) WP formulations in water. There are three types of spraying.

	Spray fluid (l/ acre)	Droplet size	Area covered/day	Equipment used
a) High volume spray	200-400	150	2.5 ac	Knapsack, Rocker sprayers
b) Low volume spray	40-60	70-150	5.6 ac	Power sprayer, Mist blower
c) Ultra low volume spray	2-4 lit.	20-70	20 ac	ULV sprayer, Electrodyn sprayer

3. **Granular application :** Highly toxic pesticides are handled safely in the form of granules. Granules can be applied directly on the soil or in the plant parts.

The methods of application are

a) **Broadcasting :** Granules are mixed with equal quantity of sand and broadcasted directly on the soil or in thin film of standing water. (eg.) Carbofuran 3G applied @ 1.45 kg/8 cent rice nursery in a thin film of water and impound water for 3 days.

b) **Infurrow application :** Granules are applied at the time of sowing in furrows in beds and covered with soil before irrigation. (eg.) Carbofuran 3G applied @3 g per meter row for the control of sorghum shootfly.

c) **Side dressing :** After the establishment of the plants, the granules are applied a little away from the plant (10-15 cm) in a furrow.

d) **Spot application :** Granules are applied @ 5 cm away and 5 cm deep on the sides of plant. This reduces the quantity of insecticide required.

e) **Ring application :** Granules are applied in a ring form around the trees.

f) **Root zone application :** Granules are encapsulated and placed in the root zone of the plant. (eg.) Carbofuran in rice.

g) **Leaf whorl application :** Granules are applied by mixing it with equal quantity of sand in the central whorl of crops like sorghum, maize, sugarcane to control internal borers.

h) **Pralinage :** The surface of banana sucker intended for planting is trimmed. The sucker is dipped in wet clay slurry and carbofuran 3G is sprinkled (20-40 g/sucker) to control burrowing nematode.

4. **Seed pelleting/seed dressing :** The insecticide mixed with seed before sowing (eg.) sorghum seeds are treated with chlorpyrifos 4 ml/kg in 20 ml of water and shade dried to

control shootfly. The carbofuran 50 SP is directly used as dry seed dressing insecticide against sorghum shootfly.

5. Seedling root dip: It is followed to control early stage pests (eg.) in rice to control sucking pests and stem borer in early transplanted crop, a shallow pit lined with polythene sheet is prepared in the field. To this 0.5 kg urea in 2.5 litre of water and 100 ml chlorpyrifos in 2.5 litre of water prepared separately are poured. The solution is made upto 50 ml with water and the roots of seedlings in bundles are dipped for 20 min before transplanting.

6. Sett treatment: Treat the sugarcane setts in 0.05% malathion for 15 minutes to protect them from scales. Treat the sugarcane setts in 0.05% Imidacloprid 70 WS@ 175 g/ha or 7 g/l dipped for 16 minutes to protect them from termites.

7. Trunk/stem injection: This method is used for the control of coconut pests like black headed caterpillar, mite etc. Drill a downward slanting hole of 1.25 cm diameter to a depth of 5 cm at a height of about 1.5 m above ground level and inject 5 ml of monocrotophos 36 WSC into the stem and plug the hole with cement (or) clay mixed with a fungicide. Pseudo stem injection of banana, an injecting gun or hypodermic syringe is used for the control of banana aphid, vector of bunchy top disease.

8. Swabbing : Coffee white borer is controlled by swabbing the trunk and branches with HCH (BHC) 1 per cent suspension.

9. Root feeding : The insecticide absorbed by root, enter the plant system and control the insect. Trunk injection in coconut results in wounding of trees and root feeding is an alternate and safe chemical method to control black headed caterpillar, eriophyid mite, red palm weevil.

11. Soil drenching : Chemical is diluted with water and the solution is used to drench the soil to control certain subterranean pests. (eg.) BHC 50 WP is mixed with water @ 1 kg in 65 litres of water and drench the soil for the control of cotton/stem weevil and brinjal ash weevil grubs.

12. Capsule placement : The systemic poison could be applied in capsules to get toxic effect for a long period. (eg.) In banana to control bunchy top vector (aphid) the insecticide is filled in gelatin capsules and placed in the crown region.

13. Baiting : The toxicant is mixed with a bait material so as to attract the insects towards the toxicant.

a) *Spodoptera* : A bait prepared with 0.5 kg molasses, 0.5 kg carbaryl 50 WP and 5 kg of rice bran with required water (3 litres) is made into small pellets and dropped in the field in the evening hours.

b) Rats : Zinc phosphide is mixed at 1:49 ratio with food like popped rice or maize or chola or coconut pieces (or) warfarin can be mixed at 1:19 ratio with food. Ready to use cake formulation (Bromodiolone) is also available.

c) Coconut rhinoceros beetle : Castor rotten cake 5 kg is mixed with insecticide.

14. Fumigation: Fumigants are available in solid and liquid forms. They can be applied in the following way. (1) Soil: To control the nematode in soil, the liquid fumigants are injected by using injecting guns. (2) Storage: Liquid fumigants like Ethylene dibromide (EDB), Methyl bromide (MB), carbon tetrachloride etc. and solid fumigant like Aluminium phosphide are recommended in godowns to control stored product pest. (3) Trunk: Aluminium phosphide 7f to I tablet is inserted into the affected portion of coconut tree and plugged with cement or mud for the control of red palm weevil

CHAPTER 9

INSECTICIDE POISONING, FIRST AIDS AND ANTIDOTES

Symptoms of mild poisoning

1. Headache
2. A feeling of Sickness (nausea)
3. Dizziness
4. Fatigue
5. Irritation of the Skin, Eyes, Nose And Throat,
6. Perspiration
7. Loss of Appetite

Symptoms of moderate poisoning

1. Vomiting,
2. Blurred vision,
3. Stomach cramps,
4. Rapid pulse,
5. Difficulty in breathing, constricted pupils of the eyes,
6. Excessive precipitation,
7. Trembling and twitching of muscles, fatigue and nervous distress headache,

Symptoms of severe poisoning

1. Convulsions
2. Respiratory failure
3. Loss of consciousness
4. Loss of pulse

Symptoms due to Chlorinated hydrocarbons poisoning

1. Uneasiness
2. Headache
3. Nausea
4. Vomiting
5. Dizziness and tremors
6. Convulsions
7. Respiratory arrest followed by coma
8. Leucocytosis and rise in blood pressure.

Symptoms due to organophosphate and carbamate insecticides poisoning

1. Headache, giddiness, vertigo, weakness, excessive mucous discharge from nose and sense of tightness are symptoms of inhaled exposures.
2. Nausea followed by vomiting, abdominal contraction, diarrhea and salivations are symptoms of ingestion.
3. Loss of muscle coordination, speech defects; twitching of muscles; difficulty in breathing; hypertension; jerky movements; convulsions and coma indicate seriousness of poisoning.
4. Death may occur due to depressions of respiratory centre
5. Headache, giddiness, vertigo, weakness, excessive mucous discharge from nose and sense of tightness are symptoms of inhaled exposures.
6. Nausea followed by vomiting, abdominal contraction, diarrhea and salivations are symptoms of ingestion.

7. Loss of muscle coordination, speech defects; twitching of muscles; difficulty in breathing; hypertension; jerky movements; convulsions and coma indicate seriousness of poisoning.
8. Death may occur due to depressions of respiratory centre

Zinc phosphide

1. Nausea
2. Vomiting
3. Diarrhea
4. Severe abdominal pain followed by symptom free period of eight hours or longer

Alluminium phosphide

1. Headache
2. Giddiness
3. Nausea
4. Diarrhea and mental confusion
5. If treatment is delayed, coma, loss of reflexes may develop and death may occur from respiratory or circulatory collapse

First Aid Operations:

Many accidental pesticide deaths are caused by eating or drinking the chemical. Some applicators die or are injured when they breathe pesticide vapors or get pesticides on their skin. Repeated exposure to small amounts of some pesticides can cause sudden, severe illness. All pesticide handlers should know and thoroughly understand first aid treatment for pesticide poisoning. Call local emergency response provider and local emergency medical facility immediately and

1. Remove patient to fresh air
2. Loosen all knots of clothes and change overalls.
3. Flush eyes with copious cold water till irritation subsides
4. Wash the patient thoroughly with plenty of soap and water.
5. Keep the patient calm, comfortable and warm.
6. In case of accidental ingestion ,induce vomiting by administering a glass of warm water mixed with two spoons of common salt or putting the forefinger at the base of plate.
7. Show label leaflet of pesticide for identification
8. If breathing is stopped provide artificial breathing.

Swallowed poisoning

1. Remove poison from the patient's stomach immediately by inducing vomiting.
2. Give common salt 15 g in a glass of warm water as an emetic and repeat until vomit fluids is clear.
3. Gently stroking or touching the throat with the finger or the blunt end of a spoon will aid in inducing vomiting when the stomach is full of fluid.
4. If the patient is already vomiting, do not give emetic but give large amounts of warm water and then follow the specific directions suggested

Inhaled poisons

1. Carry the patient to fresh air immediately,
2. Open all doors and windows.
3. Loosen all tight clothing.
4. Apply artificial respiration if breathing has stopped or is irregular and avoid vigorous application of pressure to the chest.

5. Prevent chilling and wrap the patient in a blanket.
6. Keep the patient as quiet as possible.
7. If the patient is convulsing, keep him in bed in some dark room.
8. Do not give alcohol in any form.

Skin contamination:

1. Drench the skin with water.
2. Apply a stream of water on the skin while removing clothing.
3. Rapid washing is most important for reducing the extent of injury

Eye contamination:

1. Hold eye lids open
2. Wash the eyes gently with a stream of running water immediately
3. Delay of even a few second greatly increase the extent of injury
4. Continue washing until physician reaches
5. Do not use chemicals as they may increase the extent of injury.

Antidotes:**General antidotes:**

1. Remove poison by inducing vomiting
2. Universal Antidote: It is a mixture of 7 g of activated charcoal, 3.5 g of magnesium oxide and 3.5 g of tannic acid in half a glass of warm water may be used to absorb or neutralize poisons. Except in cases of poisoning by corrosive substances, it should be followed by gastric lavage.
3. Removal of stomach contents (Gastric lavage.)
4. Demulcents : After removal of stomach contents as completely as possible, give one of the following:
 1. Raw egg white mixed with water
 2. Gelatine 9 g to 18 g dissolved in 570 ml of warm water
 3. Butter
 4. Cream
 5. Milk or Mashed potato

Specific antidotes:

1. Atropine is the usual antidote for organophosphate and carbamate poisoning. It can be given orally and in severe cases, injections are given. Repeated injections may be required.
2. 2-PAM: It is injected intravenously as an antidote in organophosphate poisoning. It should not be used in case of carbamate poisoning.
3. Calcium gluconate is recommended as an antidote for some organochlorine insecticides
4. Vitamin K is the preferred antidote for anticoagulant poisoning such as warfarin.
5. Dimercaprol (BAL) is recommended for arsenic poison.

CHAPTER 10

Introduction to the conventional pesticides for the insect pests management

Much before the advent of synthetic organic insecticides need, pyrethrum, Rotenone, nicotine and number of other lesser known Botanical pesticides were used to protect agricultural crops from the ravages of insect and non insect pest in different parts of the world.

SN	Plant name	Product/ trade name	Group/mode of action	Targets
1	<i>Lonchocarpus</i> spp. <i>Derris elliptical</i>	Rotenone	Insecticidal	Aphids, bean leaf beetle, cucumber beetles, leafhopper, red spider mite
2	<i>Chrysanthemum cinerariaefolium</i>	Pyrethrum/ Pyrethrins	Insecticidal	Crawling and flying insects such as cockroaches, ants, mosquitoes, termites
3	<i>Nicotiana tabaccum</i>	Nicotine	Insecticidal, antifungal	Aphids, mites, bugs, fungus, gnat, leafhoppers
4	<i>Azadirachta indica</i>	Azadirachtin/ neem oil, neem products, Bionimbecidine	Repellent, Antifeedant, Nematocide, Anti-fungal	Nematodes, sucking and chewing insects (caterpillars, aphids maize weevils)
5	Citrus trees	d-Limonene Linalool	Contact poison	Fleas, aphids, mites, paper wasp, house cricket
6	<i>Shoenocaulon officinale</i>	Sabadilla dust	Insecticidal	Bugs, blister beetles flies, caterpillars, potato leafhopper
7	<i>Ryania speciosa</i>	Ryania	Insecticidal	Caterpillars, beetles, bugs, aphids
8	<i>Adenium obesum</i> (<i>Heliotis</i> sp)	Chacals Baobab (Senegal)	Insecticidal	Cotton pests

The detailed description of the above pesticide is given above in the chapter 4.

CHAPTER 11

IMPLEMENTATION AND IMPACT OF IPM

IPM module of insect pests:

Strategies for IPM Implementation

The IPM packages tested at several research centres vis-a-vis the farmers' practices indicate superiority of the former. IPM practices enabled reduction in the number of chemical sprays. IPM system also resulted in increase of natural enemies by three-fold, reduced the insecticide and environmental pollution (Dhaliwal and Arora, 1996).

An integrated strategy for the management of major pests and diseases is possible by

- I. breeding new varieties with built-in resistance,
- II. evolving efficient methods of pest control through pest surveys and monitoring, and
- III. biological control of pests with the help of conservation and augmentation of natural enemies like parasites, predators and insect pathogens.

IPM for Important Pests:

Rice

Pest	Characteristic damage	Economic thresholds	Control measures
Stem borer	Death of central shoot-Dead heart(DH), white ear(WE), Loss of tillers	10% DH or 1 egg mass 1moth/m ²	Stubble destruction, Resistant varieties like Vikas Sasyasre, Ratna. *Chemical control
Gall midge	Central leaf sheath modified to a Silver shoot (SS), Loss of tillers	5% (at active tillering stage)	Early planting, Resistant varieties Phalguna, Surekha, Suraksha, *Chemical control
Brown plant hopper Whitebacked plant hopper	Plants wilt and dry- Hopper burn	10 insects per hill at veg. 20 insects/hill at later stage	Resistant varieties, Alleyways formation, Draining the fields, Judicious 'N' use, Chemical Control
Green leaf hopper	Vector of tungro disease, Plants wilt and dry in severe cases	2 insects/hill in tungro endemic areas. 20-30 insects/hill in other areas	Resistant varieties, Chemical control
Leaf folder	Leaf damage, ill filled grain	3 damaged leaves/hill post active tillering stage	Judicious 'N' use, Chemical control
Cutworm	Defoliation and damage to rachillae	1 leaf/hill stray incidence prior to harvesting	Flooding, Chemical control

* need-based

IPM - Cotton mealy bug, *Phenacoccus solenopsis*

DAMAGE SYMPTOMS: Sucking pests feed on sap – Prefers shoots and leaves. Mature and young ones suck sap from leaves, buds, petioles, internodes. In case of severe damage, sooty mould is produced. Flowers, buds, mature bolls and even leaves fall down. Growth of the plant is retarded. Incomplete opening of the bolls and reduction in the fibre quality. In case of heavy infestations white masses of wax conceal the mealy bugs

LIFE CYCLE: Egg period: 3.5 days, Nymphal period (Male/ Female): 17.5 / 15.4 days. Fecundity cum fertility/female: 390-425 eggs. Generations/year: 10-12

MANAGEMENT STRATEGY RECOMMENDED:

- Application of methyl parathion 2% dust @ 25 kg /ha followed by deep plowing. This is most important in the field where cotton was the crop in the previous year. If irrigation facility is available, apply chlorpyrifos 20 EC @ 2 liter /ha through irrigation in case of early sown crop.
- Destruction of weed host plants, particularly Cocklebur, *Xanthium strumarium*; Indian abutilon, *Abutilon auritum*, wild bhendi, *Abelmoschus (Hibiscus) manihot* and Congress grass, *Parthenium hysterophorus* from the fields, field boundaries, irrigation and drainage channels, fellow land etc. This has to be carried out on cooperative and campaign base.

MANAGEMENT STRATEGY RECOMMENDED:

- Follow inter-culturing and weeding regularly.
- Application of methyl parathion 2% dust on field boundaries.
- In the early stage of the crop, apply recommended insecticide (as spot application) on plant infested with mealy bugs (*i.e.*, when infestation is at low level and on few plants) to prevent further multiplication of the pest.
- Foliar application of insecticides (monochrotophos @ 0.04%, methyl-o-demeton @ 0.05%, quinalphos @ 0.04%, trizophos @ 0.1 %, DDVP @ 0.075%, profenophos @ 0.05%, chlorpyrifos @ 0.05% to the extent of slight run-off. Add sticker or detergent (1 g / liter water) or power oil (1 ml / liter water). Repeat the foliar application with another insecticide after one week of first application.
- Uproot and destroy the heavily infested plants during later stage of the crop to prevent further migration and spreading of pest. Apply methyl parathion 2% dust on the spots wherein the infested plants are removed.
- Immediate disposal /burning of crop residues /cotton sticks after last picking followed by application of chlorpyrifos 20 EC @ 2 litre /ha through irrigation
- Methyl parathion 2% dust @ 25 kg /ha followed by deep ploughing.
- Follow proper crop rotation. Avoid continuous cultivation of cotton crop year after year. It is advisable not to grow the cotton crop in the field which was heavily infested with mealy bugs in the previous year.
- Searching for effective natural enemies (predators like coccinellid predator, *Cryptolaemus montrouzieri*; parasitoids like; Entomopathogenic fungus like *Beauveria bassiana* and *Verticillium lacani* etc.)

IPM in Castor : 1. Deep ploughing in summer. 2. Sow castor after 15 - August. 3. Collect & destroy egg masses of *Spodoptera*. 4. Install 50-100 bird perches/ha to help birds to pick up moths/caterpillar and eat away. 5. Install 5 yellow sticky traps to monitor whitefly incidence. 6. Install 7-8 pheromone traps/ha with Spodolures. 7. Install 20 Oviposition cum poison bait traps/ha (Plastic jar of 2 lit. capacity with a castor plant of 7-8 days age and a cotton wick impregnated in a mixture of Nagata 44 EC or Endosulfan 35 EC 2 ml + 250 g jaggary + 10 ml sugarcane vinegar + 1 lit. water). 8. Spray SNPV 350 LE/ha in evening in 700 lit. water/ha twice at 15 days' interval when small larvae of *Spodoptera* are found. 9. Spray neem oil based insecticide 30 ml/10 lit. or profenophos 50 EC 20 ml or quinalphos 25 EC /chlorpyrifos 20 /10 lit. water when semil-loper exceeds 4/leaf. 10. Spray neem oil based insecticide 30 ml/10 lit. or acephate 75 SP 15 g or triazophos 40 EC 25 ml or imidacloprid 18.5 EC 5 ml/10 lit. when whitefly exceeds 10 nymph/leaf. 11. Spray quinalphos 25 EC 20 ml or methyl parathion 50 EC 10 ml or profenophos 50 EC 20 ml/10 lit. water against Capsule borer.

IPM in Groundnut

1. Install light trap after onset of first monsoon rain to attract and kill white grub beetles/moth of *Spodoptera* & *Helicoverpa*. 2. Shake the branches of host trees of white grub & collect beetles kerosinised water to kill them. 3. Prune tall host trees 9 out of 10 trees & Spray carbaryl 50 WP 40 g or quinalphos 25 EC 20 ml or monocrotophos 36 WSC 12 ml/10 lit. water on host trees within 3 days of first monsoon rain on remaining trees. 4. Sow sorghum/maize in groundnut in scattered manner. 5. Intercrop cowpea with groundnut to reduce incidence of aphids in later crop. 6. Install yellow sticky traps to monitor incidence of aphid. 7. Treat groundnut seeds with 25 ml of quinalphos 25 EC or chlorpyrifos 20 EC or imidacloprid 18.5 EC 5 ml + Tebuconazole 2 % DS @ 3 g/kg seeds and allow to dry under shed for 3-4 hours before sowing. 8. In advance sown crop/ if untreated seeds sown apply 4 lit. of quinalphos 25 EC or chlorpyrifos 20 EC by Drop by Drop method in irrigation channel or broadcast 100 kg soil impregnated with either of insecticide in standing crop when white grub damage is noticed.

IPM in Mustard

1. Sow GM-3 between 15- 25 October when temperature falls below 34 C. 2. Collect small larvae of mustard saw fly if less in number. 3. If saw fly larvae population exceeds 2 /sq feet, spray quinalphos 25 EC 20 ml/10 lit. water. 4. If aphid population exceeds 1.5 index, spray neem oil 50 ml or Growneem 1 % 50 ml or dimethoate 30 EC 10 ml/10 lit. 5. For painted bug dust 2 % methyl parathion or quinalphos 1.5 % dust 25 kg/ha.

Management of Pests of Brinjal

Spray quinalphos 25 EC 20 ml or cypermethrin 10 EC 5 ml or carbaryl 50 WP 40 g/10 in the nursery to suppress incidence of *Leucinodes*. Install 7-8 pheromone traps with Leucilure/ha to attract and kill male moths. Spray neem seed kernel suspension 5 % or neem oil 50 ml/ 10 lit. water + 10 g soap

To control whitefly. : Spray neem neem oil based insecticide 30 ml or dichlorvos 76 EC 7 ml or imidacloprid 18.5 EC 5 ml. or dimethoate 30 EC 10 ml /10 lit. to control sucking pests. Spray dicofol 18.5 EC 15 ml or propergite (Simba) 15 ml/10 lit to suppress red mite population.

Management of Pests of Okra

1. Remove and destroy alternate hosts like wild okra, *Hibiscus*, hollyhock etc. 2. Grow Earias tolerant cultivars like Guj. Okra -1, Selection-2 Parbhani Kranti and Punjab Padmini. Sow during May to escape from heavy incidence. 3. Treat seeds with imidacloprid 7.5 g or thiomethoxam 2.8 g/kg seeds to protect okra crop from sucking pests for 30-40 days. 4.

Install 7-8 pheromone traps with Eruitlure to monitor pest incidence and kill the trapped male moth.5. Remove infested shoots, flowers and pods and destroy along with larvae inside to prevent further multiplication.6. Spray neem based Replin 1%, or Neemark 1 % 30 ml/10 lit. when the incidence is low.7. Spray methyl demeton 25 EC or dimethoate 30 EC 10 ml or imidacloprid 18.5 EC 3 ml or acetamipride 20 EC 2 g/ 10 lit. water to control aphids, leaf hopper, whitefly etc.

To control heavy incidence of whitefly, spray acephate 75 SP 15 g or trizophos 40 EC 25 ml.10 lit.

Spray dicofol 18.5 EC 15 ml. or anthio 25 EC 20 ml or propergite 20 ml /10 lit. water to manage **red spider mite.**

CHAPTER 12

SAFETY ISSUES IN USE OF PESTICIDES

Pesticides are toxic to both pests and humans. However, they need not be hazardous to humans and non-target animal species if suitable precautions are taken. Most pesticides will cause adverse effects if intentionally or accidentally ingested or if they are in contact with the skin for a long time. Pesticide particles may be inhaled with the air while they are being sprayed. An additional risk is the contamination of drinking-water, food or soil. Special precautions must be taken during transport, storage and handling. Spray equipment should be regularly cleaned and maintained to prevent leaks. People who work with pesticides should receive proper training in their safe use.

Precautions

The label : Pesticides should be packed and labelled according to WHO specifications (1). The label should be in English and in the local language, and should indicate the contents, safety instructions (warnings) and possible measures in the event of swallowing or contamination. Always keep pesticides in their original containers. Take safety measures and wear protective clothing as recommended.

Storage and transport : Store pesticides in a place that can be locked and is not accessible to unauthorized people or children. They should never be kept in a place where they might be mistaken for food or drink. Keep them dry but away from fires and out of direct sunlight. Do not carry them in a vehicle that is also used to transport food.

Disposal : Left-over insecticide suspension can be disposed of safely by pouring it into a specially dug hole in the ground or a pit latrine. It should not be disposed of where it may enter water used for drinking or washing, fish ponds or rivers. Some insecticides, such as the pyrethroids, are very toxic to fish. Dig a hole at least 100 metres away from streams, wells and houses. In a hilly area the hole should be on the lower side of such areas. Pour run-off water from hand washings and spray washings into the hole, and bury containers, boxes and bottles used for pesticides in it. Close the hole as soon as possible. Cardboard, paper and cleaned plastic containers can be burned, where this is permitted, far away from houses and sources of drinking-water. For reuse of cleaned containers, see box. Pyrethroid suspensions can be poured on to dry ground where they are quickly absorbed and degraded and do not cause environmental problems. Surplus solution can be used to kill insect pests such as ants and cockroaches. Pour or sponge it on to infested places (under kitchen sinks, in corners of a house). Insect breeding can be temporarily reduced by pouring the solution in and around latrines or similar breeding places. Solutions of pyrethroids for the treatment of mosquito nets and other fabrics can be used for a few days after preparation. The solution may also be used to treat sleeping mats or string mattresses to prevent mosquitoes from biting from below. Where bedbugs are a problem, mattresses can be treated.

Spraying .

- The discharge from the sprayer should be directed away from the body. Leaking equipment should be repaired and the skin should be washed after any accidental contamination. Persons and domestic animals must not remain indoors during spraying. Rooms must not be sprayed if someone, e.g. a sick person, cannot be moved out.
- Cooking utensils, food and drinking-water containers should be put outdoors before spraying. Alternatively, they can be placed in the centre of a room and covered with a plastic sheet.

- Hammocks, paintings and pictures must not be sprayed. If furniture has to be sprayed on the lower side and the side next to a wall, care should be taken to ensure that other surfaces are not left unsprayed.
- Floors should be swept clean or washed after spraying. Inhabitants should avoid contact with the walls.
- Organophosphorus and carbamate compounds should not be applied for more than 5–6 hours a day and the hands should be washed after every pump charge.
- The mouth and nose should be covered with a simple device such as a disposable paper mask, a surgical-type disposable or washable mask, or any clean piece of cotton.
- Long rubber gloves should be worn when treating mosquito nets, clothes, screening or tsetse traps with insecticides.
- Spray workers should wear overalls or shirts with long sleeves and trousers, a broad-brimmed hat, a turban or other headgear and sturdy shoes or boots.
- Do not eat, drink or smoke while using insecticides. Keep food in tightly closed boxes.
- Use suitable equipment for measuring out, mixing and transferring insecticide.
- Do not stir liquids or scoop pesticide with bare hands.

CHAPTER 13

POLITICAL AND SOCIAL IMPLICATIONS OF IPM

Political constraints:

- The relative low status of plant protection workers in the administrative hierarchy is a constraint to general improvement in plant protection.
- Associated with the above are the moral and financial standing of this workers.
- The continuation of pesticides subsidy by the government for political reasons and its tie up with the government provided credit for crop protection acts as a major constraint to farmers acceptance of IPM.
- Various vested interest associated with the pesticides trade also act as a political constraint on the implementation of IPM.

Social constraints:

- The conditioning of most farmers and farm level extension workers by the pesticide industry has created a situation where chemicals are presented as highly effective and simple to apply. This acts as a major constraint in IPM implementation.
- There appears to be a direct conflict between Industries object of more sales, and the IPM message of rational pesticides used in the eyes of farmers.
- There is a need for private industry and public sector extension Agencies to work in a more complementary manner.
- Majority of the farmer in a study in Haryana, India, express their lack of faith in IPM.
- They considered IPM practices to be risky as compared to the use of chemical pesticides.

CHAPTER 14

CASE HISTORIES OF IMPORTANT IPM PROGRAMMES

Huffaker Project

It was the first major IPM project in the USA, spanned 1972-1978 and covered six crops viz., alfalfa, Citrus, cotton, pine, pome and stone fruits and soyabean. The crop was selected on the basis of 3 criteria *i.e.* 1) couldn't level of insecticide use (very high in cotton and citrus and very low in soyabean) 2) potential for successful biological control (alfalfa, citrus, pome and stone fruits) 3) Representation of non agricultural system (pines). An anticipated outcome of the program was 40 – 45 percent reduction in the use of more environmentally polluting insecticide within a 5 year period and 70 - 80% percent in 10 years. Advances were made in many aspects implementing improved IPM strategies for all system.

Consortium for IPM

A group of scientist under the leadership of P.L. Adkisson secured funding for the second large scale IPM Project in the US, called Consortium for Integrated Pest Management 1979-1985. The project focused on for major crops viz., alfalfa, Apple, cotton and soyabean. It was claimed that the average adoption of IPM for 4 crops was 66 per cent over 5.76 million ha. The main indicators of adoption were the use of Economic threshold and economic injury levels for spray decision, use of selective pesticide or application of low dosage of broad spectrum insecticides. A significant achievement of the program was the genuine attempt to integrate weed sciences and plant pathology and the emphasis on economic assessment of IPM adoption.

National IPM initiative

The US Department of Agriculture USDA launched national IPM initiative in 1993 the goal of which was implement IPM practices on 75 percent of the nation's crop area by 2000. To measure the level of adoption USDA put forth PAMS concept, the acronym for prevention, avoidance, monitoring and suppression. It has been estimated that some level of IPM has been implemented on about 70% of the US crop acreage. The highest percentage of cropland under IPM was in case of cotton (86) and vegetables (86) followed by soyabean (78) other crops and pastures (63), fruits and nuts (62) and Lucerne hay (40).

IPM in cotton

In India, the Indian Council of Agricultural Research, sponsored a village level IPM project to test and demonstrate the efficacy, practicability and economics of IPM in cotton in the Punjab in 1957. Initially, two or three villages were adopted for a period of 3 years after which the areas were shifted to new villages in other development blocks. In this way, a total of 15 villages in the main cotton growing districts of the state were covered during a period of 15 years. Farmers were educated regarding different insect pest problems, side effects of indiscriminate use of insecticides, cultural and mechanical practices for minimizing the incidence of insect pest and cultivation of short duration varieties. The project resulted in substantial gains. Within a period of 4 years, long duration varieties like LSS were replaced by short duration jassid -tolerant varieties. IPM Technology resulted in 73.7 and 12.4% reduction in number of insecticide sprays for the control of sucking pest and bollworms, respectively. In spite of reduced plant farmers obtained 23.2 percent higher yield and 31.7% higher net income.

A landmark in cotton IPM has been the validation of the cropping system based Holistic community approach of IPM at village Ashta (1998-2001) in Nanded dist. Of Maharashtra. the baseline information indicated less than 1 quintal average seed cotton yield per hectare in the *Helicoverpa armigera* epidemic year of 1997 when the farmers had spread more than 12-13 chemical pesticides spray rounds. All the farmers of the village were involved and the IPM approach covered 180 hectare cotton area. The offseason practices included management of *H.armigera* on pigeon pea and chickpea through use of neem seed kernel extract (NSKE) and HaNPV, field sanitation and deep ploughing. In the pre sowing practices, multiplicity of cultivars avoiding by selecting only two sucking pest moderately resistant cultivars and treating the seed with Imidacloprid. the showing of entire village was completed within a week to avoid vulnerability of Crop over a long period. the IPM interventions included use of *Trichogramma chilonis* Ishii, HaNPV and NSKE. Lastly, chemical pesticides are used when needed. The average seed cotton yield in IBM was 1018 kg per hectare with an average cost benefit ratio of 1: 1. 88 compared to 649 kg per hectare seed cotton yield and 1:1. 14 C:B ratio in non IPM. The system has become self sustainable as the farmers of Ashta have themselves become decision makers and on their own have started adopting many of the IPM practices.

Recent Methods of Pest Control

I) INSECT REPELLENTS

Definition: Chemicals which cause insects to move away from their source are referred to as repellents (or) Chemically that prevent insect damage to plants (or) animals by rendering them unattractive, unpalatable (or) offensive are called repellents.

Desirable traits of a good repellent

- a) It should be effective for a long time and on a wide range of insects.
- b) Weathering effects on it should be the least.
- c) Should not be toxic (or) irritating to man and animals.
- d) Should leave an acceptance odour, taste and touch
- e) Should be harmless to clothes.
- f) Should be cheap.

Types of repellents

Repellents are broadly classified as Physical repellents and Chemical repellents

1) Physical repellents

These produce repellence by physical means and are of the following kinds.

i. Contact stimuli repellents

These are substances (Such as dusts, granules, water, oils, leaf hairs, spines and waxes) that influence the surface texture of the plants to produce a disagreeable effect on the tactile sense of the insects.

ii. Auditory repellents

These employ sound to ward off insects. For instance, an amplified sound has been found effective in repelling mosquitoes, pyralid moths and flies.

iii. Visual repellents

White light normally attracts insects but the yellow colour light is the least attractive and to some extent acts as a visual repellent to insects.

iv. Excitatory repellents

Chemicals such as pyrethrum, DDT, BHC etc., which excite the insect's tarsi by stimulating the sensory nerves and force them to leave the treated surface.

v. Feeding repellents

Substances that inhibit feeding in insects are called feeding repellents (or) Antifeedent.

2. Chemical repellents

These are chemicals that affect tactile, olfactory (or) gustatory receptors of insects and could be plant origin (or) synthetic as follows.

i. Repellents of plant origin

The oil of citronella remained a commonly used mosquito repellent and still continues to be a constituent of a popular brand of commercial mosquito repellent, Odomos. The oil is extracted from the lemon grass, *Cymbopogon nardus* and contains citronellol, geraniol (as the main constituents), boreneol and terpenes (in small amounts) of which the first two are regarded as the main repellents for mosquitoes. Pyrethrum is another plant product which not only acts as an insecticide but in low concentrations, also as a repellent for blood – sucking insects. Clothes impregnated with some pyrethroids have been found to afford protection against the attack of many insect vectors of diseases like *Aedes aegypti*, *Anopheles quadrimaculatus* etc.,

ii. Synthetic repellents

Diethyl toluamide, protects the bearer against mosquitoes, ticks, fleas and biting flies. The others Bordeaux mixture, Dimethyl phthalate, and Indalone acts as repellents for insects.

Uses of repellents

Repellents can find several uses such as

1. They can be used on the body in some formulation to ward off insects.
2. They can be used as fumigants in an enclosed area of insects.
3. They can be used as dusts and sprays on domestic animal to protect them from noxious biting and blood – sucking insects.
4. They can be used to drive insects from their natural breeding grounds to areas treated with an insecticide (or) a chemosterilant to kill (or) sterilize them.

II) INSECT ANTIFEEDANTS

Definition: Antifeedant is a chemical that inhibits feeding but does not kill the insect directly; the insect often may remain on the treated plant material and possibly may die of starvation. These are also caused as “Feeding deterrents”.

There are three main sites for the sense of taste in insects located in the mouth, on the tarsi and on the antennae. Insect feeding deterrents may be perceived either by stimulation of specialized receptors (or) by distortion of the normal function of neurons which perceive phagostimulating compounds. Since the sugars are very important components of an insect's sustained feeding, the inhibition of its receptors is an effective antifeedant action.

Groups of antifeedants

a) Triazines

Acetanilide is an odourless and tasteless solid and not phytotoxic and inhibits feeding of most chewing surface feeders such as caterpillars, beetles and cockroaches.

b) Organotin

Triphenyl tin acetate (Brestan) was one of the earliest organotins that was found to have an antifeedant effect on the foliage – feeding insects such as the cotton leaf worm, Colorado potato beetle, larvae of potato tuber moth, *Agrotis ipsilon* and grasshoppers.

c) Carbamates

Several thiocarbamates inhibit the feeding of Mexican beetle, Colorado potato beetle and Japanese beetle. The carbamate, arprocarb (Propoxur) is systemic antifeedant against the boll weevil, *Anthonomus grandis*.

d) Botanical Extracts: Antifeedants from non-host plants of the pest can be used for their control. The following antifeedants are produced from plants.

i) Pyrethrum

From the flowers of *Chrysanthemum cinerariaefolium*, is not only insecticide but in small doses also acts as an antifeedant for the biting fly, *Glossina*.

ii) Margosa (Neem)

First reported by Pradhan *et al.* in 1962, the extracts of the leaves and fruits of neem trees (*Azadirachta indica*, family Meliaceae) act as very effective antifeedants against a large number of insects, particularly the desert locusts, *Schistocerca gregaria*, which is a very destructive polyphagous insect.

iii) Apple Factor

An Apple of the genus, *Malus* yields phenolic substance, phlorizin which stimulates probing in the apple feeding aphids (*Aphis pomi*) but acts as a feeding deterrent for the non-apple feeding aphids (*Myzus persicae*).

iv) Solanum alkaloids

Alkaloids (tomatine, solanine) extracted from some species of *Solanum* reduce feeding and survival of potato leaf hopper, *Empoasca devastans*. Besides the above, several other substances like non – essential amino acids, tannins, lignins etc. act as antifeedants to many insect pests.

v) Miscellaneous compounds: Compounds like copper stearate, copper resinate, mercuric chloride and Phosphon are good antifeedants.

Mode of action: Antifeedants inhibit the gustatory (taste) receptors of the mouth region. Lacking the right gustatory stimulus the insect fails to recognize the treated leaf as food. The insect slowly dies due to starvation.

Advantages of Antifeedants:

1. Antifeedants affect only the phytophagous insects and so do not harm the beneficial parasitoids, predators and pollinators.
2. As the pest is not immediately killed by antifeedant, its parasites and predators continue to feed on it, thrive, and keep it under control.
3. Antifeedants produce no phytotoxicity (or) pollution.

Disadvantages of Antifeedants:

1. Only the chewing type of insects are effected by antifeedants, the sucking pests remain unaffected.
2. New growths of plant are not protected.
3. As the insects are not immediately killed, they could move to untreated parts (or) other plants and damage them.
4. Antifeedants are not effective enough to become a sole control measure. They could only be promising when included in the integrated control schemes.

III) INSECT ATTRACTANTS

Definition: Chemicals that cause insects to make oriented movements towards their source are called insect attractants. They influence both gustatory (taste) and olfactory (smell) receptors (or) sensilla.

Types of Attractants

1. Pheromones
2. Natural food lures
3. Oviposition lures
4. Poison baits

1) Pheromones

In 1959 Karlson and Butenandt coined the term pheromone. For a Chemical that is secreted into the external environment by an animal and that elicits a specific response in a receiving individual of the same species. It is also referred to as “ectohormone”. Depending on their mode of action pheromones are divided into two general classes.

- i) One which gives a releaser effect – an immediate and reversible behavioural change is produced in the receiving animal.
- ii) One which gives a primer effect - a chain of physiological changes is triggered off in the receiving animal. Eg : Gustatory stimulation, controlling caste determination and reproductive control in social Hymenoptera (Ants and Bees), Isoptera (Termites).

Behaviour – releasing pheromones are typically odorous and act directly on the central nervous system of the receiving animal. Eg: Alarm, trail following, aggregation for mating, feeding (or) oviposition, The pheromones that promote aggregation are sex pheromones and aggregation pheromones.

Primer pheromones: They trigger off a chain of physiological changes in the recipient without any immediate change in the behaviour. They act through gustatory (taste) sensilla. (eg.) Caste determination and reproduction in social insects like ants, bees, wasps, and termites are mediated by primer pheromones. These pheromones are not of much practical value in IPM.

Releaser pheromones: These pheromones produce an immediate change in the behaviour of the recipient. Releaser pheromones may be further subdivided based on their biological activity into

- Sex pheromones
- Aggregation pheromones
- Alarm pheromones
- Trail pheromones

Releaser pheromones act through olfactory (smell) sensilla and directly act on the central nervous system of the recipient and modify their behaviour. They can be successfully used in pest management programmes.

a) Sex pheromones

A Sex pheromone released by one sex only triggers off a series of behaviour patterns in the other sex of the same species and thus facilitates mating. The male insects respond to the odorous chemical released by the female. In certain species of insects the males are known to produce the sex pheromone which attracts the females. In over 150 species of insects, females have been found to release sex pheromones and about 50 species males produce.

Ex : In the cotton boll weevil *Anthonomus grandis*

The sex pheromones are specific in their biological activity, the males responding only to a specific pheromone of the female of the same species, and their reactions are directed towards the air currents carrying the odour. The time of release of the pheromones by the females and response by male to them appears to be specific for each species. Effective distances for sex pheromones depend on the threshold concentration for male stimulation and release rate from the female.

Aphrodisiacs are substances that aid in courtship of the insects after the two sexes are brought together. In many cases males produce aphrodisiacs.

The following sex pheromones have been isolated and identified.

Bombycol : Silkworm, *Bombyx mori*

Gyplure : Gypsy moth, *Perthetria dispar*;

Gossyplure : Pink bollworm, *Pectinophora gossypiella*

Trimedlure : Mediterranean fruitfly, *Ceratitis capitata*

Cuelure : Melon fly, *Bactrocera cucurbitae*

Litlure : Tobacco cutworm, *Spodoptera litura*

Helilure : Red gram pod borer, *Helicoverpa armigera*

Amlure : Chaffin beetle, *Amphimallon* sp

Looplure : Cabbage looper, *Trichoplusia ni*

Ferrolure : Coconut Red Palm Weevil, *Rhynchophorus ferrugineus*

Leucilure : Brinjal Shoot and Fruit Borer *Leucinodes orbonalis*

Examples of male sex pheromones

Cotton boll weevil, *Anthonomus grandis*, Coleoptera

Cabbage looper, *Trichoplusia ni*, Lepidoptera

Mediterranean fruitfly, *Ceratitis capitata*, Diptera.

Sex pheromones in insect pest management

1) Monitoring of insect pests: Traps baited with synthetic sex pheromones is useful in estimating population and detecting early stages of pests. Four pheromone traps per acre is recommended.

2) Mass-trapping: (Male annihilation technique): Large number of pheromones baited traps can be used in the fields to capture male moths of newly emerged and reduce the number of males for mating.

3) Control of pest by mating disruption: By permeating the atmosphere with higher concentration of the pheromone the opposite sex is rendered confused and unable to locate their mates.

Merits:

1. The pheromones are species specific.
2. They are safe to natural enemies and environment.
3. They require in small doses.
4. They are economical and compatible with other components of IPM.

Demerits:

1. Synthetic pheromones are available only for a few pest species.
2. Replacement of pheromone lures at regular interval is required for good catch of moths.
3. Pheromone traps attracts only target pest even when crop is attracted by many other pests.
4. Pheromone reception and dispersal are not understood even for most important pests.

b) Aggregation pheromones

The pheromone released by one sex only elicits response in both sexes of a species. In scolytid (or) bark beetles the males secrete the pheromone into the hind gut which gets incorporated in to the faecal pellets and through them attracts flying males and females towards the galleries. In *Trigoderma granaria* mixture of fatty acid esters and methyl and oleate function as aggregation pheromones.

c) Trail marking pheromone

At low concentrations mostly used by foraging ants and white ants. In ants *Formica rupa*, formic acid while termites, *Zootermopsis nevadensis* hexanoic acid functions as the trail marking pheromone.

d) Alarm pheromones

These substances are elaborated by mandibular glands, sting apparatus, anal glands which typically results in fight or aggression. *Dolichoderine* ants – release a fruity odour by the worker that results in a erratic behaviour of workers, when this is discharged into mandibles onto an intruding insects that becomes marked as aggressor.

2) Natural Food lures

These are Chemicals present in plant and animal hosts that attract (lure) insects for feeding. They stimulate olfactory receptors and may be

1. A floral scent in case of the nectar feeding insects
2. Essential oils for the phytophagous insects.
3. Decomposing products for the scavenger
4. Carbon dioxide, lactic acid and water for the blood sucking insects.

3) Oviposition Lures

These are chemicals that govern the selection of suitable sites for oviposition by the adult female for example, P-methyl acetophenone attracts adult female rice stem borers to oviposit.

4) Poison Baits

Poison baits are a mixture of food lures and insecticides. The effort is made to make the bait more attractive to insects than their natural food and also a smaller quantity should be able to attract the largest number of insects. Baits are used when for some reason spraying (or) dusting

of insecticides is not practicable. For instance, when insects live hidden under the soil, inside the fruits and vegetables (or) for household insects like ants, cockroaches and houseflies.

Advantages of Attractants

1. Attractants do not kill the insects therefore, do not disrupt the ecosystem or food chain.
2. They are specific for some insects and so do not affect the non-targets.
3. They can be used to mass trap the insects to be subsequently killed by insecticides.
4. Since they are not long lasting, they do not cause environmental pollution.
5. They can be employed to misguide the insects to wrong host plants, wrong mating partners (or) wrong oviposition sites where by their number will go down by starvation (or) by producing unfertilized eggs.

Disadvantages of Attractants

1. Insects can always find untreated hosts, so their number may not be affected.
2. The attractants can not be relied as a sole control measure – can only be used in integrated control programmes.

IV. GAMMA RADIATION AND GENETIC INSECT CONTROL

The basic principle in genetic control of insects is to utilize factors which will lead to reproductive failure. Genetic control of insects is not limited to the use of insects sterilized by radiation or chemicals but also include cytoplasmic incompatibility, induced sterility, hybrid sterility etc.

A) Induced Sterility

i) Sterile male release technique:

Control of pest population achieved by releasing large number of sterilised male insects, which will compete with the normal males and reduce the insect population in subsequent generation.

It is usually referred as SIT (Sterile insect technique) or SIRM (Sterile insect release method). Sterile insect release method is a genetic control method. This is also called Autocidal control since insects are used against members of their own species.

When a sterile male mates with normal female there will be no progeny. If adequate number of vigorous and competitive sterile males is introduced systematically into natural population the population will soon cease to exist.

This theory of Male Sterile Technique was conceived by E F Knipling as early as 1937 and was published in 1955. He suggested two procedures,

- 1) Rearing, Sterilization and Release (@ 9:1 sterile to fertile insects) of sterile insects to compete with the normal population.
- 2) Sterilizing a portion of the natural population Eg: Screw-worm (*Cochliomyia hominivorax*) a cattle pest was completely eradicated from Curacao Islands and south eastern parts of USA by male sterilization by irradiation with gamma rays (C060).

Limitation: Applicable only to species, where the female mates only once in its lifetime.

ii) Aspermia: Inactivation of sperms. In some cases, as in mosquitoes the sperm of the incompatible male is blocked before it could fuse with the nucleus of the egg of native female. This principle was employed in eradicating *Culex pipensquinquifasciatus* in Rangoon. The possibility is, the incompatible strain could be identified, multiplied in large numbers and released in infested areas for eradicating the pests.

iii) Infecundity: Sterile eggs by dominant lethal mutations

iv) Use of non-mutagenic chemicals: To induce sterility by preventing mating by developing monogamous females, inhibition of spermatogenesis or by sperm inactivation

B) Cytoplasmic Incompatibility

Sterility is due to a cytoplasmic factor transmitted through the egg, which kills the sperm of incompatible male after its entry into the egg. Crosses between certain populations give no off-spring at all, in other cases females of one population may cross with males of another population and off-spring are produced, but the reciprocal cross is completely sterile. Recently it has been observed that in the case of some species of insects, there exist different strains with different genetic set up. When males of one such strain mate with females of another such strain, the offspring fails to develop because of incompatibility between the genes of the egg and the sperm. At an interspecific level the sperm of heterospecific males are often disadvantaged in competition with those of conspecific males.

C) Hybrid Sterility:

In some insect cross-types or races which produce fertile females but sterile males among progeny. These sterile hybrids are excellent material for use in insect control. These sterile males are more vigorous and competitive than the sterile males produced after radiation or chemosterilization.

D) Population Replacement:

The ability of disease transmission of vectors *ie* replacement of specific vector populations can as well be changed by genetic methods.

E) Auto-Sterilization:

Sterilization of native insects in their natural environment by using chemosterilants along with the species specific attractants / lures/ bait traps. Through this both the sexes can be sterilized, and also negate the reproductive ability of those insects which have escaped the lure/bait treatment.

V) INSECT GROWTH REGULATORS (HORMONES)

Insect Growth Regulators (IGRs) are compounds which interfere with the growth, development and metamorphosis of insects. IGRs include synthetic analogues of insect hormones such as ecdysoids and juvenoids and non-hormonal compounds such as precocenes (Anti JH) and chitin synthesis inhibitors.

Natural hormones of insects which play a role in growth and development are

Brain hormone: They are also called activation hormone(AH). AH is secreted by neuro secretory cells (NSC) which are neurons of central nervous system (CNS). Its role is to activate the corpora allata to produce juvenile hormone (JH).

Juvenile hormone (JH): Also called neotinin. It is secreted by corpora allata which are paired glands present behind insect brain. Their role is to keep the larva in juvenile condition. JH I, JH II, JH III and JH IV have been identified in different groups of insects. The concentration of JH decreases as the larva grows and reaches pupal stage. JH I, II and IV are found in larva while JH III is found in adult insects and are important for development of ovary in adult females.

Ecdysone: Also called Moulting hormone (MH). Ecdysone is a steroid and is secreted by Prothoracic Glands (PTG) present near prothoracic spiracles. Moulting in insects is brought about only in the presence of ecdysone. Ecdysone level decreases and is altogether absent in adult insects.

IGRs used in Pest management

Ecdysoids: These compounds are synthetic analogues of natural ecdysone. When applied in insects, kill them by formation of defective cuticle. The development processes are accelerated bypassing several normal events resulting in integument lacking scales or wax layer.

Juvenoids (JH mimics) : They are synthetic analogues of Juvenile Hormone (JH). They are most promising as hormonal insecticides. JH mimics were first identified by **Williams and**

Slama in the year 1966. They found that the paper towel kept in a glass jar used for rearing a *Pyrrhocoris* bug caused the bug to die before reaching adult stage. They named the factor from the paper as '**paper factor**' or '**juvabione**'. They found that the paper was manufactured from the wood pulp of **balsam fir tree** (*Abies balsamea*) which contained the JH mimic.

Juvenoids have **anti-metamorphic effect** on immature stages of insect. They retain *status quo* in insects (larva remains larva) and extra (super numerary) moultings take place producing intermediates which cause death of in action and they **disrupt diapauses super larva, larval-pupal and pupal-adult insects**.

Juvenoids are larvicidal and ovicidal and inhibit embryogenesis in insects.

Methoprene is a JH mimic and is useful in the control of larva of hornfly, stored tobacco pests, green house homopterans, red ants, leaf mining flies of vegetables and flowers.

Anti JH or Precocenes: they act by destroying corpora allata and preventing JH synthesis. When treated on immature stages of insect, they skip one or two larval instars and turn into tiny precocious adults. They can neither mate, nor oviposit and die soon. Eg. EMD, FMev, and PB (Piperonyl Butoxide)

Chitin Synthesis inhibitors: Benzoyl phenyl ureas have been found to have the ability of inhibiting chitin synthesis in vivo by blocking the activity of the enzyme chitin synthetase. Two important compounds in this category are Diflubenzuron (Dimilin) and Penfluron. The effects they produce on insects include

- ✓ Disruption of moulting
- ✓ Displacement of mandibles and labrum Adult fails to escape from pupal skin and dies Ovicidal effect.
- ✓ Chitin synthesis inhibitors have been registered for use in many countries and used successfully against pests of soybean, cotton, apple, fruits, vegetables, forest trees and mosquitoes and pests of stored grain.

IGRS from Neem : Leaf and seed extracts of neem which contains azadirachtin as the active ingredient, when applied topically causes growth inhibition, malformation, mortality and reduced fecundity in insects.

Hormone mimics from other living organisms: Ecdysoids from plants (Phytoecdysones) have been reported from plants like mulberry, ferns and conifers. Juvenoids have been reported from yeast, fungi, bacteria, protozoans, higher animals and plants.

Advantages of Using IGRs

- Effective in minute quantities and so are economical
- Target specific and so safe to natural enemies
- Bio-degradable, non-persistent and non-polluting
- Non-toxic to humans, animals and plants

Disadvantages

- Kills only certain stages of pest
- Slow mode of action
- Since they are chemicals possibility of build-up of resistance
- Unstable in the environment

VI) BIOTECHNOLOGY IN PEST MANAGEMENT (TRANSGENIC)

Use of molecular biology techniques for the management of insect pests. The following are some strategies.

Wide hybridization: This technique involves transfer of genes from one species to other by conventional breeding. The genes for resistance are transferred from a different species. e.g. WBPH resistant gene has been transferred to *Oryza sativa* from *O.officinalis*.

Somaclonal variability: The variation observed in tissue culture derived progeny. e.g. Somaclonal variants of sorghum resistant to *Spodoptera litura* has been evolved.

Transgenic plants: Transgenic plants are plants which possess one or more additional genes. This is achieved by cloning additional genes into the plant genome by genetic engineering techniques. The added genes impart resistance to pests.

Transgenic plants have been produced by addition of one or more following genes.

a) Bt endotoxin from *Bacillus thuringiensis*

b) Protease inhibitors

c) -Amylase inhibitors

d) Lectins

e) Enzymes

a) Bt endotoxin gene:

The gram positive bacteria *Bacillus thuringiensis* produces a crystal toxin called (delta) endotoxin. The endotoxin is a stomach poison and kills the lepidopteran insects if consumed.

The gene (DNA fragment) responsible for producing endotoxin is isolated from Bt and cloned into plants like cotton, potato, maize, etc. to produce Transgenic cotton, etc.

Transgenic Bt plants	Target insect pests
1. Cotton	Bollworms, <i>S. litura</i>
2. Maize	European corn borer
3. Rice	Leaf folder, stem borer
4. Tobacco, Tomato	Cut worms
5. Potato, Egg plant	Colorado potato beetle

b) Protease inhibitors (PI) gene

Insects have proteases in their gut which are enzymes helping in digestion of protein. Protease inhibitors are substances inhibit the proteases and affect digestion in insects. The protease inhibitor gene are isolated from one plant and cloned into another to produce transgenic plants.

e.g. Transgenic apple, rice, tobacco containing PI.

e.g. Cowpea trypsin inhibitor (CpTI) is a PI isolated from cowpea and cloned into tobacco. This transgenic tobacco is resistant to *Heliothis virescens*.

c) Amylase inhibitor gene

Amylase is a digestive enzyme present in insects for digestion of carbohydrate. - Amylase inhibitor, affect digestion in insects.

Transgenic tobacco and tomato expressing -amylase inhibitor have been produced which are resistant to Lepidopteran pests.

d) Lectins genes

Lectins are proteins that bind to carbohydrates. When insect feed on lectins, it binds to chitin in peritrophic membrane of midgut and prevents uptake of nutrients. e.g. Transgenic tobacco containing pea lectin gene is resistant to *H. virescens*

e) Enzyme genes

Chitinase enzyme gene, and cholesterol oxidase gene have been cloned into plants and these show insecticidal properties.

PYRAMIDING GENES

Engineering transgenic crops with more than one gene to get multi-mechanistic resistance is called pyramiding of genes. e.g.

The CpTi gene and pea lectin gene were cloned to produce a transgenic tobacco.

Transgenic potato which express lectin and bean chitinase have been produced.

Potentials/Advantages of Biotechnology in IPM

- Slow development of resistance against transgenic Bt, PI, lectins
- All plant parts express toxin and so no need for insecticide spray
- No need for continuous monitoring
- No environmental pollution, safe to NE, non-target organism

PRACTICES, SCOPE AND LIMITATIONS OF IPM

Concepts of IPM

IPM seeks to minimize the disadvantages associated with use of pesticides and maximizing socio, economic and ecological advantages.

1. Understanding the agricultural ecosystem

An agro ecosystem contains a lesser diversity of animal and plant species than natural ecosystem like forests. An agro ecosystem is intensively manipulated by man. Agro ecosystem is a complex of food chains and food webs that interact together to produce a stable unit.

2. Planning of agricultural ecosystem

In IPM programme the agricultural system can be planned in terms of anticipating pest problem and also the ways to reduce them that is to integrate crop protection with crop production system.

3. Cost benefit ratio

Based on the possibility of pest damage by predicting the pest problem and by defining ETL, emphasis should be given to cost benefit ratio.

4. Tolerance of pest damage

The pest free crop is neither necessary in most cases for high yields nor appropriate for insect pest management. Exceptions occur in case of plant disease transmission by vectors. The relationship between density of pest population and profitability of control measures is expressed through threshold values.

5. Leaving a pest residue

Natural enemy population is gradually eliminated not only in the absence of their respective insect hosts because of the indiscriminate use of broad spectrum insecticides, which in turn also eliminate natural enemies. Therefore, it is an important concept of pest management, to leave a permanent pest residue below economic threshold level, so that natural enemies will survive.

6. Timing of treatments

Treatment in terms of pesticide spray should be need based, with minimum number of sprays, timely scheduled, combined with improved techniques of pest monitoring and crop development.

7. Public understanding and acceptance

In order to deal with various pest problems special effort should be made for effective communication to the people for better understanding and acceptance of pest management practices. The IPM practices followed should be economical and sustainable.

Advantage of Integrated Pest Management:

1. Fits better in National Economy:

Pest control activities at present are mainly based on the application of chemical pesticides, quite a large proportion of which has to be imported. The expenditure envisaged for plant protection runs into crores of rupees even when only one or at the most two pesticide application are envisaged per crop. High yielding varieties show that many more pesticide applications are called for many crops if pest control has to depend only on the use of pesticide. Thus a time has come where Integrated Pest Management is not only advisable but also inevitable.

2. More efficient and cheaper method:

In IPM schedule efforts are made to utilize various methods of control including use of pesticides but some times and in some cases it is feasible to nip the trouble in the bud itself even by a mechanical campaign like destruction of egg masses of some pests or collecting the caterpillar stages. In such cases it envisages a lot of saving in the use of pesticides, this means

saving of money and saving of foreign exchange and also the destruction of the pest before it has been able to inflict damage.

3. Avoid upsetting the balance of nature:

Chemical control has often been reported to upset the balance of nature at times leading to upsurge of new type of pest problem which did not exist before. The seriousness of mites in many parts of the world has occurred by the use of DDT. It is confidently expected that such adverse side effects will be much less as a result of integrated pest management schedule.

4. Minimises residue hazards of pesticides:

It is obvious that in an IPM schedule the use of pesticides will be considerably reduced, hence the pesticide residue hazards will also get automatically minimised.

Limitations of IPM:

- An IPM programme requires a higher degree of management: Making the decision not to use pesticides on a routine or regular basis requires advanced planning and therefore a higher degree of management. This planning includes attention to field histories to anticipate what the pest problems might be, selecting crop varieties which are resistant or tolerant to pest damage, choosing tillage systems that will suppress anticipated pest damage while giving the crop the greatest yield potential.
- IPM can be more labour intensive, consistent, timely and accurate field scouting takes time. Without this information, intelligent management decision cannot make.
- Success of IPM programmes can be weather dependant. Therefore good IPM planners will have an alternate plan for when these problems arise.

Part IV

I . Economic importance of insect pests

A. Beneficial Insects:

Insects which produce honey, wax, lac, dyes and silk are commercially beneficial. Some insects are very helpful in destroying injurious insects.

1. Commercial Products:

Apis, the honeybees produce millions of tons of honey every year, it also gives bees wax from its combs.

Benefits of bees are cosmopolitan, not only in producing honey and wax, but also in bringing about cross-pollination of many fruits and flowers without which these plants could not exist.

Tachardia, the lac insect secretes commercial lac produced from integumentary glands as a protective covering by females, shellac is made from lac in India.

Dactylopius, the cochineal insect of Mexico is found on cacti, dried bodies of females of this scale insect are used for making cochineal dyes.

Bombyx and *Eupterote* are silk moths, they are reared in India, China, Japan and Europe, their larvae called silk worms spin cocoon of raw silk, the silk fibre is reeled off and used for making silk. In Asiatic countries over 25 million kilograms of silk are produced annually.

2. Useful Predaceous Insects: Some insects are predaceous, they feed upon and destroy a large number of injurious insects. *Stagomantis*, a mantis is voracious, it feeds on flies, grasshoppers and caterpillars, some of which are injurious to crops. The larvae and adults of *Chilomenes*, a lady-bird beetle, feed on aphids which infect cotton plants. Ladybird beetle, destroys scale insects which are pests of fruit trees. *Epicauta* is a blister beetle, it deposits eggs where locusts occur, the larvae on hatching enter egg capsules of locusts and eat up masses of eggs. *Calasoma*, a ground beetle preys upon many kinds of lepidopterous larvae which destroy cereals and cotton.

3. Beneficial Parasitic Insects: Some insects parasitise injurious insects, they usually lay eggs in the bodies of larvae and adults of harmful insects; the young on hatching from eggs finally kill their hosts. The larvae of *Tachina* and related flies are parasites of injurious lepidopterous larvae, such as army-worms which are injurious to cereals.

Larvae of hymenopteran flies and carnivorous wasps devour aphids in large numbers. Chalcids and ichneumon flies are parasitic, laying eggs in cocoon and larvae of phytophagous Lepidoptera. *Apanteles*, a hymenopteran fly lays eggs in army-worms and boll worms, the parasitic larvae gnaw their way through the skin of the host.

4. Scavengers: Some insects are scavengers, they eat up dead animal and vegetable matter, thus, they prevent decay. Some ants and larvae of some flies can devour entire animal carcasses.

B. Injurious Insects:

Compared with beneficial insects the number of injurious insects is very large.

1. Disease Transmitting Insects: Many types of white fly, aphids, jassids, mosquitoes, flies, fleas, lice and bugs transmit diseases to plant, man and domestic animals.

2. Household Insects: Human food is spoiled by cockroaches, ants, flies and weevils. Clothes moths, lay eggs on warm clothes, the larvae on hatching eat and destroy clothes, they also feed on furs, carpets and dry fruits. Carpet beetle is a scavenger eating decaying animal matter, but its larvae destroy carpets and preserved biological specimens.

Tenebrio is the mealworm beetle, its larvae are mealworms, they eat meal, flour and stored grains, such as rice. *Lepisma*, the silver fish and *Liposcelis*, the book louse live in and destroy

books and old manuscripts. Termites, the white ants cause untold destruction of books, carpets, furniture and wood-work of buildings.

3. Injurious to Domestic Animals: *Glossina*, the tsetse fly transmits *Trypanosoma brucei* which causes nagana in horses. *Tabanus* and *Stomoxys*, the blood sucking flies inject *Trypanosoma evansi* into horses and cattle which causes surra in India.

Gasterophilus, the bot-fly lays eggs on hair of horse, the larvae enter the stomach in large numbers. *Melophagus*, the sheep tick and *Hippobosca*, the forest fly of cattle and horses suck blood of their hosts and often cause haemorrhage.

4. Injurious to Crops: Many insects damage forest trees, growing farm crops, fruits and stored grain, the damage they cause annually runs into millions of rupees. The number of such insects is innumerable, they are mostly Lepidoptera, Coleoptera, Diptera and Hemiptera. *Euproctis*, the brown tail moth and *Lymantria*, the gipsy moth are serious pests of shade and foliage trees, their larvae are a menace and destroy forest trees.

Many moths, caterpillars and beetle cause a great deal of damage to stored grains: two beetles *Tenebrio* and *Tribolium* have similar habits and are commonly found in stores and granaries, the former is found in all stages in meal, flour and stored goods, its larvae are known as meal worms. *Tribolium* eats stored wheat and grain. *Calandra*, a weevil bores through grains of rice and other stored grain in India.

II. Methods of diagnosis and detection of various insect pests

Insect and non-insect pests cause a particular type of damage to the plant parts often characteristic to particular pests. The pest mostly insect not present on the site of damage makes it difficult to know the casual organism. Sometimes, the symptoms of damage caused by insects may closely resemble to those resulted due to pathogens or due to nutritional disorders. So, practical experience makes familiar about the correct diagnosis on the basis of visual symptoms of damage to take appropriate control measures.

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It is very important to know and study about the symptoms of damage by various phytophagous insect pests for proper, effective and economic management. Insect-pests found to be cause injury to plant either directly or indirectly to secure food, their development and further generations. Insect-pests attack on various parts of plant viz., root, stem, bark, leaf, bud, flower and fruit. Based on the nature and symptoms of damage, insect-pests can be classified into different groups as mentioned below.

Root and Tuber Damage

Root Damage : Larvae feed on root/ root nodules or the nymphs and adults suck the cell sap from the roots resulting in stunted growth/ poor tillering/drying of plants in isolated patches.

Wilting and drying: Wilting and drying of plants in patches. Leaves of affected plants turn pale, droop down and ultimately wither off. Cut end of affected stem of collapsed plant swells, a characteristic diagnostic symptom. Root grub, *Holotrichia* spp, *Anomala* spp

Poor tillering: Affected plant tillering is very poor. Affected plant turns yellow and stunted. Rice root weevil

Tunnels on pseudo stem: Insects can be make tunnels on pseudo stem and plants break down at tunneled portion. Plants bear few fruits and suckers, Circular holes with black rotten tissue of rhizome plugged with excreta. Banana Rhizome weevil

Wilting and death of plants: In the wheat and sorghum field, infected plants are wilting and in severe infestation condition it becomes completely drying and then death. Damaged tubers in potato, when uproot plant inside stem filled up with soil and mud.

Bored hole on stem at or just below the ground level, mature and developing pods are filled with mud in Groundnut. Earthen sheeting at the base of plant, mud filled galleries in shoots, drying of shoots in Sugarcane.

Mud galleries on tree trunk, if earthen sheet is removed eaten bark of trees is visible, Death of young plants and dry up in Mango. Mud galleries on tree trunk, bark and stem are eaten below the mud galleries, Nursery and transplanted fields show wilting of central shoot and stunted growth in coconut. Termite

Wilting and Drying of plants and presence of large number of ants at the base of ragi tillers. Ragi root aphid

Root knots: On the roots of tomato, chilli, okra, *etc* vegetables crop roots show knots. Root knot nematode, *Meloidogyne incognita*

Tuber Damage : Grubs bore the tubers and veins by making tunnel and feed on the internal content. As a result of feeding, thickening and malformation of veins and discoloration, cracking or wilting of damaged veins is noticed. An infested tuber is tunnels and attacked tubers become spongy, brownish to blackish in appearance. Potato tuber moth, Sweet potato weevil

Stem Damage : Larvae enter into the stem/ tillers and feed on inert green matter. As a result, damaged part is wilted, dried and exhibited symptoms like dead heart/ white ear. Damaged part is cut off from the main plant and affected part wilts, dries up and exhibits symptoms like dead heart/white ear/bunchy top. Stem borers of paddy, millets, sugarcane and brinjal *etc*

Ringling and girdling of stem bark : Grape vine stem girdler, *Sthenias grisator*, Amaranthus stem weevil, *Hypolixus truncatulus*, Coccinia gall fly, *Neolasioptera cephalandrae*

Galls on stem: Insect feeding inside the stem, the plant shows a characteristic swelling and gall which hinders the growth of plant. Tobacco stem borer, cotton stem weevil

SHOOT DAMAGE : Larvae attack tender shoots and bore inside during the vegetative stage of the crop growth and cause wilting, drooping of terminal plant part which later dries up. Shoot borers of brinjal, bhendi, cotton, castor, shoot fly of sorghum and black gram stem fly.

LEAF DAMAGE

Mines in leaf : Larvae mine leaves/leaflets between the epidermal layers and feed on green matter, resulting in the appearance of translucent white patches/ zig-zag galleries on leaves. Leaf miner of ground nut, chickpea, rice hispa

Serpentine mines: Thread like. American serpentine leaf miner, *Liriomyza trifoli*

Linear or serpentine mines: Thread like. Citrus leaf miner, *Phyllocnistis citrella*

Blotch mines: Blight. Patch like. Blotch leaf miner, *Acrocercops syngamma*

Punctures on leaf - Leaves show punctures made by insects for feeding or oviposition . Bean flies, *Ophiomyia phaseoli*

Defoliator: Larvae feed on the leaves completely by scraping the chlorophyll content of leaves; leaving only midrib/veins or cause numerous holes. *e. g.*, castor semilooper, red headed hairy caterpillar, Bihar hairy caterpillar, tobacco caterpillar

Leaf webber: Larvae web leaves/ leaflets by means of silken threads and feed inside the webbed leaves and the chlorophyll content. Often faecal pellets/ frass are found within the web. *e.g:* leaf Webbers on Ground nut.

Leaf webbing : Few leaves are webbed together and the larva feeds in between the leaves by scraping . Pumpkin caterpillar, *Diaphania indica*.

Terminal leaf webbing: The terminal tender leaves are webbed together and larvae and pupal stages occur in the webbed leaves. Larvae feed by scraping the surface. Sapota leaf webber, *Nephopteryx eugraphilla*

Leaf folder: Larvae fold leaves from tip to base/ longitudinally/ margin to margin edge which producing appearance of a fold/ roll. *e.g.* rice leaf folder, cotton leaf folder.

Galls on leaf: Larvae feeding inside the leaf/ flower bud stimulate excessive growth of cells at the affected portion and disturb normal growth which results in malformation of plant parts called as gall formation. Due to insect feeding on the leaves, the plant reaction results in gall formation like warts, *etc.* Mango gall fly, *Procantarina mattsiana*

Out growths on leaves: The damage makes the plant to produce felt like out growths e.g: Jasmine mite, *Aceria jasmini*

Leaf feeding:

Scraping: Early instar larvae feed by scraping the surface of leaves leaving papery patches. Larvae of *Spodoptera litura*

Papery windows: Ladder like papery windows caused by the feeding of adult beetles. Brinjal epilachna beetle, *Henosepilachna vigintioctopunctata*

Holes:

- ❖ Small round holes result due to the feeding of small adult beetles on leaves. White spotted flea beetle, *Monolepta signata*
- ❖ Medium round symmetrical holes on leaves by the larval stages. Pea nut defoliator *Helicoverpa armigera*
- ❖ Irregular bigger holes on the leaves caused by the larval stages of many lepidopteran insects. Slug caterpillar, *Latoia lepida*, Hairy caterpillar, *Euproctis fraterna*

Skolemization of leaves by completely feeding on leaf lamina, leaving only the veins by larval stages. Castor semilooper, *Achoea janata*

Free feeding: Completely the lamina and veins eaten away by the voracious feeder or in severe cases by the larvae. Lemon butterfly, *Papilio demoleus*.

Nibbling: The leaves from margins in to small U shaped cuttings is done by adult beetles. Grey weevil, *Myloccerus viridanus*

Cutting the leaves in to big semicircular shape is done by adult bees. Leaf cutting bee, *Megachile anthracina*

Crinkled leaves are due to sucking of cell sap by nymphs and adult insects. Aphids

Cupping /curling of leaves with result due to sucking of insects. Thrips

Pod/ capsule borers/ boll worm: During the reproductive stage of crop, larva enter into the pod, capsule, boll and feed on the seed/lint exhibiting symptoms like webbed condition of pods/bolls or web few pods/capsules with frass and excreta or holes of different sizes and shapes. e. g., spotted pod borer, capsule borers of castor and red gram pod fly, tobacco caterpillar, gram caterpillar, pink boll worm etc.

Tree Damage : Yellowing of trees, withering of leaves, drying of twigs or complete drying of tree. Sometimes gummy material oozes from the affected portion on the tree trunk. Tree borers of mango, cashew, coconut red palm weevil

Bark Damage: Galleries of frassy web on the stem and near bark/angles of branches, Silken ribbon plastered on stem. Bark eating caterpillars of citrus, mango, guava, casuarina and jack

FRUIT DAMAGE

Spots on outer surface indicate the oviposition punctures of insects on fruits e.g., Mango fruit fly, Ber fruit fly. Corky layer on fruit surface is caused by laceration of cells Grape vine thrips, Bore holes plugged with excreta on the fruits are done by larvae Bhendi shoot and fruit borer, *Earias vittella*. Bore holes without excreta and sometimes, larva is seen outside Tomato fruit borer, *Helicoverpa armigera*. Spots on outer surface indicate the oviposition punctures of

insects on fruits. Mango fruit fly, *Bactocera dorsalis*, Ber fruit fly, *Carpomyia vesuviana* and cucurbit fruit fly *Bactocera cucurbitae*

SEED DAMAGE: (STORED GRAIN PESTS)

Seed feeder (stored grain pests): Larvae feed on stored seeds either as internal/external feeders/by webbing the food particles. *e.g.* rice weevil, red rust flour beetle, rice moth etc.

Sap feeder:

a. From grain: Nymphs and adults suck juice from developing ovaries/ milky grains resulting in the formation of shrivelled/chaffy grains *e.g.* rice gundhy bug, sorghum ear head bug, sorghum midge.

b. From tender plant parts: Nymphs and adults suck the cell sap from the base of the plant/leaves/ tender terminal plant parts/ flowers, thereby affect the vigour and growth of the plants. Different insects exhibit different symptoms. In case of severe infestation, sooty mould develops on the plant parts covered with honey dew excreted by insects while feeding. *e.g.* paddy brown plant hopper, white backed plant hopper, paddy leafhopper, cotton aphid.

All these insect pests causing damage to different parts of plant and based on the symptoms of damage the name was given. This will be helpful for identifying the insect pest damage during field visit.

Example: Rice weevil, red rust flour beetle, rice moth

DIAGNOSIS BY LOCATING SIGNS ON/NEAR PLANTS

Diagnosis by locating signs: Black ants, *Componotus compressus* movement on plant parts, honey dew secretion on plant parts; Sooty mould development on plant parts. All the above indicate the presence of Homopteran insects. Mealy bug *Planococcus lilacenus*, Aphid, *Aphis craccivora*, Whitefly, *Bemisia tabaci*

Excreta of Insects: Black spots are found due to drying of excreta on leaves by thrips. Presence of excreta indicate usually the lepidopteran larvae

Scale covering: The stem, leaves *etc* are covered heavily by the scale covering

Exuviae of insects: Moulded skins of leafhoppers, aphids *etc* present usually on lower surface of leaves BPH moulded skins at base of plant and floating in water.

Black spots are found due to drying of excreta on leaves by thrips

III. Importance of Economic Threshold Level

Economic Threshold Level (ETL) : The density at which control measures should be applied to prevent an increasing pest population from reaching the economic injury level. OR An increasingly damaging population can occur as a result of an increase in density-no. of individual or an increase in bio-mass-size of individuals. OR The economic threshold always represents a pest density lower than that of the economic injury level to allow the initiation of control measures so that they can take effect before the pest density exceeds the ETL.

Factors Influencing ETL and EIL

a. Market value of crop Primary factors :When crop value increases, EIL decreases and vice-versa.

b. Management costs: Management of injury per insect - When management costs increase, EIL also increases

c. Degree of injury per insect Secondary factors: Insects damaging leaves or reproductive parts have different EIL (Lower EIL for Rep. part damages). If insects are vectors of disease EIL is very low even 1 or 2 insects if found management to be taken. If insects found on fruits - Marketability reduced - EIL very low

d. Crop susceptibility to injury: If crop can tolerate the injury and give good yield. EIL can be fixed at a higher value. When crop is older, it can withstand high pest population - EIL can be high

How Thresholds are Developed?

Thresholds, mainly thresholds used by commercial growers, can be developed from the following factors:

1. Amount of physical damage related to various pest densities; How large the pest population can grow before it causes a certain level of damage.
2. Monetary value and production costs of the crop at various levels of physical damage
3. Monetary loss associated with various levels of physical damage.
4. Amount of physical damage that can be prevented by the control measure.
5. Monetary value of the portion the crop that can be saved by the control measure.
6. Monetary cost of the control measure.
7. History of the field.
8. Determining the danger of the pest at different stages of the crops development.
9. The pest distribution.
10. How much aesthetic or economic damage can be tolerated.
11. Establish a treatment level that keeps the pest population small enough so it does not cause an unacceptable level of damage.
12. Ultimate destination of the crop, what the standard of the end consumer is.
13. Ability to control the pest rapidly and effectively

Importance of Thresholds

1. The main importance is for decision making on scheduling of control and control methods
2. To establish the optimal amount of control which can be used to minimize risk of economic damage and environmental hazards

What factors are important when determining ET?

- Lifecycle of your pest
- Time required for your control action to take effect
- Environmental conditions

IV ECOLOGICAL MANAGEMENT OF THE CROP ENVIRONMENT / ECOFRIENDLY IPM

IPM which lays more importance on environmental safety. All methods except the use of chemical insecticides are encouraged. 'Organic farming' is a new concept where no chemical pesticide or fertilizer is used in agriculture. Ecofriendly IPM may be followed in organic farming. Ecofriendly IPM uses methods like biological control, behavioural method, physical, cultural and mechanical methods. Here more stress is given to environmentally sustainable pest management.

Indigenous/Traditional technologies in IPM

The following are some examples of traditional technologies in IPM

- i. **Cultural methods:** (a) Farm level (b) Community level, which were originally practiced by farmers.
- ii. **Physical and mechanical methods** originally followed by farmers e.g. Use of storage bins, treatment of stored grain with vegetable oil etc.,
- iii. **Farmers' wisdom on pest control tactics as follows** (a) Use of chilli mash and garlic juice spray against rice earhead bug. Many other similar techniques are followed by farmers. (b) Use of ak (*Calotropis*) for termite control. Research has to be done to prove their usefulness in IPM.

I. Cultural methods/Practices:

Purpose: To make the environment less favourable for pest and/ or favourable for its natural enemies. To reduce or avoid pest damage

Ecological base management: "Since cultural control manipulations are based on habitat management and component of the agro-ecosystem in which the pest thrive, this approach has also been called as Ecological management or environmental control"

Cultural practices include:

❖ Planting time:

- **Asynchrony** between host plant and pest
- **Synchronizing** insect-pests and their N.E.
- **Crop production** with available alternate host plants
- **Delayed planting**- Castor semilooper
- **Early planting** - Sorghum shoot fly, Rice gall midge, and leaf folder, Mustard aphid, Sugarcane borer, *Helicoverpa* in chickpea

❖ Seed rate and plant spacing:

- High seed rate – Sorghum shoot fly
- **Closer spacing** – Increase the incidence of -WBPH, BPH, gall midge, folder in Rice, Jassid, whitefly, bollworms in Cotton, Whitefly in Soybean, Borers in Sugarcane
- **Closer spacing** – lower incidence of- GLH, rice hispa, whorl maggot in Rice, Thrips, jassids, miners in Groundnut, Aphids in chickpea

❖ Tillage:

- Type and timing of tillage
- Influence the soil environment and
- Affect the survival of insect-pests or N.E.
- Pupation in soil
- Egg laying in soil

- Hibernating site-E.g. fruit flies, GHC, *Helicoverpa*, armyworm, G.H., sugarcane shoot borer (light earthing up.)
- ❖ **Intercropping:** Cotton with black gram, green gram, cowpea etc -Divert the population of sucking pests and *Helicoverpa*. Cotton with groundnut, cowpea, soyabean, instead of monoculture of cotton. Groundnut with bajra -Reduces thrips, jassid, leafminers. Chickpea with wheat, barley, linseed, mustard, safflower -Reduce the population of *Helicoverpa* as compare to sole crop of chickpea
- ❖ **Trap Cropping:** Planting small areas of a crop or other plants on the borders or even in the main crop may serve as a trap crop for some insect-pests. Attractiveness of trap crop may be enhanced by use of Insect-pheromones, plant kairomones or insect food supplements.

Cotton---Castor or African yellow flower marigold, Tobacco---Castor , Citrus--- Tomato, Cabbage---Mustard, Tomato- Marigold- for *Helicoverpa*
- ❖ **Crop rotation:** Effective against the pests that have narrow host range and dispersal capacity. Cotton followed by ragi, maize, rice, groundnut, soybean- Reduce the incidence of insect-pests
- ❖ **Nutrient management:**
 - High rate of N -Increase the incidence of WBPH, BPH, GLH, stem borer, folder in rice.
 - K₂O & P₂O₅-Lower incidence of many insect-pests
 - Deficiency of N₂-Increase w.fly in sugarcane
- ❖ **Water management:** Flooding of fields-Cutworms, army worms, termite, white grubs. Water logged condition- Build up sugarcane whiteflies
- ❖ **Sanitation:** Destroying or removing of crop residues- To eliminate pest overwintering sites & reduce the spreading
- ❖ **Harvesting practices:** Selective harvesting => Suppressing the insect population & Strip harvesting => Conserving their N. E

II Mechanical Methods:

- ❖ **Manual devices:** The reduction or suppression of insect population by means of manual devices. **Hand picking:** Hand-picking and destruction of large sized, conspicuous immature or mature stages of insect e.g. *Spodoptera*, GHCP, Rice yellow stem borer, sugarcane borers, sorghum borer
- B. Exclusion by screens and barriers:**
 - **Deep trenches:** digging of 30-60 cm wide and 60 cm deep trenches or erecting 30 cm height tin sheet barriers around field- to prevent the moving bands of locust, Hairy C. P. armyworms
 - **Barrier crop:** Grow 2-3 lines of bajra around Groundnut to prevent the spreading of thrips
 - **Wrapping:** fruits wrapped in paper bags or cloths or
 - Straw- E.g. fruitfly, fruit sucking moth, Anar butterfly
 - **Bands:** sticky and slippery bands at the base end of tree trunk- to prevent mealy bug nymphs from climbing.
 - **Trapping and suction devices:**
 - **Devices:** Mechanical cleives are used for collecting insects - Light-traps, Sticky traps/ yellow sticky traps, Pheromone traps, Methyl eugenol traps, Black tulsī trap
 - **Clipping, pruning and crushing:**
 - **Effective:** against scale, mealybug, gallmidges- To check the multiplication of insects. Clipping of tips of rice seedling- rice stem borer
 - **Flaming and burning:** Locust, GH, armyworm, GHCP

- **Washing, cleaning and soaking:** Soft bodied insect/ small insects

III. Physical methods:

- Use of certain physical forces to eradicate the insect population
- Heat, cold, humidity, sound, energy in the form of light traps and light regulation
- ❖ **Hot and cold treatment:**
 - Sun heat- seed expose
 - Hot water or hot air treatment. E.g. s.cane scale, mealybug
 - Flame thrower- locust, hopper, adults
 - Cold storage- fruitfly, potato tuber moth
 - Empty godown, hot air treatment (50-55 °C)
 - Cold application (5-10°C) - development checked
- ❖ **Moisture:** Well dried grains (below 8% moisture) - dev. Inhibited
- ❖ **Light-traps:** Attracting and mass killing of several species of moths/ beetles. Monitoring E.g. GHCP, whitegrub, s.cane root borer
- ❖ **Sound:** Affect the insect- physiological activities, mating Behaviour
- ❖ **Protective packaging:** Wooden boxes, Hard board boxes, Small iron tins

IV. Biological control:

Biological control is a process in which one species population lowers the numbers of another species by mechanisms such as predation, parasitism, pathogenesis or competition.

Microbial Control: when microbial organisms or their (toxins) are employed by man for the control insect, animals and plants a particular area is referred as Microbial Control . It includes (i) Viral pathogens, (ii) Fungal Pathogens, (iii) Bacterial Pathogens, (iv) Nematodes

V. Botanical pesticides :

- ❖ Neem, *Azadiracta indica* A Juss
- ❖ Dharek, *Melia azedaracta*.
- ❖ Pyrethrum, *Chrysanthemum cinerariaefolium*
- ❖ Rotenone, *Derris elliptica*
- ❖ Nicotine, *Nicotiana tobacum*
- ❖ Ryanodine, *Ryani speciosa*
- ❖ Pellitorine, *Anacyclus pyrethrum*
- ❖ Quassin, *Quassia amara*
- ❖ Sabadilla, *Sabadilla officinarum*
- ❖ Pongamia, *P. pinnata* (Karanja)
- ❖ Custard apple, *Annona squamosa*

V. Methods of Pest Surveillance and Forecasting

Pest Surveillance -Refers to the constant watch on the population dynamics of pests, its incidence and damage on each crop at fixed intervals to forewarn the farmers to take up timely crop protection measures.

Pest Monitoring- Monitoring phytophagous insects and their natural enemies is a fundamental tool in IPM - for taking management decision

Monitoring - estimation of changes in insect distribution and abundance

- information about insects, life history
- influence of biotic and abiotic factors on pest population

Concepts of Pest Management: is primarily to reduce the plant protection bill, which is achieved by adopting need-based insecticide application based on economic threshold (ET).

Possible: Such decision making is possible when the Surveillance Programme is effectively implemented.

❖ Objectives of Pest Surveillance

- to know existing and new pest species
- to assess pest population and damage at different growth stage of crop
- to study the influence of weather parameters on pest
- to study changing pest status (Minor to major)
- to assess natural enemies and their influence on pests
- effect of new cropping pattern and varieties on pest

❖ Types of Pest Surveillance:

1. Rapid Roving Survey
2. Fixed Plot Survey

1. Rapid Roving Survey:

- ✓ Assessment of pest population/damage from randomly selected spots representing larger area. Large area surveyed in short period. Provides information on pest level over large area. Roving survey is undertaken in villages by Govt. agencies. This is a quick survey methods and field are visited randomly once during the week. Minimum 4 places are selected for observation every 10 km's.

2. Fixed Plot Survey:

Assessment of pest population/damage can be carried out from a fixed plot selected in a field. The data on pest population/damage recorded periodic from sowing till harvest. e. g. sq. m. plots randomly selected from 5 spots in one acre of crop area in case of rice. From each plot 10 plants selected at random. Total tillers and tillers affected by stem borer in these 10 plants counted. Total leaves and number affected by leaf folder observed. Damage expressed as per cent damaged tillers or leaves. Population of BPH from all tillers in 10 plants observed and expressed as number/tiller.

Monitoring can be done by: Surveying with the help of diff. types of traps –

- ✓ Light trap
- ✓ Pheromone trap
- ✓ Water trap
- ✓ Sticky trap etc.

After detection: After detecting the arrival of entrance of pest in an ecosystem, the most imp. Technique is the **Surveillance and forecasting** of the pest species.

Basic component of pest Surveillance:

1. Determination of the level of incidence of pest species.
 2. Determination of what loss the incidence will cause
 3. Determination of the economic benefits or other benefits, the control will provide.
- The above information would be of immense use in pest control strategy.

Forecasting:

Complex: surveillance activities connected with pest forecasting are complex.

Require: forecasting pest incidence often requires systematically recorded specific field data in an elaborated manner over considerable period of time which can be easily retrieved and analysed.

Useful: Advance knowledge of probable pest infestation or outbreak would be very useful not only to plan the cropping pattern in such a way as to minimize the damage but also to get best advantage of pest control measure.

Forecasting serves:

1. To predict the forth coming infestation level of pest
2. To find out the critical stage at which the application of insecticide should be made for maximum protection.

Forecasting of pest infestation must be related to the economic threshold of pest and can be made through:

1. Population Studies (Quantitative studies)
 2. Studies on the pest life history
 3. Field studies of the effects of climate on the pest and environment
1. **Population studies:** This can be done by proper survey and sampling method. Such survey is to be carried out for several years and seasons. The seasonal count should be related with climatic factors.
 2. **Studies on the pest life history:** The possible numbers of the generation and behaviour of the diff. larval instars under controlled condition in the insectory. Fecundity and length of life cycle both in the field and in the laboratory can be related to the range of environment factors.
 3. **Field studies of the effect of climate:**
 - Climatic factor usually affects the **pest number** and its N. E directly or indirectly.
 - **The spread** of pest from area to area largely determined by **wind currents**. Therefore, a nation-wide surveillance Centre are to be more helpful for system occurrence of insect pest and disease.

Methods of Pest Forecasting can be classified into 3 categories:

- 1) Forecasting based on observation of environment factors.
 - 2) Forecasting based on observation of climatic area.
 - 3) Prediction from empirical observation.
- 1) **Forecasting based on observation of environment factors.**
 - **Biotic and abiotic:** Among the various biotic and abiotic environmental factors, **temperature** and **humidity** are the most important and used for forecasting.

2) Forecasting based on observations of Climatic area:

Areas: The areas where there is a probability of occurrence of pest species can also be forecasted.

Factor: In this method the biotic factor as well as topographic or climatic factors are most important combination of temperature and rainfall, Temperature and atmospheric humidity and

in soil – inhabitant, insect-pest, the combination of soil-temperature and soil- moisture are most important.

Geographical distribution zones:

- i) Zone of normal abundance:** Pest is persistent occurrence i.e. some detectable pests can always be found on a regular basis. Such areas may be termed as endemic areas.
- ii) Zone of occasional abundance:** Pest occurs throughout the year but population is maintained at **low level** as **climatic factors** are not **favourable**. Under certain condition, there may be **upsurge of population** of insects.
- iii) Zone of possible abundance:** Pest does not occur normally. Migration of pest from the adjoining area and occurrence can be detected. If climatic conditions permit, the pest may assume a high level of population, thus causing outbreak.

3) Prediction from empirical (experiential) observation:

Predicted: The population can be predicted by taking into consideration the population counts of previous year and regular meteorological observations are gathered and Nation-wide forecasting information is published once a month by plant protection Division. This is helpful only in the static pests only.

Limitation of forecasting:

- ✓ Still it is not standard
- ✓ Time consuming and labour intensive
- ✓ Continuous evaluation is required for its validity due to changing in the agro – ecosystem.
- ✓ Faulty forecasting may led to disastrous consequences.

However, some sort of monitoring is primary requisite in the modern concepts of insect control.

In India: Central plant protection and quarantine established a nation-wide centre for the key pest.

In Gujarat : SAUs, Department of Entomology/ Pathology, sub centres, and Department of Agriculture → joint venture for survey & forecasting of major insect pest and diseases of major crops.

Lecture Note
of
Fourth Semester UG course
(As per fifth Deans Committee Recommendations/syllabus)



Ag. Ento. 4.3: Management of Beneficial Insects
(1 + 1 = 2)

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Academic Year: 2019-20

COURSE CONTENT (SYLLABUS)

Ag. Ento. 4.3

Management of Beneficial Insects

Credit: 1 + 1 = 2

THEORY SYLLABUS:

Part I: Importance of beneficial Insects, Beekeeping, pollinating plant and their cycle, bee biology, species of honey bees, commercial methods of rearing, equipment used, seasonal management, bee enemies and diseases. Bee pasturage, bee foraging and communication. Division and uniting of honey bee boxes. Toxicity of pesticides to honey bees.

Part II: Types of silkworm, voltinism and biology of silkworm. Mulberry/castor cultivation, mulberry varieties and methods of harvesting and preservation of leaves. Rearing and mounting larvae and harvesting of cocoons. Pest and diseases of silkworm and management. Rearing appliances of mulberry silkworm and methods of disinfection.

Part III: Species of lac insect, morphology, biology, host plant, lac production – seed lac, button lac, shellac, lac- products. Enemies of lac insects.

Part IV: Identification of major parasitoids and predators commonly being used in biological control. Insect orders bearing predators and parasitoids used in pest control and their mass multiplication techniques. Important species of pollinator, weed killers and scavengers with their importance.

PRACTICAL SYLLABUS:

Honey bee species, castes of bees. Beekeeping appliances and seasonal management, bee enemies and disease. Bee pasturage, bee foraging and communication. Division and uniting of honey bee boxes. Migration of honeybee boxes. Types of silkworm, voltinism and biology of silkworm. Mulberry/castor cultivation, mulberry varieties and methods of harvesting and preservation of leaves. Species of lac insect, host plant identification. Identification of other important pollinators, weed killers and scavengers. Insect orders bearing predators and parasitoids used in pest control and their mass multiplication techniques. Visit to research and training institutions devoted to beekeeping, sericulture, lac culture and natural enemies.

SUGGESTED READINGS:

- A text book of Applied Entomology, Vol. II by K. P. Srivastava and G. S. Dhaliwal, Kalyani Publisher
- Elements of Economic Entomology by B. V. David and V. V. Rammurthy. Namrutha Publications (7th Edition)
- Principles of Applied Entomology by K. N. Ragumoorthy, M. R. Srinivasan, V. Balasubramani and N. Natarajan Published by A. E. Publication, Coimbatore
- Modern Entomology by D. B. Tembhare, Himalaya Publishing House (ISBN : 978-93-5051-828-1)
- Essentials of Agricultural Entomology by G.S. Dhaliwal, Ram Singh and B.S. Chillar, Kalyani Publisher
- Element of Agricultural Entomology by G.S. Dhaliwal (2015). Published by Kalyani Publishers, New Delhi (ISBN: 978-93-272-5134-0).

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Part- I: Honey bee

Importance of honey bees:

The field of entomology may be divided into two major aspects, as fundamental entomology or general entomology and applied entomology or economic entomology.

Fundamental Entomology deals with the basic or academic aspects of the Science of Entomology. It includes morphology, anatomy, physiology and taxonomy of the insects. In this case we study the subject for gaining knowledge on Entomology irrespective of whether it is useful or harmful.

Applied Entomology or Economic Entomology deals with the usefulness of the Science of Entomology for the benefit of mankind. Applied entomology covers the study of insects which are either beneficial or harmful to human beings. It deals with the ways in which beneficial insects like predators, parasitoids, pollinators or productive insects like honey bees, silkworm and lac insect can be best exploited for our welfare. Applied entomology also studies the methods in which harmful insects or pests can be managed without causing significant damage or loss to us.

There are two type of insects (i) Beneficial insects e.g. Honeybee, Silk worm, Lac insect etc.

(ii) Harmful insect e.g. *Helicoverpa*, *Spodoptera*, Aphids, etc.

Beneficial insects are important as they are:

(i) Productive insects:

A. Products from secretion of insects and forest trees (Industrial Entomology)

- Silk (silkworm) (**Sericulture**)
- Bees wax (honey bees) (**Apiculture**)
- Shellac (lac insect) (**Lac culture**)

B. Collect, elaborate and store plant product

- Honey (Honey bee) (**Apiculture**)

(ii) Helpful insects:

- Aid in pollination (**Pollinators**)
- Parasitoid and predators of injurious insects (**Biological control**)
- Destroy weeds (**Weed killers**)
- Improve soil fertility (**Agricultural entomology**)
- As scavengers
- Insects and their products useful in medicine (**Cantharidine**)
- Helpful in solving crimes (**Forensic entomology**)

(iii) Beekeeping is an ideal subsidiary or whole time occupation. It fits well in diversification of agriculture. Besides adding to the farm income through production of honey, beekeeping also leads to the generation of other sources of income and employment opportunities including the development of several allied industries.

BEEKEEPING

Beekeeping is an art and skill maintaining the bees in modern movable frame hives for hobby or fascination, production of hive products (honey, bee wax etc.) and for pollination services **OR** the practice of rearing bee is called **beekeeping or Apiculture**. Apiculture is synonym of the beekeeping and is derived from Latin word 'Apiscultura'. *Apis* means 'bee' and *cultura* means 'cultivation through education'. The place where the hives are maintained is called an **Apiary**. Beekeeping is a high profit enterprise it can be taken up both as subsidiary industry and as well as whole time profession.

Initially in 1953 as many as 230 beekeepers, who maintained around 800 bee colonies in modern bee boxes and were producing 1, 200 Kg of honey annually. Presently it is estimated that with 25.00 Lakhs of bee colonies, 2.50 Lakhs beekeepers and wild honey collectors' harvest around 56, 579 MT of honey in country, which valued Rs. 476.04 crores. The average annual per capita consumption in India is 8.4 g.

HISTORY OF BEEKEEPING –WORLD

It is not clear when man started beekeeping, but there are archaeological evidences that about 4,000 years ago, the Egyptians kept bees in clay pots and used not only for honey, but also for propolis and wax. In fact, the honeybee was the symbol of Lower Egypt. Still many rock and cave paintings are available across the world depicting the honey bee in different shapes.

In ancient Greece and Rome, apiculture was a common practice. The philosopher Aristotle in his book "*Historia Animalum*" talked about honeybees' floral fidelity, division of labour within the colony and winter feeding. He also described some brood disease. Hippocrates, the Father of Medicine, depicts the nutritional and pharmaceutical value of honey. Greek athletes used honey as an energy boost.

Commercial beekeeping started during the second half of the 19th century. In 1851, **Rev. L. L. Langstroth** discovered the concept of '**bee space**' (3/8 inch space is kept by the bees between two adjacent combs as their passage for free movement all around the combs). Bee space or passage way is the space required between any two frames for the bees to move about conveniently between two combs. Based on this concept, modern age '**Langstroth bee hive**' with movable parallel frames/combs was developed by **L. L. Langstroth** is known as **Father of Modern Beekeeping**.

HISTORY OF BEEKEEPING – INDIA

Bees and honey were known to human being in India since time immemorial as their references are mentioned in epics, on murals, sculptures, etc. Vaishali Stupas in Muzaffarpur (Bihar) were built in commemoration of offering of honey to Lord Buddha by king of monkeys and his people whenever Lord Buddha visited the place. Several references of bees have been made in the oldest scripture of India, the **Rig Veda**.

The earliest method of keeping bees was to use hollowed out tree trunks, empty pots or any other suitable receptacles smeared with wax and sweet scented leaves of *Cinnamomum iners* on the inner surface; these receptacles were kept in jungles to entice (invite) the bees during swarming seasons. When the bees had settled there, these receptacles were carried to and kept in desired places. This type of hive is called *pot hive* and it was in practice in Mysore, Coorg, Malabar, Godavari, Kashmir, etc.

In our country, first attempt to keep honey bees in movable frame hive was made in early 1880s in pre-partition Bengal and Punjab. Commercial beekeeping in India started in 1910 in South when **Rev. Newton** devised a movable frame hive suitable for Asiatic hive bee, *Apis cerana*. This hive was named after him as '**Newton Hive**'. This hive is still popular for keeping the indigenous hive bee, *A. cerana*. During 1911-17, Newton also trained a large number of beekeepers in Southern India.

The Royal Commission on Agriculture (1928) recommended development of beekeeping as a cottage industry in India. The **All India Beekeepers' Association (AIBA)** was established in 1938-39. This association started publishing the **Indian Bee Journal (IBJ)**. During 1880, high yielding **European bees, *A. mellifera***, were introduced in our country. A sizable quantity of this species was imported from 1920 to 1951 in the states of Maharashtra, Kerala, Karnataka, Tamil Nadu, West Bengal, Punjab and Kashmir but none succeeded to establish this exotic honey bee species in the country.

STRENGTHENING OF BEE KEEPING RESEARCH AND DEVELOPMENT IN THE COUNTRY

After independence, **Khadi and Village Industries Commission (KVIC)**, Govt. of India took up beekeeping as one of its ventures. Some states like Jammu and Kashmir, Karnataka, Uttar Pradesh and Himachal Pradesh established Departments of Beekeeping under their Ministry of Agriculture/Industries. Further, considering the importance of applied and basic research in apiculture, KVIC established **Central Bee Research and Training Institute (CBRTI)** at Pune (Maharashtra) in 1962.

The research in beekeeping started when Indian Council of Agricultural Research (ICAR), New Delhi started funding to the different projects. Two Beekeeping Research Stations were also established at **Nagrota-Bagwan** (erstwhile Punjab, now in H.P.) in 1945 and at **Coimbatore** (Tamil Nadu) in 1951. Recently in Gujarat, Department on Entomology, N.M. College of Agriculture, Navsari Agricultural University, Navsari has initiated research on honey bees and other pollinators sponsored through ICAR, New Delhi with Project entitled “**All India Co-ordinated Research Project on Honey bees and Pollinators from the year 2015-16**”

SUCCESSFUL INTRODUCTION AND ESTABLISHMENT OF *Apis mellifera* IN INDIA

After a long gap of unsuccessful attempts of *A. mellifera* introduction in our country, Professor **A. S. Atwal**, an Entomologist of the Punjab Agricultural University (PAU), Ludhiana with his associates introduced *A. mellifera* in 1962 at Beekeeping Research Stations of Nagrota-Bagwan (H.P.) by adopting the '**Inter-specific Queen Introduction Technique**'. They imported disease free *A. mellifera* gravid queens along with worker bees. Later the worker bees were burnt and *A. mellifera* queens were introduced one each into the de-queened colonies of Asiatic hive bee (*A. cerana*). After the adaptation of *A. mellifera* queens, the workers of Asiatic hive



bee (*A. cerana*) reared the brood. It resulted in gradual replacement of workers of *A. cerana* who died with the age. Thus, *A. mellifera* stocks were further strengthened by importing disease free consignments of the gravid queen bees.

Convinced with the performance of *A. mellifera* in the Punjab, H.P. and Haryana and due to the outbreak of Thai Sac brood Viral Disease causing large scale mortality of *A. cerana* colonies during late 1970s to early 1980s in the states, practicing *A. cerana* beekeepers of many other states expressed desire to adopt *A. mellifera*. Due to this, ICAR in 1986 decided to extend this species from Punjab to other states. Now, this exotic honey bee (*A. mellifera*) has been spread to almost whole of the country. During 1993, **Department of Agriculture and Cooperation (DAC)**, Ministry of Agriculture, Govt. of India laid special emphasis on beekeeping and started a National Scheme on the '**Development of Beekeeping for Increasing Crop Productivity**'. Under this Scheme, beekeeping research, training and development projects were sanctioned to various State Agriculture Universities (SAUs), State Agriculture Departments, Government and Non-Government organizations (NGOs). Govt. of India established **National Bee Board in 2006**.

1. Honey bee:

Scientific classification 		
Kingdom	:	Animalia
Phylum	:	Arthropoda
Class	:	Insecta
Order	:	Hymenoptera
Family	:	Apidae
Subfamily	:	Apinae
Tribe	:	Apini Latreille, 1802
Genus	:	<i>Apis</i> Linnaeus, 1758

Biology/ Life history of Honey bee:

Eggs:

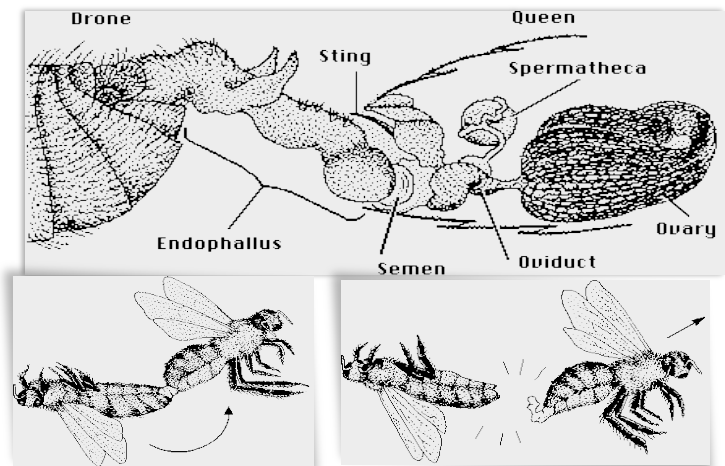
Eggs are laid by queen and when a colony wants to produce a new queen, the special cell is constructed at the lower border of the brood comb. On these cells, single egg is laid by the queen in each cell which hatched after 3 days. The newly hatched grubs are provided with royal jelly. The grub is fully developed in 5 or 6 days and then queen cell is capped where grub changes into pupa and after a week adults come out by biting the cap of queen cell. The adult who comes out earlier become the daughter queen and it kills the remaining pupae before their emergence.

Nuptial flight:

After 2-3 days the daughter queen takes nuptial flight accompanied by hundreds of drones during day. She overtakes drone in flight. The drone which follows her takes the chance of copulation. The male soon dies after copulation and the mated queen return to the comb. She mate only once in her life time. The seminal fluid (male sperms) is collected in a special receptacle (spermatheca) and used as and when required.

Drone honeybee die after copulation.....WHY??

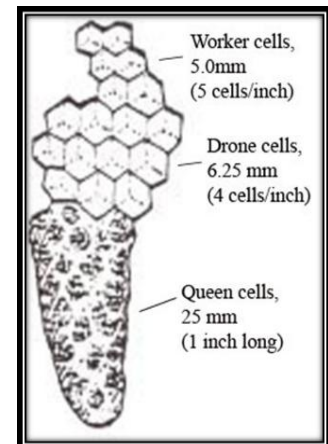
The drone mounts the queen, inserts his endophallus, and ejaculates his semen. During ejaculation, the male falls back and his endophallus is ripped out of his body and remains attached to the queen. Drones mounting later remove the previous drone's endophallus and lose their own through similar matings. The emasculated drones die very quickly with their abdomens burst in this fashion.



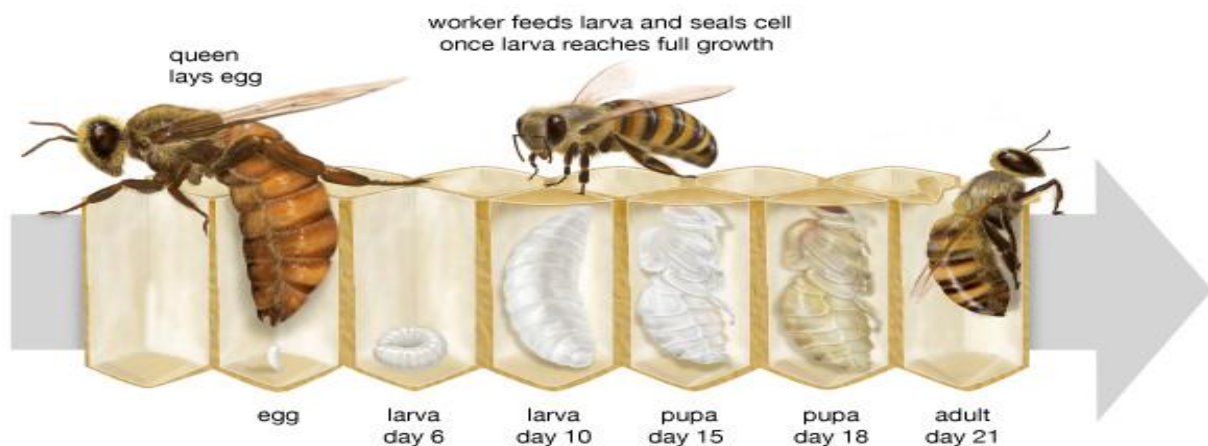
Oviposition

After some times the daughter queen starts eggs laying and is called as mother queen. She lays fertilized or unfertilized eggs at her will. Once egg is laid in a cell, it hatched in 3-4 days. The eggs are long, oval and light brown in colour.

The **queen measures the cell opening with her front legs** as she inspects each cell prior to laying her egg. Worker bees develop horizontally in hexagonal cells of approximately 0.2 inch (5 mm) diameter (5 cells/inch). Drones develop in slightly larger horizontal cells. The female queen develops in a vertically-oriented cell. The existing queen herself lays fertilized eggs in special cup-like structures, called **queen cups**, oriented vertically on the face of the horizontal worker and drone comb or more usually **at the bottom margin** of the comb.



Life cycle of honeybees



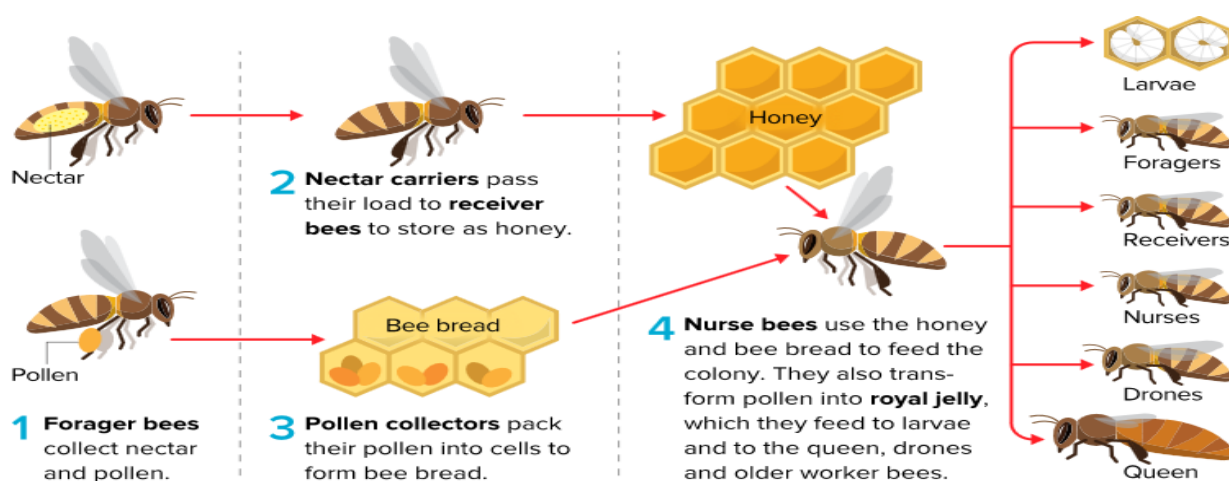
Grub:

From the fertilized eggs the **queen and worker** are developed, while from the unfertilized eggs **drones** are developed. The grubs are cylindrical in shape and light yellow in colour, they fed with the royal jelly for 2-3 days after that they are provided with honey and nectar, etc. The grub period lasts for about 5-6 days.

Worker bees are raised in the multipurpose, horizontally arranged cells of the comb. Future workers receive the royal jelly only during the first 3 days as compared to future queens, who are fed with royal jelly throughout their larval life.

The developing queen larva is always surrounded by royal jelly, a special highly nutritious food produced by head glands of the workers. This feeding scheme, called massive provisioning is unique to the queen and continues throughout her entire developmental period.

Worker bees mix the honey with pollen and feed to the drone larvae. Future drones receive royal jelly for the first 3 days. After that, they are shifted to progressive feeding as discussed in worker feeding.



Pupa:

Full grown grub forms a cocoon and pupates inside the cell. The pupal period lasts for about 7-14 days depending upon the type of adult to be produced. The time required for development of different castes of *A. mellifera* is given below:



Adult	Eggs	Grub	Pupa	Total
Queen	3 days	6.5 days	6.5 days	16 days
Worker	3 days	8.0 days	10.0 days	21 days
Drone	3 days	9.5 days	11.5 days	24 days

Total lifespan/biology of honey bee:

Development Stage	Castes		
	Queen	Worker	Drone
Egg	3 days	3 days	3 days
Unsealed stage	5 days	5 days	7 days
Cell sealed	8 th day	8 th day	10 th day
Cocoon information	10 th day	11 th day	14 th day
Adult formation	15 th day	20 th day	22 nd day
Adult emergence	16 th day	21 st day	24 th day
Sexual maturity	within 2-3 days	-	13 days
Adult longevity	3-4 years	6 weeks	2-3 months

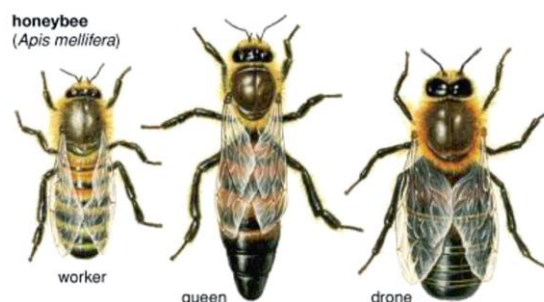
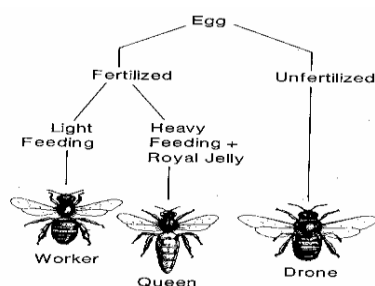
Honey bees are the only bees to die after stinging WHY??

Because when a honey bee stings a person, it cannot pull the barbed stinger back out. It leaves behind not only the stinger, but also part of its abdomen and digestive tract, plus muscles and nerves. This massive abdominal rupture kills the honey bee.



HONEY BEE CASTES

The honeybee is a social insect and lives in colonies with a highly organized system of division of labour. Many combs are found in a colony in which the members of the same family used to live. Each family consists of three castes: queen (fertile female), drones (males) and workers (sterile females). Each caste has its special function in the colony. The workers are undeveloped females, the drones are known as males and the queen is the fully developed female. Every honey bee colony comprises of 35000 to 70,000 members includes a queen, 200-300 drones and several thousand workers.



Sex differentiation in bees

A. Queen:

The queen is a **true mother bee**. Queen is the only female that is completely developed sexually from fertilized egg. This is a result of a total diet of **royal jelly** during the developmental period. She has a long abdomen extending well beyond the apical margins of the wings. In the colony, she is found in the area of the brood nest. A well developed queen is generally two to three times bigger than a worker and measures about 15-20 mm in length.

Duties of a queen:

1. The only individual which lays eggs in a colony (**Mother of all bees**).
2. Lays upto 2000 eggs/day in *Apis mellifera* and maintaining a populous colony.
3. Five to ten days after emergence, she mates with drones in one or more nuptial flights.
4. When her spermatheca is filled with sperms, she will start laying eggs and will not mate any more.
5. **She lives for 3 years** and when it is weak or unable to lay eggs it is replaced by one of the daughter queen.
6. The secretion from mandibular gland of the queen is called **queen's substance**.
7. The queen substance if present in sufficient quantity performs following functions.
 - a) Prevent swarming and absconding of colonies.
 - b) Prevent development of ovary in workers.
 - c) Colony cohesion is maintained.
8. The queen can lay either fertilized or sterile eggs depending on the requirement.

B. Drone:

Drones, the functional males of the colony are produced from unfertilized eggs, and are larger and darker than the worker. It is smaller than queen and measures about 15-17 mm in length. Drones are not a permanent member of colony. The queen can control whether or not the egg is fertilized as she lays it. The compound eyes are holoptic i.e. very large and are united at the vertex. The end of the abdomen is blunt and is covered with a tuft of small hairs. **Drones cannot sting**. As the sting is a modified structure of the female genitalia, drones do not have stings. They also **do not have any of the structures necessary to collect nectar and pollen**. It dies after successful mating with the queen.

Duties of a drone

1. Their important duty is to fertilize the queen.
2. They also help in maintenance of hive temperature.
3. They cannot collect nectar / pollen and they do not possess a sting.

C. Workers

Workers are **sexually sterile female** caste and is the smallest in size as compared with the above two castes. On ventral side of the abdomen, **wax glands** are present. Hind legs are modified for **pollen collection**. The mandibles are flattened and spoon shaped which are used for molding the wax for comb building. They do the work of the colony and maintain it in good condition. Workers have special structures and organs which are associated with the duties they perform.

Duties of a worker

1. Their adult life span of around 6 weeks can be divided into:
 - (i) First three weeks- house hold duty.
 - (ii) Rest of the life- out door duty.

[i] House hold duty includes:

- a. Build comb with wax secretion from wax glands.
- b. Feed the young larvae with **royal jelly** secreted from **hypopharyngeal gland**.
- c. Feed older larvae with bee-bread (pollen+ honey).
- d. Feeding and attending queen.

- e. Feeding drones.
- f. Cleaning, ventilating and cooling the hive.
- g. Guarding the hive.
- h. Evaporating nectar and storing honey.

[ii] Outdoor duty includes:

- 1. Collecting nectar, pollen, propolis and water.
- 2. Ripening honey in honey stomach.

Schedule of a worker bee in the hive

Days after emergence	Task
1–2	Clean cells and warm the brood nest
3–5	Feed older larvae with honey and pollen
6–10	Feed younger larvae with products of the head glands
11–18	Ripen nectar, produce wax and construct comb
19–21	Guard and ventilate the hive, take exercise and orientation flights to learn to fly and locate the hive
22 +	Forage for nectar, pollen, water or propolis

❖ **Morphological differentiation among different castes of *A. mellifera***

Character	Queen bee	Drone bee	Worker bee
Adult			
Body size	Longest	Medium	Smallest
Wings	Do not completely cover the abdomen	Completely cover the abdomen	Completely cover the abdomen
Head	Triangular and little roundish	Roundish	Triangular
Abdomen	Long, gradually tapering	Tip of abdomen blunt and hairy	Tip of abdomen conical and subtly pointed
Compound eyes	Small and well apart	Large kidney shaped, meeting at vertex	Small and well apart
Pollen collecting legs	Not developed	Not developed	Well developed
Sting	Present but without barbs	Absent	Present with barbs

DIFFERENT SPECIES OF BEES AND THEIR IMPORTANT CHARACTERS:

The honey bees belong to superfamily Apoidea and the family Apidae and the order Hymenoptera. There are six species of *Apis* viz., *Apis cerana*, *Apis florea*, *Apis dorsata*, *A. andreniformis*, *A. laboriosa* and *A. koschevnikovi* which are indigenous to India and *A. mellifera* which has been introduced from European countries. The commercialized honey bees in India are two domesticated/hive bees, *Apis mellifera* Linn. and *Apis cerana* F. and two well-known wild species, *Apis dorsata* F. and *Apis florea* F. They have well developed stings. The Dammer bee or little bee, *Trigona iridipennis* (Meliponinae) has only a vestigial sting. All five species are social insects living in colonies with remarkable degree of social instincts and division of labour among the different members of the colony.

There are five important species of honey bees as follows.

Scientific name	Common name
(1) <i>Apis dorsata</i>	: The rock bee
(2) <i>Apis cerana indica</i>	: The Indian hive bee
(3) <i>Apis florea</i>	: The little bee
(4) <i>Apis mellifera</i>	: The European or Italian bee
(5) <i>Trigona iridipennis</i> (<i>T. laeviceps</i>):	Dammer bee, stingless bee

(1) The rock bee or giant bee, *Apis dorsata* Fabricious

1. It is largest of the honey bees and measuring about 20 mm in length.
2. It construct single comb of huge size in open (About a meter in diameter)
3. The comb is fully exposed and hung from inaccessible branches of trees, along sides of steep rocks in the forest and even from the walls, rafters and other parts of buildings.
4. It produces plenty of honey i.e. **37 Kg honey /comb/year**.
5. It represents a major portion of honey sold in our markets.
6. Rock bees are irritable and ferocious in nature and difficult to rear.
7. They shift the place of the colony often. In winter, they migrate to plains and come back to hills during summer season.

(2) Indian hive bee/Asian bee, *Apis cerana indica* Fabricious

1. It is common Indian bee found in both forest as well as in plains throughout country.
2. It is smaller than the rock bee but the larger than the little bee. Bee measures about 15 mm in length.
3. They make **multiple parallel combs** on trees, cavities, caves in darkness and such other hidden sites, the combs being parallel to the direction of the entrance in the plains and the right angle to the entrance in cold regions.
4. It is mild and capable of being domesticated and is commonly reared in south India.
5. They produce about **2 - 5 Kg of honey/year/colony**.
6. A queen can lay 350 – 1000 eggs per day.
7. They are more prone to swarming and absconding.
8. They are native of India/Asia.

(3) The little bee, *Apis florea* Fabricious

1. It is known as the little bee since it is smallest of the four species of *Apis*. Bee measures about 7 mm in length.
2. It is seen only in the plains and not in hills above 450 mt MSL.
3. It does not like darkness therefore forms its comb in the open place e.g. bushes, hedges, buildings, caves, empty cases etc.
4. It builds a single comb which is very small and produces about **0.5 to 1 kg honey/year/hive** and so it is not domesticated and reared.
5. A queen can lay 323 – 365 eggs per day.
6. They are not rearable as they frequently change their place.

(4) European bee or Italian bee, *Apis mellifera* Linnaeus

1. It is extensively reared in Europe and America.
2. It was introduced in India in the year 1962 by **Prof. A. S. Atwal** in Nagrota (HP) from European countries (Italy). He is called as “**Father of Modern Beekeeping in India**”.
3. The behaviour and appearance of *A. mellifera* is similar to *A. cerana*.
4. It makes its nest in enclosed space (in darkness) in **multiple parallel combs** and is endowed with all the good qualities of a hive bee, i.e. has a prolific queen, swarms less, gentle tempered so, domesticable, good honey gatherers and can guard its nest against enemies.
5. They yield on an average **45-180Kg honey/hive/year**
6. They are larger than Indian bees but smaller than Rock bees.

(5) Dammer bee or stingless bee, *Trigona irridipennis* Dal. (*T. laeviceps*)

1. This is the smallest species and differs from other bees in its appearance and habitats.
2. They do not have sting i.e., stingless.
3. They built their comb in hollow walls or tree trunks.
4. They construct their comb with a dark material called “**Cerumen**” which is a mixture of earth and wax or resin collected from plants as they do not secrete wax to build combs.
5. It is very poor honey gatherers and yields only **60-180 ml/colony/year**.
6. Its honey is used in **Ayurvedic medicine**.

Identification/differentiation among different bee species

Sr. No.	Characteristics	The rock bee, <i>Apis dorsata</i> (Giant honey bee)	The little bee, <i>Apis florea</i>	Indian hive bee/Asian bee, <i>Apis cerana indica</i> (Asiatic honey bee)	European bee or Italian bee, <i>Apis mellifera</i> Linnaeus	Dammer bee or stingless bee
1.	Body size	Largest	Smallest	Medium	Medium	Smallest
2.	Body colour	Head blackish, abdomen reddish-yellow anteriorly	Abdomen orange anteriorly with black & white stripes posteriorly	Body colour blackish, abdomen with white & black stripes	Body golden yellow, profusely hairs with faint black and yellowish stripes	Body is reddish brown in colour

		& black at the tip			posteriorly	
3.	Wings	Smoky	Transparent	Transparent	Transparent	Transparent
4.	Proboscis size	Largest	Smallest	Medium	Medium	Smallest
5.	No. of worker cells/4 linear inches	18.75	32.8 to 36.0	21.25 to 25.00	19.3	--
6.	Nature and Temperament	Wild bee, hostile	Wild bee, relatively less hostile	Can be hived, docile	Can be hived, docile	Can be hived, docile, do not have sting i.e., stingless.
7.	Comb construction	Single, large (5-7' x 2-4') combs, constructed under the roof projections, water reservoirs and on trunks of tall trees	Single, small (Palm to quarter plate size) combs, constructed in bushes/hedges, cotton sticks	Many parallel combs inside the enclosure/cavities or in bee hives	Many parallel combs inside the enclosure/cavities or in bee hives	Built their comb in hollow walls or tree trunks.

MAJOR ACTIVITIES OF HONEY BEES:

The honey bees remain active generally throughout the year except during severe winter. Following are the main activities of honey bees:

1. Foraging:

The field bees get activated in the morning and go out on foraging and collect pollen, nectar, propolis and water, carry them to the hive and make a number of trips till sunset. The bees that go out first to find out new sources of these materials are called **searcher bees or scout bees**. They return to the hive and communicate the message to young foraging bees by means of definite patterns of **dancing**. At any time bees collect most of the materials from a single or a few plant species but bees in two different colonies located side by side may visit entirely different sources, mainly due to the differences in discoveries by the scout bees. The bees collect materials from a source till they are exhausted when they may go in search of new areas. The honey bees usually forage within about **100 meters distance** from the hive but they can **go up to 1.5 km**. They are capable of flying at a speed of **25-30 km per hour**. The bees are most active in foraging

within a temperature range of 25-27°C. The bees do not go out for foraging at wind speed of more than 24 km per hour.

Nectar is collected by the foragers from the flowers and is stored in the crop where it is mixed with saliva. The **invertase** contained in the saliva acts upon sucrose of the nectar and converts it to **dextrose or levulose**. The bee returns to the hive and regurgitates the contents of the stomach into comb cells which are covered by flat airtight cappings. The weight of nectar load varies from **25 to 40 mg**. On a given trip, a bee visits and exploits 1-500 flowers and makes, on an average, 10-15 trips in a day. During honey flow when there is abundance of food available, bees work to their full capacity and may make upto **150 trips a day**. The pollen is collected and carried to the hive by the bees in the pollen baskets located in their hind tibiae. The bee returns to the hive and the pollen pellets are pushed down to the appropriate cells by means of spine in the middle leg. The weight of pollen load varies from **10 to 30 mg**. The workers make about 6,000 trips to collect 0.5-1 g of pollen. The **propolis** is also carried in the pollen basket by the worker bees. As soon as the collecting bee returns to the hive, another worker unloads the propolis from the former, carries the same in its mandibles to the place requiring cementing and presses it into the crevices in the comb.

2. **Combing:**

The comb of honey bees comprises of several **hexagonal cells** on both side of mid-rib. The combs are built with **beeswax** which is secreted by 4 pairs of wax glands located on 3-6 abdominal sterna. The wax secreted in a liquid form, collects in the intersegmental regions, hardens into thin flakes that are picked up by the legs and passed on to the spatulate mandibles for being kneaded and stuck to the top of nesting cavity and extended downwards bit by bit. Several bees hang like a sting to do the job. Usually, the cells meant for honey storage are located uppermost near the point of attachment below which are pollen cells spread in 5 cm wide band, further down are worker brood cells which are followed by the drone and queen cells. The worker cells are the smallest, drone cells larger than the worker cells and queen cells the largest. Worker and drone cells are directed sideways and queen cells vertically with open ends downwards. Cells of the size of worker and drone cells are used for storing honey and pollen. **Cells containing unripe honey or developing brood are uncapped; those with fully ripe honey and fully fed grubs are capped, and pollen cells are generally not capped.** Freshly built comb is generally white, but becomes dark after some time.

3. **Swarming:**

Swarming is a **method of reproduction** in which a part of the colony migrates to a new site to make a new colony. During spring and summer when conditions are favourable and food is available in plenty, the bees multiply greatly with the result the comb becomes crowded and the bees begin to make preparations for swarming. At this stage, the daughter queen cells are built at the bottom and when new queen is ready to emerge out, the new queen and a large number of workers which have previously filled the cells with honey, leave the nest to start a new colony. Swarm settles in a suitable place already searched out by the workers for building new comb. In a parent colony the first daughter queen which emerges after swarming, kills the baby queen in the other cell and establishes herself as a mother queen. After that, they start their routine work of gathering nectar and pollen.

4. Abscinding and migration:

Complete **desertion of a hive** is known as absconding. This may occur due to lack of water, exhaustion of food store (either due to short supply of nectar or robbery of honey), unfavourable environment, constant pest attack (ants, wax moth, etc.) and even by excessive interference by the beekeeper in which case he is regarded as an enemy. Prior to absconding, the bees 'drink' whatever honey their nest has and then migrate leaving behind empty combs, brood and sometimes even food. Absconding can be prevented by providing water or sugar solution near the hive particularly during summer.

5. Language of bees:

Honey bees have a unique and one of the best understood animal languages with which they inform each other the distance and direction of the source of food. The **forager bee** on return to the nest makes two kinds of dances on the surface of the comb, i.e. **round dance and tail-wagging or figure of eight dance** (Fig. 1), which the insiders perceive by contacting the forager's body with their antennae. In the round dance, which is used to indicate a short distance (less than 50 m in case of *A. mellifera*), the bee runs in circles, first in one and then in opposite direction (clock and anticlockwise), while in the tail-wagging dance which is used to indicate a longer distance (beyond 50 m in case of *A. mellifera*), the bee makes two half-circles in opposite directions with a straight run in between. During the straight run, the bee shakes its abdomen from side to side and the number of wags per unit time is related to the distance the food was located, i.e. **more the wags, nearer is the food**. The direction of the food is conveyed by the angle that the dancing bee makes its straight run and top of the hive which is the same as between the direction of the food and direction of the sun. **Prof. Karl von Frisch was awarded the Nobel Prize** in Physiology and Medicine in 1973 for discovering and interpreting the language of the honey bees in early 1920s. Later on, it was found that honey bees employ both dance and sound in their language.

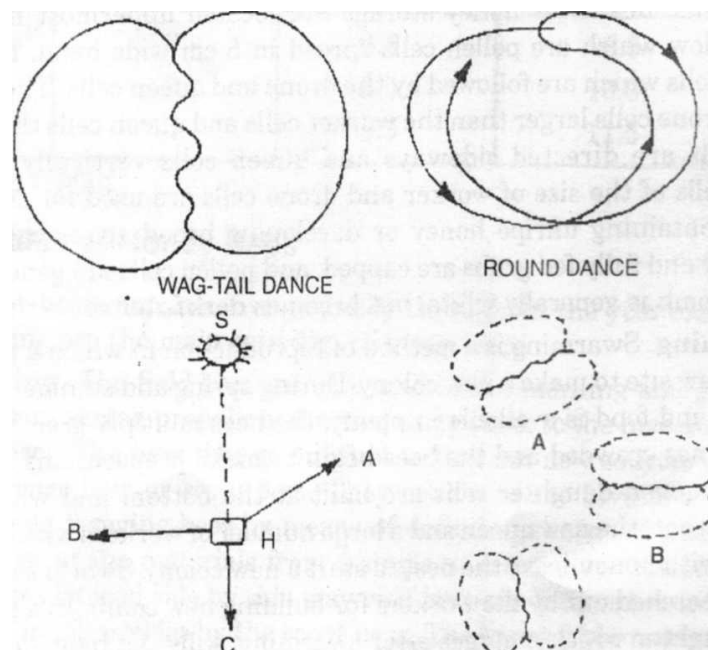


Fig-1: Communication dances in honey bees according to location of the food source and direction of the sun (A, B, C = Directions. S=Sun. H=Beehive)

6. Air conditioning:

Among the living creatures, honey bees are the only organisms which make their comb air-conditioned. They keep their comb warm in winter and cool during summer. The brood temperature is stabilized between 33 and 36°C averaging about 34.5°C. Clustering begins when the temperature inside the nest dips below 18°C and they generate heat by sitting on one another and rubbing their legs due to which the temperature of the comb rises. In summer, when the temperature rises above 33°C, the bees start fanning with their wings at the gate inside as well as outside with the result water evaporates from the honey and comb remains cool. The brood nest is usually kept at 40 per cent relative humidity.

A large number of foragers start collecting water from outside, that is received by house bees inside and carried by them to the site where most needed and evaporated. They spread minute drops of water in cells and also form thin films from regurgitated water on their tongues for evaporation. In the event of extreme hot weather they even suspend collecting concentrated nectars but prefer dilute nectars in case water is in scarcity, as the dilute nectars may be used for making thin films.

COMMERCIAL METHODS OF REARING OF HONEY BEES

Rearing the bees in artificial hives is known as **beekeeping or apiculture**. In India, the beekeeping industry started with the designing of a small hive suitable for *A. cerana* by Rev. Father **Newton in 1910**. This hive named '**Newton Hive**' is still popular for keeping of *A. cerana*. The father also trained a large number of beekeepers in Southern India and helped them to establish beekeeping as an economically viable proposition. Mahatma Gandhi realized the importance of beekeeping and included it in his rural development programmes. He inspired rural freedom fighters to take up beekeeping as a venture of livelihood. In earlier times, people after wrapping the blanket on the body or after smoking in night and collect honey from the comb. This was a **crude method**. After some times, people thought to keep the honey bees and many villagers took interest in keeping honey bees and provided various types of hives in their houses.

Thus, beekeeping can be divided into primitive and modern methods:

A. Primitive or Indigenous Methods

This is primitive and unplanned method of apiculture. In this method, two types of hives are used,

- **Fixed type:** Providing a receptacle in the wall of the house with an entrance and observation holes.
- **Movable type:** Providing a basket, empty boxes, hollowed logs, bamboo, mud pipes, earthen pots, etc. Anything that can protect bees from sun and rain.

In the indigenous method, the bees are first killed or made to escape from the hive with the help of smoke when the bees are at rest during night. This method has many drawbacks and it is not suitable for commercial large-scale production of honey. The following are the disadvantages of indigenous method:

1. The honey cannot be extracted in the pure form. The extracted honey also contains the larvae, pupae and pollen cells.
2. The future yield of the honey is affected as the colony has to be destroyed to extract the honey. Moreover, it takes lot of energy of the bees to build new hive.

3. The bees may not construct the new hive in the same place as the old one.
4. The natural hives also have the danger of attack by the enemies like rats, monkeys, ants etc. The natural hives can also be damaged by the climatic factors.
5. Also scientific intervention is difficult in the indigenous method and thus improving of the bee race is impossible.

B. Modern Method or Frame Hive Method

Frame hives are fitted with movable frames on which the bees are persuaded to build their combs. They are usually composed of several boxes, one on top of the other, in which hive frames are suspended. The lower boxes (1-2) are used for holding the brood and the upper ones (1-2) are used for collection of honey, pollen and propolis. The artificial comb was first introduced by Revd. L.L. Langstroth in 1851 in America. In India, during 1910 Rev. Father Newton designed a small hive suitable for *A. cerana*.

Beekeeping with Frame Hive Method:

Apiary is the place where the honey bees are reared for honey and wax either commercially or as a hobby. Often a beekeeper is left with no choice for location of his hives, when he intends to keep them in his backyard or a small home garden. But where a selection among many possible sites can be exercised, the following points.

Requirements for site selection for apiary:

- **Apiary** should be located where there is abundance of nectar and pollen yielding plants within the radius of one to one and half kilometer.
- The site should not be exposed to strong winds or at least the hives should not face the direction of the prevailing winds. Trees and bushes may be provided to make the site less windy.
- The site should be flat but with good drainage facilities.
- Clean and fresh running water should be available to the bees in or near the apiary.
- A young orchard is an ideal choice.
- If the site is shade less and exposed, an artificial shade may be provided.
- An apiary should not be located too near highways.
- A good barbed wire fence or live hedge may be provided to keep out intruder/thief.
- The site should be free from termite and black ant infestation.

I. Bee hives: Various types of bee hives are available for beekeeping. They are wooden boxes having two parts: upper $\frac{1}{4}$ comb is chamber and lower $\frac{3}{4}$ is brood chamber. Following types of bee boxes are used in beekeeping.

Sr. No.	Box type	Dimensions	Remark
1.	Ghos box	36 cm x 21.5 cm	These two types of bee hives are more popular in India. In India Newton's beehive are manufactured based on Bureau of Indian Standards (BIS) specifications and called as BIS hives .
2.	Newton box (BIS hive)	20.2 cm x 14.0 cm	
3.	Langstroth hive	42.2 cm x 31.1 cm	Some other familiar bee

	(American hive)		boxes. Nowadays these boxes are widely used in commercial beekeeping. Langstroth hive is suited to <i>A. mellifera</i>.
4.	Pant, Kanje and Jeolikote No.1	42.2 cm x 12.3 cm	
5.	Dadant box (Russian hive)	47 cm x 28.6 cm	
6.	Thompson box	30.5 cm x 15.2 cm	

Hive parameters	BIS hive C type for <i>A. mellifera</i> (Modified Langstroth type)	BIS hive A & B type for <i>A. cerana</i> (Modified Newton and Jeolikote types)
Frames	Contains 10 frames	May contain 4, 8 or 10 frames
Super Chamber	Generally full super chamber is used.	Half (shallow) super chamber is generally used.
Brood/super frame size	Outside: 448 x 232 mm Inside : 428 x 192 mm	Type A: Modified Newton Type Outside: 230 x 165 mm Inside : 210 x 145 mm Type B: Modified Jeolikote Type Outside : 300 x 195 mm Inside : 280 x 175 mm
Bee space	10 mm	Type A : 7 to 9 mm Type B : 8 or 9 mm

II. Equipments used in commercial beekeeping:

A movable frame hive is composed of the following parts/appliances

1.	Bee hive: - It is movable wooden hive for bees with an entrance and parallel movable frames on which bees raise their combs. - It provides protection to the colony from adverse effects of external environment. The important parts of the hive are bottom/floor board with alighting board, entrance, lower/brood chamber, frames, dummy board, super/honey chamber, inner cover (crown board) and top cover.
2.	Nucleus hive: Small bee hive for keeping 4-6 frames. These are used for mating of queens and division of colonies.
3.	Observation hive: Small hive with glass sides to observe movements and behaviour of bees.
4.	Synthetic combs: - It is made up of high density polythene (plastic). It can be used in both super and brood chambers. - Since the comb is fully moulded, bees only put wax caps on the cells. Advantages of synthetic combs viz., More honey can be extracted, Combs can be easily sterilized, Resist to wax moth attack, Combs will not be damaged during honey extraction.
5.	Hive stand: This is used to keep the bee hive above the ground so as to protect the colony from termites, ants and other crawling insects and also prevent soil moisture getting into the

	hive or facilitate ventilation from below the hive. • The stand is made of wood or iron tubing or angle iron. • Any four legged stand of 15-25 cm high is sufficient. • Ant wells of 15 cm in diameter kept under four legs to prevent ants and other crawling insects entering into the hive.
6.	Bottom board: • It forms the floor of the hive made up of a single piece of wood or two pieces of wood joined together. • Wooden beading are fixed on to the lateral sides and back side. • There is a removable entrance rod in the front side with two entrance slits to alter the size of the hive entrance based on need. • The board is extended by 10 cm in front of the hive body which provides a landing platform for bees. • Size of alighting board is 40 x 28 cm (BIS hive).
7.	Brood chamber: • It is a four sided rectangular wooden box without a top and bottom. • It is kept on the floor board. • A rabbet is cut in the front and back walls of the brood chamber. • The brood frames rest on the rabbet walls. • In brood frames, bees develop comb to rear brood. • Size of brood frame is (outer dimensions) 29 x 29 x 17 cm. • There will be 8 frames. Length and height of frame is 20.5 x 14.0 cm (BIS hive).
8.	Super chamber: • It is kept over the brood chamber and its construction is similar to that of brood chamber. • Super frames are hung inside. • The length and width of this chamber is similar to that of brood chamber. • The height may also be similar if it is full depth super as in Langstroth hive. But the height will be only half if it is a shallow super as in Newton's hive. • Surplus honey is stored in super chamber.
9.	Hive cover/Top cover: • It insulates the interior of the hive. • In Newton's hive, it has sloping planks on either side. • On the inner ceiling plank there is a square ventilation hole fitted with wire gauze. • Two holes present in the front and rear also help in air circulation. • In Langstroth hive and BIS hive, the hive cover consists of a crown board or inner cover and an outer cover.
10.	Inner cover: • The inner cover is provided with a central ventilation hole covered with wire gauze help in air circulation. • The outer cover is covered over with a metallic sheet to make it water proof to rain water.
11.	Hive frames: • The frames are so constructed that a series of them may be placed in a vertical position in the brood chamber or the super chamber so as to leave space in between them for bees to move. • Each frame consists of a top bar, two side bars and a bottom bar nailed together. • Both the ends of the top-bar protrude so that the frame can rest on the rabbet.
12.	Dummy or Division board/ Movable wall: • It is a wooden board slightly larger than the brood frame.

	• It is placed inside the brood chamber. • It prevents the bees from going beyond it. • It can be used as a movable wall there by limiting the volume of brood chamber which will help the bees to maintain the hive temperature and to protect them from enemies. • It is useful in managing small colonies.
13.	Bee feeder: • Used for providing sugar syrup as feed to the bees during dearth period. • A normal method of providing feeding is to keep a can with small holes punched on its lid. The can is filled with sugar syrup and kept over the frames in an inverted position.
14.	Queen excluder: • It is made up of perforated zinc sheet. • The slots are large enough to allow the workers to pass through but too narrow for the queen. • A wire grid/dividing grid with parallel wire mounts can also be used as a queen excluder. • It is inserted in between the brood frames and super chamber.
15.	Queen gate: • It is a piece of queen excluder sheet and fitted on the slot of entrance gate. • The holes in the sheet are large enough to allow free movement of worker bees in and out of the hive, but too small to allow queen's passage. • It confines the queen inside the hive. It is useful to prevent swarming and absconding. It also prevents the entry of bee enemies like wasps into the hive.
16.	Queen cage: • This is used for transport of queen either with a few attendant worker bees, in packages. • It is a cage made up of wood or wire gauge or plastic structure. This is useful for queen introduction.
17.	Queen cell protector: • It is a cone shaped structure made of a piece of wire wound spirally. It fits around a queen cell. • It is used to protect the queen cell, given from a queen right to queen fewer colonies until its acceptance by bees.
18.	Swarm trap: • It is a rectangular box used to trap and carry the swarm. • It is fixed near the hive entrance with one or two combs inside during the swarming season. • This box traps and retains the queen only. But the swarm coming out from the hive reenters the hive and settles on the comb, since the queen is trapped.
19.	Drone excluder or drone trap: • It is a rectangular box with one side open. The other side is fitted with queen excluder sheet. • At the bottom of the box there is a space for movement of worker bees. There are two hollow cones at the bottom wall of the box. • Drones entering through the cones into the box get trapped. • The narrow end of the cone is wide enough to let the bees pass out but not large enough to attract their attention or re-entry. This device is used at the entrance to reduce the drone population inside the hive.
20.	Pollen trap: • Pollen trapping screen inside this trap scrapes pellets from the legs of the returning foragers. • It is set at the hive entrance.

	The collected pollen pellets fall into a drawer type of receiving tray.
21.	Hive tool: - It is a piece of flattened iron with flattened down edge at one end. - It is useful to separate hive parts and frames glued together with propolis. - It is also useful in scrapping excess propolis or wax and superfluous combs or wax from various parts of the hive.
22.	Protective dress: (a) Bee veil: - It is worn over the face for protection against stings. - It is particularly useful for a beginner, for protecting face from bee stings during the handling of bees. (b) Gloves: - These are used while inspecting and handling colonies to protect hands and arms. Soft leather gloves with canvas gauntlets to the elbow are the best for use. (c) Boots: - A pair of gum boots will protect the ankles and prevent bees from climbing up under trousers. (d) Overalls: - White overalls are occasionally worn. Light colored cotton materials are preferable since they are cooler and create less risk for antagonizing bees.
23.	Bee brush: A soft-camel-hair brush is used to brush the bees off the honeycomb before it is taken for extraction.
24.	Smoker: - The smoker is used to calm bees and drive away bees from super. - It consists of a metal fire pot with a funnel shaped cover and a bellow. - A smoke releasing fuel (dried cow dung, hessian, waste jute bags or cardboard, old rag, wood shaving etc.) is burnt in the fire pot. - Air is injected into the pot by operating the bellow and the smoke is directed to the desired spot.
25.	Decapping knife/ uncapping knife: Single or double edged steel knife is used for removing wax capping from the honey comb before putting it in the honey extractor.
26.	Honey extractor: - It is invented by Frang von Hruschkain 1885. - It consists of a cylindrical drum. - A rack is fixed inside the drum to hold the supper frames. - The rack is rotated by a set of gear wheels. - The decapped honey frames are kept in the slots of the rack. The rack is rotated by operating the handle. Honey flow out from the combs by centrifugal force. The excreted honey comes out through the spout present at the bottom of the container. - The honey comb is not damaged. So, it can be reused.
27.	Travelling screen/net: It is a wooden frame with wire screen. It is highly useful for migration of honey bee colonies during hot summer season.
28.	Comb foundation mill: - This is a machine to prepare comb foundation sheet used in beekeeping to make-bees build regular combs in frames that are convenient to handle. J. Mehring of Germany made the first comb foundation in 1857.

	• Comb foundation is made by passing plain sheets of beeswax between two rollers that have the regular 3-faced cell base pattern embossed on them. • The patterns on the two rollers interlock properly, so that the 3-faced cell base on one roller matches with the base of each of the three cells on the other roller. • The distance between the rollers is fixed in such a way that a thin foundation is made that is readily accepted by the bees. • The rollers rotate on opposite sides. • The rotation is done by a handle attached to the lower roller. The cell size in the cell base pattern varies according to the size of the brood cells.
29.	Comb foundation sheet: • It is a thin sheet of bee wax embossed with a pattern of hexagons of size equal to the base of the natural brood cells on both sides. • The size of the hexagon varies with bee species. For <i>A. mellifera</i> there are 19 cells and for <i>A. cerana</i> 22- 23 cells/100 mm linear length.
30.	Embedder: • It is a small tool with a spur or round wheel on the top. It is used to fix the comb foundation sheet on the wires of the frame. • Electric wire is also used for this purpose which is useful to reinforce the comb and give extra strength to the comb.
31.	Miscellaneous: • Apart from these equipments, there are several miscellaneous equipment which are required from time to time viz., propolis screen, venom extractor, drip tray, swarm basket, wax melter, queen bee rearing equipment, comb foundation making equipment, honey straining, storage and processing equipment, etc.

DIVISION AND UNITING OF HONEY BEE BOXES:

I. Division of honey bee boxes:

Colony division is a method of multiplying bee colonies, *i.e.* producing two or more colonies from a mother colony. Colony division is used to control swarming as well as in commercial beekeeping to increase the number of colonies.

Methods for colony division:

(i) Natural division using queen cells developed during swarming

The presence of multiple queen cells in a colony during the swarming season indicates a need for division. Dividing such colonies and using the queen cells in new daughter colonies can help control swarming. However, although it solves the immediate problem of swarming it does not help improve the genetic traits.

(ii) Colony division from queen production

Select the best colony based on the selection criteria given above. Produce queens from this colony before the onset of honey flow. These queens can be used to replace the old queen and to start new daughter colonies. The mother colony can be multiplied into several nucleus colonies but each should have at least 2 brood combs and 3–4 combs with food (nectar and pollen). The prepared colonies can then be sold or migrated according to need.

(B) Uniting of honey bee boxes:

Uniting two colonies into one is done when one of them is weak or queen less or for other reason like bad traits etc. Each colony has its own colony specific odours and it is very difficult to combine the two colonies unless their odour is mixed well. Any attempt to unite these colonies without mixing their odour result in infighting and deaths will occur on large scale. Therefore,

first step will involve bringing the two colonies into contact with each other. If uniting is done abruptly, the field workers of the colony shifted will not recognize the new place and returning to their original place will persist. This problem can be overcome by moving a hive gradually at the rate of two or three feet per day, so that the field bees get habituated to the changing position of their hive and will not drift back to the old site. When colonies are sufficiently close, one or two feet apart, they are ready for uniting. They can be united by three methods either (1) Direct uniting (2) Newspaper method (3) Smoking method.

(i) Direct uniting:

The two hives to be united are brought near gradually and kept side by side. The queen with undesirable traits in one of the hives is removed. Next morning, when the bees are busy, the frames of two hives are gently put in one. The success of this method depends upon the skill with which it is done.

(ii) Newspaper method:

Top cover is removed and the frames are covered with a piece of newspaper having a few holes made with a small nail the bottom, board of the upper colony is then removed and the brood chamber, is placed above the other colony, the newspaper forming a partition between the two. After a day or two, the odours of the colonies will mix and the bees will cut through the paper and will unite together, forming a single colony. After a few days all the frames can be placed in one hive and the upper chamber can be removed.

(iii) Smoking method:

Colonies can be united using smoke method. When the colonies to be united have been brought close to each other, both should be smoked heavily and thin sugary syrup scented with oil of peppermint or wheat flour sprinkled over them. The combs with the bees of the colony to be united should be altered with the combs of the other colony. More smoke and syrup or flour should be applied and the colony closed. The work of the queen may be checked up after three or four days. It is better to unite a laying worker colony to several strong colonies by giving from one to two frames to each of them. If all its frames are united to one colony there is danger of latter's queen being killed by the laying workers.

Note: See schematic representation of division/uniting of bee boxes at the end of notes.

SEASONAL MANAGEMENT OF HONEY BEE BOXES:

Pollens and nectar are available only during certain period. When surplus food source is available is known as “**honey flow season**”. In contrast during **dearth period** there will be scarcity of food. Suitable season for starting beekeeping coincides with mild climatic conditions and availability of bee flora in plenty. Normally, spring (February-April) and post-monsoon (Sep.-Nov.) seasons are the best periods to start beekeeping. Indian seasons are Spring season (*Vasant ritu*: mid February – mid April), Summer season (*Grishma ritu*: mid April to mid June), Monsoon season (*Varsha ritu*: mid June to mid August), Autumn season (*Sharad ritu*: mid August- mid October), Pre-winter season (*Hemant ritu*: mid October- mid December) and Winter season (*Shishir ritu*: mid December- mid February). Various operations required to be undertaken for augmenting colonies productivity are given below:

I. SPRING MANAGEMENT

Management operations to be undertaken during spring are given below:

1. Examination of colonies

- a) On some warm and sunny day, examine the colonies quickly and carefully with least exposure to the chilling weather and robber bees.
- b) Unpack the colonies, clean the bottom board and replace the worn out hive parts.
- c) Assess the colony condition, working of the queen bee, brood rearing and food reserves.
- d) Provide early season stimulative **sugar feeding (sugar: water =1:2)**, pollen or pollen substitute feeding to increase the foraging and brood rearing activity.
- e) Inspect the brood rearing. If there is no brood, the colony may be queenless. If there is less brood, the queen may be old and exhausted. Unite the weak/queenless colonies with the other colonies. If fresh dead bees are found, try to find out the cause. Bee mortality may be due to the bee disease or infestation of mite.

2. Equalizing the colonies

The colonies can be equalized by:

- a) Substituting the combs with food reserves/supplementary feeding.
- b) Providing the emerging bee combs.
- c) Uniting the bee combs/colonies.
- d) Giving young bees to the weaker colonies.

3. Provision of space

During spring, the colonies enhance the brood rearing. Hence, there should be no dearth of space to cope up with increased egg laying by the queen bee.

- a) Add good quality drawn combs (with worker cells) or frames with good quality comb foundations to the brood chamber as and when required.
- b) Avoid adding raised combs with too many drone cells.
- c) While providing super chamber, lure the bees to the super chamber with some bait in the form of a brood/honey comb.

4. Swarm prevention and control

- a) Examine the colonies and remove congestion. Provide more drawn combs/comb foundations, supers, etc.
- b) Improve ventilation and provide required shade.
- c) Clip the wings of the laying queen.
- d) Use wire entrance guard/queen excluder at the bottom board.
- e) Reversing brood and honey chambers for mitigating congestion in brood chamber.
- f) Destruction of the queen cells raised due to swarming instinct,
- g) Dividing over-crowded colonies.

5. Control of mites and brood diseases

Examine the symptoms of various mites and brood diseases. On spotting any, take appropriate management measures to contain the menace.

6. Colony multiplication and commercial queen rearing

March-April is the best season for colony multiplication and commercial queen rearing. Improve the existing stock by selective breeding of best performing colonies. Mass reared queen bee can also be used for multiplication of existing stock and also for replacement of older queen bees (re-queening).

7. Extraction of spring season honey

Multiple extractions of honey during this period are possible. Only ripe honey from broodless combs from super chamber should be extracted.

II. SUMMER MANAGEMENT

Mid April to June months are extremely hot. However, this is the major honey flow period too. The following operations need to be considered during the season.

1. Shifting the colonies to thick shade

Colonies should be moved to shady places every day by less than three feet.

2. Regulating the microclimate of the colonies

By using wet gunny bags over the colonies and sprinkling water around the colonies in the apiary during noon hours, temperature in the apiary can be reduced and humidity increased in hot and dry months of May and June.

3. Provision of ventilation

Improve the ventilation of the colonies to cope up with the respiration of the bees and hastening the honey ripening by:

- a) Widening the entrance of the colony.
- b) Providing additional entrance in multi-chambered colonies.
- c) Staggering the chambers.
- d) Placing thin wooden splinters between two adjacent chambers for the circulation of fresh air.

4. Provision of fresh water

- a) Running water channel in the field.
- b) Cemented water reservoir tanks near the tube wells/pump sets with a sufficient number of sticks or wood pieces in the tank for the bees to sit on and lap the water.
- c) Earthen water bowls underneath the legs of hive stand also fulfill the water requirement of the colonies.
- d) An earthen pitcher with a small hole at its bottom is placed on a tripod and a slanting wooden plank is kept below the hole of the pitcher.

5. Honey extraction

Summer season honey can be extracted.

III. MONSOON MANAGEMENT

Manage the colonies during this season as below:

- a) Ensure colonies placement on upland area and away from village water ponds.
- b) Clean and bury deep the debris lying on the bottom board.
- c) Keep the surrounding of the colonies clean by cutting the unwanted vegetation which may hamper circulation of air.
- d) Provide **sugar feeding (sugar : water=1:1)**, if required.
- e) Check robbing within the apiary.
- f) Unite weak/laying worker colonies. Control wax moth, ants, wasps and bee eating birds.

IV. AUTUMN MANAGEMENT

Important operations to be undertaken during this season, are:

- a) Provision of space.

- b) Strengthening the colonies to stimulate drone brood rearing, if queen bee rearing is to be undertaken.
- c) Control of ectoparasitic mites, brood diseases, wax moths and wasps.
- d) Autumn honey extraction before the winter sets in.

V. WINTER MANAGEMENT

Normally winter extends from December to mid February but this period may vary from region to region. During winter, very low temperature, westerly chilly winds, foggy/cloudy days and winter hamper the bee activity. *Brassica* comes in bloom during January. To perpetuate the colonies through winter, following operations are generally required:

1. Colony examination

Examine the colonies on a warm, sunny day for the presence of queen, brood and food reserves. Open the colony for minimum time to avoid chilling of brood. Weak colonies should be united with stronger ones so that the strong unit over-winters well.

2. Feeding

If there is food scarcity or expected in the ensuing winter, feed concentrated (**sugar: water = 1:1**) **sugar syrup** (supplementary feeding) by filling in the drawn combs at the onset of severe winter.

3. Shifting colonies to sunny places

The colonies should be shifted to sunny places with hive entrances facing south-eastwards.

4. Protection from the chilly winds

Plug cracks and crevices and narrow down the hive entrance.

5. Unite weak colonies with stronger ones

Follow newspaper method for uniting the colonies.

6. Removal of extra drawn combs and winter packing

Remove the extra empty combs and store them properly to save them from mice/rats. Depending upon the strength of the colonies and severity of winter, provide one or two-sided inner winter packing combined with need based outer packing.

MIGRATORY BEEKEEPING (HONEY BEE BOX MIGRATION)

While preparing the honey bee colonies for migration, a number of points needed to be considered are given below:

1. Season:

- a) Fasten the various hive parts and move the colonies during late evening, night or early morning, when all the bees are inside the hive, after closing the hive entrances with wire screen, ensuring required ventilation.
- b) In cold and rainy weather, the hives should be covered with a tarpaulin when being moved. Exposure to cold has the effect of causing bees to consume stores heavily to produce more heat and cluster together on the nest as they do in winter.
- c) During summer or monsoon season, colonies should be migrated during night when it is cooler and in hives with enough ventilation by exchanging the inner cover with traveling-screen.

2. Distance of migration site:

- a) Very long distance migrations of apiaries during winter at a stretch are possible provided the

bees have sufficient food reserves and required ventilation. During cold weather, bees consume excessive food stores to produce heat and cluster together over the brood.

- b) The hive body and supers should be nailed or fixed properly to avoid their slipping *enroute*.
- c) During summer, it is better to have one or two halts/ journey breaks for short temporary sitting of the apiary for a day or two at some suitable place having some bee flora for easing out the confined bees. Moving the colonies continually for more than 48 h often leads to their brood mortality.

3. Number of hives:

If the number of colonies is small, it will not be economical to migrate them as the carriage/ transport charges per colony will be much higher than when the beekeeper has full vehicle load. However, in such cases, make it a full truck load by joining with other fellow beekeepers who also intend to take up migration to the same or nearby areas.

4. Colony strength:

Bees are killed very often by overheating and lack of aeration but seldom by getting too cold. If weather is very hot and the colony is populous and hive is not spacious enough to allow expansion of the cluster, bees may very quickly smother/ get suffocated even when the top of the hive is covered with full wired travelling-screen. Thus, alternatively, the populous colonies may be divided and empty combs may be added for the expansion of the cluster in the hives before migration.

5. Preparation and packing of the colonies for migration:

- a) Extract the surplus honey, if any, a few days prior to migration.
- b) All cracks and crevices in the hive should be sealed to bee-tightness.
- c) Excessively broken hive parts should be replaced with new ones.
- d) The hive body, bottom board and inner cover should be fastened together by stapling/ nailing.
- e) Always use two nails in slanting position on each side of every juncture. An alternative to the nails is to use metal or nylon travelling belts (migration belts) around the hive.

6. Type of the vehicle, and loading and unloading the colonies:

- a) While migrating the colonies in vehicles such as trucks, the jerking movements will be forward and backward, hence, the length side of the hives should be kept parallel to the length of the vehicle.
- b) While loading the colonies in a tractor-trailer where the jerking movements are sideways, the bee hives (colonies) should be loaded with their length side parallel to the breadth of the vehicle or the axle of the vehicle.

7. Time of the day:

If the whole of the apiary is to be shifted, it is better to move the bees in the evening or at night (when all the bees are inside the hive and temperature is low) or during rainy or cold weather when the bees are not foraging.

8. Timing in relation to flowering of crops:

Colonies should not be taken to crop needing pollination until it is flowering sufficiently to be the predominant species in the locality. The delay in shifting colonies to the crop until flowering has begun, always increases pollination, particularly when the crop has short flowering period and is less attractive to bees than the other crops in the area. The same is true for honey production.

9. Placement of the migrated stock

- a) The migrated honey bee colonies should be sited away from the passages/ walkways where human or domestic animals' movements are expected.
- b) If migration is for pollination purpose, the bee colonies be placed within the crop and should be evenly distributed in the area to harvest the maximum pollination benefits and should not be crowded at one place.

HONEY BEE PASTURAGE, FORAGING AND COMMUNICATION:

Honey bees gather nectar and pollen from plants as their food. Honey bees collect nectar and pollen from flowering plants. **Nectar** is a sweet secretion from the floral and extra-floral nectaries of flowers and is the raw material for honey. **Pollens** are protein-rich food for the bees. As nectar and pollen are basic raw materials for beekeeping, a thorough knowledge of the bee flora of a locality is essential. Efficient beekeeping means managing honey bee colonies in such a way to obtain maximum colony population to coincide with the major honey flow in an area and to utilize the honey production and pollination.

To judge the potential of a locality for beekeeping, followings points should be considered:

1. Are blooming plant species available in abundance within **two kilometer radius** of the locality?
2. During which period of the year, the bee flora is on bloom?
3. How long is their blooming duration?
4. Whether they are source of nectar, pollen or both?
5. Whether the flora is annual or perennial?
6. Which utility category do they belong to?
7. How long is the duration of nectar and pollen dearth period?

Important terminologies:

1. **Bee flora or bee pasturage or bee forage:** The plants that yield nectar and pollen are collectively called bee flora or bee pasturage or bee forage.
2. **Honey flow period:** The period when a good number of plants providing nectar and pollen are available to bees is called honey flow period.
3. **Major honey flow period:** If the nectar yield is copious from a good number of plants of a particular species, it is called major honey flow period.
4. **Minor honey flow period:** When the amount of nectar to be collected is small, it is called minor honey flow period.
5. **Dearth period:** The day when there is no honey flow is called the dearth period.
6. **Foraging:** This refers to collection of nectar and pollen by bees.
7. **Nectar foragers:** They collect the nectar from flowers by using lapping tongue and pass the nectar to hive bees. Hive bees repeatedly pass the nectar between pre-oral cavity and tongue to ripen the honey. Later they drop ripened honey into cells.
8. **Pollen foragers:** They collect pollen by passing through different flowers. Pollen sticking to the body is removed by using pollen comb. Then it is packed by using pollen press into corbicula or pollen backset. A single bee carries 10 to 30 mg of pollen which is 25% of bee's body weight. Then the pollen is dislodged by means of middle leg into cells. Pollen is mixed with honey and stored.

9. **Floral fidelity:** A bee visits same species of plant for pollen and nectar collection until the source is exhausted. This is known as floral fidelity. Bees travel 2 to 3 km distance to collect pollen and nectar.

Duties of forager bees

Collect i) pollen, ii) nectar, iii) water, iv) propolis v) juice of damaged fruits (when bloom is scarce)

Use of pollen: Major food for grubs in combination with honey; also required by adult bees secreting royal jelly.

Use of nectar: Raw material for honey; honey is reserve food for the colony; food for grubs as well as adults

Use of propolis: Comb repair; protect the colony from large enemies like mouse which enter the hive; water proof the hive

Use of water: hive temperature maintenance (air – conditioning system); and to dilute the honey before catering it.

Utility of bee flora to honey bees:

In general, a honey bee depends on a wide variety of plants for nectar and pollen. These include several species of wild and cultivated plants. For commercial beekeeping, large crop acreage with good floral qualities is required. A beekeeper must have the details about the availability and suitability of bee flora.

Following are the qualities of good bee flora:

- Long flowering period
- High density of flowers per unit of the plants
- Good quality of nectar with high concentration of sugars
- Easy accessibility of the nectaries to the honey bees and ease in collection of nectar
- Availability of flora in the close vicinity of the apiary

LIST OF IMPORTANT BEE FLORA IN INDIA

S. No.	Botanical Name	Common Name	Family	Flowering period	Source type
Field crops					
1.	<i>Eleusine coracana</i>	Ragi	Poaceae	3-4	P ₂
2.	<i>Oryza sativa</i>	Rice	Poaceae	9-10	P ₁
3.	<i>Pennisetum typhoides</i>	Bajra	Poaceae	11-10	P ₂
4.	<i>Sorghum bicolor</i>	Sorghum	Poaceae	9-10	P ₂
5.	<i>Zea mays</i>	Maize	Poaceae	1-12	P ₃
6.	<i>Fagopyrum esculentum</i>	Buck wheat	Polygonaceae	7-9	N ₁
Legume Crops					
7.	<i>Cajanus cajan</i>	Red gram	Fabaceae	8-11	N ₃ P ₂
8.	<i>Cicer arietinum</i>	Bengal gram	Fabaceae	12	N ₂ P ₂
9.	<i>Dolichos biflorus</i>	Horse gram	Fabaceae	10	N ₁ P ₁
10.	<i>Medicago sativa</i>	Lucerne	Fabaceae	3-4	N ₂ P ₂
11.	<i>Phaseolus mungo</i>	Black gram	Fabaceae	8 - 10	N ₁
12.	<i>Phaseolus radiatus</i>	Green gram	Fabaceae	8	N ₁ P ₁
13.	<i>Pisum sativum</i>	Peas	Fabaceae	8-9	N ₁
14.	<i>Sesbania aegyptica</i>	Sesbania	Fabaceae	10-11	P ₁
15.	<i>Sesbania graniflora</i>	Dhiancha	Fabaceae	6- 7	P ₁

16.	<i>Trifolium alexandrium</i>	Berseem	Fabaceae	3-4	N ₃ P ₂
17.	<i>Vigna unguiculata</i>	Cowpea	Fabaceae	8	N ₁ P ₁
Oilseed Crops					
18.	<i>Arachis hypogea</i>	Groundnut	Fabaceae	8-9	N ₂ P ₂
19.	<i>Brassica campestris</i> var. <i>sarson</i>	Sarson	Brassicaceae	10-11/10-1	N ₁ P ₁
20.	<i>Brassica campestris</i> var. <i>toria</i>	Toria, Indian rapeseed	Brassicaceae	10-11	N ₁ P ₁
21.	<i>Brassica juncea</i>	Raya, Indian mustard	Brassicaceae	12-2	NP
22.	<i>Brassica napus</i>	Rapeseed	Brassicaceae	12-3	N ₁ P ₁
23.	<i>Brassica nigra</i>	Black mustard	Brassicaceae	8-9	N ₃ P ₃
24.	<i>Brassica rapa</i>	Turnip, Canola	Brassicaceae	2-4	N ₂ P ₂
25.	<i>Carthamus tinctorius</i>	Safflower	Asteraceae	12-1	N ₃ P ₂
26.	<i>Eruca sativa</i>	Taramira, Rocket	Brassicaceae	12-8	N ₂ P ₂
27.	<i>Guizotia abyssinica</i>	Niger	Asteraceae	4-5	N ₁ P ₃
28.	<i>Helianthus annuus</i>	Sunflower, Surajmukhi	Asteraceae	1-12	N ₁ P ₃
29.	<i>Linum usitatissimum</i>	Linseed, Flax	Linaceae	2-3	N ₂ P ₂
30.	<i>Ricinus communis</i>	Castor	Euphorbiaceae	8-9	N ₁ P ₁
Fiber Crops					
31.	<i>Corchorus olitorius</i>	Jute	Malvaceae	3-4	N ₂ P ₂
32.	<i>Gossypium arborium</i>	Cotton	Malvaceae	4-1	N ₁ P ₁
33.	<i>Hibiscus cannabinus</i>	Kenaf	Malvaceae	4- 6	N ₁ P ₁
34.	<i>Crotalaria juncea</i>	Sun hemp	Malvaceae	8-11	N ₃
Vegetable crops					
35.	<i>Abelmoschus esculentus</i>	Lady's finger	Malvaceae	1-12	N ₃ P ₂
36.	<i>Allium cepa</i>	Onion	Liliaceae	5-7	N ₃ P ₃
37.	<i>Amaranthus viridis</i>	Amaranthus	Amaranthaceae	1-12	N ₁
38.	<i>Brassica oleracea. capitata</i>	Cabbage	Brassicaceae	2-4	N ₃ P ₂
39.	<i>Brassica oleracea botrytis</i>	Cauliflower	Brassicaceae	2-4	N ₃ P ₂
40.	<i>Capsicum annum</i>	Chilli	Solanaceae	1-12	N ₃ P ₁
41.	<i>Capsicum chinense</i>	Capsicum	Solanaceae	11-2	N ₃ P ₁
42.	<i>Coccinia indica</i>	Little gourd	Cucurbitaceae	1-8	N ₃ P ₂
43.	<i>Coriandrum sativum</i>	Coriander	Apiaceae	2-3	N ₁ P ₁
44.	<i>Cucumis melo</i>	Muskmelon	Cucurbitaceae	3-4	N ₃ P ₂
45.	<i>Cucumis sativus</i>	Cucumber	Cucurbitaceae	10-11	N ₃ P ₂
46.	<i>Cucurbita maxima</i>	Squash gourd	Cucurbitaceae	2-3	N ₃ P ₁
47.	<i>Daucus carota</i>	Carrot	Apiaceae	3-4	N ₂ P ₂
48.	<i>Dolichos lablab</i>	Field bean	Fabaceae	9	N ₂ P ₁
49.	<i>Glycine max</i>	Soybean	Fabaceae	8-9	N ₁ P ₂
50.	<i>Ipomea batatas</i>	Sweet potato	Convolvulaceae	10-12	N ₁ P ₁
51.	<i>Lagenaria vulgaris</i>	Pumpkin	Cucurbitaceae	3-9	P ₁
52.	<i>Lagenaria siceraria</i>	Bottle gourd	Cucurbitaceae	1-12	N ₃ P ₂
53.	<i>Luffa acutangula</i>	Ridge gourd	Cucurbitaceae	11-2	N ₃ P ₁
54.	<i>Lycopersicon esculentum</i>	Tomato	Solanaceae	1-12	P ₁
55.	<i>Momordica charantia</i>	Bitter gourd	Cucurbitaceae	4-7	N ₂ P ₂
56.	<i>Moringa oleifera</i>	Drumstick	Moringaceae	12-4	N ₁ P ₁

57.	<i>Phaseolus vulgaris</i>	French bean	Fabaceae	1-12	N ₁ P ₁
58.	<i>Raphanus sativus</i>	Radish	Brassicaceae	2-4	N ₃ P ₁
59.	<i>Solanum melongena</i>	Brinjal	Solanaceae	1-12	P ₁
60.	<i>Solanum tuberosum</i>	Potato	Solanaceae	12-2	P ₁
61.	<i>Trigonella foenumgracum</i>	Methi	Fabaceae	1 -12	N ₁
Plantation Crops					
62.	<i>Cocos nucifera</i>	Coconut	Arecaceae	1 -12	P ₃
63.	<i>Coffea arabica</i>	Coffee	Rubiaceae	4-5	N ₃ P ₁
64.	<i>Hevea brasiliensis</i>	Rubber	Euphorbiaceae	3	N ₁
65.	<i>Nicotiana tabaccum</i>	Tobacco	Solanaceae	12-1	P ₁
Fruit Crops					
66.	<i>Anacardium occidentale</i>	Cashewnut	Anacardiaceae	12-2 9-10	N ₂ P ₁
67.	<i>Annona squamosa</i>	Custard apple	Annonoaceae	4- 6	N ₁ P ₂
68.	<i>Areca catechu</i>	Arecanut	Arecaceae	1 -12	P ₃
69.	<i>Artocarpus integrifolia</i>	Jack fruit	Moraceae	12-3	P ₁
70.	<i>Averrhoa carambola</i>	Carambola	Averrhoaceae	5-7	N ₃ P ₁
71.	<i>Carica papaya</i>	Papaya	Caricaceae	7-9	N ₃ P ₂
72.	<i>Cinnamomum verum</i>	Cinnamon	Lauraceae	12-2	N ₂
73.	<i>Citrus spp.</i>	Citrus	Rutaceae	2-3	N ₁ P ₁
74.	<i>Citrus medica var acida</i>	Acid lime	Rutaceae	1 -12	N ₁ P ₁
75.	<i>Fragaria spp..</i>	Strawberry	Rosaceae	5-9	N ₂ P ₂
76.	<i>Litchi chinensis</i>	Lychee	Sapindaceae	3-4	N ₁
77.	<i>Malus domestica</i>	Apple	Rosaceae	3-4	NP
78.	<i>Mangifera indica</i>	Mango	Anacardiaceae	12-3	N ₁ P ₁
79.	<i>Manilkera achras</i>	Sapota	Sapotaceae	10-3	N ₁
80.	<i>Muntingia calabura</i>	Singapore cherry	Eleocarpaceae	1-12	N ₂ P ₁
81.	<i>Musa paradisiaca</i>	Banana	Musaceae	1 -12	N ₁ P ₁
82.	<i>Phoenix dactylifera</i>	Date palm	Palmae	6-7	N ₂ P ₃
83.	<i>Prunus armeniaca</i>	Apricot	Rosaceae	3-4	N ₁ P ₁
84.	<i>Prunus domestica</i>	Plum	Rosaceae	2-3	N ₁ P ₁
85.	<i>Prunus dulcis</i>	Almond	Rosaceae	5-8	N ₁ P ₁
86.	<i>Prunu spersica</i>	Peach	Rosaceae	2-3	N ₂ P ₂
87.	<i>Psidium guajava</i>	Guava	Myrtaceae	2-4	N ₃ P ₃
88.	<i>Punica granatum</i>	Pomegranate	Punicaceae	4-7	N ₁ P ₂
89.	<i>Pyrus communis</i>	Pear	Rosaceae	2-8	N ₂ P ₂
90.	<i>Rubus spp.</i>	Raspberry	Rosaceae	2-6	N ₃ P ₂
91.	<i>Sechium edule</i>	Chow chow	Cucurbitaceae	8	N ₁ P ₁
92.	<i>Sesamum indicum</i>	Sesamum	Pedaliaceae	4-9	N ₃ P ₃
93.	<i>Syzigium cumini</i>	Nerala	Myrtaceae	2-5	N ₂ P
94.	<i>Syzigium jambos</i>	Rose apple	Myrtaceae	12- 4	N ₃ P ₂
95.	<i>Vitis vinifera</i>	Grape	Vitaceae	9-12	N ₂ P ₁
Ornamental Plants					
96.	<i>Ageratum conyzoides</i>	Ageratum	Fabaceae	12-3	N ₁ P ₁
97.	<i>Antigonon leptopus</i>	Mexican creeper	Polygonaceae	4-5	N ₃ P ₃
98.	<i>Aster thomsoni</i>	Aster	Asteraceae	8 - 10	N ₁ P ₁
99.	<i>Barleria cristata</i>	Barleria	Acnthaceae	1-12	N ₁ P ₂
100.	<i>Calendula officinalis</i>	Calendula	Asteraceae	6-10	N ₃ P ₁
101.	<i>Callistemon lanceolus</i>	Bottle brush	Myrtaceae	5-7	N ₃

102.	<i>Cassia spp.</i>	Cassia	Caesalpinaceae	4-7	N ₂ P ₂
103.	<i>Celosia argentea L. var cristata</i>	Cockscomb	Amaranthaceae	1-8	N ₁
104.	<i>Celosia argentea L. var plumosa</i>	Celosia	Amaranthaceae	1-8	N ₁
105.	<i>Chrysanthemum coronarium</i>	Chrysanthemum	Asteraceae	7-10	N ₁ P ₁
106.	<i>Cosmos bipinnatus</i>	Cosmos	Asteraceae	3-5	N ₃ P ₂
107.	<i>Cosmos sulphureas</i>	Cosmos	Asteraceae	6-11	N ₁ P ₁
108.	<i>Delonix regia</i>	Gulmohar	Fabaceae	3-5	N ₁ P ₁
109.	<i>Euphorbia mili</i>	Euphorbia	Euphorbiaceae	11-2	N ₁ P ₁
110.	<i>Euphorbia pulcherrima</i>	Poinsettia	Euphorbiaceae	11-2	N ₁ P ₁
111.	<i>Evolvulus glomeratus</i>	Blue daze	Convolvaceae	1-12	N ₁ P ₁
112.	<i>Gerbera launiosa</i>	Gerbera	Agavaceae	1-12	N ₁ P ₂
113.	<i>Hamelia patents</i>	Hamelia	Asteraceae	5	N ₂ P ₁
114.	<i>Helichrysum arenarium</i>	Everlasting flower	Asteraceae	1-3	N ₃ P ₃
115.	<i>Hibiscus rosasinensis</i>	Shoeflower	Malvaceae	1-12	N ₂ P ₂
116.	<i>Impatiens balsamina</i>	Garden Balsam	Balsaminaceae	6-10	N ₁ P ₁
117.	<i>Ipomea carica</i>	Railway creeper	Convolvulaceae	1-12	N ₂ P ₂
118.	<i>Jacquemontia violacea</i>	Jacquemontia	Convolvulaceae	1-12	N ₂
119.	<i>Jasminium angustifolium</i>	Wild jasmine	Oleaceae	12-6	N ₃ P ₂
120.	<i>Lagerstromia indica</i>	Pride of India	Lythraceae	2-4	P ₁
121.	<i>Melampodium paludosum</i>	Melampodium	Asteraceae	6-10	N ₂ P ₂
122.	<i>Petrea volubilis</i>	Purple wrath	Verbenaceae	2-4	N ₂ P ₂
123.	<i>Poinsettia pulcherrima</i>	Poinsettia	Euphorbiaceae	11-2	N ₁ P ₁
124.	<i>Polyanthus tuberosa</i>	Polyanths	Agavaceae	1-12	N ₂
125.	<i>Rosa indica</i>	Rose	Rosaceae	6-7	N ₃ P ₃
126.	<i>Tagetes minuta</i>	marigold	Asteraceae	1-12	N ₂ P ₂
127.	<i>Thevetia peruviana</i>	Kanagila	Apocynaceae	1-12	NP
128.	<i>Zinnia elegans</i>	Zinnia	Asteraceae	6-10	P ₂
129.	<i>Zoysia sp.</i>	Mexican grass	Poaceae	4-7	N ₁ P ₁
Medicinal and Aromatic plants					
130.	<i>Ammi mages</i>	Honey plant	Apiaceae	3-4	N ₃ P ₃
131.	<i>Anethum graveolens</i>	Dill	Apiaceae	12-3	N ₃ P ₃
132.	<i>Apium graveolens</i>	Celery	Apiaceae	6-8	N ₂ P ₂
133.	<i>Bacopa monnieri</i>	Brahmi	Scrophulariaceae	5-7	N ₁ P ₁
134.	<i>Bidens pilosa</i>	Bidens	Asteraceae	6-2	N ₂ P ₂
135.	<i>Carvia callosa</i>	Karvi	Acanthaceae	8-10/7-9	N ₁ P ₁
136.	<i>Centratherum sp.</i>	Wild cumin	Asteraceae	5-9	N ₂ P ₁
137.	<i>Foeniculum vulgare</i>	Fennel	Apiaceae	4-5	N ₃ P ₃
138.	<i>Lavandula stoechas</i>	Lavender	Lamiaceae	6-11	P ₂
139.	<i>Lathyrus sativus</i>	Khesari	Euphorbiaceae	3-4	N ₁ P ₂
140.	<i>Lawsonia inermis</i>	Mehandi	Lythraceae	2-5	N ₁ P ₁
141.	<i>Matricaria chamomilla</i>	Chamomile	Asteraceae	5-9	N ₃ P ₃
142.	<i>Mentha spicata</i>	Spear mint	Lamiaceae	1-12	N ₃
143.	<i>Nepeta cataria</i>	Cat mint	Lamiaceae	1-12	N ₃ P ₃
144.	<i>Ocimum basilicum</i>	Sweet basil	Lamiaceae	2-8	N ₂ P ₃
145.	<i>Ocimum canum</i>	Hairy basil	Lamiaceae	1-12	N ₁ P ₁

146.	<i>Ocimum gratissimum</i>	Clocimum	Lamiaceae	1-12	N ₂ P ₁
147.	<i>Ocimum kilimandscharium</i>	Camphor Basil	Lamiaceae	1-12	N ₂ P ₃
148.	<i>Ocimum sanctum</i>	Sacred basil	Lamiaceae	1-12	N ₂ P ₂
149.	<i>Porana volubilis</i>	Snow creeper	Convolvulaceae	3-5	N ₂ P ₂
150.	<i>Ruta graveolens</i>	Garden rue	Rutaceae	1-12	N ₁ P ₁
151.	<i>Salvia spp.</i>	Sage	Lamiaceae	7-10	N ₂ P ₂
152.	<i>Trachyspermum ammi</i>	Ajwain	Apiaceae	3-7	N ₂ P ₂
Weeds					
153.	<i>Abelmoschus ficulneus</i>	Van Bhindi	<i>Malvaceae</i>	8-9	N ₃ P ₂
154.	<i>Argemone mexicana</i>	Yellow mexican poppy	Papavaraceae	11-3	N ₁ P ₁
155.	<i>Artemisia vulgaris</i>	Mugwort	Asteraceae	2-7	N ₁ P ₂
156.	<i>Crotan sparciflora</i>	Mirchaiya	Euphorbiaceae	7-8	N ₃ P ₂
157.	<i>Dhatura fistula</i>	Dhatura	Salanaceae	1-12	N ₃ P ₂
158.	<i>Jatropha curcus</i>	Boghandi	<i>Euphorbiaceae</i>	9-10	N ₂ P ₂
159.	<i>Lantana camera</i>	Lantana	Verbenaceae	1-12	N ₁
160.	<i>Leucas aspera</i>	Leucas	Lamiaceae	11-6	N ₂ P ₁
161.	<i>Mimosa pudica</i>	Touch me not	Mimosaceae	1-12	N ₂ P ₂
162.	<i>Nerium indicum</i>	Sormari	<i>Apocynaceae</i>	9-10	N ₂ P ₂
163.	<i>Plectranthus rugosus</i>	Shain/ chhihhri	Lamiaceae	8-10	N ₁ P ₃
164.	<i>Prosopis juliflora</i>	Mesquite	Mimosaceae	7-11	N ₃ P ₁
165.	<i>Stachytarpheta indica</i>	Stachytarpheta	Verbenaceae	1-12	N ₁
166.	<i>Tridax procumbens</i>	Tridax	Asteraceae	1-12	N ₁ P ₂
Trees					
167.	<i>Acacia arabica</i>	Babul	Mimosaceae	7-11	N ₁ P ₁
168.	<i>Acacia catechu</i>	Khair	Mimosaceae	7-9	P ₁
169.	<i>Acacia modesta</i>	Acacia	Mimosaceae	5-7	N
170.	<i>Actinodaphn ancustifolia</i>	Pisa	Lauraceae	10-3	N ₁
171.	<i>Actinodaphn hookeril</i>	Pida	Lauraceae	10-1	N ₃ P ₁
172.	<i>Adhatoda vasica</i>	Maker	Acanthaceae	8-10	N ₃ P ₄
173.	<i>Aegel marmelos</i>	Bad	Rutaceae	5-6	N ₂ P ₂
174.	<i>Aeqiceras corniculatum</i>	Mangrove	Myrsinaceae	1-2, 7	N ₃ P ₂
175.	<i>Albizia lebbeck</i>	Siris tree	Mimosaceae	2-4	N ₁ P ₁
176.	<i>Albizia amara</i>	Chigere	Mimosaceae	1-3	P ₁
177.	<i>Azadirachta indica</i>	Neem	Meliaceae	3-4	N ₂
178.	<i>Bauhinia purpurea</i>	Khairwal	Fabaceae	2-8	N ₁ P ₁
179.	<i>Bombax ceiba</i>	Simal	Malvaceae	1-3	N ₁ P ₂
180.	<i>Boreria stricta</i>	Boreria	Rubiaceae	1-12	P ₁
181.	<i>Butea monosperma</i>	Dhak	Fabaceae	2-3	N ₁ P ₁
182.	<i>Callistemon lanceolatus</i>	Bottle brush	Myrtaceae	1-12	N ₃ P ₁
183.	<i>Canthium parviflorum</i>	Canthium	Rubiaceae	3- 6	N ₂ P ₂
184.	<i>Cassia javanica</i>	Cassia	Caesalpinaceae	3-5	N ₁ P ₁
185.	<i>Ceiba pentandra</i>	White silk cotton tree	Bombaceae	2-4	N ₁
186.	<i>Chenopodium album</i>	White goose foot	Chenopodiaceae	6- 9	N ₁ P ₁
187.	<i>Crotolaria striata</i>	Crotolaria	Fabaceae	1-5	P ₁
188.	<i>Dalbergia sissoo</i>	Sissoo	Fabaceae	3-4	N ₁

189.	<i>Datura stramonium</i>	Thorn apple	Solanaceae	11-6	P ₁
190.	<i>Ehretia acuminata</i>	Puna	Boraginaceae	4	N ₁
191.	<i>Elaeagnus umbelata</i>	Wild olive	Elaeagnaceae	4-5	N ₂ P ₃
192.	<i>Eucalyptus spp.</i>	Safeda	Myrtaceae	11-4	N ₁ P ₁
193.	<i>Eugenia spp.</i>	Bhedas, Gudda	Myrtaceae	2-4	N ₁
194.	<i>Gliricidia septium</i>	Gliricidia	Caesalpinaceae	2-4	N ₁ P ₁
195.	<i>Grewia spp.</i>	Phalsa	Teliaceae	7-11	N ₂ P ₁
196.	<i>Jacaranda acutifolia</i>	Jacaranda	Bignoniaceae	2- 4	N ₁ P ₁
197.	<i>Kaya sinegensis</i>	Kaya	Meliaceae	1-3	N ₂
198.	<i>Lagascea mollis</i>	Lagascea	Asteraceae	7-12	N ₃ P ₁
199.	<i>Leucaena leucocephala</i>	Subabul	Mimosaceae	1-12	P ₁
200.	<i>Madhuca longifolia</i>	Madhua	Sapotaceae	2-3	N ₁
201.	<i>Mallotus philippensis</i>	Kumkum	Euphorbiaceae	11-2	P ₁
202.	<i>Manihot glagiovii</i>	Rubber Tree	Euphorbiaceae	7-8	N ₃
203.	<i>Michalia champaka</i>	Michalia	Magnoliaceae	4- 6	N ₁
204.	<i>Morus alba</i>	Mulberry	Moraceae	2-6	P ₁
205.	<i>Parthenium hysterophorus</i>	Congress weed	Asteraceae	1-12	P ₁
206.	<i>Peltophorum ferrugineum</i>	Copper pod	Caesalpinaceae	5-7	N ₂ P ₃
207.	<i>Phyllanthus emblica</i>	Amla	Euphorbiaceae	2-4	N ₁ P ₁
208.	<i>Pithecolloium dulce</i>	Manila	Caesalpinaceae	2-4	N ₁
209.	<i>Polygonum glabrum</i>	Polygonum	Polygonaceae	12-3	N ₁ P ₁
210.	<i>Pongamia pinnata</i>	Karanj, Sukhchain	Caesalpinaceae	3-4	N ₁ P ₂
211.	<i>Pterospermum personatum</i>	Pterospermum	Bignoniaceae	4i-5	N ₁ P ₁
212.	<i>Rubinia pseudoacacia</i>	Rubinia	Fabaceae	9-4	N ₁ P
213.	<i>Samanea saman</i>	Rain tree	Mimosaceae	3-6	N ₁ P ₁
214.	<i>Santalum album</i>	Sandal wood	Santalaceae	12-7	N ₁
215.	<i>Sapindus laurifolius</i>	Soap nut	Sapindaceae	3-5, 10-12	N ₁ P ₁
216.	<i>Saraca indica</i>	Saraca	Caesalpinaceae	2- 4	N ₁
217.	<i>Simaruba glauca</i>	Simaruba	Simaroubaceae	2-3	N ₃ P ₃
218.	<i>Spathodea campanulata</i>	Scarlet bell	Bignoniaceae	1-12	N ₃
219.	<i>Sterculia foetida</i>	Foetid tree	Sterculiaceae	11-2	P ₃
220.	<i>Tabubia argentia</i>	Tabubia	Bignoniaceae	2-3	N ₁ P ₁
221.	<i>Tamarindus indica</i>	Tamarind	Caesalpinaceae	5-6	N ₁ P ₁
222.	<i>Tecoma stans</i>	Tecoma	Bignoniaceae	1-12	N ₁ P ₁
223.	<i>Terminalia arjuna</i>	Arjuna	Combretaceae	3-5	N ₁
224.	<i>Thelepaepale spp.</i>	Whayati	Acanthaceae	4-1	N P
225.	<i>Toona ciliata</i>	Tun	Meliaceae	3-4	N ₁ P ₃
226.	<i>Wendlandia spp.</i>	Tiliya	Rubiaceae	2	N ₁ P ₁
227.	<i>Zizyphus jujuba</i>	Wild Ber	Rhamnaceae	5-6	N ₃ P ₂
228.	<i>Zizyphus mauritiana</i>	Ber	Rhamnaceae	3-5	N ₁ P ₁
N : Source of nectar; Flowering Period (Month):- January to December (1-12)					
P: Source of pollen Source:-1: Major; 2: Medium; 3: Minor					

II. Communication in honey bees

Bees communicate by using various pheromones including the **queen's substance**, **vasanov gland secretion**, **alarm pheromone** emitted from sting and secretion of tarsal gland. In addition to that the bees also communicate by performing certain dances. When scout bees return

to the box after foraging they communicate to the other foragers present in the box about the direction and distance of the food source from the hive by performing dances.

The important types of dances are noticed.

1. Round dance is used to indicate a short distance (Less than 50m in case of *A. mellifera*). The bee runs in circles, first in one direction and then in opposite direction, (clockwise and anticlockwise).

2. Tail wagging dance or Wag-tail dance:

This is used to indicate long distance (more than 50 m in case of *A. mellifera*). Here the bee makes two half circles in opposite directions with a straight run in between. During the straight run, the bee shakes (wags) its abdomen from side to side, the number of wags per unit time inversely proportional to the distance of the food (more the wags, less the distance.). The direction of food source is conveyed by the angle that the dancing bee makes between its straight run and top of the hive which is the same as between the direction of the food and direction of the sun. The bees, can know the position of the sun even if it is cloudy.

TOXICITY OF PESTICIDES TO HONEYBEES AND PRECAUTIONS TO REDUCE THE TOXICITY TO BEES:

The use of pesticides has become inevitable in modern agriculture. During the last four decades the consumption of pesticides in India has increased several folds. Pesticides used on field crops for the control of pests have the side effect, one of which is toxicity to honey bees. Honey bees are susceptible to many pesticides. Three Types of harmful effect evident in Agriculture are:

- Loss in production of honey
- contamination of bee products
- Reduction in the yield of cross pollinated crops

The harmful effects may be due to direct exposure of honey bees to pesticides or through indirect contact with their residues. Direct exposure occurs from treatment of bee hives with pesticides for disinfestation purpose or bees visiting the fields at the time of spray. While the indirect exposure occurs from spray drift from nearby fields or bee foraging in sprayed crops.

Symptoms of bee poisoning:

- Dead or dying bees near the entrance of hives /colonies.
- Dead bees on the top of frames or bottom board.
- Lack of recognition of guard bees.
- Aggressiveness.
- Fighting among bees.
- Paralysed bees crawling on nearby objects.
- Sudden decline in food storage and brood rearing.
- Dead and deserted brood in the hive.
- Poor recognition of pollen and nectar by bees.
- Finally results in contamination of bee products

Causes of poisoning:

- Pesticides application during crop bloom.
- Drift of toxic chemical on to flower, pollen and nectar.

- Bee feeding on contaminated food and water sources.
- Use of broad spectrum insecticides (chlorinated hydrocarbons, synthetic pyrethroids).
- Type of formulation used like dust, EC which are more harmful than WP and granules.
- Types of spray, fineness of spray, stage of crop, weather condition and age of the colony.
- Use of insect growth regulators may inhibit brood production.
- Herbicides indirectly affect through damage to the foliage.
- Use of diesel oil as a carrier in insecticide formulations.

Management of bee poisoning

The basic principle in the management of bee poisoning is to avoid the exposure of honey bees to toxic effects. This could be achieved with the help of both beekeepers and the farmers. The practice to be followed by bee keepers includes the following.

- Bee colonies should be maintained where use and drift of pesticide is minimum
- Close co-operation with farmers to avoid irrational use of pesticides
- Feeding of colonies with sugar syrup at the time of pesticide application to reduce bee foraging

Management practices

- Need based use of pesticides.
- Informing the beekeepers in advance about the spray programme.
- Use of less hazardous, selective and repellent insecticides.
- Spraying in the evening when the bee activities subside.
- Granules, EC are preferred compared to dusts.
- Avoid formulations with attractants like Sevimol during crop bloom period.
- Development of bee strain resistant to toxic effects of pesticides.
- Addition of adjuvant, Sylgard 309 silicon surfactant to reduce the bee mortality.

Less hazardous insecticides

- Granules: Fenthion and phorate
- EC: Phosalone and fluvalinate

Highly hazardous insecticides

- Dust: Carbaryl, diazinon and fenvalerate
- WP: Carbaryl
- EC: Chlorpyrifos, cypermethrin, deltamethrin, diazinin, dichlorvos, dimethoate, ethion, fenitrothion, fenthion and fenvalerate
- SL: Imidacloprid

PESTS AND DISEASES OF HONEY BEE:

Bee enemies cause great loss to honey bee colonies. These bee enemies destroy the raised combs, hives and hive parts, catch and kill bees and brood, adversely affect colony development, eat away the food reserves and cause nuisance to the bees and beekeeper thereby reducing the colony productivity and returns per colony. Major bee enemies are wax moths, wasps, birds, ants and mites, etc.

A. Wax moths

Colonies of all honey bee species are attacked by two species of wax moths viz. Greater wax moth, *Galleria mellonella* Linnaeus and Lesser wax moth, *Achroia grisella* Fabricius. Out of these two species, *G. mellonella* is more damaging to the bee hives.

1. Greater wax moth (*G. mellonella*)

Greater wax moth is present throughout the world with rare exception at high elevations. Its life cycle is completed in four stages viz. egg, larva, pupa and adult. Eggs are smooth, spherical, pinkish to creamish white with size ranging between 0.4-0.5 mm. Eggs are laid in clusters of 50 to 150 in cracks and crevices. Single female lays on an average of 300-600 eggs (the number may reach up to 1800) in its life time of two weeks. Larva is white to dirty grey in colour, 3-30 mm in size. After hatching, it feeds on **honey, nectar and pollen**. It lives in long **silken tunnels**. The larva makes burrows/ tunnels in combs and extends these to the midrib of comb. It spins silken galleries that give it protection from bees and trap the newly emerged bees in their cells. This condition is known as **Gallariasis**. The larva moults 4 to 6 times in its life. Pupa is brownish white to dark brown and 14-16 mm long in size. Pupation takes place in silken cocoons spun around them by the last instar larvae. The larva moves to hive body and make a small depression in the wood in which it pupates. These cocoons may be found on inner walls of chamber, inner cover and on frames. The white colour cocoons are present in clusters. Adult moths are brownish grey; the females are lighter in colour, larger and heavier than males. In the females, the outer margin of fore wing is smooth while semi-lunar notch is found in males. Life cycle is completed in four weeks to six months.

Seasonal activity:

Stored and deserted combs, improperly cleaned wax and weak or poorly managed colonies and deserted combs of wild bees are constant source of wax moth population. Depending upon the availability of food, temperature and habitat of the pest, several overlapping generations can be produced in a year. Wax moths are active from March to October, but peak activity is from August to October. It **over-winters in larval and pupal stages** in stored combs during November to February.

Nature of damage:

This pest is more serious during dearth and monsoon. The moth infests combs with all stages of **brood, cells and pollen**. Silken galleries spun by wax moth larvae around them near the mid-rib of the brood comb is the cause of **Gallariasis**, a condition in which adult bees are unable to come out of cells as their legs get entangled in the silken galleries underneath. Wax moth larvae can reduce the combs to a mass of web and debris which has black thin and elongated excreta entangled in it. Severe infestation leads to suspension in brood rearing, foraging activity and ultimately desertion of colony. *A. mellifera* species collect more propolis; hence, it is less prone to the attack of wax moth than other *Apis* species.

2. Lesser wax moth (*A. grisella*)

It is troublesome particularly in stored combs. Its egg stage varies between 2 to 4 days, larval 34-48 days, pupal 5-12 days and adult longevity is about 7 days. *A. grisella* larvae are 15-20 mm in size, white in colour with brown head and live segregated in silken tunnels covered with frass and webbings whereas greater wax moth larvae congregate. Moths are smaller than greater wax moth and silver grey without markings on wings. Female moth may lay 250-300 eggs. They complete 3-4 generations during active season and hibernate as larvae or pupae.

Management of wax moths:

- Maintain strong and healthy colonies.
- Close all cracks and crevices of the hive and reduce entrance size.
- Keep the bottom board clean. Collect and burn the debris periodically.
- Control diseases and other pests that make the colony weaker.
- Avoid pesticidal poisoning which otherwise weaken the colonies.

- Remove excessive combs from the hive, especially during dearth period.
- Destroy the silken tunnels of wax moth larvae to kill larvae in initial stages.
- Destroy severely attacked combs and melt them in water to render bees wax.
- Keep empty infested combs in sun for a few minutes or in hot water (60°C) for 4-5 h to kill the larvae.
- Artificial cold e.g. -6.7°C for 4-5 hrs, or -12.2°C for 3 hrs or -15°C for 2 hrs is effective in killing all the stages of wax moth.
- Fumigation with following chemicals is effective in killing the larvae in stored combs in air tight rooms/containers/ chambers:
 - (i) Aluminium phosphide @ 0.75g/ m³ space

B. Predatory wasps

Wasps/ hornets are known to cause serious damages to honey bees. These are especially serious during rainy season when their population is nearly at peak in their nests. Their attack causes colonies to diminish or abscond.

While adult wasp feed on liquid food, their brood feed on animal food which is provided by the adult wasps. The adult wasps catch honey bees and their brood for feeding to their own brood.

Wasp species	Identifying characteristics	Nesting behaviour
<i>Vespa mandarinia</i> (Giant brown wasp)	Largest, dark brown, hairy and has a robust look. Head bright orange, rear part of thorax has two eye spot like markings; has strong mandibles.	Lives in the hollows of tree trunks. Seasonal activity: Sept-Nov
<i>Vespa tropica</i> (Yellow banded wasp)	Has a yellow broad band in the middle of the dorsum of abdomen.	Nests in the ground. Seasonal activity: Aug-Oct
<i>Vespa basalis</i> (Black wasp)	Brown coloured head, abdomen black; with fine hair; medium sized.	Papery round nest on top of the tree. Seasonal activity: Sept-Nov
<i>Vespa velutina (auraria)</i> (Brown wasp)	Reddish brown with fine hair; medium sized.	Papery ovoid nest atop the tree. Seasonal activity: July-Sept
<i>Vespa orientalis</i> (Yellow banded brown wasp)	Deep brown yellow bands with brown spots on abdomen; yellow frons, smaller sized.	Irregular, simple nests in hidden places in walls or hollows of trees. Seasonal activity: July-Dec

Management of wasp:

- Killing of gravid wasp queens, found building nest, early in the spring i.e. by sweeping in net or by thrashing.
- Nest destruction: Their nest can be traced by tying a thread to a worker wasp and following its flight and the nest can then be destroyed.
- Killing wasps by fly-flappers during peak attack hours (noon) for 30 minutes results in its reduced attack during following hours and days owing to reduced population.
- Elimination of alighting board also reduces losses due to wasps attack.
- Use of wasp traps and poisoned baits (candy, meat, rotten fish, apple, etc.) are also helpful.

- Destroying wasp nests with kerosene torches or fumigation with aluminium phosphide or spraying insecticides.
- Use of wasp barrier in front of honey bee colonies reduces the loss from the wasps.
- Use of long and narrow mud tunnels at the bee colonies' entrances prevent wasps entry into the colonies and helps in loss reduction.
- Mass poisoning of wasps by gluing poisoned jaggery filled gelatin capsules on to the thorax of foragers, about 6-12 loads sent this way are sufficient to kill the whole colony of the wasp.

C. Ants

Ants are usually not serious pests of honey bee colonies. Occasionally, however, certain species may enter colonies in search of food or establishing nesting sites. Ants are typically found between the inner and outer covers of the hive and in pollen traps.

Nature of damage:

Sometimes persistent attacks by ants trigger absconding in honey bee colonies. Even though majority of the ants' species seldom disturb the bees, but these can be a nuisance to the beekeeper in performing routine beekeeping operations.

Management of ants:

- Fill cracks and crevices in the hive.
- Maintain strong colonies.
- Keep bottom boards raised off the ground. Place the colony on stand with oil or sticky barrier. Alternatively, put legs of the stand in broad earthen bowls full of water (ant wells) to check entry of ants into the hive.
- Digs open the underground nests of the ants.
- Drench underground nests of ants with chlorpyrifos (0.2%).
- Colonies capable of defending by fanning should be selected and used as breeder colonies for mass rearing of queen bees.
- Repellents e.g. sulphur powder, borax powder, sodium fluoride, etc. can be used around the colonies against ants.

D. Birds

Several birds predate on honey bees. Important bee eaters include Green Bee-eaters (Little Green Bee-eater, *Merops orientalis* Latham and Olive Bee-eater, *Merops superciliosus* Madagascar) and Black Drongo/ King Crow, *Dicrurus ater* Hermann).

Management of birds

- Scaring (Use of sound in high pitch with different notes; Beating the drums and empty tins; Throwing pieces of stones/ pebbles through *Gulel* or hand; Use of sulphur-potash mixture for producing regular blasts. Hanging 2-3 dead bee eaters at 5m height; Producing distress call/ voice of injured bee eater by recording audio cassette and playing on the amplifier).
- Reflective tapes (Reflective tapes of different colours (1m x 3.5cm) fixed on string at a distance of 20-30 cm at height 5 m on two poles/ stems to ward off the birds)
- Keep bee hives under thick canopy of trees.
- Destroy nesting sites of bee eating birds.

D. Varroa mite or Ectoparasitic mite, *Varroa destructor* Anderson & Trueman

Adult female mite is dorso-ventrally flattened, brown to dark brown and shining in colour, shaped like a tiny crab, sideways oblong (broader than length), measuring 1155-1182 µm long

and 1730-1773 µm wide. The mite can be seen easily with the naked eye on infested bee larvae, pupae and adult bees. Adult males are yellowish with lightly tanned legs and spherical body shape measuring 791-887 µm long and 791-862 µm wide.

Symptoms of infestation:

In the infested colonies, adult mites can be seen on adults, larvae and pupae of honey bees. Two to six mites on an infested individual honey bee adult/ brood result in decline in colony size and activity. The infested brood has **perforations in their cell cappings**. The heavy infestation results in typical bald-brood symptoms. The higher number of mites in drone brood implies the preference of this mite for drone brood than the worker brood for its development.

Management strategies:

Management of the mite involves Integrated Varroa Management (IVM) for which various strategies as campaign are required to curb this menace.

Non-chemical methods:

1. **Destruction of drone brood:** Since the Varroa mite is attracted to drone brood and has higher multiplication rate on it, the destruction of unwanted drone brood by cutting out. The sealed drone brood part of the comb and its destruction or burying deep into the soil will be highly helpful in bringing down its population and carry over to the next brood cycle.
2. **Trapping Varroa on drone brood:** By putting one empty drone in the brood nest area to trap Varroa mites and restricting the queen bee on this comb and then subjecting it to freezing, heat treatment or simple destruction of sealed drone brood and burying it deep into the soil provides an effective control of the mite by shifting its population from worker brood to the drone brood and rendering the former safe.
3. **Queen arrestation:** Caging the queen bee for two weeks to create bloodlessness conditions also has adverse effect on the development and multiplication of the mite.
4. **Shook-swarm method:** Shaking bees from infested colony onto frames with comb foundation or broodless combs in another hive for about two weeks and destruction of infested brood on the original combs is also helpful to free the bees from the mite. However; sugar feeding has to be provided to the colony established in the second hive.
5. **Use of sticky papers:** Varroa adult mites adhering to the body of adult bees often are fallen down by grooming of the bees particularly at night. These mites fall on the floor board climb up again and move to the bee/ brood combs. The placement of a sticky paper on floor board covered with 8 mesh plastic screen prevents the mite to return to the brood combs as the mites get stuck to these sticky papers.
6. **Use of Varroa boards:** Screened floor boards on high legged hive stands would result the mites to fall through on the ground and starved to death. This is considered to be continuous and effective control. However, the robbing and prevailing temperature conditions must be viewed while following this method.
7. **Dusting powdered sugar:** Dusting very fine (particle size <5µm) sugar @ 30 gram per 10 bee frame, uniformly between the combs though the bee space in the late evening, is also effective to check this mite menace. This method of controlling mite can be used during honey flow, when other chemical means cannot be used.

Chemical methods:

1. Slow release strip formulations like fluvalinate, flumethrin, bromopropylate and amitraz have been reported to be effective for the control of this mite abroad but these pesticides are not

registered and available in our country. Alternatively, the following chemical (generic) control measures, which are adopted and followed world-wide, are suggested:

Formic acid: Formic acid (85%) @ 5 ml per day continuously for two weeks is to be administered to the infested colonies. **Oxalic acid:** This organic acid, available from chemical dealers in anhydrous form, it is effective against the mite. Its 4.2 per cent aqueous solution in 60 per cent sugar solution in water @ 5 ml of this resultant solution is to be sprayed per comb or trickled down between every two combs for this mite management.

B. Endoparasitic mite

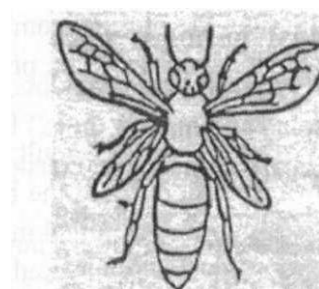
1. *Acarapis woodi* Rennie (Acarine mite / Tracheal mite)

This mite is internal parasite of adult bees and found in their respiratory tract (tracheae). They are essentially microscopic in size. They can be seen only after killing and examining the dissected out tracheae of an individual bee.

a) Symptoms of infestation



Healthy bee



K-winged bee

- Crawling bees on the ground with disjointed wings called **K-winged bees**. Such bees cannot fly.
- Infested crawling bees try to climb on a grass blade and finally fall down.
- If tracheae are dissected, irregular dark stains are initially seen on the infested tracheae which eventually blacken.
- All the three castes are equally susceptible.
- Mite can cause severe bee losses, sometimes weakening and destroying the entire colony.
- Mite attack shortens the adult bee longevity.
- The infestations diminish colony strength.

Management

Use of formic acid @ 5 ml daily for 21 days to be applied as suggested in the case of Varroa Tropilaelaps mite.

Other pests:

King crow: *Dicrurus macrocercus*: Bee eater: *Merops orientalis*

They capture bees and devour them. Since birds help in keeping down insect population, no large – scale measures against them can be recommended.

Lizards, toads and frogs: Vertebrata, All the three have sticky tongue, which helps them to capture bees. They remain on the alighting board and catch the bees.

Spiders (Aranae: Arachnida): In nature, spiders spin web nearby hives. When the bees caught in the silken web. Spiders feed them.

Diseases and their management:

I. Bacterial Bee diseases and their management

1. American foulbrood (AFB)

It is a bacterial disease of pupal stage caused by Gram positive sporulating *Paenibacillus larvae larvae* (White) Heyndricx *et al.* This disease results in occasionally the death of pupae in the sealed cells. Cell cappings are sunken, watery, discoloured and sometimes punctured with irregular holes. Dead pupae are dull-white and watery changing to brown ropy stage. At this stage, if a match is thrust into dead pupa and then removed, a semi fluid ropy thread is drawn. Affected colony gives a distinct fish or glue-pot like odour.

2. European foulbrood (EFB)

It is caused by the bacterium *Melissococcus plutonius* (White) Truper & De'Clari. This disease is occasionally found in both *A. mellifera* and *A. cerana* colonies in India. Larvae get displaced in their cells and die in the unsealed cells when they are only 4-5 days old. Dead larvae become soft, watery and dull yellow. Their breathing tubes are prominent at this watery stage. The affected larvae are discoloured, first creamy yellow, then turn to light brown and then dark brown and occasionally black. The infected larvae lie upright attached with side walls of the cells and sometimes appear just melted down at the base of the cells. Dead larvae finally dry to brown removable rubbery scales at the bottom of the cell.

Management of AFB:

- Feeding of sodium sulphathiazole @ 0.1 g/l, oxytetracycline (Terramycin®) @ 0.25-0.5 g/l or streptomycin @ 0.05 to 0.15 g/l in sugar syrup were recommended in some countries.
- But waiting period for the sale of the honey following such treatment has to be at least six months.
- Sterilization of combs and other hive parts with Formalin @ 150 ml/l water for 48 h at 43 °C in fumigation chambers.
- Sterilization of combs with ethylene oxide @ 1 g/l for 48 h at 43°C in fumigation chambers.
- Due to highly resistant spores, in European countries, burning of colonies including bees and combs and scorching of hive body

Management of EFB

- Feeding oxytetracycline @ 0.5 g per 500 ml sugar syrup or sprinkling it on bee cluster gives good bacteriostatic effect. The use of antibiotic, as above, was recommended in some countries. But waiting period for the sale of the honey following such treatment has to be at least six months.
- Sterilization of combs and hive parts with formalin and acetic acid, as in case of AFB, is also recommended.
- Swarm shook coupled with provisioning of either brood alone or brood + pollen combs from the healthy colony are effective in controlling the disease.

II. PROTOZOAN DISEASES

1. Nosema disease

This disease is caused by *Nosema apis* Zander. It is disease of adult bees and the protozoan parasitizes all the castes. The infectious spores germinate in the ventriculus of the host. Its spores are shed in the lumen of digestive tract of the affected bee and are then excreted out. Infection spreads through ingestion of faecal matter with contaminated food. This disease is dent on *A. mellifera* colonies in the eastern part of the country.

a) Symptoms

- Bees start foraging at younger age.
- Bees are less able to fly and fall down during their return journey.

- iii) Bees crawl up the grass blades and fall down on the ground and such affected fatigued bees gather in depressions / ditches.
- iv) Abdomen is distended with faecal matter.
- v) Body hair are lost and bees become shiny.
- vi) Mid intestine is swollen and if dissected, shows dull greyish white contents.
- vii) Bees soil the hive entrance and also the ground in from of the entrance with black excreta.

b) Disease management

- Arrange the provision of fresh running water.
- Drain off stagnant water from the apiary.
- While transporting queens, select healthy attendant bees.
- Provide upward ventilation to reduce humidity.
- Use of feeding fumagillin (Fumadil) in concentrated sugar syrup is recommended in many countries. It inhibits DNA replication of the pathogen. However, in Assam where this disease is found in *A. mellifera* colonies, Antkon-M @45.5 ppm in sugar **syrup** is recommended for feeding to the honey bee colonies.
- Disinfect the empty hives with ethylene oxide or acetic acid fumigation @ 120 ml / hive.

2. Amoeba disease

It is caused by *Malpighamoeba mellifecae* Prell. This infection is caused by ingesting the cysts along with contaminated food. Cysts germinate, amoeba migrate to malpighian tubes and feed on cell contents. Cysts accumulate in the mid-gut / rectum. Cysts are shed in the intestine and are excreted out with faecal matter. Spring dwindling of colony strength can be experienced in such case.

Disease management:

- Ensure proper hygienic conditions.
- Scarp off the bottom board and disinfect it with 2 per cent carbolic acid.
- Disinfection of hives and equipment with acetic acid is also helpful.

C. FUNGAL DISEASES

Two fungal diseases are important viz. Chalk brood and Stone brood.

1. Chalk brood

This disease is caused by *Ascosphaera apis* (Maassen ex Claussen) Olive & Spiltoir. It is of very rare occurrence and is found in weaker colonies in high humid areas.

- a) Brood dies and turns into hard white mummies full of mycelium.
- b) Spores are formed within dark-greenish fruiting bodies when male and female mycelia unite. Then mummified larvae turn dark grey or black.
- c) The mummies are heard to rattle when combs are shaken.
- d) On inverting the comb, the mummies get out and fall down.
- e) Its endemic infection is damaging otherwise it is a less serious disease. Old larvae (3-4 days) and those on periphery of brood area are more susceptible. The spores of fungus remain viable for 15 years.

2. Stone brood

This disease is caused by *Aspergillus flavus* Link. Its spores are ingested with food. These spores germinate in the alimentary canal. The mycelia attack the soft tissues. The spores also germinate on the cuticle and mycelia penetrate inside.

- Infected larvae and pupae when dead become hard and stony mummies.

- If infected, the abdomen of adult bees is also mummified.
- The affected adult bees show restlessness, feebleness and paralysis, abdomen gets dilated and then mummified.
- Younger bees die earlier.

Management of fungal diseases:

- These have no chemical control.
- Removal of mummies by bees results in natural control of the diseases.
- Collect and burn the mummified larvae.
- Improve ventilation of the colonies and reduce humidity.

D. VIRAL DISEASES

1. Sacbrood disease

This disease is caused by Sacbrood Virus (SBV). The virus is ingested with food. Two days old larvae are more susceptible for catching the infection. Virus multiplies in body tissues. Disease in the colony is spread nurse bees and among the colonies through swarming, drifting and robbing.

- Occasionally larva in late stage or near cell sealing and more commonly at prepupal stage dies.
- Brood is stretched on the back.
- Cell cappings are sunken and brood is patchy.
- Sometimes the infected prepupa does not have cell capping.
- Dead brood remains upright in the cell.
- Dead brood skin becomes tough.
- Its colour changes to pale yellow to brown.
- Head and thorax regions are darker.
- Brood if pulled out with a tweezer, it comes out like a sac.
- If it is held against sun, two layers of cuticle surrounding the body are visible, the outer being the molten cuticle of the last larval instar which is not shed and held along. Between the two, a thin layer of yellowish green fluid (molting fluid) will be visible which in a few seconds will start accumulating towards the lower side i.e. the rear end of the prepupa.
- Dried scale is boat shaped.

2. Chronic bee paralysis

This disease is also called hairless black bee syndrome / little black robbers. Infected bees die within a week. The causal viral particles are irregular in shape. Enzyme ribonuclease found in nectar destroys viral RNA. Bees become hairless, shiny and small.

- Bees have uncoupled wings.
- Affected bees are nibbled by healthy bees, as robbers are nibbled.
- Bees experience trembling and jerky movements.
- Sick bees gather on top bars or crawl out.
- Dead bees are seen in front of hive entrance.

3. Iridescent virus

This disease is caused by iridovirus. Its infection is serious during hot / dearth seasons. It is transmitted by nurse bees through glandular secretion (food).

- Reduced egg laying / brood rearing. Bees become sluggish and cluster.
- The infected bees crawl on the ground.
- The affected bees cease foraging, reduce honey collection, and the colony face starvation

and starts dwindling.

- Illuminated body tissue under microscope look bluish / greenish.

Management of viral diseases

For viral pathogens, there is no chemical control. The affected colonies should be isolated beyond their flight range. Adopt all the management operations to keep colonies stronger. Provide proper ventilation to reduce humidity. Cage the queen for a week and then requeen. Use sterilized equipment / combs. Check robbing, drifting and swarming. Provide supplement feeding. Feeding oxytetracycline hydrochloride @ 0.5-10 g per colony is recommended in many countries to protect the colonies against secondary infections.

General management practices for the management of diseases

- Maintain strong and vigorous colonies through appropriate management/ by uniting weaker ones.
- Provide supplementary sugar, pollen or pollen substitute feeding during their dearth or shift colonies to areas with good bee pasturage.
- Never transfer combs between colonies, without first checking for the signs of brood disease.
- Isolate the disease suspected colonies and do not exchange its combs and other hive part; with healthy colonies. Burn if the diseased colonies are a few and very high incidence of infection is detected in early stages.
- Sterilize the beekeeping equipment used for diseased colonies using formalin and carbolic acid. Take appropriate measures to check robbing, drifting, etc. in the apiary. Never leave combs or honey exposed to robbing bees.
- If a colony dies out at any time, seal the hive to prevent the remaining stores being robbed out, pending examination of the brood combs for signs of disease.
- Be suspicious of the swarms of unknown origin as these might carry the infection. Hive them on foundations rather than drawn combs, and inspect them for diseases once they have become established.
- Dequeen the colonies for a few days followed by requeening with healthy and vigorous queens. The bees relieved of brood care activity will clean out the infected brood.
- Select colonies showing disease resistance or hygienic behaviour for their use as breeder colonies for requeening or multiplication of stock or for sale purpose.
- To prevent spread of bee diseases, safe distance has to be maintained among apiaries at migration site. Furthermore, before migration, all the colonies should be inspected and the diseased colonies should not be moved along with the healthy apiary. Inspect your colonies every spring and autumn, specifically to check for the diseases. If you are unsure, seek the expert advice immediately.

Part-II: Silkworm

INTRODUCTION:

Sericulture is an agro based Industry, the term which denotes production of Silk through silk worm rearing or in other words commercial production of Silk through silkworm rearing. Sericulture is a labour intensive agro industry ideally eradicates unemployment. Further improves their economic standards of rural poor. “Silk” the queen of textiles has a great importance ever before pre Vedic era. The term ‘Silk’ was mentioned in Rig-Veda, Ramayana and Mahabharata. It is estimated that one of mulberry and its allied activates can provided employment to people either directly or indirectly. Sericulture improves frequent returns throughout the year with relatively less expenditure and some common inputs.

HISTORY OF SILKWORM IN WORLD:

Today there are more than 29 countries in the world are practicing Sericulture; Historical evidence shows that, silk was discovered in China and later the industry spread to other parts of the world. The earlier reference to silk was found in the chronicles of Chou – King (220 BC). The discovery of silk is legend that during 2500 BC, one day in the garden. She saw some tiny insects feeding on some kind of leaves. Few days later she found the worms to have grown very big, and the curious queen continued to observe the process till the cocoons were spun by the worms. After the formation of cocoons, the queen collected them and preserved till moths have evolved. One day accidentally she dropped some cocoons into hot tea cup, when she tried to remove them from the cup; a fine lustrous yarn came out of the cocoons. Historical evidence reveals that sericulture was practiced in the China long back and preserved the secrete for more than 3000 years and the Chinese maintained the monopoly about 3000 years and they built a prosperous silk trade with the rest of world. The Chinese emperor ruled that, revealing of worm eggs or mulberry seed was bound to meet the very severe punishment. However 500 years later there is a reference in mulberry cultivation in ‘Seminyojutu’ such as mulberry layings, seedlings. During this period only mulberry cultivation technique appeared to have been taken up very seriously.

HISTORY OF SERICULTURE IN INDIA:

According to western historians, mulberry cultivations spread to Indian about 140 BC from China through Tibet. The mulberry cultivation and Silk industry first began in the areas beside the rivers Brahmaputra and Ganges the Aryans discovered the Silk worm in Sub Himalayan regions even though mulberry cultivation may have come to India from china. The silk from Kashmir became very famous in the beginning of christen era. This may be the fact that, the Arabs obtained the silkworm eggs and mulberry seeds from India during the early days of christen era. During 4th century AD, when the sericulture industry established in India and central Asia, raw silk and silk goods were exported to Persia and Rome. In 553 AD, Sericulture was spread to Constantinople. Gradually, Sericulture industry developed in venation Republic and was able to meet the entire demand of silk in European by eleventh century. Silk from Kashmir and Bengal was exported to the European markets during the 14th and 15th century, from 1761 to 1785 the export of Bengal silk to the European markets. East India Company started to modernize the silkworm rearing and silk reeling techniques. In 1771, the Chinese Silk was introduced with the object of the quality of Cocoons. Between 1717 and 1775, the Haitian methods of rearing were introduced by East India. The attempt to replace indigenious breeds of Silkworm by the new varieties of mulberry plant without scientific study eventually is the whole industry to chaos. Louis Pasteurs (1870) discovery of the method of mother moth examination could control pebrine disease. A silk conference was called for by the British Govt. in 1942 at Delhi. The Government

launched an ambitious project called ‘Silk Expansion scheme’. In 1948 the Country was divided into India and Pakistan. As a result some silk Producing areas have gone to Pakistan and East Bengal. During 19th century when the silk industry was at peak in France, the epidemic of pebrine wiped out the sericulture industry not only in France but also in Europe and Middle East. This disease was reported in Bengal during the 19th century.

RESEARCH AND TRAINING INSTITUTES ON SERICULTURE IN INDIA

Central Silk Board (CSB), Ministry of Textiles, Govt. of India, Bangalore (Karnataka) is a nodal agency: The main Research & Training Institutes of the CSB provide scientific and technological support for enhancing production and productivity for sustainable sericulture through innovative approaches. The main institutes working under CSB are as follows:

1. Central Sericultural Research & Training Institute (**CSRTI**), **Mysore** (Karnataka) deals with Mulberry sericulture.
2. Central Sericultural Research & Training Institute (**CSRTI**), **Berhampore** (West Bengal) deals with Mulberry sericulture.
3. Central Sericultural Research & Training Institute (**CSRTI**), **Gallandarpore**, **Kashmir**, (J&K) deals with Mulberry sericulture.
4. Central Tasar Research and Training Institute (**CTRTI**), **PO- Piska-Nagri Ranchi- 835 303** (Jharkhand) deal with Tasar sericulture.
5. Central Muga Eri Research and Training Institute (**CMER & TI**), **P.O. – Lahdoigarh, Jorhat**, Assam deals with Muga and Eri sericulture.

Regional Sericulture Research Stations (RSRS/RTRS/RMRS) for Mulberry and Vanya sericulture have been functioning for the development of region specific technology package and dissemination of research findings as per regional needs. Besides, a network of Research Extension Centre (RECs) & its sub units for mulberry and vanya silk are also functioning to provide extension support to sericulturists. In order to provide R&D support in post cocoon sector, the Board has established a **Central Silk Technological Research Institute (CSTRI) at Bangalore**. In addition, the CSB has also set up **Silkworm Seed Technology Laboratory (SSTL) in Bangalore (Karnataka)**, **Central Sericultural Germplasm Resource Centre (CSGRC) at Hosur (Tamil Nadu)** and **Seri-Biotech Research Laboratory (SBRL) at Bangalore (Karnataka)**. In Gujarat, Department on Entomology, N.M. College of Agriculture, Navsari Agricultural University, Navsari is working on silkworm under Plan scheme (Development Charges) Project entitled “**Research Studies on Mulberry Sericulture in South Gujarat Region**” since 1991.

During 2017-18, the total raw silk production in the country was 31906 MT. The highest raw silk production was noticed in Karnataka (9322 MT) followed by Andhra Pradesh with 6778 MT.

Glossary of Silk/Silkworm:

1. *Antheraea mylitta*, *Antheraea pernyi* and *Bombyx croesi* – Species of wild (undomesticated) moths that produce silk fibre. The silk filament is about three times heavier than that of the cultivated (domesticated) silkworm and is a coarser fibre. It is called tussah.
2. Artificial silk – Material that is similar in look to genuine silk, but is made from man-made fibres such as polyester, nylon or acetate.
3. *Bombyx mori* – The native (domesticated) variety of silkworm that produces Thai silk.
4. Cellule - A plastic black conical cup used to cover paired moths and female moth during ovi position.

5. Cocoon – The small, egg-shaped enclosure that a silkworm spins around itself, by creating silk filaments, to allow it to metamorphose inside to emerge as a moth.
6. De-gumming – The process of washing raw silk in warm soapy water to remove the sericin. This process can reduce the weight of the silk by as much as 25%. De-gummed silk is creamy white in colour and quite soft.
7. Denier – A unit of measurement of the fineness of silk and other fibres. One denier is equivalent to the weight of a single strand of silk thread of 9,000 meters in length, usually equal to one gram.
8. Dupion (or dupioni) – Yarn made from "double" cocoons that are spun by two silkworms simultaneously.
9. Fibroin – The protein that makes up the fibre of silk filaments.
10. Floss – Low-grade silk from the outer part of the cocoon. It can also refer to a soft silk yarn without any twist that is often used in embroidery.
11. Loom – A device for weaving threads together to make fabric. Hand-loomers are usually made mostly of wood. Looms usually have a number of peddles to raise and lower alternate warp threads.
12. Mulberry – The tree whose leaves are the staple diet of silkworms. Approximately 200 kilograms of mulberry leaves will be eaten to produce one kilogram of raw silk.
13. Mulberry Silk – Another name for silk produced by *Bombyx mori* silkworms because they eat mulberry leaves.
14. Polyvoltine – The term used to describe silkworms that can be harvested several times a year. The native variety of silkworm in Thailand is polyvoltine.
15. Raw Silk – Silk thread that has been reeled from cocoons and is still in its natural state. It consists mainly of fibroin (the filament) with about 10-25% sericin (a gluey secretion). Raw silk is golden yellow in colour and somewhat stiff.
16. Reeling – The process of unwinding raw silk filaments from cocoons to produce a raw silk thread.
17. Sericin – A gluey protein secreted by silkworms that holds silk filaments together in a cocoon.
18. Sericulture – The process of rearing silkworms to the cocoon stage where they can then be reeled.
19. Silkworm – The larval stage of the *Bombyx mori* moth that produces silk fibres.
20. Skein – A coil of silk thread.
21. Slub – Tiny irregularities in the silk thread created by hand-making the thread.
22. Throwing – The process of taking raw silk threads and twisting them together to form skeins of silk yarn that will eventually be used for weaving. Different throwing techniques are used to produce warp and weft threads.
23. Tussah – Silk produced by wild silkworms; for example, *Antheraea mylitta*. Its silk filament is about three times heavier than that of the cultivated silkworm, *Bombyx mori*, and is a coarser fibre.
24. Weaving – The process of using a loom to interlace weft and warp threads to produce lengths of finished fabric.
25. Weighted silk – Silk that is coloured with dye and to which metallic substances have been added during the dying process. This adds back weight which is lost during de-gumming and also adds body to the fabric. If weighting is not done properly, it reduces the life of the fabric. Pure-dye silk is considered superior.

26. Wild Silk – Silk made by wild silkworms; for example, *Antheraea mylitta* and *Antheraea pernyi*. Also called tussah.

27. Yarn – Silk thread that is ready to use for weaving.

Types of silkworm, voltinism and biology of silkworm:

Sericulture:

The practice of rearing silkworms for production of silk is called **Sericulture**. Silk producing insects are commonly referred to as serigenous insects. Silkworm is a common name for the silk-producing larvae of silk moths. Silk is the secretion from the salivary glands which are found on both sides of the alimentary canal of silkworm larvae and this secretion harden into fine threads called silk. The cocoons with which pupae are covered by the worms are utilized for silk production.

Types of silkworms:

There are four kinds of natural silk, which are commercially known and produced. Among them, mulberry silk is the most important and contributes as much as 95% of world production. The other non-mulberry silks are eri silk, tasar silk and muga silk.

Characters	Mulberry silkworm	Eri silkworm	Tassar silkworm	Muga silkworm
Species	<i>Bombyx mori</i>	<i>Philosamia ricini</i> <i>P. cynthia</i>	<i>Antheraea pernyi</i> <i>A. mylitta</i> <i>A. yamamai</i>	<i>A. assama</i>
Family	Bombycidae	Saturniidae	Saturniidae	Saturniidae
Host plants	Mulberry	Castor	Terminalia, Dalbergia, Shorea, Zizyphus, Ficus, etc.	Som <i>Machilus bombycina</i> ; Soalu, <i>Litsaea polyantha</i>
Cocoon	Silvery white in colour. Continuous and uniform type with high silk production.	White or brick red in colour. Neither uniform nor continuous type with moderate silk production.	Brown in colour. Continuous and uniform type with high silk production.	Lustrous golden yellow in colour. Continuous and uniform type with less silk production.
Domestication feasibility in India	Easy and economical	Rare	The moths do not mate and so cannot be domesticated	Rare and confined to Assam

A. Mulberry silkworm: The maximum quantity of silk about 95% produced in the world is the mulberry silk.

Classification of mulberry silkworm is based on:

1. Geographical distribution:

- **Japanese:** Uni- or bivoltine, produces green, yellow or white coloured cocoon, larval phase is prolonged, silk is thick, short length and are better adapted in unfavourable conditions. They usually produce double cocoons.
- **Chinese:** Uni-, bi- or multivoltine; larval growth rate high, feeding rate is high, cocoon is oval, white or golden, yields much longer fine silk with less diameter.
- **European:** Univoltine, eggs are larger, cocoon is long, or oval, white or yellow coloured, yield much longer silk. Larvae are with higher feeding rate, larval phase is prolonged, can't endure higher temperature and humidity.
- **Indian:** Multivoltine takes less time to complete life cycle; cocoon is small, elliptical, yellow or green coloured and yields silk of considerable length.

2. Number of generation per year (Voltinism):

- **Univoltine:** It refers to organisms having one brood or crop or generation per year. Their larvae are of robust size and consume much more food. These produce larger sized cocoons having 200–300 mg shell weight. Such cocoon yields 800 – 1200 m silk. They show diapause.
- **Bivoltine:** It refers to organisms having two broods or crop or generations per year. Their larvae are comparatively of moderate size. Shell weight of the cocoon is 150 – 200 mg. They yield 600 – 800 m silk.
- **Multi or Polyvoltine:** It refers to organisms having more than two broods or crop or generations per year. Their larvae are comparatively of small size. Shell weight of the cocoon is 100 – 150 mg. They yield 300 – 400 m silk.

3. Number of moults:

- **Trimoulter:** Their larvae moult three times in their larval period. The weight of cocoon, shell ratio, the length of silk obtained from their cocoon is much less.
- **Tetramoulter:** Their larvae moult four times in their larval period. The weight of cocoon, shell ratio, the length of silk obtained from their cocoon is comparatively better.
- **Pentamoulter:** Their larvae moult five times in their larval period. The weight of cocoon, shell ratio, the length of silk obtained from their cocoon is of higher quality.

4. Genetic nature: Pure strain, hybrid strain, mono hybrid and poly hybrid.

Morphology and biology of mulberry silkworm: Silkworm passes through a complete metamorphosis from egg to adults' stage.

1. Egg:

- Eggs are laid in clusters on the under surface of mulberry leaves during night time.
- A female lays about 300-400 eggs popularly called as silk-seeds measuring about 1 to 1.3 mm in length and 0.9 to 1.2 mm in breadth.
- The eggs are small, ovoid, flat, ellipsoid or oval pale, white or yellow and seed like in appearance.
- At the time of hatching, it become black and hatch within 10-12 days during summer and 30 days during winter. In the univoltine race, the eggs do not hatch during winter and undergoes into hibernation.
- One generation is completed in univoltine race/year whereas 2-7 generations completed in multivoltine race/year.

2. Larva:

- The newly hatched larva is white to dark in colour and measures about 3 mm in length.
- There are 3 pairs of thoracic and 5 pairs of abdominal legs which are situated on the 3,4,5,6 and 10th abdominal segments.
- On the dorsal side of the eighth abdominal segment, the larva carries the caudal horn.
- The larva moults 4-5 times and becomes mature in 30-35 days.
- The full grown larva is creamy white in colour and measures about 75 mm in length.
- In the female, a pair of milky white spots is appearing on each of the eighth and ninth segments.
- In male, a small milky white body appears at the centre of the ventral side between the eighth and ninth segments.
- Cocoons formation takes place within 25 hours.

3. **Pupa:**

- The cocoon measures about 38 mm in length and 19 mm in breadth. Oval in shape and white or yellowish in colour.
- The larva pupates inside the cocoon which is made up of a single thread.
- The pupa inside the cocoon is reddish-brown in colour and measures about 25 mm x 7 mm.
- The pupal period lasts for 10-15 days.
- At the time of emergence of adult, it secretes an alkaline fluid which pierces the cocoon and adult comes out.

4. **Adult:**

- The moth of silkworm is a creamy white colour measuring about 30 mm in length and a wingspan of about 40-50 mm.
- The female is bigger and less active than male.
- The head is small and bears a pair of black compound eyes and bipectinate antennae.
- The mouth parts are vestigial; therefore the moth does not take food and lives only for about 2 to 3 days.
- The anterior portion of thorax is narrower than the posterior.
- The fore wings are provided with dirty dark coloured stripes and the body is covered with hairs.

B. **Morphology and biology of eri silkworm:**

The eri silkworm is multivoltine and reared indoors about 5-6 times in a year. The required optimum weather conditions are 24-28⁰C temperature and 85-90% humidity.

1. **Eggs:**

- The colour of eggs turns dark when they are about to hatch.
- The little black spot can be seen on egg as it is the heads of the emerging silkworms.
- The incubation period is about 9.0 to 10.0 days in summer and 10 to 15 days in winter season.

2. **Larvae:**

- Larvae are covered with tiny hairs.
- Larvae are very imposing and looking with all those spiky knobs but they are quite soft.
- Total larval period lasts for about 20-25 days.

3. **Pupa:**

- The cocoons are whitish in colour.
- It is loose type of cocoon.

- Pupa is brown in colour.
- The pupal duration is about 15 to 18 days during summer and 35 to 40 days during winter.

4. Adult:

- Adult moths are large with wings spanning about 10 cm.
- The wings are greyish brown in colour.
- Adult moths emerge during morning hours to mid day; males emerge earlier than the females. After an hour of emergence, mating occurs and continues till evening.
- Males are then separated.
- Both male and female have brown (chocolate), black or green coloured wings with white semi-circular markings and woolly white abdomen.
- The male is smaller than female and bear bushy antennae and narrow abdomen.
- About 400 to 500 eggs are laid by each gravid female during her lifespan.
- Eri silkworm completed its life cycle in 6 weeks during summer and 12 weeks during winter season.

CULTIVATION OF SILKWORM FOOD PLANTS

Components of sericulture:

Sericulture is an agro based industry comprising three main components, viz. cultivation of food plants of the silkworms, rearing of silkworms, and reeling and spinning of silk. The first two are agricultural and the last one is an industrial component.

I. Mulberry cultivation:

Moriculture: The cultivation of mulberry plants for silkworm rearing is called Moriculture as the plant belongs to the family Moraceae. Among 20 species of mulberry, the most common are *Morus alba*, *M. indica*, *M. serrata* and *M. latifolia*, while the local *M. indica* offers certain good features like quick growing, hardiness, flush remains throughout the year but with comparative low yield.

Soil and climate:

The soil should be deep fertile, well drained clayey loam. Saline and alkaline soils are not preferred. Mulberry can be grown up to 800 metre MSL, Mulberry can be grown in a rainfall ranged from 600mm to 2500mm.

Plantation season:

Mulberry cuttings can be planted in the month of September-October under irrigated condition. While in rainfed condition, saplings can be planted in the month of April-May.

Mulberry varieties:

Irrigated: S-30, S-36, S-41, S-54, S-1635, JL-1, C-776, TR-10, VR-9 and Kanva-2, etc

Semi-Irrigated: Kanva-2 and MR-2, etc

Rainfed: S-13, S-34, RFS-135, RFS-175 and S-1635, etc

Selection of planting material:

The mulberry plants are raised from semi-hard wood cuttings. The cuttings are selected from well established garden of 8 - 12 months old. The length of cuttings should be 15 - 20 cm with 3 - 4 active buds.

Nursery:

Select red loamy soil of 800 sq. m. for raising sapling for planting one hectare of main field. Apply FYM @ 20 t/ha as a basal dose in the nursery area. Size of raise nursery beds should be of 3 m x 1.7 m size.

Pre-treatment of cuttings and planting:

Cuttings are treated with biofertilizer, *Azospirillum* @ 1 kg/40 litres of water for 30 minutes before planting for inducement of early rooting. Apply VAM @ 100 g/m² of nursery area. Irrigate the nursery bed. Plant the cuttings in the nursery at 15cm x 7cm spacing at an angle of 45°. Ensure exposure of one active bud in each cutting. Irrigate the nursery once in three days. The saplings are ready for transplanting in the main field after 90-120 days of planting.

Planting method and spacing:

Planting method	Irrigated		Rainfed	
	Spacing (cm)	No. of cuttings/ha.	Spacing (cm)	No. of cuttings/ha.
Ridges and furrows	60 x 60	27780	90 x 90	12350
Pit systems (45 x 45 cm pit)	90 x 90	12350	90 x 90	12350

Manure and fertilizers for main field:

Apply FYM @ 20 t/ha for the irrigated crop and 10 t/ha for rainfed crop during last ploughing. Apply organic manure (FYM) or compost 1.25 kg/pit in case of pit system is adopted.

1. Irrigated / Semi irrigated:

Particular	Row system (Kg/ha)			Pit System (Kg/ha)		
	N	P	K	N	P	K
Recommendation	300	120	120	280	120	120
Split doses						
First dose	60	60	60	60	60	60
Second dose	60	-	-	40	-	-
Third dose	60	60	60	40	-	-
Fourth dose	60	-	-	60	60	60
Fifth dose	60	-	-	40	-	-
Sixth dose	-	-	-	40	-	-

2. Rainfed:

Particular	N (Kg/ha)	P (Kg/ha)	K (Kg/ha)
Recommendation	100	50	50
First dose	50	50	50
Second dose	50	-	-

Bio-fertilizers:

Apply *Azospirillum* @ 20 kg/ha in five split doses along with phosphobacterium @ 10 kg/ha in two equal splits. Mix the bio-fertilizers with 50 kg FYM for uniform distribution. Apply the bio-fertilizers once in six months. Ensure irrigation after application. Do not mix bio-fertilizers with inorganic fertilizers.

Irrigation:**1. Ridge and furrows method:**

It is most efficient method of irrigation. Comparatively less amount of water is required. These furrows can be used as drainage channel during rainy season.

2. Flatbed method:

Rectangular beds can be prepared. Water runoff is relatively less. This is labour intensive method. Better crop growth can be maintained in this method.

Weed management: Operate country plough after pruning in the interspaces. Use Grammoxone @ 2-3 lit/ha as post-emergence weedicide. Apply the weedicide immediately after pruning or within 2-3 days after pruning. Remove the weeds by hand hoe.

Pruning of mulberry plants:

Pruning is the process of removing the branches of mulberry plant with the objective to give a convenient shape and size to increase the leaf yield and to improve its feeding value. Pruning of mulberry plant is also useful in adjusting the production period to synchronize with the leaf requirement for silkworm rearing and also to extend the leaf production period throughout the year.

1. Bottom pruning: Plants are cut at ground level leaving 10-15 cm stump above the ground once in a year.

2. Middle pruning: Branches are cut at 40- 60 cm above the ground level. After bottom prunings, subsequent cuts are made at 45-50 cm height.

3. Kolar or Strip system: Branches are cut at ground level every time in closely planted area. Thus, it receives five pruning every year. This type of severe pruning requires heavy fertilization and irrigation.

Harvesting of mulberry leaves:

There are three methods of harvesting mulberry leaves viz., (1) Leaf picking (2) Branch cutting and (3) whole shoot harvest.

1. Leaf picking: Picking starts at 10 weeks after bottom pruning and subsequent pickings are done at an interval of 7-8 weeks with harvesting of individual leaves with or without petiole.

2. Branch cutting: Entire branches are cut and fed to the worms. Before that, toping is done to ensure uniform maturity of the lower leaves.

3. Whole shoot harvest: Branches are cut at ground level by bottom pruning. Shoots are harvested at an interval of 10-12 weeks and thus five harvests can be made in a year.

Time of harvest: It is preferable to harvest the leaves during morning hours.

Preservation of leaves: Use wet gunny bags to store the leaves or cover the bamboo basket with wet gunny bags to keep it cool and fresh.

Mulberry leaves yield:

The yield of irrigated varieties are about 40 tonnes leaves/ha/year while rainfed varieties can yield about 15 to 20 tonnes leaves/ha/year with proper cultivation practices.

Major insect pests and diseases of mulberry crop:

1. Major insect pests of mulberry crop:

Sr. No.	Common Name	Scientific Name	Order	Family	Damaging Stage
1.	Pink mealy bug	<i>Maconellicoccus hirsutus</i>	Hemiptera	Pseudococcidae	Nymphs and adults
2.	Jassid/ leaf hopper	<i>Empoasca flavescens</i>	Hemiptera	Cicadellidae	Nymphs and adults
3.	Black Scale	<i>Saissetia nigra</i>	Hemiptera	Coccidae	Nymphs and adults
4.	Red Scale	<i>Aonidiella auranti</i>	Hemiptera	Diaspididae	Nymphs and adults
5.	Spiralling whitefly	<i>Aleurodicus</i>	Hemiptera	Aleyrodidae	Nymphs

Sr. No.	Common Name	Scientific Name	Order	Family	Damaging Stage
		<i>disperses</i>			and adults
6.	Thrips	<i>Pseudodendrothrips mori</i>	Thysanoptera	Thripidae	Nymphs and adults
7.	Tobacco leaf caterpillar	<i>Spodoptera litura</i>	Lepidoptera	Noctuidae	Larvae
8.	Moringa hairy caterpillar	<i>Eupterote mollifera</i>	Lepidoptera	Eupterotidae	Larvae
9.	Tussock caterpillar	<i>Euproctis fraterna</i>	Lepidoptera	Erebidae	Larvae
10.	Brown hairy caterpillar/Tussock moth	<i>Porthesia scintillans</i>	Lepidoptera	Lymantriidae	Larvae
11.	Leaf webber	<i>Glyhodes pulverulentalis</i>	Lepidoptera	Pyralidae	Larvae
12.	Ash weevil	<i>Mylloceris sp.</i>	Coleoptera	Curculionidae	Grubs
13.	Grasshopper	<i>Neorthacris acuticeps nilgriensis, Cytocanthacris panacea</i>	Orthoptera	Acirididae	Nymphs and adults
14.	Stem girdler beetle	<i>Sthenias grisator L.</i>	Coleoptera	Cerambycidae	Grubs and adults
15.	Termite/White ant	<i>Odonototermes sp.</i>	Isoptera	Termitidae	Workers
16.	White grub	<i>Holotrichia spp.</i>	Coleoptera	Melolonthidae	Grubs
17.	Mango stem borer	<i>Batocera rufomaculata</i>	Coleoptera	Cerambycidae	Grubs
18.	Bark eating caterpillar	<i>Indarbela quadrinotata</i>	Lepidoptera	Metarbelidae	Larvae

2. Major diseases of mulberry crop:

Sr. No.	Common Name	Causal organism
1.	Leaf spot	<i>Cercospora moricola</i>
2.	Powdery mildew	<i>Phyllactinia corylea</i>
3.	Leaf rust	<i>Cerotelium fici</i>
4.	Root rot	<i>Macrophomina phaseolina, Fusarium solani, F. oxysporum</i>
5.	Violet root rot	<i>Rhizoctonia bataticola</i>
6.	Stem canker	<i>Lasidiplodia (Btryodiplodia) theobromae</i>
7.	Bacterial blight	<i>Pseudomonas mori</i>
8.	Root knot nematode	<i>Meloidogyne incognita</i>

II. Castor cultivation (*Ricinus communis* L.):

The silk produced by *Philosamia ricini* is called Eri silk. Eri silkworm is a polyphagous insect feeds primarily on castor leaves. However, Kessuru (*Heteropanax fragrans* Seem) is used as an alternative food plant during the scarcity of castor leaves. Besides these, some other alternative plants viz., Tapioca or Cassava (*Manihot esculenta*), Papaya (*Carica papaya*), Payam (*Evodia flaxinifolia*) and Plum, *Plumeria acutifolia* can be used as food plants. Among all, castor is well known and suitable food plant of worm for the successful growth and development.

Soil and climate:

Highly susceptible to water logged conditions. Red loam soils or light alluvial soils are suitable. It cannot tolerate alkalinity of soil but withstand slight to moderate acidity of soil. Moderately high temperature (20 to 27°C) with low humidity, 80-100 mm rainfall, clear warm sunny days are found suitable for better growth of the crop.

Varieties:

Non-bloom varieties are found suitable for growth and yield of eri silkworm viz., NBR-1. High leaf yielding varieties like GCH-3, GCH-4, GCH-6 and GCH-7 can be raised.

Field preparation:

Castor being a deep-rooted crop requires deep summer ploughing. Disc harrowing should be done followed by ploughing to break clods, level the seedbed and destroy weeds.

Sowing time:

Irrigated crop - 1st July to 15th August. Rainfed crop - 15th June.

Seed rate:

Irrigated crop - 5 to 6 kg/ha - by dibbling method. Rainfed crop - 10 to 12 kg/ha.

Seed treatment:

Seeds should be treated with Carbendazim @ 1g or Thiram @ 3 g /kg of seeds for controlling seed and soil borne diseases.

Spacing:

Irrigated crop - 90 cm x 60 cm, Fertile soil - 120 x 60 cm. Rainfed crop - 90 cm x 20 cm. The seeds may be sown at 8 cm depth behind the plough or maize planter.

Manures and fertilizers: FYM or compost @ 25 cart loads/ha

Rainfed crop:			
Stage of application	N kg/ha	P₂O₅ kg/ha	K₂O kg/ha
As basal application	20	40	0
At flowering stage i.e. 45 DAS	20	0	0
Total	40	40	0
Irrigated crop:			
As basal application	37.5	50	0
At flowering stage i.e. 45 DAS	37.5	0	0
Total	75	50	0

Bio- fertilizer: Seed treatment with Azospirillum or Phosphorus Solubilizing Bacteria @ 50 gm /kg seed.

Sulphur application: Apply sulphur @ 20kg /ha through gypsum to oil seeds crop only.

Irrigations:

Irrigated crop: 3-4 irrigations at an interval of 15 to 20 days.

Weeding and interculturing: Two hands weeding, one at 30 days of crop growth and the other after 60 days of crop growth should be given. Incorporation of Pendimethalin 0.9 kg a.i./ha immediate after sowing but before sprouting in the soil.

Crop rotation and inter cropping:

Crop rotation: Castor – Wheat/ Mustard/ Onion, Castor – Pearl millet - Groundnut/ Cluster bean

Crop sequences: Castor – Groundnut, Castor – Sorghum, Castor – Vegetables, Castor – Pearl millet.

Intercropping: Castor + Sun flower (1: 2), Castor + Soybean (1: 1), Castor + Cluster bean (2:1), Pearl millet – Groundnut bunch (1: 3)

Nipping of axillary buds: If all axillary buds on the main shoot are nipped soon after emergence of the primary spike and thus a single main spike is allowed to develop, not only the duration of the crop is reduced but also yields are increased substantially. This practice is followed for local varieties only.

Capsules harvesting: It takes 145-180 days to mature. Harvesting is done when capsules turn yellowish for capsule yield.

Castor leaves yield:

Pluck tender leaves for young age worms and semi-mature/matured leaves for 4th and 5th stage worm. The optimum quality castor yield is about 12-14 tonnes leaves/ha/year.

Major insect pests and diseases of castor crop:

1. Insect pests of castor crop:

Sr. No.	Common Name	Scientific Name	Order	Family	Damaging Stage
1.	Capsule and Shoot borer	<i>Conogethes punctiferalis</i>	Lepidoptera	Pyraustidae	Larvae
2.	Castor semi-looper	<i>Achaea janata</i>	Lepidoptera	Noctuidae	Larvae
3.	Slug caterpillar	<i>Parasa lepida</i>	Lepidoptera	Cochilididae	Larvae
4.	Hairy caterpillar	<i>Euproctis fraterna</i>	Lepidoptera	Lymantriidae	Larvae
5.	Hairy caterpillar	<i>Portrhesia scintillans</i>	Lepidoptera	Lymantriidae	Larvae
6.	Tussock caterpillar	<i>Notolophus posticus</i>	Lepidoptera	Lymantriidae	Larvae
7.	Hairy caterpillar	<i>Dasychira mendosa</i>	Lepidoptera	Lymantriidae	Larvae
8.	Castor butterfly / spiny caterpillar	<i>Ergolis merione</i>	Lepidoptera	Nymphalidae	Larvae
9.	Leaf hopper	<i>Empoasca flavescens</i>	Hemiptera	Cicadellidae	Nymphs and adults
10.	Whitefly	<i>Trialeurodes ricini</i>	Hemiptera	Aleyrodidae	Nymphs and adults
11.	Thrips	<i>Retithrips syriacus</i>	Thysanoptera	Thripidae	Nymphs and adults
12.	Castor gall fly	<i>Asphondylia ricini</i>	Diptera	Cecidomyidae	Maggots

2. Diseases of castor crop:

Sr. No.	Common Name	Causal organism
1.	Seedling blight	<i>Phytophthora parasitica</i>
2.	Rust	<i>Melampsora ricini</i>
3.	Leaf blight	<i>Alternaria ricini</i>
4.	Brown leaf spot	<i>Cercospora ricinella</i>

5.	Powdery mildew	<i>Leveillula taurica</i>
6.	Stem rot	<i>Macrophomina phaseolina</i>
7.	Bacterial leaf spot	<i>Xanthomonas campestris</i> pv. <i>ricinicola</i>
8.	Wilt	<i>Fusarium oxysporum</i>

Rearing techniques of silkworm

I. Equipments used in Sericulture Unit:

1.	Rearing house: The rearing house should meet certain specification, as the silk worms are very sensitive to weather conditions like humidity and temperature. The rearing room should have proper ventilation, optimum temperature and proper humidity. It should be ensured that dampness, stagnation of air, exposure to bright sunlight and strong wind should be avoided. General specification of rearing house: ➤ Rearing house should be built depending on the brushing capacity and the method of rearing. The rearing area of 2 sq. feet per DFL (Disease Free Laying, about 400-450 eggs are present in one DFL) for floor rearing and 3 sq. ft per DFL for shoot rearing is the general criteria. About 480 sq. feet area is required for rearing 100 DFL. ➤ The rearing house should have sufficient number of windows to permit cross ventilation. ➤ It should be well high (9 – 10 feet) from the ground. ➤ It should be surrounded by open verandah (7 feet wide). ➤ Doors and windows should be made up of glass. Its roof should be made up of straws and wood. ➤ The number of ventilators should be of considerable number. ➤ The house should be divided into five rooms; the first room - chawki room (10 feet × 14 feet) should contain 1st, 2nd and 3rd instar larvae, the next room (12 feet × 16 feet) should contain 4th and 5th instar larvae, the 3rd room can be used as laboratory and the 4th room should be used for leaf preservation. Before entering the first room there must be an anteroom (8 feet × 8 feet). ➤ Temperature and humidity of the house must remain under control. ➤ Rearing house has to be built in such a way to provide optimum temperature of 26-28°C and RH of 60-70% for the growth of silkworm at minimum operational cost. In tropical climate the house should face east-west while in temperate climate it should face north-south direction. ➤ Doors and windows must be protected by fine net to check pest infestation. ➤ Provision should be made to make it airtight for proper disinfection. ➤ Rearing house must avoid damp condition, stagnation of air, direct and strong drift of air, exposure to bright sunlight and radiation. ➤ Growing trees around rearing house will help to maintain favourable environment. ➤ Rearing house should have facilities for disinfection, washable floor, etc.
2.	Rearing stand: Rearing stands are made up of wood or bamboo and are portable. These are the frames at which rearing trays are kept. A rearing stand should be 2.5 m high, 1.5 m long and 1.0 m wide and should have 10 shelves with a space of 20 cm between the shelves. The

	trays are arranged on the shelves, and each stand can accommodate 10 rearing trays.
3.	Ant well: Ant wells are provided to stop ants from crawling on to trays, as ants are serious menace to silk worms. They are made of concrete or stone blocks 20 cm square and 7.5 cm high with a deep groove of 2.5 cm running all round the top. The legs of the rearing stands rest on the centre of well filled with water.
4.	Rearing tray: These are made of bamboo or wood so that they are light and easy to handle. These are either round or rectangular.
5.	Paraffin paper: This is a thick craft paper coated with paraffin wax with a melting point of 55 ⁰ C. It is used for rearing early stages of silk worms and prevents withering of the chopped leaves and also helps to maintain proper humidity in the rearing bed.
6.	Foam rubber strips: Long foam rubber strips 2.5 cm wide and 2.5 cm thick dipped in water are kept around the silkworm rearing bed during first two instar stages to maintain optimum humidity. Newspaper strips may also be used as a substitute.
7.	Chopsticks: These are tapering bamboo rods (1cm in diameter) and meant for picking younger stages of larvae to ensure the hygienic handling.
8.	Feathers: Bird feathers preferably white and large are important items of silkworm rearing room. These are used for brushing newly hatched worms to prevent injuries.
9.	Chopping board and Knife: The chopping board is made up of soft wood it is used as a base for cutting leaves with knife to the suitable size required for feeding the worms in different instar stages.
10.	Leaf chambers: These are used for storing harvested leaves. The sidewalls and bottom are made of wooden strips. The chamber is covered on all sides with a wet gunny cloth.
11.	Cleaning net: These are cotton or nylon nets of different mesh size to suit the size variations of different instars of the silk worm. These are used for cleaning the rearing beds, and at least two nets are required for each rearing tray.
12.	Mountages: These are used to support silkworm for spinning cocoons. These are made up of bamboo, usually 1.8 m long and 1.2 m wide. Over a mat base, tapes (woven out of bamboo and 5-6 cm wide) are fixed in the form of spirals leaving a gap of 5-6 cm. In hindi they are also called chandriks . Other types of mountage such as centipede rope mountage, straw cocooning frames etc. are also used.
13.	Feeding stands: These are small wooden stands (0.9 m height) used for holding the trays during feeding and bed cleaning.
14.	Hygrometers and Thermometers: These are used to record humidity and temperature of the rearing room.

15. Feeding basins, sprayer, and leaf baskets may also be required.

II. Rearing techniques of various silkworms:**A. Rearing of mulberry silkworm:**

Silkworms must be reared with utmost care since they are susceptible to diseases. Therefore, to prevent diseases, good sanitation methods and hygienic rearing techniques must be followed. The appliances and the rearing room should be thoroughly cleaned and disinfected with 2-4% formaldehyde solution. Room temperature should be maintained around 25⁰ C.

Growth and feeding rates of different larval instars of *B. mori*.

Instar	Weight increase (mg)	Duration (Days)	Leaf consumed (gm)
I	1 time (0.45 mg)	3-4	17
II	13 times	2-3	80
III	17 times	3-4	320
IV	70 times	5-6	2200
V	10000 times	7-8	20000

Procurement of quality seeds:

The most important step in silkworm rearing is the procurement of quality seeds free from diseases. Seeds are obtained from grainages, which are the centres for production of Disease Free Layings (DFL) or seeds of pure and hybrid races in large quantities. These centres purchase cocoons from the certified seed cocoon producers. These cocoons are placed in well-ventilated rooms with proper temperature (23-25⁰ C) and humidity (70-80 %), and emergence of moth is allowed. Grainage rooms may be kept dark, and light may be supplied suddenly on the expected day of emergence to bring uniform emergence. Emerging moths are sexed and used for breeding purposes to produce seed eggs. Three hours of mating secures maximum fertilized eggs. The females lay eggs on paper sheets or cardboard coated with a gummy substance. Egg sheets are disinfected with 2% formalin, and then washed with water to remove traces of formalin and then dried up in shades. The eggs are transported in the form of egg sheet. However, it is easy to transport loose eggs. To loosen the eggs, the sheets are soaked in water. The loose eggs are washed in salt solution of 1.06-1.10 specific gravity to separate out unfertilized eggs and dead eggs floating on surface. Prior to the final washing, the eggs are disinfected with 2% formalin solution. Eggs are dried, weighed to the required standard and packed in small flat boxes with muslin covers and dispatched to buyers.

Quality food:

Younger larvae (I and II stage) instars are to be given tender succulents leaves with high moisture content and whereas older instars fed with mature but soft leaves with lesser moisture content.

Brushing:

The process of transferring the silkworm to rearing trays is called brushing. Suitable time for brushing is about 10.00 am. Eggs at the blue egg stage are kept in black boxes on the days prior to hatching. The next day they are exposed to diffused light so that the larvae hatch uniformly in response to photic stimuli. About 90% hatching can be obtained in one day by this method. In case of eggs prepared on egg cards, the cards with the newly hatched worms are placed in the rearing trays or boxes and tender mulberry leaves are chopped into pieces and sprinkled over egg cards. In case of loose eggs a net with small holes is spread over the box containing the hatched larvae and mulberry leaves cut into small pieces are scattered over the net. Worms start crawling over the leaves on the net; the net with worms is transferred to rearing tray.

Preparation of feed bed and feeding:

After brushing, the bed is prepared by collecting the worms and the mulberry leaves together by using a feather. The bed is spread uniformly using chopsticks. The first feeding is given after two hours of brushing. Feed bed is a layer of chopped leaves spread on a tray or over a large area. The first and second instar larvae (Up to 2nd moult) are commonly known as **chawki worms**. For chawki worms, paraffin paper sheet is spread on the rearing tray. Chopped mulberry leaves are sprinkled on the sheet and hatched larvae are brushed on to the leaves. A second paraffin paper sheet is spread over the first bed. In between two sheets water soaked foam rubber strips are placed to maintain humidity.

The 4th and 5th instars are reared in wooden or bamboo trays by any of the three methods: viz., **shelf-rearing, floor-rearing and shoot-rearing**. In **shelf rearing**, the rearing trays are arranged one above the other in tiers on a rearing stand which can accommodate 10 -11 trays. This method provides enough space for rearing, but it is uneconomical as it requires large number of labours to handle the trays. Chopped leaves are given as feed in this method. In **floor rearing**, fixed rearing sheets of 5-7x1-1.5m size are constructed out of wooden or bamboo strips in two tiers one meter apart. These sheets are used for rearing. Chopped leaves are given as feed. This method is economical than the first one because it does not involve much labour in handling of trays. **Shoot-rearing** is most economical of the three methods. The rearing sheet used is one meter wide and any length long in single tier and the larvae are offered fresh shoot or twigs bearing leaves. This method can be practiced both outdoors and indoors depending upon the weather.

Each age of the silk worms could be conveniently divided into seven stages:

1. Feeding stage, 2. Sparse eating stage, 3. Moderate eating stage, 4. Active eating stage, 5. Premoulting stage, 6. Last feeding stage and 7. Moulting stage. The larvae have good appetite at first feeding stage and comparatively little appetite at sparse and moderate eating stages. They eat voraciously during active stage to last feeding stage after which they stop feeding.

Bed cleaning:

Periodical removal of left over leaves and worms' excreta may be undertaken and is referred to as bed cleaning. It is necessary for proper growth and proper hygiene. Four methods are adopted: conventional method, husk method, net method, and combined husk and net method.

Moulting:

Remove the paraffin paper. Larvae should be evenly spread in the rearing bed 6-8 hrs before settling the moulting. Provide proper ventilation to avoid excess humidity in rearing room. Provide charcoal stove/heater to raise the room temperature during winter season. Apply lime powder 60 minutes before resumption of feeding daily during rainy and winter season to avoid Muscardine disease infection.

Spacing:

Provision of adequate space is of great importance for vigorous growth of silkworms. As the worms grow in size, the density in the rearing bed increases and conditions of overcrowding are faced. Normally it is necessary to double or triple the space by the time of moult from one to other instar stage, with the result that from the first to third instar, the rearing space increases eight fold. In 4th instar, it is necessary to increase the space by two to three times and in 5th instar again twice. Thus, the rearing space increases up to hundred folds from the time of brushing till the time of maturation of worms.

Mounting:

Transferring mature fifth instar larvae to mountages is called mounting. When larvae are fully mature, they become translucent, their body shrinks, and they stop feeding and start searching for suitable place to attach themselves for cocoon spinning and pupation. They are picked up and put on mountages. The worms attach themselves to the spirals of the mountages and start spinning the cocoon. By continuous movement of head, silk fluid is released in minute quantity which hardens to form a long continuous filament. The silkworm at first lays the foundation for the cocoon structure by weaving a preliminary web providing the necessary foot hold for the larva to spin the compact shell of cocoon. Owing to characteristic movements of the head, the silk filament is deposited in a series of short waves forming the figure of eight. This way layers are built and added to form the compact cocoon shell. After the compact shell of the cocoon is formed, the shrinking larva wraps itself and detaches from the shell and becomes pupa or chrysalis. The spinning completes within 2-3 days in multi-voltine varieties and 3-4 days in uni- and bi-voltine.

Harvesting of cocoons:

The larva undergoes metamorphosis inside the cocoon and becomes pupa. In early days, pupal skin is tender and ruptures easily. Thus, early harvest may result in injury of pupa, and this may damage the silk thread. Late harvest has a risk of threads being broken by the emerging moth. It is, therefore, crucial to harvest cocoons at proper time. Cocoons are harvested by hand. After harvesting the cocoons are sorted out. The good cocoons are cleaned by removing silk wool and faecal matter and are then marketed.

The cocoons are sold by farmers to **filature units** (a place where silk is obtained from silkworm cocoons) through Cooperative or State Govt. Agencies. The cocoons are priced on the basis Rendita and reeling parameters. **Rendita** is defined as number of kg of cocoon required for the production of 1 kg of raw silk.

Post cocoon processing:

It includes all processes to obtain silk thread from cocoon.

Stifling:

The process of killing pupa inside cocoon is termed as stifling. Good-sized cocoon 8-10 days old are selected for further processing. Stifling is done by subjecting cocoon to hot water, steam, dry heat, sun exposure or fumigation.

Reeling:

The process of removing the threads from killed cocoon is called reeling. The cocoons are cooked first in hot water at 95-97°C for 10-15 minutes to soften the adhesion of silk threads among themselves, loosening of the threads to separate freely, and to facilitate the unbinding of silk threads. This process is called **cooking**. Cooking enables the **sericin protein** to get softened and make unwinding easy without breaks. The cocoons are then reeled in hot water with the help of a reeling machine. Four or five free ends of the threads of cocoon are passed through eyelets and guides to twist into one thread and wound round a large wheel. The twisting is done with the help of **croissure**. The silk is transferred finally to spools, and silk obtained on the spool is called the **Raw Silk** or **Reeled Silk**. The Raw silk is further boiled, stretched and purified by acid or by fermentation and is carefully washed again and again to bring the luster. Raw Silk or Reeled Silk is finished in the form of skein and book for trading. The waste outer layer or damaged cocoons and threads are separated, teased and then the filaments are spun. This is called **Spun silk**. **Denier** is a unit of measurement that is used to determine the fiber thickness of individual threads or filaments. Denier expresses weight in grams of 9000 meter length of the material.

B. Rearing of eri silkworm:

Disease free seed cocoons are obtained from **Grainages** or Agencies and reared fully indoors. Healthy cocoons are spread on bamboo trays in cool dark room. On hatching, active males are separated from passive females and are then allowed to mate in quiet dark room. Fertilized females are then tied to '*kharikas*' (Egg laying device) by passing a thread around the shoulder joint of the right wings. *Kharikas* are then suspended from a string. Eggs are laid within 25 hours on *Kharika* are normally selected for rearing. The eggs are white, oval and covered with a gummy substance, which makes them adhere to one another. The eggs are disinfected with 2% formalin solution and then washed thoroughly with water. Eggs are incubated at 26⁰ C, the colour changes to blue on the day prior to hatching. Hatching takes place in the morning after ten days of incubation. The newly hatched larvae are yellow with black segments. These larvae are brushed to rearing trays over which few tender leaves are spread and crowding is avoided. As the worms advance in age, older leaves can be given as food at four hours interval for four to five times.

Rearing house for Eri culture:

Eri silkworms are reared indoor. The plinth area 10 m x 5 m size rearing house having tin or thatch roofing with 1.5 m *varandah*/passage all around is ideal for accommodating 100 dfls for commercial silkworm rearing per crop. Rearing house should be well ventilated and fly proof.

Disinfection and prophylactic measures:

Disinfection made before and after each rearing is considered as the key for a successful cocoon harvest. Disinfect the rearing house at least 7 days before and soon after the rearing. Disinfection should be carried out on bright sunny days. Wash the rearing houses and appliances with 5 % bleaching powder solution before rearing. Sprinkling of 2 % bleaching powder-lime mixture in the surroundings of the rearing house is equally effective. Fumigate with 5% formaldehyde solution under high humid condition. Open the room after 24 hours. Thereafter, windows and ventilators should be kept open for proper aeration and free circulation of air.

Season:

Rearing can be done throughout the year. However, March-April and September-October are the best seasons for rearing of silkworm.

Egg incubation:

Incubate the DFLs at 24-26°C temperature and 75-85% relative humidity.

Brushing:

Hands should be washed with 2% formalin solution and then with water. Brush newly hatched worms on tender leaves during morning hours. Use paraffin paper and water soaked foam pad in rearing tray to maintain temperature and humidity.

Feeding:

Feed 1st instar worms on tender, 3rd and 4th instar on semi-matured and 5th instar on matured leaves. Feed the worms with minimum 4 times a day.

Bed cleaning:

This work is carried out at regular interval in the same way as adopted for the mulberry silkworm. The growing worms undergo four moults and have five instar stages. Resort to bed cleaning daily. **Nylon net** can be used for easy bed cleaning. The 5th instar mature larvae stop feeding and start searching for a proper place to spin the cocoon. At this stage, the mature worms are picked up and transferred to **mountages (Chandrikes)**. In wild race, cocoons are spun between folds of leaves. The spinning is completed within 2-3 days. The cocoons are open mouthed, white or brick red, 5 cm long in case of female and 4.6 cm in male, tapering at one end

and flat rounded at open end, flossy and without a peduncle. The silk filaments are not continuous.

Late stage rearing:

Rear maximum 300 number of 5th instar worms per 3 feet x 3 feet diameter tray. Low cost bamboo platform rearing equipment is the best for rearing late stage worms considering the limited rearing space and frequent bed cleaning. The structure with 6ft (L) x 5.5 feet (H) x 3 feet (W) dimensions can accommodate 25-30 DFLs.

Ripe (Mature) worm collection:

Ripe worms become yellowish white and start roaming for selection of site for cocoon formation. In mulberry silkworm larvae become yellowish in colour. It is ready for cocooning. While picking up the matured worms and rubbing in between fingers, **a sound of hollowness is produced in eri silkworm**. Mature worms are collected and put for the cocoon formation on mountages. Besides traditional net/*Jali*, bamboo *Chandrikes*, bamboo stripe type mountage and plastic collapsible mountage are used for cocooning.

Harvesting of cocoons: As per mulberry silkworm.

Post cocoon processing:

Stifling is done by spreading and exposing the cocoons to sun for 1-2 days. For degumming, cocoons are tied in a cloth sac and dipped in boiling soda solution. After sufficient boiling, the cocoons are taken out, washed with water several times to remove soda, squeezed to remove water and then spread on mats to dry. Being open mouthed, the thread of the cocoons is discontinuous. So, the thread can only be spun and not reeled. Traditionally spinning is done in wet condition on **Takli** and in semi dried condition on a **charkha**. Improved spinning machines like **N.R. Das type charkha** and **Chaudhury type charkha** are also available for spinning of silk from Eri cocoons.

NATURAL ENEMIES OF SILKWORM:

A. Important pests of silkworm with their management:

Pests	Nature of Damage	Management
Uzi fly <i>Exorista sorbillans</i> (Tachinidae: Diptera) (Endo-parasitoid of silkworm)	• The flies lay eggs on grown up larvae of silkworm and maggots on hatching feed the body contents of caterpillar. • Mature maggot causes reduction in yield of cocoons and cocoon quality. • Also causes death of silkworm larva. • Presence of creamy white oval eggs on the skin of larvae in the initial stage. • Presence of black scar on the larval skin. • Silkworm larvae die before they reach the spinning stage (if they are attacked in the early stage). In later	• Prevent fly's access to silkworms by mechanical means. • Fly proof rooms/doors/ventilators. • All crevices of the rooms should be closed to prevent maggots pupating in the soil. • Dusting of China clay @ 3g/100 on spinning larvae before mounting.

Pests	Nature of Damage	Management
	stage, pierced cocoon is noticed.	
Beetles <i>Dermestes</i> <i>cadeverinus</i> (Dermestidae: Coleoptera)	- The adults and grubs are attracted to smell of the cocoons. - They eat the cocoons, enclosed pupae and often the eggs of silkworms. - The females lay eggs in the crevices, organic matter and wooden boards. - Grubs and adults bore into the cocoons and eat the dried pupae, attack pierced and melted cocoons stored within the grainage. - Presence of small holes (pierced cocoons) in the pupae and abdominal parts are damaged in the adult moths.	- Closure of cracks and crevices. - Thorough cleaning of rearing room. - Fumigation of rooms with methyl bromide. - Store the pierced cocoons in a separate room. - Avoid long storage of pierced cocoons. - Sun dry the pierced cocoons once in a week.
Ants (Hymenoptera)	The ants attack silkworms in rearing trays.	- Legs of the rearing stands should be dipped in ant wells (water + kerosene). - Use of ash or kerosene at the handles of the mountages at the time of spinning.
Lizards, birds, rats and squirrels	- They feed on silkworms. - Mammals predate on pupae by biting open the cocoons.	- Rearing rooms should be kept free from lizards. - Setting of traps for rat and squirrel control. - Scaring of birds from the vicinity.

B. Important diseases of silkworm with their management:

Diseases and Causal organism	Susceptible stages/Mode of infection	Damage symptoms	Management
Pebrine disease (Protozoa transmitted) <i>(Nosema bombycis)</i>	Eggs, Larvae, pupae, adults Mode of infection: Ingestion of spores	- It is a chronic disease. - Eggs laid by moth are fewer and do not firmly attach to the egg sheet. - Peeper like black spots. - Laying of unfertilized and dead eggs. - Diseased larvae have poor appetite, retarded growth, undersized and flaccid. - Larvae are comparatively paler, translucent and delays to moult.	- Mother moth examination. - Use of disease free females. - Sterilization of eggs with 2% formalin. - Destruction of infected eggs and females. - Bed disinfectant: <i>Vijetha</i> powder

Diseases and Causal organism	Susceptible stages/Mode of infection	Damage symptoms	Management
		- Silk gland will have white pustules on its surface. - Dead larvae remain rubbery for some time and then turn black. - Diseased pupa may develop black markings on the surface. - Moth appears malformed. - The wings are stunted and crippled - The infection spreads to successive generation through eggs of diseased moth (TOT: Transovarial Transmission). Responsible factor: - Infected seeds (eggs)	
Flacherie disease (Bacteria transmitted) <i>(Bacillus bombysepticus)</i>	Larvae Mode of infection: Ingestion of spores	- Loss of appetite, semisolid excreta, becomes lethargic. - Skin becomes flaccid body purification and emission of foul smell. - Larvae vomits gut juice and develop dysentery. Responsible factor: - Bad rearing condition (High temperature and humidity). - Poor ventilation, over crowding - Bad leaves and over feeding	- Proper incubation of eggs. - Proper rearing conditions. - Disinfectant: Slaked lime solution 0.3% - Bed disinfectant: Vijetha powder
Grasserie disease (Virus transmitted) (Nuclear Polyhedrosis Virus) Milky disease	Larvae Mode of infection: Ingestion of polyhedra (Chrystal virus particle)	- Swelling of inter segmental region and easy rupture of skin. - The integument will be fragile and breaks easily oozing turbid milky fluid. - Body fluid becomes thick and cloudy and they die. - The larvae do not settle for moult and their integument become shining Responsible factor: - Bad rearing condition (High temperature and humidity). - Poor ventilation, over crowding - Bad leaves and over feeding	- Avoidance of injury. - Disinfection of seed production unit, appliances, silkworm rearing house surroundings and silkworm egg surface. - Disinfectant: Slaked lime solution 0.3% - Bed disinfectant: Vijetha powder

Diseases and Causal organism	Susceptible stages/Mode of infection	Damage symptoms	Management
Muscardine disease (Fungal transmitted) 1. White Muscardine <i>(Beauveria bassiana)</i> 2. Green Muscardine <i>(Spicaria prasina)</i> 3. Yellow Muscardine <i>(Iscaria farinosei)</i>	Larvae/ pupae/ adults Mode of infection: Penetration of skin by germinating spores of conidia	• Larvae loose appetite, become inactive and flaccid on death. • Hyphae come out from inter-segmental membranes. • Body becomes too hard. • Mummified larvae vomit and shows diarrhea like symptoms. Responsible factor: • Bad rearing condition (High temperature and humidity). • Poor ventilation, over crowding • Bad leaves and over feeding	• Proper rearing conditions. • Sterilization. • Formalin 3% or bleaching powder 2% or Slaked lime solution 0.3% as disinfectant. • Bed disinfectant: <i>Vijetha</i> powder

Part-III: Lac Insect

INTRODUCTION

Lac is a natural resinous substance of profound economic importance in India. Besides silk and honey which are commercial products of insect origin, lac is also a product of a beneficial insect *Kerria lacca* (Kerr.). Millions of these sessile lac insects sustain their life on specific host plants, secreting resin as their body covering, which eventually harvested in the form of resin, dye and wax of commercial importance. It is the only resin from animal origin lending itself to diverse applications e.g. as a protective and decorative coating in the form of thin films, adhesives and plastics. It makes a small but significant contribution to the foreign exchange earning of the country, but the most important role of lac is considered to be an important cash crop by the poor cultivators (usually the tribal peoples) in almost all the major lac-growing states i.e. Jharkhand, Chhattisgarh, Odisha, West Bengal, Madhya Pradesh, Maharashtra and UP. The lac plays in the economy of the country is that roughly 3-4 million tribal people, who constitute the socio- economically weakest link of Indian population earn a subsidiary income from its cultivation.

India is the major producer of lac, accounting for more than 50% of the total world production. It virtually held a monopoly in the lac trade during the period of the world war-I, producing nearly 90% of the world's total output. Today an average of about 20 -22 thousand tonnes of stick lac (raw lac) is produced in the country per year.

Most of the lac produced in our country is from homestead land, wasteland and rural areas, a large number of poor cultivators producing lac in very less quantity. For them, there is hardly any investment, except in years of adverse conditions. They either own a few lac hosts or take them out on lease or rental basis, and generally only part-time family labour is employed. When the lac matures, it fetches them ready cash. Usually host trees standing on **Raiyati lands** (A person who hold the land for the purpose of cultivating it by himself or by members of his family) are used for lac cultivation and in some areas trees on Government land are taken on lease or rental basis.

Why lac cultivation?

- A good source of livelihood resource for poor farmers.
- Assured source of income during drought years.
- Require meager inputs (like water, pesticides etc.)
- Most suitably grown on marginal and degraded land.
- No competition with other horticultural, agricultural crops for land and farm operation.
- Do not harm host tree health neither other flora nor fauna.
- Avoids migration of rural population to urban areas.
- Increases opportunities for women for better occupation and returns.

HISTORY OF LAC:

Lac is a resinous exudation from the body of female scale insect. Since Vedic period, it has been in use in India. The term “Lac” synonyms Lakh in Hindi which itself is derivative of Sanskrit word “*Laksha*” meaning a hundred thousand and is suggestive of the large number of

insects involved in its production. It would appear that Vedic people knew that the lac is obtained from numerous insects and must also know the biological and commercial aspects of lac industry. The description of the insect and its host plant (Food plant) – Palas (*Lakshataru*) is recorded in the *Atharva Veda*. It is mentioned in the *Mahabharata* that *Kauravas* built the highly inflammable **Lakhagriha or Jadugriha (Lac house)** with a motive of physically eliminating *Pandavas* by setting the lac palace on fire. It is also worth to mention that a **Laksh Griha** would need a lot of lac which could only come from a flourishing lac industry during that period.

The Ain-i-Akbari of 16th Century records the use of pigmented lac varnishes for painting screens. Since ancient times, Greeks and Romans were familiar with the use of lac. The cultivation of lac insects has a long history in Asia, with some suggestion that it is as old as 4000 years in China where its cultivation accompanied the development of the silk industry. Increasing demand of lac products after World War-II has received attention in the present century. In order to increase the production of lac by scientific methods, an association named **Indian Lac Association (ILA)** was formed in 1921, **Lac Research Institute (LRI)** was established at Namkum, Ranchi in 1924, with a view to have greater participation of the Government. In 1930, the **Indian Lac Cess Committee (ILCC)** was formed and the committee took over the **Indian Lac Research Institute (ILRI)** in 1957. Then the need for a Lac Extension wing was felt and thereafter a **Lac Extension Wing (LEW)** under the **Indian Lac Cess Committee (ILCC)** was created. The **Indian Lac Research Institute (ILRI)** was taken over by the **Indian Council of Agriculture Research (ICAR)** in 1966.

Responding to the opening up of economic policies, globalization of industries and agricultural enterprises, the **Indian Lac Research Institute (ILRI)** has undergone a structural change. Besides research and development on all aspects of lac; processing and product development of other natural resins and gums have been brought under the ambit of research. Therefore, ILRI has been upgraded as **Indian Institute of Natural Resins and Gums (IINRG)**, Namkum (Ranchi) from the September 20, 2007. The **IINRG** is a nodal Institute at national level for research and development on all aspects of natural resins, gums and gum-resins including LAC, such as production, processing, product development, training, information repository, technology dissemination and national / international cooperation.

Recently in Gujarat, Department on Entomology, N.M. College of Agriculture, Navsari Agricultural University, Navsari has initiated research on lac insect and its cultivation under Tribal Area Sub-Plan plan (TASP) Development Charges (Plan Scheme) Project entitled **“Strengthening Research on Sericulture and Lac Culture” since 2017-18.**

Lac is Nature’s gift to mankind and the only known commercial resin of animal origin. It is the hardened resin secreted by tiny lac insects belonging to a bug family. To produce 1 kg of lac resin, around 3,00,000 insects lose their life. The lac insects yields resin, lac dye and lac wax. Application of these products has been changing with time. Lac resin, dye etc. still find extensive use in Ayurveda and Siddha systems of medicine.

With increasing universal environment awareness, the importance of lac has assumed special relevance in the present age, being an eco-friendly, biodegradable and self-sustaining natural material. Since lac insects are cultured on host trees which are growing primarily in wasteland areas, promotion of lac and its culture can help in ecosystem development as well as reasonably high economic returns. It is a source of livelihood of tribal and poor inhabiting forest and sub-forest areas.

TAXONOMY OF LAC INSECT

Scientific study of lac started much later. In 1709 Father Tachard discovered the insect that produced lac. In 1782 a detail study was made by J. Kerr and named as *Coccus lacca* which was published in Philosophical Transaction of Royal Society of London (vol. 71, pp. 374-382). In 1815 *Coccus lacca* was put in new genus *Laccifer* by Oken. Later *Coccus lacca* was synonymized as *Tachardia lacca* following the name of French Missionary Father ‘Tachardia’. It was later changed to *Laccifer lacca* (Kerr.) The other name given to it has been *Kerria lacca* (Kerr.) in 1883 by Blanchard. Presently a total nine genera and 87 species have been described worldwide in which two genera and 23 species are reported from India (Sharma and Ramani, 2011).

A number of species of lac insects are known, of this ***Kerria lacca*** is by far the most important and produces the bulk of the lac for commercial use. It belongs to—

Phylum	: Arthropoda
Class	: Insecta
Order	: Hemiptera
Super-family	: Coccoidea
Family	: Kerriidae
Genus	: <i>Kerria</i>
Species	: <i>K. lacca</i>

Lac is a natural, biodegradable, non-toxic, odourless, tasteless, hard resin and non-injurious to health. Lac is in fact a resinous protective secretion of tiny lac insect, *Kerria lacca* (Kerr.) which belongs to the family Lacciferidae in the super family Coccoidea of the order Hemiptera which includes all scale insects. Scale insect is a common name for about 2000 insect species found all over the world. Scale insects range from almost microscopic size to more than 2.5 cm.

The lac insect is a pest on a number of plants both wild as well as cultivated. These insects attach themselves in great numbers to plants. The mouth part of these insects is piercing and sucking type. They can be very destructive to tree-stunting or killing twigs and branches by draining the sap. The tiny red-coloured larvae of lac insect settle on the young succulent shoots of the host plants in myriads and secrete a thick resinous fluid which covers their bodies. The secretion from the insects forms a hard continuous encrustation over the twigs. The encrusted twigs are harvested and the encrusted twigs scraped off, dried and processed to yield the lac of commerce which is regarded as Non Wood Forest Product (NWFP) of great economic importance to India.

There are six genera of lac insects, out of which only five secrete lac and **only one, i.e. *Laccifer secretes recoverable or commercial lac***. The commonest and most widely occurring species of lac insect in India is *Laccifer lacca* (Kerr.) which produces the bulk of commercial lac. However, *K. chinensis* in northeastern states and *K. sharcla* in coastal regions of Orissa and West Bengal are also cultivated to certain extent lac insect of South East Asia is referred to as *K. chinensis*.

DISTRIBUTION

Since the lac insects thrive and feed on certain species of the tropical trees it is found distributed in South-East Asian countries. Lac insects are concentrated in tropical and sub-tropical regions between 40° latitude above and below the equator on both Hemispheres (Varshney, 1976). Lac is currently produced in India, Myanmar, Thailand, Malaya, Lao and Yunnan province of China. India and Thailand are main areas in the world while India has prime position in relation to lac production. Lac cultivation is introduced into Thailand from India.

Over 90% of Indian lac produced comes from the states of Bihar, Jharkhand, West Bengal, Madhya Pradesh, Chhattisgarh, Eastern Maharashtra and northern Orissa. Some pockets of lac cultivation also exist in Andhra Pradesh, Punjab, Rajasthan, Mysore, Gujarat and Uttar Pradesh.

LIFE CYCLE OF LAC INSECT

Lac insect is a minute crawling scale insect which inserts its suctorial proboscis into plant tissue, sucks juices, grows and secretes resinous lac from the body. Its own body ultimately gets covered with lac in the so called 'CELL'. Lac is secreted by insects for protection from predators. The life cycle of lac insect mainly depends on the ecological factors of the region like the temperature, humidity and the host plant species. It includes three stages; egg, nymph and adult. The eggs reached the adult stage within six months. The following are the stages involved in the reproduction of lac insects.

Egg

After fertilization, the females grow rapidly until it begins to lay eggs. By the same time female starts to lay the eggs, its body contracts to the ventral side and gradually vacating the place for the eggs to be accommodated inside the resin cell. After egg laying the female secretes the lac resin at a faster rate. After about 14 weeks, female shrinks in size, allowing the light to pass into the cell and onto the eggs.

At this stage, two yellow spots appear at the rear end of the resin cell. These spots gradually enlarge and turn orange in colour. This indicates the completion of egg laying by female. A female is capable of producing about 1000 eggs (average 200-500). The egg laying period may last from 7 to 10 days. After egg laying female dies. Now the resin cell with eggs is called 'ovisac'. The ovisac appears orange in colour due to crimson fluid called lac dye. This indicates that eggs are about to hatch in a week. After six weeks, the eggs are hatched into first instar larvae called crawlers.

Nymphs

Following hatching, the first instar nymph stays within the cell for a brief period. Then the crimson red coloured nymphs, referred to as '**crawlers**' come out of the cell in search of suitable place for settlement generally larvae prefer succulent shoots. The larvae emerge out in very huge numbers; this emergence is termed as '**swarming**' that continues for several weeks. **Boat shaped** nymphs are very small in size (0.5 mm) and divisible into head, thorax and abdomen. Head bears a pair of antennae, a pair of simple eyes and a single proboscis. All three thoracic segments are provided with a pair of walking legs. Thorax also bears two pairs of spiracles for respiration. Abdomen is provided with a pair of caudal setae.

On reaching soft succulent twigs, the nymphs settle down close together and start to suck phloem sap through their suctorial proboscis. After one day or so of settling, the nymphs start secreting lac from the hypodermal glands lying under their cuticle keeping open their mouthparts, breathing spiracles and anus. The secreted semi-solid lac hardens on exposure to air and the nymph gets fully covered by the lac encasement, called as '**lac cell**'. Within the cell, the nymphs moult thrice before reaching maturity. Larvae moult in their respective cells. During first moult both male and female nymphs **lose their appendages, legs and eyes**. Following this moult, dimorphism appears in their cells. The second stage larva undergoes pseudo-pupation for a brief time, whereby it changes into adult stage. Inside the male cells, the male nymph casts off their second and third moult and matures into adults.

Adult

The sex can be determined even during the early stages of development. As in case of males the growth is more on the longitudinal axis and in females the growth is more in vertical axis. The life span of the female is longer than that of the males. **Most of the lac is secreted by the females.**

On maturity, the **males lose their proboscis and develop antennae, legs and a pair of wings**. The male brood cell is **slipper shaped**. It bears a pair of **branchial pores** on the anterior side and a single large **circular pore** on the posterior side. The posterior hole remains covered by a round trap door or **operculum** through which adult males emerge.

The adult male is red in colour and smaller in size than the female insect. The length is about 1.2-1.5 mm. Head bears reduced eyes and ten segmented antennae. Mouth parts are similar to that of the females. Thorax has three pairs of legs. The male lac insect may be either winged with one pair of hyaline wing on its thorax or wingless (apterous). The eight segmented abdomen ends into a short chitinous prominent sheath containing penis. A pair of white elongated caudal seta or filament is present on either side of this sheath.

The female brood cell is larger globular in shape that remains fixed to the twig. The **female cell also has a pair of branchial pore** and a single round anal tubular opening through which protrudes waxy white filaments (it indicates that the insect inside the cell is alive and healthy). These filaments also prevent the blocking of the pore during excess secretion of lac. Following second and third moulting, the females retain only mouthparts but **fail to develop any wings, eyes or appendages**. While developing into adult, the female becomes immobile and large in size to accommodate huge number of eggs.

The **female lac insect has a pyriform body** measuring about 4-5 mm in length. The body is indistinctly divided into head, thorax and abdomen. Head bears **a pair of degenerated antennae**. Eyes are absent. Mouthparts are of piercing and sucking type. Posterior to mouth lies a pair of spiracles which ensures smooth breathing of the insect during lac secretion. Thorax has degenerated legs and lack wings. At the posterior part of the body is triangular in shape which consists the anal tubercle encircling and setae. Near to it two branchial openings and one small chitinous spine called dorsal spine are present.

Fertilization

Lac insects are **ovoviviparous types of fertilization**. The females get attached to the host plant inside the resinous mass. After attaining the maturity, males emerge out from their cells and walk over the resinous covering of the female. The male enters the female cell through anal tubular opening and inside female cell it fertilizes the female. **After copulation, the male dies**. One male is capable of fertilizing several females. A male has life of 62-92 hours. Females develop very rapidly after fertilization. They take more sap from plants and exude more resin and wax. **Parthenogenesis:** In the life history of lac insect, parthenogenesis is known to occur when unfertilized eggs are directly hatched into nymphs. It is common in Kartiki crop of Rangeeni Strain.

After hatching, the nymphs are emerge and the whole process begins all over again. After one cycle has been completed and around the time when the next generation begins to emerge, the resin encrusted branches are harvested. From each crop, some encrusted twigs are retained for inoculation to the new host plants.

LAC AND ITS FORMS

Based on the methods of collection and processing various forms of lac known in commerce are as follows:

Ari lac	:	If lac crops are harvested by cutting down the lac bearing twigs a little before the larval emergence, that lac is known as ari lac (immature lac) .
Phunki lac	:	If lac crops are harvested by cutting down the lac bearing twigs after the larval emergence is over, that is called phunki lac (empty lac) .
Stick lac	:	It is raw lac , obtained by scrapping the lac encrustation from the dry twigs cut down before emergence of the new insect. It contains dead bodies of the lac insect, bark of the host plant, dried leaves, dust and other extraneous impurities. OR The lac encrustations is separated by knife or broken off with finger from the twig of host plants and is known is stick lac or crude lac or raw lac.
Seed lac	:	The semi-refined product obtained after crushing, sieving and winnowing of stick lac, followed by washing and drying is called seed lac . It contains impurities such as sand, insect debris, etc. OR

		The stick lac, after grinding and washing is called seed lac or chowri.
Shellac	:	It is the refined form of lac, available in the form of thin flakes. It is obtained by stretching the heat softened seed lac, freed from infusible materials. It is the commercial lac and is graded based on its colour and wax content. OR The manufactured product prepared from stick lac after washing and melting, which takes the form of yellow coloured flakes, is called shellac. Shellac is natural gum resin. It is non-toxic, hard, amorphous, brittle and also edible. Its colour varies from dark red to light yellow. When heated slowly, it melts at 89-90°C. It is insoluble in water, but dissolves readily in alcohol and organic acids. It is used in fruit coating, as binder for nail varnish, mascara, as enteric coating for tablets, in manufacturing of photographic materials, in preparation of gramophone records, as sealing wax, as a filling material in the hollows of ornaments, in preparation of toys, buttons, pottery and artificial leather. Apart from these conventional uses, being eco- friendly and renewable raw material, it is also used in industries like textile (as stiffeners), electrical (for insulation, capping, etc.), paint, aluminium, pharmaceuticals, confectionary, food processing, cosmetics, antique, etc.
Button lac	:	It is another form of heat purified lac, where the molten resin is cast into button shaped cakes instead of being drawn into sheets, as in the manufacture of shellac. The cakes are largely used for bonding mica splitting into micanite. OR After melting process, lac is dropped on a zinc sheet and allowed to spread out into round discs of about 3” diameter and 1/4” thickness is called button lac.
Garnet lac	:	It is prepared from inferior seed lac or kiri by the solvent extraction process. It is dark in colour and comparatively free from wax.
Bleached lac	:	A major portion of lac consumed in the world today is in the form of bleached lac or 'White Lac'. It is prepared by dissolving shellac or seed lac in Sodium carbonate solution, bleaching the solution with sodium hypochlorite and precipitating the resin with sulphuric acid. Bleached lac deteriorates quickly and should be used within 2-3 months of manufacture. It is non-toxic and physiologically harmless and thus is widely used in food industries, food packaging and allied industries. It is also used in binding and adhesive drying-related works. Besides, it can also be used in industries related with flexographic printing, confectionary, stamping ink, coating for processed food and dry flowers, textiles; cosmetics, wood finishing, fireworks and pyrotechnics (as binder for fireworks, match sticks etc.), grinding wheels, rubber and plastic, electronics, <i>etc.</i>
Dewaxed	:	Lac from which wax has been removed is known as dewaxed lac. This non-

Lac		toxic shellac is a bit harder and brighter than other shellac. It is completely free from wax and has high gloss and excellent adhesive quality to various substrates. It can safely be used in cosmetics (hair sprays, shampoo, perfumes, lipsticks, nail polish, eyeliners, etc.), confectionary (coating of cakes, eggs, chewing gums, cheese, fruit coating), etc. Shellac aleuritic acid is now being used in synthesis of glucose mono-aleuritate (a non-toxic, non-hemolytic water soluble compound), an isocaloric substitute for dietary tripalmitin. Aleuritic acid esters are used in plastic, fibre materials and perfume industries also.
Lac Wax	:	Lac wax is a mixture of higher alcohols, acids and their esters. It can be used in preparation of polishes to be applied on shoes, floor, automobiles, etc. It is also used in food and confectionary, drug tablet finishing, crayons, lipsticks, <i>etc.</i>
Lac Dye	:	Lac dye is traditionally used to colour wool, silk, food and beverages. Being eco- friendly in nature, it is nowadays used as a colouring material. Its demand has made it rival to other synthetic colouring agents.
Lac resin	:	It is an ester complex of long chain hydroxy fatty acids and sesquiterpenic acid.

COMPOSITION OF LAC

The major constituents of stick lac or crude lac are resin, sugar, protein, soluble salt, colouring matter, wax, volatile oils, sand, woody matters and insect bodies. The resin is always associated with an odoriferous principle, a wax and a mixture of three dyes. Removal of both wax and dye results in a marvelous colourless and transparent resin having all the characteristic properties of the resin.

Chemical analysis has revealed that the resin is made of at least six major chemical components of different molecular complexities.

The approximate percentage of different constituents of lac is given below:

Composition of stick lac		
Lac resin	-	68 to 90%
Lac wax	-	5 to 6%
Lac dye	-	2 to 10%
Mineral matter	-	3 to 7%
Albuminous matter	-	5 to 10%
Water	-	2 to 3%

PROPERTIES OF LAC

The important properties of lac are as follows;

- Lac is soluble in alcohol and weak alkalis but insoluble in water.
- It has capacity of forming uniform durable film.
- It possesses high scratch hardness.

- Resistance to water and Heat soluble, at 80°C it melts.
- It is good adhesive in nature.
- Ability to form good sealers, undercoat primers.
- It has a capacity to allow quick rubbing with sandpaper without slicking or gumming.
- It is non-conductive and non-toxic.

No other single resin, both natural and synthetic, possesses so many desirable properties and so lac is also termed as multipurpose resin.

LAC HOSTS

Lac insects thrive on twigs of certain plant species and get settled upon it, suck the plant sap and grow. The plants preferred for feeding and development are called **host plants**. Although lac insect is natural pest on host plant, these insects enjoy the privileged position not being treated as pest. This is because: i) They yield a useful product, ii) The host plants are economically not so important and iii) The insects cause only temporary and recoverable damage to the host plants. About 113 species of host plants are found to be as lac host plant, but only few of them are found to be commercially important for lac culture in India. Of these host plants, *Butea monosperma* (**Palas**), *Schleichera oleosa* (**Kusum**) and *Ziziphus mauritiana* (**Ber**) are of major importance. These host plants contribute about 90 % of total national lac production. In addition to these host plants, a bushy host plant species, *Flemingia semialata* **Roxb.** (**Leguminosae: Papilionaceae**), has been identified and field tested as a potential fast growing host for intensive lac cultivation during winter season **lac crop of Kusmi strain (Aghani)** for increasing lac production to match with the growing global demand of lac. However, *Prosopis juliflora* (in Gujarat areas) are expected to enhance Kusmi lac cultivation.

Table-1: Common lac host plants in India

Host plant	Common name	Suitable for strain	Distribution
Major (Traditional)			
<i>Butea monosperma</i>	Palas	Rangeeni	All major lac growing states
<i>Schleichera oleosa</i>	Kusum	Kusmi	All major lac growing states
<i>Ziziphus mauritiana</i>	Ber	Kusmi/rangeeni	All major lac growing states
Major (Emerging)			
<i>Flemingia macrophylla</i>	Bhalia	Kusmi	All major lac growing states
<i>Flemingia semialata</i>	Van chhola	Kusmi	All major lac growing states
Minor (Regional)			
<i>Acacia auriculiformis</i>	Akashmani	Kusmi	West Bengal, Jharkhand
<i>Acacia catechu</i>	Khair	Kusmi	J&K
<i>Albizia lucida</i>	Gulwang	Kusmi	Gujrat,
<i>Cajanus cajan</i>	Pigeon-pea	Rangeeni	Assam
<i>Ficus benghalensis</i>	Bargad	Rangeeni	West Bengal, Jharkhand
<i>Ficus religiosa</i>	Peepal	Rangeeni	West Bengal, Jharkhand
<i>Grewia letiaefolia</i>	Dhaman	Kusmi	Assam
<i>Grewia disperma</i>	--	Kusmi	Assam
<i>Grewia serrulata</i>	Pansaura	Kusmi	Assam

<i>Shorea letura</i>	Sal	Rangeeni	Karnataka
<i>Samanea saman</i>	Rrain tree	Kusmi	Odisha, West Bengal, Assam
<i>Zizyphus xylopyrus</i>	Khatber	Rangeeni	MP

ESSENTIAL CHARACTERISTICS OF A LAC HOST

The factor that determines whether the lac insect will flourish on a particular host species or not is the character of the sap of host plant. It is believed that the sap reactions of a good lac host should be near about neutral or slightly acidic (e.g. pH values between 5.8 and 6.0) and that the sap density of good lac host plants is lower than that on non-lac hosts. The sap reactions of non-lac hosts show distinct acidity or alkalinity.

LAC PRODUCTION IN INDIA

India and Thailand are the two major producers of lac. The main lac producing states in India are Chhattisgarh, Jharkhand, Madhya Pradesh, West Bengal, Uttar Pradesh, Orissa, Maharashtra and Gujarat. The cultivation of lac is at present mainly confined to the conventional lac hosts trees of Palas, Ber and Kusum. At present total annual average production of stick lac in India is approximately 20-22 thousand tons which forms the raw material for lac industries. Chhattisgarh ranks 1st position among the states followed by Jharkhand, Madhya Pradesh, Maharashtra and West Bengal. These five states contribute around 95 % of the national lac production. Nearly 75-80% of the finished product is exported and only a small portion nearly 20 to 25 % is consumed within the country.

Table-2: State wise lac producing districts in the country

Sr.	State	Districts
1	Jharkhand	: Palamau, Latehar, Garhwa, Ranchi, Lohardaga, Gumla, Simdega, Saraikela, Hazaribagh, Chatra, East Singhbhum & West Singhbhum
2	West Bengal	: Purulia, Bankura, Midnapur, Murshidabad & Malda
3	Madhya Pradesh	: Balaghat, Mandla, Hoshangabad, Shahdol, Jabalpur, Indore, Chhindwara, Rewa & Seoni
4	Chhattishgarh	: Bilaspur, Raipur, Sarguja, Bastar, Rajnandgaon, Durg,,Kanker, Dhamtari, Korba & Raigarh
5	Maharashtra	: Bhandara, Chandrapur, Gharchiroli, Gondia
6	Orissa	: Mayurbhanj, Kendujargarh, Sundargarh, Kalahandi, Bolangir, Koraput, Sambalpur, Nabrangpur, Keonjhar, Balasore
7	Gujarat	: Vadodara, Panchmahal, Sabarkantha and some part of The Dangs
8	Uttar Pradesh	: Mirzapur, Sonbhadra
9	Bihar	: Gaya
10	Assam	: Karbi Anglong, North Silchar Hill, Nagaon
11	Andhra Pradesh	: Adilabad, Nizamabad
12	Meghalaya	: Khasi hills, Garo hills

STRAINS OF LAC AND LAC CROPS

Two strains of the lac insects are recognized in India, the **Rangeeni** and **Kusumi**. Each strain completes its life cycle twice a year but the seasons of maturity differ considerably. In Mysore, the Rangeeni strain completes their life cycle in 13 months on Jallari (*Shorea talura*).

There are four lac crops in a year that are named after the *Hindi* months. The following table summarizes the information about four lac crops.

Table-3: Strains of lac and lac crops								
Sr	Inoculation with Lac Swarming larva	Lac Host Plant	Weather	Seed Inoculation	Emergence of male insects	Crop harvested	Female insects mature and give rise to swarming larvae	Time (In month)
A.	RANGEENI CROPS							
i	Katki crop (June –July)	Palas	Rainy Season	June-July	Aug-Sept	Oct-Nov	Oct-Nov	4
ii	Baisakhi crop (Oct – Nov)	Palas	Summer	October - Nov	Feb-March	April-May leaving a certain amount of lac on trees to mature and act as brood in July	June-July	6-8
		Ber	Summer	October - Nov	Feb-March	May-June	July-Aug	6
B.	KUSUMI CROPS							
i	Aghani crop (June-July)	Ber	Winter	June-July	September	Dec-Jan	Jan-Feb	6
ii	Jethwi crop (Jan-Feb)	Kusum	Summer	January-February	March - April	June –July	June –July	6

Lac is not always left on the trees until it matures fully, particularly in case of *Baisakhi* crop. When it is not mature, it (*Baisakhi – ari*) is cut, leaving a certain amount on the tree to act as brood for the next crop. In *Rangeeni*, three crops can be obtained from the host tree such as Jalari (*Shorea talura*) mostly found in Karnataka (Mysore region) and Rain tree (*Samanea saman*), mostly located in coastal region of West Bengal. These crops are commonly known as Trivoltine crop in which the lac insects pass through three life cycles in thirteen months.

CROP WISE LAC PRODUCTION

Regarding share of different crops, *Katki*-33.39% (rainy season crop of *Rangeeni*) contributed the most in national lac production followed respectively by *Baisakhi*- 27.35% (summer season crop of *rangeeni*), *Jethwi* 19.50% (summer season crop of *Kusmi*) and *Aghani* 19.42% (winter season crop of *Kusmi*).

Traditional cultivation practices of lac

The cultivation practices followed by the lac cultivators are essentially the same throughout India except for slight deviation here and there to suit local conditions. It consists of taking repeated partial lac crop on the same tree after allowing a few shoots, carrying lac for self-inoculation every time or when the crop is harvested. Keeping the trees under continuous lac inoculation and heavy pruning of branches repeatedly to collect lac crop, leads to general loss of vitality of the trees. Also the self inoculation of the trees lead to over-infection on the twigs and this quite often results in whole sale mortality of the crop in season of extreme summer. Besides, this helps multiplication of enemy insects of lac resulting in failure of crops, which ultimately forces the cultivator to abandon cultivation on most of the lac host trees. In such seasons brood lac is not readily available for purchase and if at all, a very high price has to be paid which the cultivator cannot afford to pay. The cultivator usually purchases his brood to the extent he can afford at that time and puts it on a few trees and start cultivation cycle afresh. In favorable seasons, he reaps his crops and inoculates more of his trees and continues the self inoculation repeatedly till the crop fails again.

Thus production is unsteady and usually a bumper crop is obtained in cycles of 3 to 4 years. Being a subsidiary crop, lac cultivation is carried on a casual manner and the cultivator is generally satisfied with whatever he gets.

SCIENTIFIC METHOD OF LAC CULTIVATION

To start lac cultivation, two things are mainly to be taken into consideration:

- a. The suitable host plant on which the lac insect thrives
- b. Availability of healthy brood lac in time

MAJOR LAC CULTIVATION OPERATIONS/PRACTICES

1. Selection of suitable host plants
2. Infestation of lac hosts (inoculation)
3. Removing of used-up broodlac sticks (*Phunki*)
4. Insect pest management
5. Harvesting
6. Scraping of lac from twigs

1. SELECTION OF SUITABLE HOST PLANTS:

Selection of suitable host plants for lac cultivation is of paramount importance because quality and yield of lac depend on this. Under systematic working, the host plants are cultivated and rested in turn in **coupe system**. The host trees should be properly pruned to put forth young succulent shoots before inoculation. Only natural enemy free brood lac should be used for inoculation. Lac crops being highly sensitive to change in local weather conditions, care has to be taken to provide optimum conditions for successful results.

Selected lac hosts should have the following salient features:

- Fairly fast growing.
- Lower sap density.
- Well adapted to pollarding.

Selection of suitable site for lac cultivation

As lac can grow only in open areas, the sites for lac host plantation should be in such a place where free circulation of air around the host is assured. Cultivation should not be attempted at places where fire susceptibility is there. When starting cultivation in new areas having lac host. It is always desirable to prune them before infection to ensure good lac production.

Coupe System: a sustained yield basis of lac cultivation

The coupe system has been developed for lac production on sustained yield basis. If the same tree is continuously inoculated, its vitality suffers and the yield of crop progressively diminishes. It is therefore, important that host plants are given periodic rest. The coupe system of cultivation provides for a maximum use of host plant resources consistent with their vigor and well being.

In Rangeeni farms, *two coupe systems* with equal number of palas (*Butea monosperma*) trees in two coupes having six months rest is adopted for raising *Baisakhi-cum-Katki* crops in alternate seasons. The trees are inoculated with about 500g of *rangeeni* brood lac per tree, in the month of Oct.-Nov. Harvesting is done after a year, after allowing self-inoculation in June-July by partial harvesting and then harvesting the combined *Baisakhi-cum-Katki* crop in next Oct. Nov.

In the *Kusumi* farms, Kusum (*Schleichera oleosa*) is the major lac host plant species of *Kusumi* stain of lac insect. *Five coupe system* with equal number of trees in each coupe having 18 months rest in between pruning and inoculation is adopted. The trees are pruned 18 months prior to inoculation. Thereafter in the subsequent crops, harvesting will serve the purpose of pruning. The harvesting of crop is done after six months of inoculation.

Preparation of feeding ground for lac insects

To get a good quality lac through cultivation, it is necessary to ensure proper type of feeding ground to the lac insects. The insects have to be provided with succulent shoots, as it cannot drive its slender proboscis through thick bark. For getting a good number of requisite succulent shoots the most essential operation is pruning.

Pruning Operation

Pruning at proper time is one of the important operations where the branches/ twigs are cut in order to get the maximum numbers of succulent shoots to facilitate feeding of the lac insects. Improvised scientific method of pruning which is done in the brood lac farms is as follows:

Pruning is done lightly, because light pruning avoids stunted growth and allows gradual increase in the frame of the tree. Branches more than 2.5 cm in diameter (more than thickness of one's thumb) are not cut. Branches 1.25 cm or less in diameter are cut flush with a branch or trunk from where they arise. Branches between 1.25 cm to 2.5 cm in diameter are cut, so as to leave behind a stalk of about 30-45 cm in length. Dead and diseased branches are removed, split or broken branches are cut below the split.

If trees are old and have lost their capacity to produce vigorous shoots of new flush, heavier pruning is carried out to produce the new wood at the expense of the old. Such operation

will bring the tree to a better shape, so that subsequent pruning will give the desired flush. Proper pruning should result a good shape and give plenty of room for the development of new shoots.

Objectives of Pruning

- To ensure new, good, healthy and succulent shoots.
- To ensure availability of large number of shoots (larger area for lac insect settlement).
- To provide rest to host plant for maintaining its vigour.
- To remove dead, diseased and broken branches.

Types of pruning in lac host plants

Two types of pruning/ coppicing have been recommended for lac culture.

1. Apical/ light pruning: Branches less than 2.5 cm diameter should be cut from base and branches more than 2.5 cm diameter should be sharply cut leaving a stump of 30-45 cm from the base. Diseased and dead portion of branches should be removed completely. Light pruning is recommended for slow growing conventional tree host species like palas, kusum and ber.

2. Basal / heavy pruning: Branches having less than 7 cm thickness should be removed from the base, whereas thicker branches should be cut at a place where it has a diameter of 7 cm. In quick growing bushy host, pruning should be done at a height of 10-15 cm from the ground level e.g. *Flemingia macrophylla*, *F. semialata*.

Pruning time

After several years of investigation at Indian Lac Research Institute (presently I.I.N.R.G.), Ranchi, Jharkhand, it has been found that the best results are obtained by **pruning in February for raising the Katki crop and in April for raising the Baisakhi crop in the case of major Rangeeni host, ber and palas**. Pruning in these months will give shoots four and six months old respectively for the lac larvae to feed on.

In case of **kusum, pruning is best done in the month of June-July and January – February**. These months coincide with those in which the crops mature and so harvesting of the mature crop serves the purpose of pruning also. Pruning time will, however need to be adjusted to suit local conditions.

Pruning instruments

Most of the lac cultivators do pruning with axes. Proper pruning cannot be done with the axe. If branches are cut with axe, they will either break or split. In both the cases damage to tree will be caused at cutting place in form of scraping of bark or splitting, giving opportunity for insect pest attack. The ideal pruning instruments are **secateurs** and long handled **tree pruners**. Of these instruments, the most valuable are the long handled tree pruners. There are two types of secateurs. These are Roll cut secateur and the French secateur. The former is better and easier to use but is easily damaged by careless handling

Pruning is also done with **pruning knife** and Dauli. The use of pruning shear and pruning saw fitted in long handle makes the operation easier as the pruning is done directly by standing on ground and climbing is avoided.

2. INFESTATION OF LAC HOSTS (INOCULATION):

Brood lac is mature lac from where the young insects are ready to come out within the time specified. For getting the best result out of lac cultivation, the work should be planned on systematic basis. Such planning will aim at a sustained annual yield and also ensure that area under cultivation acquires self sufficiency of brood lac.

Collection of brood lac

Lac sticks, having mature female insects ready to give rise to the next generation are called *brood lac*. As the female lac insect is capable of giving rise to a large number of larvae and to get the maximum benefit, it is essential that the brood should be cut at the proper time, so as to secure the emergence of the maximum possible number of larvae from it.

For quality of brood lac, lac crops should be harvested only when mature. The cutting of brood lac should be taken up at the correct time keeping in view the swarming period i.e. the expected date of larval emergence. The ideal time of cutting would be that which will result in the swarming, starting immediately or within a couple of days of tying the brood on the host plant.

Selection of brood lac

After the brood lac has been cut from the plants, it is necessary to subject it to proper examination, so that only healthy lac with the minimum signs of predator and parasitoid damage is selected for use as brood lac. This is necessary to minimize the chances of propagation of the insect enemies of lac insects.

Inoculation of brood lac

This operation includes **putting of bundles of brood lac** (*lac sticks containing gravid females*) in the host twigs for allowing young lac larvae (*crawlers*) to come out of their mother cells and settle on the host plant.

Following aspects should be taken into consideration during inoculation operation:

- Pest -free healthy brood lac should be used.
- The leaves and unwanted portion of the shoot from broodlac sticks should be removed.
- Cut broodlac sticks preferably 15 -20 cm in length.
- Weigh about 1 kg broodlac and divide into approximately into 10 equal parts.
- Bundles of brood lac (about 100g by weight) are to be prepared and put these bundles **inside 60 mesh nylon netting bags** (approx. size 30 x 10 cm.). These will entrap all the predators and parasitoids but allow the lac larvae to come out.
- The brood lac bundles are tied onto the branches parallel to shoots.
- One meter long brood lac is sufficient to inoculate 10-15m long shoots of equal length.
- During the period of inoculation, there are chances of brood bundles falling off and one should go round the inoculated trees in each branch and put such bundles back on the tree.
- Attempts should be made to see that the brood lac bundles are not kept on the tree for more than the minimum period required for complete inoculation. Ordinarily, this period will be two to three weeks. If the brood lac is kept even after the lac larvae have

completely emerged, there is the danger of a larger number of enemy insects emerging from the **empty (phunki) brood lac sticks** and infesting the field heavily.

- While inoculating kusum trees, prefer to inoculate the trees with broodlac on outer side for *Aghani* and inner side of the host crown for raising *Jethwi* crop.

Table-4: Host pruning and lac inoculation schedule for different host plant

Host	Pruning	Waiting period	For raising	Inoculation	Maturity
Kusum	Jan/ Feb	18 Month	Aghani	June/ July	Jan/Feb.
	June/July	18 Month	Jethwi	Jan/Feb.	June/ July
Palas	Feb/March	6 Month	Katki	June/July	October/Nov.
	April	6 Month	Baisakhi	October/Nov.	June/July
Ber	April	6 Month	Baisakhi	October/Nov.	June/July
<i>Flemingia semialata</i>	Jan/ Feb	6 Month	Aghani	June/ July	Jan/Feb.
	June/July	6 Month	Katki	Jan/Feb.	June/ July

3. REMOVING OF USED-UP BROODLAC STICKS (*Phunki*):

Used up broodlac sticks after complete emergence of lac larvae from female cells are called **phunki**. This operation should be done to prevent access of the insect predators and parasitoids of lac insect to new lac crop and to avoid wastage of lac after drying up of phunki and prevent its falling on ground. It should be done as soon as emergence of lac crawlers is over. Generally the emergence of lac larvae from the brood lac ceases after three weeks. The phunki lac so removed is scrapped off thereafter in the brood lac for more that three weeks from the start of larval emergence to avoid emergence of enemy insects. Phunki bundles are pulled down from the trees with the help of pole mounted phunki hook or by climbing on trees.

4. PEST MANAGEMENT PROGRAMME:

There are many natural enemies of lac insects which include vertebrates, invertebrates (insect predators and parasitoids) and microbial flora.

Vertebrate enemies of lac insects

The important vertebrate enemies are squirrels and rats and the damage caused by those enemies can be as serious as 50 per cent of brood sticks in worst condition. Squirrels are active during the day time and the damage by them is more common under forest condition. Rats are active at night time and the damage usually occurs near about the villages.

Towards the crop maturity, these pests both gnaw the mature lac encrustation on the tree or the brood lac tied to trees for inoculation, and consumes the full grown lac female insects with plenty of eggs inside them. The damage to brood lac tied to trees interferes with the inoculation, as the brood bundles and lac encrustations drop to the ground while the larval emergence is taking place. Besides squirrels and rats, monkeys also cause some damage to lac encrustations and to the newly developing shoots from pruned trees by breaking them.

Control

It is difficult to control the squirrels and rats under the open field conditions where lac is cultivated. However scaring away of these animals or poisoning them may be adopted to keep the rodents under attack.

Insect enemies of Lac insect

It has been estimated that on an average, up to 30 to 40 per cent of the lac cells are destroyed by insect enemies of lac crop. At times, the enemy attack can be so serious as to result in crop failures.

These are two kinds of insect enemies:

1. Parasitoids: All parasitoids causing damage to lac insect belong to the order hymenoptera of class Insecta.

Table-5: List of parasitoids associated with lac insect, *Kerria lacca*

Sr. No.	Name of the parasitoid	Family
1.	<i>Anicetus dodonia</i>	Encyrtidae
2.	<i>Atropates hautefeuilli</i>	Encyrtidae
3.	<i>Aphrastobracon flavipennis</i>	Encyrtidae
4.	<i>Bracon greeni</i>	Encyrtidae
5.	<i>Campyloneurus indicus</i>	Encyrtidae
6.	<i>Coccophagus tchirchii</i>	Aphelinidae
7.	<i>Erencyrtus dewitzi</i>	Encyrtidae
8.	<i>Eupelmus tachardiae</i>	Eupelmidae
9.	<i>Eurymyiocnema aphelinoides</i>	Aphelinidae
10.	<i>Lyka lacca</i>	Encyrtidae
11.	<i>Marietta javensis</i>	Aphelinidae
12.	<i>Parageniaspis indicus</i>	Encyrtidae
13.	<i>Parechthrodryinus clavicornis</i>	Encyrtidae
14.	<i>Protyndarichus submettalicus</i>	Encyrtidae
15.	<i>Tachardiaephagus tachardiae</i>	Encyrtidae
16.	<i>Teachardiobius nigricans</i>	Encyrtidae
17.	<i>Aprostocetus(Tetrastichus) purpureus</i>	Eulophidae

Among the parasitoids listed above, *Tachardiaephagus tachardiae* and *Tetrastichus purpureus* are the most abundant lac associated parasitoids. They lay their eggs in the lac cells and the grubs (larvae) hatching out feed on the lac insect within its cell.

2. Predators

The predators on the other hand are more serious and may cause damage up to 30 to 35 per cent to the lac cells in a crop.

Table-6: Table: List of predators associated with lac insect, *Kerria lacca*

Sr. No.	Insect Predator	Order	Family
1.	<i>Eublemma amabilis</i>	Lepidoptera	Noctuidae
2.	<i>E. coccidiphaga</i>	Lepidoptera	Noctuidae
3.	<i>E. cretacea</i>	Lepidoptera	Noctuidae
4.	<i>E. scitula</i>	Lepidoptera	Noctuidae
5.	<i>Pseudohypatopa pulverea</i>	Lepidoptera	Blastobasidae

6.	<i>Catablemma sumbavensis</i>	Lepidoptera	Blastobasidae
7.	<i>Cryptoblabes ephestialis</i>	Lepidoptera	Blastobasidae
8.	<i>Phroderces falcatella</i>	Lepidoptera	Cosmopterygidae
9.	<i>Lacciferophaga yunnanea</i>	Lepidoptera	Momphidae
10.	<i>Chrysopa madestes</i>	Neuroptera	Chrysopidae
11.	<i>C. lacciperda</i>	Neuroptera	Chrysopidae
12.	<i>Berginus maindroni</i>	Coleoptera	Mycetophagidae
13.	<i>Silvanus iyeri</i>	Coleoptera	Cucujidae
14.	<i>Tribolium ferrugineum</i>	Coleoptera	Tenebrionidae
15.	<i>Phyllodromia humbertiana</i>	Dictyoptera	Blattellidae
16.	<i>Ischnoptera fulvastrata</i>	Dictyoptera	Blattellidae

Among the above mentioned predators, ***Eublemma amabilis*** and ***Pseudohypatopa pulvereana*** are the most destructive key pests of lac insects and are in regular occurrence but their incidence may vary from season to season, place to place and crop to crop.

***Eublemma amabilis*:**

It is the most destructive predator of lac insect and causes most damage during *Katki* and *Aghani* lac crops i.e. during the rainy season in comparison to the other two crops.

Life history

The female moth lays grayish-white, flat round eggs, deposited in the center with beautiful sculpturing on the chorion. The eggs are laid singly on cell of the lac insect. Newly emerged larva is about 0.51 to 0.54 mm in length. It is creamy-white and pinkish in colour. The larva enters the lac insect either through the openings in the cell or by tunneling hole through the encrustation. Mature larva measures about 9 to 11 mm in length and dirty yellowish-white in colour. Head is dark brown in colour and partly retractable in the prothorax. A single larva can destroy 40 to 60 lac insect cells in its whole larval period. It has six generations in a year and the duration of the generations is about 37, 45, 42, 125, 80 and 40 days, respectively. Attacked lac cells can easily be identified because of its pinkish colouration due to presence of pink coloured discs of excreta inside the hollow lac cells. Pupa is on obtect, adecticous type and dark brown in colour. Adult is white-pinkish in color.

Pseudohypatopa pulvereana

It is also destructive predator of lac insects and found in all lac growing areas of the country. It feeds on the live and dead lac insects and found in large numbers in stored lac and so it is responsible for the qualitative and quantitative deterioration of stored lac.

Life history

It lays oval (0.5 mm x 0.3 mm) colourless eggs on the cell of lac insects singly. Normally larvae pass through five instars but the hibernating larvae have nine instars. The newly hatched larva is about 1.35 mm long whereas a mature larva is 10 to 12 mm in length and 2 mm in breadth. Larva feed on the lac larvae and spins a loose web. A single larva is capable of destroying 45 to 60 mature lac cells.

Management of insect enemies:

Preventive measures:

- Only healthy, **pest-free brood lac** should be used for inoculation.
- The twigs for inoculation should be cut just before swarming to get healthy brood.
- Entire crop should be harvested at the maturity.
- Self inoculation of lac crops should be avoided as far as possible.
- Inoculated brood bundles should be kept on the host tree for a minimum period only.
- Phunki (empty brood lac sticks) should be removed from the inoculated trees within 2 to 3 weeks.
- All lac cut from the tree and all phunki should not use for brood purpose, it should be scraped or fumigated or immersed in water to kill the pest.
- Stick lac should be scrapping as soon as possible and should be processed immediately to convert into seed lac.
- Infected stick lac should be treated with fumigant insecticide along with predators and pests.
- Remove eggs of *Chrysoperla* from the plant or lac cells time to time.
- Regular monitoring is necessary for observation of any deformity or attack of insect pest.
- Cultivation of kusumi strain of lac should be avoided in predominantly rangeeni area and vice- versa.

Mechanical control:

Uses of 60 mesh synthetic netting (brood bag) to enclose brood lac for inoculation purposes which can reduce infestation of insect enemies of lac insect. The emerging lac larvae easily crawl out from the minute holes of the net and settle on the twigs of the lac host plants, whereas the emerging adult predator cannot comes out of the brood bags and get entrapped within the net. This can check the egg laying by the predator moths on the new crop.

Chemical control:

- Spraying should be done on the culture of lac insect settled on shoot and not over leaves or shoot without lac insect. Avoid pesticide spray at male emergence.
- First spray should be done at one month after inoculation with ethofenprox 10EC with 0.02% or cartap hydrochloride 50SP with 0.05%.
- Second spray after one month from the first spray, if necessary.
- Spraying should be done only before male emergence period or when fertilization is completed.
- For summer crop of *Rangeeni (Baisakhi)*: cartap hydrochloride 50SP with 0.05% (10g in 10 liter of water) or ethofenprox 10EC with 0.02% (20ml in 10 liter of water) at one month of inoculation sometimes in November and second spray in January or March (no spray between 105 to 125 days during *Baisakhi* and 42 to 58 days of inoculation for *Katki* crop).
- Summer crop of *Kusmi (Jethwi)*: ethofenprox 10EC with 0.02% (20ml in 10 liter of water) on one month and two month after inoculation or larval emergence (No spray between 65 to 90 days of inoculation).

- Winter crop of *Kusmi (Aghani)*: cartap hydrochloride 50SP with 0.05% (10g in 10 liter of water) or ethofenprox 10EC with 0.02% (20ml in 10 liter of water) + carbendazim 50WP with 0.01% (2g in 10 liter of water) on one month after inoculation. Repeat same after one week (second spray) and third spray on two month after inoculation, if lac crop is attacked by *Chrysoperla sp.* and fungi (No spray between 40 to 58 days of inoculation).
- Spray carbendazim 50WP with 0.01% (2g in 10 liter of water) only, especially in rainy season or during cloudy weathers at the interval of 15 days but not during mating period.
- For *Chrysoperla* spray dichlorovos 76%EC with 0.03% (4 ml in 10 liter of water).

Microbial control

Use of biopesticide, Thuricide (*Bacillus thuringiensis*) at 30 to 35 days stage of crop is the effective microbial control measure for important enemy insects of lac in field condition.

Biological control

Two predatory ants viz. *Camponotus compresus* and *Solenopsis geminate rufa* are the most important and promising for biological control of predator enemies of lac in field condition.

Egg parasitoids viz. *Trichogramma pretiosum*, *T. chilonis*, *T. poliae*, *Trichogrammatoidea bactrae* and *Telenomus remus* have been found to be effective in management of lac predators.

5. HARVESTING:

Harvesting is the process of collection of lac from host trees. Two type of harvesting process is used in most of the regions; Ari lac harvesting and mature harvesting. It is done by cutting the lac encrusted twigs when is crop is mature. It may be of two types:

A. Ari lac harvesting

Immature harvesting and collection of lac before swarming is known as ‘Ari lac’. The immature harvesting has drawbacks, as the lac insects may be damaged at the time of harvesting. However, in case of rangeeni lac it is found that ari lac gives better production. Hence, ari lac harvesting is recommended in case of rangeeni only.

B. Mature harvesting

In mature harvesting lac is collected after swarming. The lac obtained is known as mature Lac. To know the exact date emergence and swarming of nymph a simple visual method is adopted. **A yellow spot develops on the posterior side of lac cell towards crop maturity.** This spot spread forwards until it covers half of the cell. Cutting of twigs for harvest can be done at any time between the stages while yellow spot occupies one third to one half of the cell area. It is sometimes desirable to wait till the emergence of the first few nymphs. The harvesting periods of different crops are different. The katki crop is harvested in Oct. /Nov.; baisakhi in May/June; Aghani in Jan/Feb.; and Jethwi in June/July.

Mature lac harvesting is of two types in practice as:

a. Partial harvesting: This harvesting is performed when surplus brood lac is on the tree and sufficient branches are available on the tree for next generation.

- It should be done in the month of January/February or June/July whenever larval emergence starts from kusum tree.

- One should harvest lac encrusted shoots from places where there is no further space for the insect settlement.
- While harvesting leave lac encrusted twigs at places where space for lac insect settlement is available.

b. Complete harvesting: In this process lac is fully harvested from the plant and plant is pruned and left for new shoot emergence.

Following consideration are recommended for harvesting:

- Lac crop should be harvested only when mature. Immature or Ari lac cutting should be avoided, though it is recommended in case of rangeeni. Secateur should be preferred for harvesting of broodlac.
- A mature crop is said to be the one from which nymphs will emerge in 7 to 10 days. So, the crop should be harvested within the above said days prior to nymphal emergence. If cutting earlier there is a chance of nymphs dying. If cutting is late the nymphs may already have emerged before inoculation is adopted.
- Attempt should be made to reap the entire crop if self inoculation is not required. In the case of *rangeeni* crop only lac encrusted twigs are cut, while in the case of *kusumi* one, reaping should combine with pruning.
- The brood sticks harvested should be utilized for inoculation as soon as possible. If storage is needed these have to be stored in a well ventilated room or under shade in open prevented from rain and heat.
- Harvesting of lac crop at maturity can solve the crisis of brood lac dearth to a large extent without affecting the quality of lac obtained as phunki lac. This will also reduce the loss of brood lac and enhance the yield.
- The pruning should be done as per pruning methodology described earlier while harvesting from kusum.

6. Scrapping

Removal of lac resin incrustation from lac host stick is called scraping. After harvesting of matured lac and sometime immature lac is need to be scraped as primary processing for long time storage. This practice is done with the help of scraping knife. Scraping of stick lac has following benefits:

- Help for quick dry and minimize the moisture content
- Save the lac loss from lac predators
- Easy storage
- Escape from fungal attack
- Hidden insect stages can be killed and removed
- Increases the storage life

Part-IV: Predators and Parasitoids

(Predators and parasitoids used in pest control programme)

Introduction:

A large numbers of predators, parasitoids, bacteria, fungus, and viruses regulate the population of insect pests under natural field condition. Biological control came into prominence in recent times owing to some spectacular success achieved in various parts of the world. Biological control is a process in which one species population lowers the numbers of another species by mechanisms such as predation, parasitism, pathogenesis or competition or Biological control involves use and manipulation of natural enemies by man.

History of biological control:

- 900 AD- First use of red ant, *Oecophylla smaragdina* to control leaf chewing insects on mandarin trees.
- 1200 AD- Ants were used for control of date palm pests in Yemen (south of Saudia Arabia). Usefulness of ladybird beetles recognized in control of aphids and scales.
- 1602 - Aldrovandi noted the hymenopteran parasite, *Apanteles glomeratus* laying eggs in the pupae of the cabbage butterfly, *Pieris brassicae*.
- 1726- The first insect pathogen was recognized by de Reaumur. It was a *Cordyceps* fungus on a noctuid.
- 1762 - Indian mynah bird, *Gracula religiosa* exported from India to Mauritius to control red locust, *Nomadacris septemfasciata*.
- 1776- Control of the bedbug, *Cimex lectularius*, was successfully accomplished by release of the predatory pentatomid, *Picromerus bidens* in Europe.
- **In 1868 Cottony cushion scale, *Icerya purchasi* Maskell**, was introduced into California in ca. around the Menlo Park (CA) area (near San Francisco) by 1887 it spread to southern California. C. V. Riley (Chief of the Division of Entomology, USDA) employed Albert Koebele and D. W. Coquillett in research on control of the cottony cushion scale and found no methods to control.
- In 1888- Koebele was sent to Australia to collect natural enemies of the scale, He sent ca. 12,000 individuals of *Cryptochaetum iceryae* and 129 individuals of *Rodolia cardinalis* (the vedalia beetle)
- **1888- Vadalial beetle, *Rodolia cardinalis*** was brought from Australia and introduced into California (Control) cottony cushion scale, *Icerya purchasi* on citrus. It's a first well planned and successful classical biological control attempt made Overview of The Cottony Cushion Scale Project.
- 1898- Austalian *Cryptlaemus montrouzieri* in India on *Coccus viridis*.
- 1902- The Lantana Weed Project in Hawaii (1902) first published work on BC of weeds.
- 1911- Berliner described *Bacillus thuringiensis* as causative agent of bacterial disease of the Mediterranean flour moth.
- 1919- USDA laboratory for biological control established in France.
- 1920 - A parasitoid *Aphelinus mali* introduced from England into India to control Woolly aphid on Apple, *Eriosoma lanigerum*.
- 1927- The Imperial Bureau of Entomology created the Farnham House Laboratory for BC work in England.

- **1929-31 - *Rodolia cardinalis* imported into India (from USA) to control cottony cushion scale *Icerya purchasi* on Wattle trees.**
- 1930 to 1940- Peak in BC activity in the world (57 different natural enemies established) World War II caused a sharp drop in BC activity with switch to pesticide research.
- 1947- The Commonwealth Bureau of Biological Control (CBBC) was established.
- 1951- CBBC renamed as Commonwealth Institute for Biological Control (CIBC). Headquarters are currently in Trinidad, West Indies.
- 1955- The Commission Internationale de Lutte Biologique contre les Enemis des Cultures (CILB) was established.
- 1958-60 - Parasitoid *Prospatella perniciosus* imported from China.
- 1960 - Parasitoid *Aphytis diaspidis* imported from USA both parasitoids used to control Apple Sanjose scale *Quadraspidotus perniciosus*.
- 1962- The CILB changed its name to the Organization Internationale de Lutte Biologique contre les Animaux et les Plantes Nuisibles. Also known as the International Organization for Biological Control (IOBC).
- 1964 - Egg parasitoid *Telenomus sp.* imported from New Guinea to control Castor semilooper *Achaea janata*.
- **1964- Paul DeBach** and Evert I. Schlinger (Division of Biological Control, University of California, Riverside) published an edited volume titled “Biological Control of Insect Pests and Weeds”.
- 1965 - Predator *Platymerus laevicollis* introduced from Zanzibar to control coconut Rhinoceros beetle, *Oryctes rhinoceros*.

Classical biological control achieved in India

Definition: Classical biological control (CBC) is defined as the introduction of a natural enemy of exotic origin to control a pest, usually also exotic, aiming at permanent control of the pest.

Successful examples of examples:

- 1795- Cochineal insect, *Dactylopius ceylonicus* was introduced from Brazil against carmine dye producing insect, *D. coccus*.
- 1921- the agromyzid seedfly, *Ophiomyia lantanae* against *Lantana camara* from Hawaii (origin: Mexico) and released in south India.
- 1926- The coccinellid beetle, *Rodolia cardinalis* against cottony cushion scale, *I. purchasi*
- 1941- Tingid lace bug, *Teleonemia scrupulosa*, against *L. camara* from Australia.
- 1951- *C. Montrouzieri* against mealy bugs.
- 1963- The gallfly, *Procecidochares utilis* against Crofton Weed, *Ageratina adenophora* from New Zealand to Nilgiris (Tamil Nadu), Darjeeling and Kalimpong areas (West Bengal).
- **1979 to 1982- An ectoparasite, *Epiricania melanoleuca* Fletcher was introduced from Ravalgaon (Maharashtra) and Karnal (Haryana) against of *Pyrilla perpusilla* Walker in South Gujarat of India. Now, this parasitoid is well established in sugarcane ecosystem.**
- 1982- Three exotic natural enemies were introduced viz., hydrophilic weevils – *Neochetina bruchi* (Ex. Argentina) and *N. eichhorniae* (Ex. Argentina) and galumnid mite *Orthogalumna terebrantis* (Ex. South America) against water hyacinth.
- 1983-1984- Exotic weevil, *C. Salviniae* from Australia against water fern, *Salvinia molesta* in a lily pond in Bangalore.

- 1983- The encyrtid parasitoid *Leptomastix dactylopii* against *Planococcus citri* and *P. lilacinus* from Trinidad, West Indies.
- 1983-A chrysomelid beetle *Zygogramma bicolorata* against **parthenium from Mexico.**
- 1988- The coccinellid predator, *Curinus coeruleus* against *H. cubana* from Thailand.
- 2010-Three exotic encyrtid parasitoids viz., *Acerophagus papayae*, *Anagyrus loecki* and *Pseudleptomastix mexicana*, against papaya mealybug, *Paracoccus marginatus*.

RESEARCH AND TRAINING INSTITUTES ON BIOLOGICAL CONTROL IN INDIA

National Bureau of Agricultural Insect Resources (NBAIR), formerly **National Bureau of Agriculturally Important Insects (NBAII)** is located in **Bangalore**, Hebbal in the same premises at which The Commonwealth Institute of Biological Control (CIBC), Indian Station was established in 1957. The advent of CIBC marked the beginning of organized and systematic biological control research in India. During this period, our knowledge of natural enemies of crop pests and weeds increased manifold. CIBC Indian station was closed during 1987 and All India Coordinated Research Project on Biological Control of Crop Pests and Weeds (AICRP-BC&W), which was launched in 1977 under the aegis of the Indian Council of Agricultural Research was shifted to the same campus in 1988. The centre was named as Biological Control Centre and the entire programme functioned under the administrative/financial control of the National Centre for Integrated Pest Management (ICAR). In the eighth five-year plan, the project was elevated to an independent Project Directorate of Biological Control, with its headquarters in Bangalore during 1993. PDBC was the nodal agency in the country that organizes biological control research at the national level with 16 centres spread across the country. The Directorate at Bangalore carried out basic research on the biosystematics of important groups of insect bioagents. The reference collection maintained at PDBC was catalogued in the form of a technical bulletin on and also available in a retrievable, electronic format. Besides, work on strain development, molecular characterization, mass production technologies, semiochemicals, biopesticides work for insect and disease management was intensified. During 11th plan, PDBC was upgraded as National Bureau of Agriculturally Important Insects (NBAII) to act as a nodal agency for collection, characterization, documentation, conservation, exchange and utilization of agriculturally important insect resources (including mites and spiders) for sustainable agriculture. In the twelfth five year plan the Bureau is now re-named as National **Bureau of Agricultural Insect Resources (NBAIR)** and the bureau's activities are divided in three divisions.

In Gujarat, Department on Entomology, N.M. College of Agriculture, Navsari Agricultural University, Navsari is working on biological control of crop pests under Plan scheme (Development Charges) Project entitled “**Strengthening Research in Biological Control of Crop Pests**” since 2007-08. Moreover, at AAU, Anand (Gujarat) is working on ICAR sponsored “**All India Coordinated Research Project (AICRP) on Biological Control of Crop Pests and Weeds**” since 1977.

Definitions of biological control:

1. H. S. Smith (1919) defined First used term "**biological control**" to signify the use of natural enemies (whether introduced or otherwise manipulated) to control insect pests.
2. **Biological control** is defined as the action of parasites, predators, or pathogens in maintaining another organism's population density at a lower average than would occur in their absence (Paul DeBach, 1964).

3. Van den Bosch *et al.* (1982) defined the **applied biological control** as the "manipulation of natural enemies by man to control pests. They further noted **natural biological control** as that "control that occurs without man's intervention.

Important terminologies:

Biological control: Biological control is a process in which one species population lowers the numbers of another species by mechanisms such as predation, parasitism, pathogenesis or competition or Biological control involves use and manipulation of natural enemies by man.

Biological control practices involves three major techniques (Three pillars)

1. **Introduction or classical biological control:** It is the deliberately introduction and establishment of natural enemies to a new locality where they did not occur or originate naturally. When natural enemies are successfully established, it usually continues to control the pest population.
2. **Augmentation:** It is the rearing and releasing of natural enemies to supplement the numbers of naturally occurring natural enemies. There are two approaches to augmentation.
 - **Inoculative releases:** Large numbers of individuals are released only once during the season and natural enemies are expected to reproduce and increase its population for that growing season. Hence control is expected from the progeny and subsequent generations and not from the release itself.
 - **Inundative releases:** It involves mass multiplication and periodic release of natural enemies when pest populations approach damaging levels. Natural enemies are not expected to reproduce and increase in numbers. Control is achieved through the released individuals and additional releases are only made when pest populations approach damaging levels.
3. **Conservation:** Conservation is defined as the actions to preserve and release of natural enemies by environmental manipulations or alter production practices to protect natural enemies that are already present in an area or non use of those pest control measures that destroy natural enemies.

Important conservation measures are: Use selective insecticides which are safe to natural enemies. Avoidance of cultural practices those are harmful to natural enemies and use favorable cultural practices. Cultivation of varieties those favour colonization of natural enemies. It will provide the alternate hosts for natural enemies. Preserve the inactive stages of natural enemies. Provide pollen and nectar for adult natural enemies.

- **Predator:** A predator is free living organism throughout its life, it kills and prey, is usually larger than its prey and require more than one prey to complete its development. e.g. *Chrysoperla zastrowi sillemi*.
- **Parasitoid:** A parasitoid is a specific kind of parasite which is often about the same size as its host, kills its host and requires only one host (prey) for development in to free living adults. e.g. Braconids wasp.
- **Parasite:** A parasite is an organism which is usually much smaller than its host and a single individual usually doesn't kill the host. Parasite may complete their entire life cycle (eg. Lice) or may involve several host species. OR Parasite is one, which attaches itself to the body of the other living organism either externally or internally and gets nourishment and shelter at least for a shorter period if not for the entire life cycle. The organism, which is attacked by the parasites, is called hosts.
- **Parasitism:** Is the phenomena of obtaining nourishment at the expense of the host to which the parasite is attached.

- **Microbial Control:** When microbial organisms or their product (toxin) are employed by man for the control of insects, animals and plants in particular area, is referred as microbial control e. g. Virus, Bacteria, Protozoa , Fungi, etc.

Qualities of a Successful Parasitoid in Biological Control Programme:

A parasitoid should have the following qualities for its successful performance. It should be adaptable to environmental conditions in the new locally. It should be able to survive in all habitats of the host. It should be specific to a particular species of host or at least a narrowly limited range of hosts. It should be able to multiply faster than the host. It should have more fecundity. Life cycle must be shorter than that of the host. It should have high sex ratio. It should have good searching capacity for host. It should be amenable for mass multiplication in the labs. It should bring down host population within three years. There should be quick dispersal of the parasitoid in the locality. It should be free from hyperparasitoids.

Some successful examples of biological control of insect pests:

1. Control of cottony cushion scale, *Icerya purchasi* on fruit trees by its predatory *Vidalia* beetle, *Rodolia cardinalis* in Nilgiris. The predator was imported from California in 1929 and from Egypt in 1930 and multiplied in the laboratory and released. Within one year the pest was effectively checked.
2. For the biological suppression of Water Fern, *Salvinia molesta*, the weevil, *Cyrtobagous salviniae*, was imported from Australia in 1982. Exotic weevil, *C. salviniae* was released for the control of water fern, *S. molesta* in a lily pond in Bangalore in 1983-84. Within 11 months of the release of the weevil in the lily pond the salvinia plants collapsed and the lily growth, which was suppressed by competition from salvinia resurrected.
3. Biological Control of Water Hyacinth, *Eichhornia crassipes*, three exotic natural enemies were introduced in India viz., hydrophilic weevils - *Neochetina bruchi* and *N. eichhorniae* (Argentina) and gallmid mite, *Orthogalumna terebrantis* (South America) in 1982 for the biological suppression of water hyacinth.
4. Apple woolly aphids, *Eriosoma lanigerum* in Coonor area by *Aphelinus mall* (parasitoid).
5. Control of shoot borers of sugarcane, cotton bollworms, stem borers of paddy and sorghum with the egg parasitoid, *Trichogramma australicum* @ 50,000/ha/week for 4-5 weeks from one month after planting.
6. *Centroccocus isolitus* on brinjal; *Pulvinaria psidi* on guava and sapota; *Meconellicoccus hirsutus* on grape and *Pseudococcus carymbatus* on citrus suppressed by *Cryptolaemus montrouzieri*.

Parasites can be grouped as furnished below;

I. Depending upon the nature of host,

Zoophagous	:	that attack animals (cattle pests)
Phytophagous	:	that attack plants (crop pests)
Entomophagous	:	that attack insects (parasites)
Entomophagous insects	:	parasitoids

II. Based on the specialization of the site of parasitisation

1. **Ectoparasites:** they attack its host from the outside of the body of the host. The mother parasite lays its eggs on the body of the host and after the eggs are hatched the larvae feed on the host by remaining outside only. E.g. *Epiricania melanoleuca*, etc.

2. **Endoparasite:** They enter the body of the host and feeds from inside. The mother parasite either lays its eggs inside the tissues of the host or on the food material of the host to gain entry inside. Eg. Braconids and Ichneumonids, *Apanteles flavipes* on sorghum stem borer larvae.

III. Specialization based on the stage of the host

Eg. Host: Coconut black headed caterpillar, *Opisina arenosella*

1. Egg parasite : *Trichogramma australicum*
2. Early larval parasite - *Apanteles taragama*
3. Mid larval parasite - (*Micro*) *Bracon hebetor*
4. Prepupal parasite - *Goniozus nephantidis*
5. Prepupal parasite - *Elasmus nephantidis*
6. Pupal parasite - *Stomatoceros sulcatiscutellum*, *Trichospilus pupivora*, *Tetrastichus israeli*,

IV. Depending upon the duration of attack

1. **Transitory parasite:** It is not permanent but transitory parasite which spends a few stages of its life in one host and other stages on some other species of hosts or as a free living organism. Eg. Braconids and Ichneumonids.
2. **Permanent parasite:** This spends all the stages of its life on the same host. Eg. Head louse.

V. Depending upon degree of parasitization

1. **Obligatory parasites:** Parasite, which can live only as a parasite and cannot live away from the host even for shorter period. E.g. Bird lice, Head louse.
2. **Facultative parasite:** Parasite, which can live away from the host at least for a shorter period E.g. Fleas.

VI. Depending upon the food habits

1. **Polyphagous:** develops on number of widely different host species E.g. *Bracon* sp. *Apanteles* sp on lepidopteran caterpillars.
2. **Oligophagous:** which has very few hosts (more than one host) but all the hosts are closely related. E.g. *Isotema javensis* on sugarcane and sorghum borers.
3. **Monophagous:** which has only one host species and can't survive in another species i.e. host specific. E.g. *Goniozus nephantidis* on *Opisina arenosella*.

Kinds of Parasitism

- I. **Parasite:** A parasite is an organism which usually much smaller than its host and a single individual usually does not kill the host.
- II. **Super parasitism:** It is type of parasitism where more individuals of the same species are present in a single host and that can complete development in a normal way. Generally survive one per host. Phenomenon of parasitization of an individual host by more larvae of single species that can mature in the host. E.g. *Apanteles glomeratus* on *Pieris brassica*, *Trichospilus pupivora* on *Opisina arenosella*.
- III. **Multiple parasitisms:** It is the type of parasitism where the host is attacked by two or more species of parasitoids. Usually death results in the death of less aggressive species of parasitoids. Phenomenon of simultaneous parasitization of host individual by two or more different species of primary parasites at the same time. E.g. *Trichogramma*, *Telenomus* and *Tetrastichus* attack eggs of paddy stem borer *Scirpophaga incertulas*. Super parasitism and multiple parasitisms are generally regarded as undesirable situations since much reproductive capacity is wasted.

- IV. Hyper parasitism:** It is type of parasitism in which a parasitoid attacks another parasitoid. Secondary parasitoids is harmful, while tertiary useful. When a parasite itself is parasitized by another parasite. E.g. *Goniozus nephantidis* is parasitized by *Tetrastichus israeli*, Most of the Bethyids and Braconids are hyper parasites.
- V. Simple parasitism** irrespective of number of eggs laid the parasitoid attacks the host only once. E.g. *Apanteles taragamae* on the larvae of *Opisina arenosella*, *Goniozus nephantidis*.

Hierarchy of parasitism:

- 1. Primary parasite:** A parasite attacking an insect which itself is not a parasite (Beneficial to man.).
- 2. Secondary parasite:** A hyperparasite attacking a primary parasite (Harmful to man)
- 3. Tertiary parasite:** A hyperparasite attacking a secondary parasite (Beneficial to man)
- 4. Quaternary parasite:** A hyperparasite attacking tertiary parasite (Harmful to man)

A primary parasitoid becomes harmful in case of productive insects like silkworms, *Bombyx mori* and lac insect *Kerria lacca*.

Predators and Predatory mechanism:

A predator is one which catches and devours smaller or more helpless creatures by killing them in getting a single meal. It is a free living organism throughout its life, normally larger than prey and requires more than one prey to develop.

Insect predator qualities:

A predator generally feeds on different species of prey, thus being a generalist or polyphagous nature. A predator is relatively large compared to its prey, which it seizes and devours quickly. Typically individual predator consumes large number of prey in its life time E.g. A single coccinellid predator larva may consume hundreds of aphids. Predators kill and consume their prey quickly, usually via extra oral digestion. Predators are very efficient in search of their prey and capacity for swift movements. Predators develop separately from their prey and may live in the same habitat or adjacent habitats. Structural adaptation with well developed sense organs to locate the prey. Predator is carnivorous in both its immature and adult stages and feeds on the same kind of prey in both the stages. May have cryptic colourations and deceptive markings. Eg. Preying mantids and Robber flies.

Predatory mechanism:

Based on the degree of use fullness to man, the predators are classified as on entirely predatory, E.g. lace wings, tiger beetles lady bird beetles except *Henosepilachna* genus. Mainly predator but occasionally harmful. E.g. Odonata and mantids occasionally attack honey bees. Mainly harmful but partly predatory. E.g. Cockroach feeds on termites. Adult blister beetles feed on flowers while the grubs predate on grass hopper eggs. Mainly scavenging and partly predatory. E.g. Earwigs feed on dead decaying organic matter and also fly maggots. Both ways, it is helpful. Variable feeding habits of predator, E.g. Tettigonidae: omnivorous and carnivorous but damage crop by laying eggs. Stinging predators. In this case, nests are constructed and stocked with prey, which have been stung and paralyzed by the mother insect on which the eggs are laid and then sealed up. Larvae emerging from the egg feed on paralyzed but not yet died prey. E.g. Spider wasps and wasps, etc.

1. Parasitoids Order:

A. Order: Hymenoptera	The ovipositor originates and protrudes ventrally from the abdomen and is used to

	insert eggs into their hosts. There are three super families.
a.	Super Family: Ichneumonoidea • Possess long and filiform antennae. • Wings are veined.
1.	Family: Ichneumonidae • Eg. <i>Eriborus trochanteratus</i>, a larval parasitoid on coconut black headed caterpillar, <i>Opisina arenosella</i>. • Antennae longer with more than 16 segments. • Trochanter two segmented. • Possesses two recurrent veins and rarely one. • Abdomen three times as long as the rest of the body. • Ovipositor longer than the body. • Large slender black, yellow or reddish yellow insects. • Larvae are endo or ecto parasitic on many groups of insects and spiders.
2.	Family: Braconidae • Eg. <i>Bracon brevicornis</i>, a larval parasitoid on <i>O. arenosella</i>, <i>Chelonus blackburni</i>, egg larval parasitoid on cotton spotted bollworms, <i>Earias</i> spp. • Adults are relatively small; body is stouter than ichneumonids. • Abdomen is about as long as the head and thorax combined. • Not more than one recurrent vein. • Adults not as bright as ichneumonids. • Mostly endoparasitic on lepidopteran larvae.
b.	Super Family: Chalcidoidea • Mostly smallest parasitoids and gregarious. • Antennae geniculate. • Abdomen very short or globular with very slender propodeum. • Wings without veins.
1.	Family: Chalcididae • Eg. <i>Brachymeria nephandidis</i> a larval parasitoid on <i>O. arenosella</i>. • Minute insects. • Abdomen humped. • Hind femur enlarged and toothed. • Wings are not folded longitudinally when at rest. • Ovipositor straight and short. • Parasitic on Lepidoptera, Diptera and Coleoptera.
2.	Family: Trichogrammatidae • Eg. <i>Trichogramma chilonis</i>, an egg parasitoid on many lepidopterous pests. • Mostly egg parasitoids. • Minute insects (0.40 to 0.70 mm long) with three segmented tarsi and broad and elongated forewings with rows of microscopic hairs on them. • Hind wings reduced with hairs.
3.	Family: Eulophidae • Eg. <i>Trichospilus pupivora</i> and <i>Tetrastichus israeli</i>, pupal arasitoids on <i>O. arenosella</i>.

	- Adults have four segmented tarsi. - Many have brilliant metallic colouring. - Males of many species have pectinate antennae. - Mostly parasitic on aphids and scales and some are on pupae of Lepidoptera.
c.	Super family: Bethyloidea Smaller than ichneumonoidea and larger than Chalcidoidea.
1.	Family: Bethylinidae: - Eg. <i>Parasierola</i> (= <i>Goniozus</i>) <i>nephantidis</i>, a larval parasitoid on <i>O. arenosella</i>. - Small to medium sized, usually dark coloured wasps. - Females of many species are wingless and antlike in appearance. - In a few species, both winged and wingless forms occur in each sex. - Parasitic on Lepidoptera and Coleoptera.
B.	Order: Diptera
1.	Family: Tachinidae - Eg. <i>Sturmiopsis inferens</i>, a larval parasitoid on sugarcane shoot borer, <i>Chilo infuscatellus</i>. - Large bristle flies. - Eggs may be macrotype or microtype. - Macrotype eggs are laid directly on the host's body usually attached to the neck region by a glutinous secretion. - Eg. <i>Spoggosia bezziana</i> on <i>O. arenosella</i>. - Microtype eggs are laid on the host plant and the host larvae feeding on the plant tissue ingest them.
C.	Order: Lepidoptera
1.	Family: Epiricanidae - Eg. <i>Epiricania melanoleuca</i>. - Parasitic on nymphs and adults of sugarcane leafhopper, <i>Pyrilla perpusilla</i>.

2. Predators Order:

A.	Order: Odonata
a.	Sub order: Anisoptera Eg. Dragon fly Sub order: Zygoptera Eg. Damsel fly - Relatively larger sized insects. - Immature stages are aquatic (naiads) feeding on aquatic insects. - In naiads, labium is modified into a prehensile organ called mask for catching the prey. - Adults feed on midges, mosquitoes, flies and small moths. - Adults are capable of catching prey during flight with the help of basket shaped legs.
B.	Order: Dictyoptera
1.	Family: Mantidae - Preying mantids are large elongate insects. - Nymphs and adults are cryptically coloured with long prehensile raptorial forelegs. - Highly predaceous feeding on variety of insects like flies, grasshopper and many caterpillars Eg. <i>Mantis religiosa</i>.

C.	Order: Hemiptera
1.	Family: Reduviidae • Assassin bugs or cone nose bugs or kissing bugs. • Usually blackish or brownish in colour. • The beak or proboscis is short and three segmented. • Most are predaceous and some are blood sucking. • Both nymphs and adults are predaceous. • Eg. <i>Harpactor costalis</i> on the red cotton bug <i>Dysdercus cingulatus</i>.
2.	Family: Pentatomidae • Stink bugs. • Bugs are shield shaped with 5 segmented antennae. • Some of the species are predaceous on lepidopterous larvae. • Both nymphs and adults are predaceous. • Eg. <i>Eucanthecona furcellata</i> on the larvae of red hairy caterpillar, <i>Amsacta albistriga</i> and gram caterpillar, <i>Helicoverpa armigera</i>.
3.	Family: Belostomatidae • Giant water bug. • Elongate oval and somewhat flattened with raptorial forelegs. • Feed on variety of aquatic insects.
4.	Family: Miridae • Elongated soft bodied insects. • A few species are predaceous. • Eg. Green mirid bug, <i>Cyrtorhinus lividipennis</i> feeds mainly on the eggs and early stage nymphs of green leaf hopper (GLH), brown plant hopper (BPH) and white backed plant hopper (WBPH) in rice.
5.	Family: Veliidae • Ripple bugs. • Aquatic insects living on the surface of water. • Brown or black in colour. • Eg. <i>Microvelia atrolineata</i> feeding on the first instar caterpillar of lepidopteran pests and GLH, BPH and WBPH in rice ecosystem.
D.	Order: Neuroptera
1.	Family: Myrmeliontidae • Ant lions • Larvae construct pit falls and remain buried in the soil. • Feed on the ants and other insects that fall into the pits. • Feed by inserting the mandibulo-suctorial mouth parts into the prey and sucking the internal contents.
2.	Family: Chrysopidae • Aphid wolves aphid lions or green lace wings. • Adults are green in colour with golden or copper colored eyes. • Feed on more than 18 families of insects. • The larvae are predaceous mainly on aphids and also on eggs of lepidopteran insects,

	psyllids, coccids, thrips and mites. • Larvae have sharp mandibles. • The eggs of aphid lions are stalked (pedicellate).
E.	Order: Diptera
1.	Family: Asilidae • Robber flies • Adults are mostly elongate with tapering abdomen. • Body is covered with dense hairs. • Legs are long, strong and well developed. • Adults are predaceous and attack a variety of insects like wasps, bees, grasshoppers, flies etc. • Mouth parts are piercing type. They feed by sucking the body fluid of the prey.
2.	Family: Syrphidae • Hover fly adults are brightly coloured and resemble various bees and wasps. • Good pollinators. • Maggots are green in colour and feed on aphids by sucking their body fluids.
F.	Order: Coleoptera
1.	Family: Coccinellidae • Lady bird beetles • Beetles are small, oval, convex and often brightly coloured. • Grubs are elongate, somewhat flattened and covered with minute tubercles or spines. • Adults and grubs feed on aphids, coccids, mealy bugs, whiteflies and other soft bodied insects. • Except one or two species in the family all are predaceous. • Eg. <i>Rodolia cardinalis</i> on cottony cushion scale, <i>Icerya purchasi</i>.
2.	Family: Carabidae • Ground beetles. • Dark in colour and shiny and somewhat flattened. • Most of them feed on caterpillars. • Eg. <i>Anthia sexguttata</i>, <i>Ophionea indica</i>.
3.	Family: Cicindelidae • Tiger beetles. • Beetles are very active and brightly coloured. • They run and fly rapidly. • Both adults and grubs are predaceous. • Adults capture the prey with sickle shaped mandibles. • Eg. <i>Cichidela</i> spp.
4.	Family: Staphylinidae • Rove beetles. • Eg. <i>Paederus fuscipes</i> feeds on rice leaf folder.
G.	Order: Hymenoptera
1.	Family: Vespidae • Wasps collect various insects and feed their larvae with them.

	• Mud wasps construct nests made of mud and provide caterpillars for the young ones in the nest.
2.	Family: Sphecidae • Digger wasps construct nests made of mud and feed its young ones with insect caterpillars.
3.	Family: Formicidae • About half the members of the family are predaceous upon insects.
H.	Order: Lepidoptera
1.	Family: Pyralidae • Eg. <i>Dipha aphidivora</i>. • Feed on nymphs and adults of sugarcane woolly aphid, <i>Ceratovacuna lanigera</i>. • A single larva of <i>D. aphidivora</i> consumed on an average 6000 sugarcane woolly aphids during its 25 days of total larval period.

PART-IV: PREDATORS AND PARASITOIDS

(MASS PRODUCTION TECHNIQUES OF BIOAGENTS)

Mass production technology:

[1]. Methodology for mass production of *Trichogramma chilonis* Ishii

A large number of Trichogrammatids are reported as egg parasitoids of 200 insect species belonging to 70 families and 8 orders in diverse habitats of the world. In India about 26 *Trichogramma* species are recorded of which *T. chilonis*, *T. japonicum* and *T. achaea* etc. are widely distributed and are key mortality factors for many crop pest. These parasitoids attack eggs of many lepidopterous pest such viz., *Chilo* spp., *Scirpophaga excerptalis*, *Scirpophaga incertulas*, *Helicoverpa armigera*, *Agrotis* spp. *Pectinophora gossypiella*, *Earias* spp., *Chilo partellus* etc. The **Trichogrammatids are minute parasitic wasps measuring 0.40 to 0.70 mm in length**. It completes its developments in about 8-10 days. For mass production of Trichogrammatids, rice moth, *Corcyra cephalonica* is used as laboratory host in India. However, in many European countries, Angoumois grain moth, *Sitotroga cerealella* is used as factitious host for its mass production.

Mass production of *Corcyra cephalonica* (Stainton):

Materials required: Round iron or galvanized trays or rectangular wooden trays, broken grains for sorghum or maize, yeast powder, muslin cloth, oviposition cage provided with an inlet to introduce the moths and the bottom fitted with 40 mesh wire net, moth collecting glass tubes with funnel mouth, plastic tube, wooden racks, petri dishes, oven, honey solution, etc.

Methodology: Broken sorghum or maize grains are first sterilized at 70°C for 2 hours in a hot air oven. Thereafter, the same grain should be conditioned (keep grains for overnight in laboratory) before use. The sterilized grains are mixed with dried yeast powder @ 2 g/kg and 2.5 kg grains are kept in each tray. One cc eggs of *Corcyra* are sprinkled in each tray and kept for development. The tray are covered with a thick cloth or kept open in a low roofed rearing room. After emergence larvae feed on the grains and pupate inside the tray itself. The moth emergence starts from 30th day onwards. The moths are collected daily and in oviposition cages for deposition. The moths lay most of the eggs within 3 days after emergence. The eggs are collected from the oviposition cages early in the morning and are used for the multiplication of *Trichogramma*.

Mass production of *Trichogramma chilonis* Ishii

Materials required: Glass jar/plastic bottles for keeping (exposed/parasitized) egg cards, egg cards, petri dishes, measuring cylinder, sieves, plastic trays, microscope, UV chamber, gum, camel hair brush, etc.

Methodology: The *Corcyra* eggs are obtained by confirming the moths in an oviposition cage. The eggs collected are passed through 25, 30 and 40 mesh sieves and run over a slope of paper to eliminate dust particles and scales of *Corcyra*. The eggs are exposed to ultra violet rays (15 Wt UV tube) for 30 minutes in UV chamber to kill the embryo. The sterilized egg are filled in plastic vial (9x5 cm) and closed with a lid of wire mesh (40 mesh) for uniform spreading on cards pasted with a thin layer of dilute gum, *Acacia*. The eggs are glued to Trichocards of 15 x 10 cm size which are perforated to obtain 10 pieces (measuring 2.5 cm) leaving uncovered one end to facilitate stapling. The cards are placed in plastic bottles in which freshly emerged parasitoids are present or place the parasitized egg cards from which adult emergence is expected in a day. Host parasitoid ratio of 6:1 is to be maintained to avoid super parasitism. The jars/bottles are kept at 27± 2° C. Normally the eggs are exposed for parasitization for 24 to 48 hours. Parasitized eggs

start turning black on 3rd day after parasitization. Normally 80 to 90 % parasitization is expected in healthy culture. Parasitized egg cards can be stored in refrigerator at 12-15°C for 10 to 15 days. Prolonged storage will impair emergence, longevity and fecundity of the progeny. Only freshly laid eggs are preferred by *Trichogramma* female for oviposition.

Transport of egg cards:

The parasitized egg cards can be easily transported in the pupal stage (3 days after parasitization) by folding the cards and kept in polythene bags.

Release of *Trichogramma* in field:

The parasitoid may be released in the field as adults or the parasitized egg cards and it may be stapled to the underside of the leaves of crop plant by keeping eggs side on ground direction. The egg card can also be kept in plastic release boxes fitted with wire mesh at the bottom for adult emergence. The boxes may be either fixed on wooden poles or hung on host plant. The trichocards may be cut in to pieces through markings and hanged under plastic cup tied in inverted manner below plant twig.

Precautions:

It is advisable to observe the following precautions during packaging and release of *Trichogramma* for better results.

- Trichocards should be packed keeping the surface with the parasitized eggs on the inner side.
- Emergence date should be specified on cards for the guidance of the end user.
- Cut pieces of Trichocards should be stapled on the inner side of leaf to avoid direct sunlight.
- Card pieces should be stapled in morning hours just before emergence to avoid predation.
- If adults of *Trichogramma* are to be released, the farmers should open the jar containing adult trichogrammatids and go on tapping the jar till all the adults fly out while walking in the field.
- Refrain from using pesticides for a week in the field where *Trichogramma* are released. If need arises use botanical or selective/safer insecticides.

[2] Methodology for mass production of *Chrysoperla zastrowi sillemi*:

Sucking pests cause serious losses to many field, plantation and horticultural crops. Green lace wing (Aphid lion), *Chrysoperla zastrowi sillemi* is a potent predator of many sucking pests. The mass production technique of a predator is given below:

Materials required: *Corcyra cephalonica* rearing unit for the egg production, nucleus culture of *Chrysoperla spp.*, rearing trays, plastic jars, slotted angle iron racks, working tables, weighing balance, scissors, brushes, cotton wool, forceps, tissue paper, brown paper separators, Foam sheet, sponge, acrylic sheet, Fructose, protinex, honey, yeast, castor, pollen, etc.

Methodology: Steps involved in mass rearing of *Chrysoperla zastrowi sillemi*

- Conceal 200 pairs of adults in oviposition case, measuring 75 x 30 x 30 cm. The sides of the cage are lined with smooth nylon wire mesh (not preferred for egg laying) and the sliding top cover is fitted with **black cloth for obtaining eggs**. To prevent damage to the eggs, the top is slides over a comb fitted on both the sides of the cage. The sliding top cover is replaced on alternate days starting from 4th day onwards. The oviposition cage is kept for 30 days and the dead adults are removed every alternate day.

- The adults in oviposition cage are fed on alternate days on cotton wool swabs soaked with the ingredients in a proper way viz., Drinking water, Honey 50% solution, Protinex mixture (equal quantity of protinex + fructose + powdered yeast dissolved in small quantity of water). Two swab of each of the three liquid should be hanged in case with the help of thread and thin iron wire. If sometime such case is not available, the emerged adults may be kept in desiccators or plastic jar containing honey solution soaked cotton wicks and closed with black cloth. Keep in side cotton leaves or tissue paper or brown paper or black paper for oviposition.
- One day old eggs (Egg chorion gets hardened) are dislodged from the black cloth top cover of oviposition cage by gently moving a piece of sponge. Thus, eggs collected can be used for further multiplication.
- Since the larvae of chrysopids are cannibalistic, rear them individually in plastic louvers/vials or in hexagonal cells. Place a foam sheet of the convenient size in the plastic rearing tray. Then, put the paper separators having hexagonal cells on the foam. Sprinkle about 300 to 400 *Corcyra* eggs (already inactivated by exposure to 15 W UV light for an hour) in each hexagonal cell. Introduce 3 day old 1-2 Chrysopid eggs / hexagonal cell. The cover may be secured with the help of lid of the tray. Small opening at the centre of the lid should be provided with wire mesh for aeration.

Utilization for field release and dose: Normally Chrysopids are released in the fields in its 1st instar larval stage against different field crops at the rate of 50,000 to 1, 00,000 larvae/ha or 10-20 larvae/fruit plants. Depending upon pest saturations, 2 releases at fortnightly interval are recommended for control of sucking pests and early instar larvae of Lepidopteran pests.

Methods of release: The *Chrysopid* larvae can be released in the field by;

- Broadcasting larvae with saw dust on thick crop canopy.
- Stapling of Chrysopa card as per the methodology suggested for Trichocards.
- Dropping 1 or 2 larvae per plant on leaves or 10-20 larvae/tree placing corrugated paper strip on the plants/trees or the eggs mixed in saw dust are dropped on crop canopy.

Precautions:

- Rear the grub stage individually to avoid cannibalism.
- Release should be made in early morning hrs to settle larvae on crop canopy.
- Avoid to release freshly laid eggs as they may be parasitized or predated in more numbers in the field.
- Do not use pesticides in the field where the predators are released: otherwise use selective/safer pesticides after or before 10-15 days of release following strip or staggered spray method.

[3] **Methodology for mass production of *Cryptolaemus montrouzieri* Mulsant:**

C. montrouzieri has been introduced from Australia for the control of *Coccus viridis* on coffee. But the predator has established on many species of mealy bugs and green shield scale. In the field its practical use for the suppression of mealy bugs viz., pink mealy bug, *Maconellicoccus hirsutus*, citrus mealy bug *Planococcus citri*, tailed mealy bug, *Ferrisia virgata* and mealy scale *Pulvinaria maxima* on citrus, coffee, grapes and several other fruit crops and ornamentals has been demonstrated. Use of *C. montrouzieri* is the breakthrough in applied classical biological control.

Production procedures of predator:

In the laboratory, the life cycle is completed within approximately 30 days. The pre-mating and pre-oviposition periods are about 5 and 10 days, respectively. The oviposition is about 10 days. Eggs are laid from late evening to early morning. They are pale yellowish white, the surface being smooth and shiny. It is oval to cylindrical, both the ends being smoothly rounded. Incubation period ranges from 5 to 6 days but extended in winter months. Viability of eggs is 90-100%. The newly hatched grub is sluggish but becomes active after 3 to 4 hours. The tiny grub is pale grayish with white lines across the body along intra segmental regions. These white lines become prominent after few hours and white wax strands develop after a day. The grub has four larval instars, and the larval stage occupies about 20 days. They feed on all stages of mealy bugs. Duration of first, second, third and fourth instar grubs are 3-4, 4, 4-5 and 7-8 days, respectively. Grownup grubs are entirely covered with white wax strands. When the grub is disturbed, it exudes a yellow fluid from the dorsal surface of the body for defensive purpose. The pre-pupal period is 2 to 4 days when it suspends feeding activities. The pupal period varies from 7 to 9 days.

The adult spends about one day in the pupal case before it emerges. It is covered with a white powder like substance for a day. The male could be distinguished from the female by the colouration of first pair of legs. The first pair of legs in the case of male is brown and the latter two pairs being black, whereas in the female all the three pairs are black. Male to female ratio is 1: 1. Adults are also known to attack and feed the mealy bugs. Longevity of adults ranges from 50 to 60 days and the fecundity is about 200-220 eggs.

Feeding behaviour:

Both adults and grubs are predating almost all stages of the mealy bug. However the grubs are voracious feeders. The coccinellid grub consumes a total of 900 to 1500 mealy bug eggs in its development. A single grub can eat as many as 30 nymphs or 30 adult mealy bugs. Fourth instar grub is the most voracious feeder of the mealy bugs. After 15 days of infestation of pumpkins with bugs they are exposed to a set of 100 beetles for 24 hrs. After exposing, the pumpkin is kept back in a cage as described for under production of *M. hirsutus*. The beetle during the period of exposure feed on mealy bugs as well as deposits their eggs singly or in groups of 4-12. The grubs are visible in such cages within a week of exposure to beetles. The young grubs feed on eggs and small mealy bugs but as they grow they become voracious and feed on all stages of mealy bugs. For facilitating the pupation of grubs dried guava leaves or pieces of papers are kept at the base of each of the cages. The first beetle from the cages starts emerging on 30th day of exposure to *C. montrouzieri* adults. The beetles are collected daily and kept in separate cages for about 10-15 days to facilitate completion of mating and pre-oviposition. The beetles are also fed on diet containing agar powder (1 g), sugar (20 g), honey (40 cc) and water (100 cc). The adult diet is prepared by boiling sugar in 70 ml of water, adding 1 g agar, diluting 40 ml honey in 30 ml of water and adding to the sugar and agar mixture when it comes to boiling point. The hot liquid diet is kept on small white plastic cards in the form of droplets which get solidified on cooling. Such cards containing adult diet can be fed not only to *C. montrouzieri* but also to many other species of coccinellids. From each cage about 175 beetles are obtained. The emergence of the beetles is completed within 10 days. Beetles can also be reared on *Corcyra cephalonica* eggs but empty ovisacs of *Planococcus citri* are to be kept for inducing egg laying by the beetles.

Precautions:

All due precautions should be taken to avoid scarcity of food for the grubs to avoid cannibalism by grubs. All the pumpkins showing signs of rotting should be properly incinerated.

Storage of lady bird beetle:

Eggs/larvae are not advisable for storage.

Adult: Keep them in transparent container of about 2 l capacities. Keep artificial diet in the container. Store under refrigerator conditions at $7 \pm 1^\circ \text{C}$ temperature. A total of 150-200 adults can be stored in one container.

Transportation:

Larvae: Keep the larvae in specially made plastic capsules having some diet and minute holes for aeration. Take all required precautions/cares.

Handling, storage and transportation of important bio-agents:

Care requires: A material of bio-agents should be live, it should not be adversely affected by other biotic factors and it should fulfill requirement of farmers. Bio-agents should be taken care of for taxonomical studies, educational studies, bio-assaying studies. It should be capable of introduction/inundative/inoculative releases. It should be re-cultured and capable of redistribution.

Shipment of bio agents: To dispatch of bio-agents from one place to another place is known as introduction. For insects which are produced from the laboratory or collected from the field are usually shipped. The insects collected from field in mass usually used for rearing/mass multiplications. Insects are transported or sent in a plastic/paper container with good perforation. If the insects are transported in plastic container keep some pieces of tissue papers to provide crawling surface and to absorb excess moisture.

General cares while transporting bio-agent: Provide crawling surface by adding creased/crumpled tissue paper or towel. Remove excess moisture from containers. Provide adequate ventilation by creating punch holes on lids with pin/needle for breathing. Predators like spider/ants should not be trapped while sorting/packaging in the containers. Do not expose bio agents to heat above 80°F , keep container at cool places and out of direct sunlight. Provide sugar cubes/honey soaked moist sponge when adults are shipped. Containers should be sealed with adhesive tape to avoid entry of ants. Container/packets to be labeled with red bold letter with red pen as **HANDLE WITH CARE, DON'T EXPOSE TO SUN' INSECTS OF GREAT SCIENTIFIC VALUE**. To be sent by personal message through courier/private vehicle or speed post or air-mail or any other fast mode of transport. If it is sent out side India a custom clearance certificate is requires pasting on container/consignment. It should be sent through quarantine department. There should not be presence of any hyper parasite in the container.

PART-IV: PREDATORS AND PARASITOIDS....continue
(IDENTIFICATION OF OTHER IMPORTANT POLLINATORS, WEED KILLERS AND SCAVENGERS)

I. Pollinators:

A pollinator is the biotic agent (vector) that moves pollen from the male flower to the female flower to accomplish fertilization.

Role of pollinators:

- Pollination refers to the transfer of anther to stigma in flowering plants for sexual reproduction.
- An insect plays great role in cross-pollination of fruits, vegetables, ornamentals, cotton, tobacco, sunflower and many other crops.
- Insect pollination helps in uniform seed set, improvement in quality and increase in crop yield.

Entomophily refers to cross pollination aided by insects

Pollination	Type of insects
Melitophily	Bees
Cantharophily	Beetles
Cantharophily	Syrphid and Bombylid flies
Sphigophily	Hawk moths
Phalaeophily	Small moths

1. Honeybees as pollinators

- All bee species aid in pollination
- Value of honey bees in pollination is 15-20 time higher than that of the honey and wax it produces.

Crop	Per cent increase in yield due to bee pollination
Mustard	43 %
Sunflower	32-48 %
Cotton	17-19 %
Lucerne	112 %
Onion	93 %
Apple	44 %
Cardamom	21-37 %

2. Hoverflies *Syrhus sp.* (Syrphidae: Diptera)

- Brightly coloured flies
- Body is striped or banded with yellow or blue
- Resemble bees and wasps
- Larval stage predatory, adults are pollinators
- Crops pollinated – carrot, cotton, pulses

3. Carpenter bee, *Xylocopa sp.* (Xylocopinae: Anthophoridae)

- Robust dark bluish bees with hairy body
- Dorsum of abdomen bare, pollen basket absent
- Adults are good pollinators
- Construct galleries in wood and store honey and pollen

4. Digger bees, *Anthophora sp.* (Anthophoridae: Hymenoptera)

- Stout, hairy, pollen collecting bees
- Abdomen with black and blue bands

5. Fig wasp, *Blastophaga psenes* (Agaonidae: Hymenoptera)

- Fig is pollinated by fig wasp only.
- There is no other mode of pollination.
- There are two types of fig **CAPRI FIG and SMYRNA FIG.**

CAPRI FIG	SMYRNA FIG
• It is a wild type of fig-not edible • Has both male and female flowers • Pollen is produced in plenty • Natural host of fig wasp	• It is the cultivated type of edible fig • It has only female flowers • Pollen not produced • Not the natural host of fig wasp

In fig wasps males are wingless, present in Capri fig and females winged. Female wasp lays eggs in Capri fig, larvae develops in galls in the base of the flowers. Male mates with female even when the female is inside gall. Mated female wasp emerges out of flower (Capri fig) with lot of pollen dusted around its body. The female fig wasp enters Smyrna fig with lot of pollen and deposits it on the stigma. But it cannot oviposit in the ovary of smyrna fig which is deep seated. It again moves to Capri fig for egg laying. In this process Smyrna fig is pollinated. Capri fig will be planted next to Smyrna fig to aid in pollination.

6. Oil palm pollinating weevil: *Elaeidobius kamerunicus* (Curculionidae: Coleptera)

- Aid in increasing oil palm bunch weight by 35 per cent and oil content by 20 per cent.

7. Other Pollinators

- Butterflies (e.g. *Deilaphila* spp.) and moths (*Acherontia* spp.)
- Ants, flies, stingless bees, beetles, etc.

II. Weed Killers:

Few insects are feed upon unwanted weeds. Because they damage the noxious and menacing weeds, these insects are considered helpful or friendly to man. In many cases the occurrence of these insects has contributed much towards eradication of the weed or at least keeping it in check.

Insects as agents for weed control:

From the year 1902, when eight species of insects were introduced into Hawaii from Mexico for the control of *Lantana camera*, insects have been principal agents used in biological control of weeds. These insects feed on various parts of the weed plants and destroy them. Important groups of insects which have been successfully used for weed control are:

Lepidoptera	Phycitidae, Trotricidae
Hemiptera	Coreidae, Tingidae, Coccidae
Coleoptera	Cerambycidae, Chrysomelidae, Buprestidae, Cuurculionidae, Galeuricidae
Diptera	Agromyzidae, Trypetidae

Action on weeds:

Insects often destroy weeds through direct destruction of vital parts. Ex: Action of *Cactoblastic cactorum* on *Opuntia*. The weed may die quickly or die during the next season. Insects also attack weeds indirectly through creating favorableness to infection by plant pathogens. Affecting the competitive advantage of the weed.

Desirable attributes of a weed killer:

1. It should not be a pest of cultivated plants (as *Orthezia insignis*) and should not even at a later date turn to attack useful crops, which is often the case with weed killing insects.
2. It should be effective in damaging and controlling the weeds.
3. It should preferably be a borer or internal feeder of the weed. Leaf feeders have also been found to be equally effective in checking weeds.
4. It should be able to multiply in good number without being affected very much by parasitoids and predators.

Examples of biological control of weeds with insects:

1. **Lantana weed, *Lantana camara*:** It is a perennial shrub, native of Central America; is used extensively throughout the world as an ornamental plant. *Ophiomyia lantanae* was introduced into India from Hawaii for the control of Lantana. But an introduced coccid (scale insect) *Orthezia insignis* besides its failure to effectively check the weed began to infest economic plants like citrus, coffee, cinchona and tomato.
2. **Prickly pear, *Opuntia* spp:** The prickly pear, *Opuntia inermis* (*O. stricta*) got accidentally introduced into country by 1840. The cactus spread was so rapid that in the year 1925, 24 million hectares of cultivable land were rendered useless. Control of this weed by chemical and mechanical means was not feasible and was too costly. In 1925 the moth borer, *Cactoblastis cactorum* (Pylalidae: Lepidoptera) was introduced from Argentina and the plants were killed by damaging them into papery structures. Within few years the weed population was reduced to a very great extent that *Opuntia* was no more a problem.

In India, *Opuntia dillenii* was wrongly introduced in 1780 in the place of *O. coccinellifera* for the cultivation of the commercial cochineal insect *Dactylopius coccus* valued for its dye. The cactus got established and spread rapidly assuming a serious proportion as a noxious weed. *Dactylopius tomentosus* was introduced from Sri Lanka in 1926 and within two years the insect effected a striking control of *Opuntia dillenii* in about 1,00,000 acres.

3. **Crofton weed, *Eupatorium adenophorum*** in Nilgiris and Palani hills was controlled by introducing an exotic Tephritid fly, *Procecidochares utilis* from New Zealand.
4. **Water hyacinth, *Eichhornia crassipes*** was successfully controlled with *Neochetina eichhorniae*, *N. brunchi* and mite *Orthogalumna terebrantis* in Kerala and Karnataka.
5. **Water fern, *Salvinia molesta*** was successfully controlled with *Cryptobagus cingularis* (Curculionidae) in India.
6. **Siam weed, *Chromolaena odorata*** by release of *Parenchaetes pseudoinsulata* (Arctiidae) has been found promising in Kerala and Karnataka.
7. **Congress grass, *Parthenium hysterophorus*** (Carrot weed, white top) has been successfully controlled in Karnataka by Mexican beetle, *Zygogramma bicolorata* (Chrysomelidae).

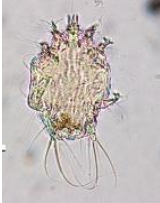
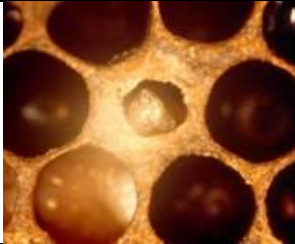
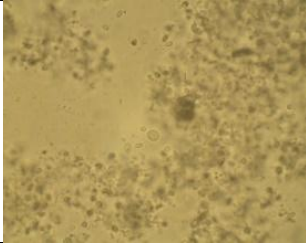
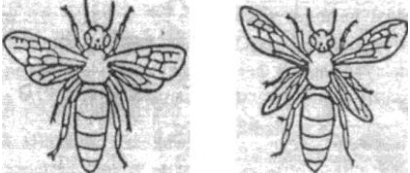
III. Scavengers:

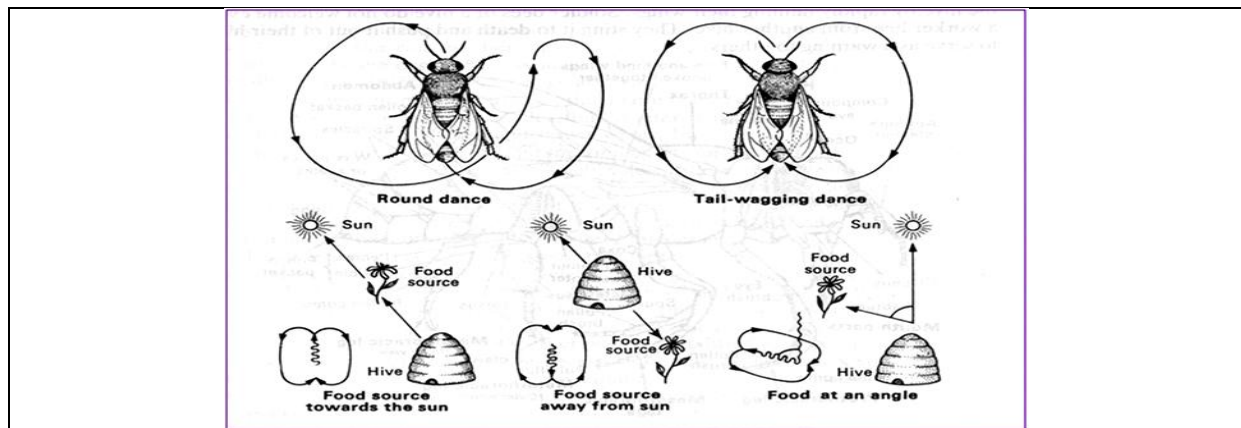
Insects which feed on dead and decaying plant and animal matter are called scavengers. Remove decomposing material and prevents health hazard. Convert complex material into simple substances e.g. dung roller.

- Rove beetles (Staphylinidae: Coleoptera): Adults and larvae feed on decaying matter.
- Chafer beetles (Scarabaeidae: Coleoptera); Bark beetles (Tenebrionidae: Coleoptera); Nitidulids (Nitidulidae: Coleoptera); Water scavenger beetle (Hydrophilidae: Coleoptera); Daddy long legs (Tipulidae: Diptera); Muscid flies (Muscidae: Diptera)
- Termites (Isoptera); Ants (Hymenoptera) – live and feeds upon dead animal and decaying vegetation.

		
<i>Apis dorsata</i>	<i>Apis cerana indica</i>	<i>Apis florea</i>
		
<i>Apis mellifera</i>	<i>Trigona iridipennis</i>	Hive stand
		
Bottom board	Brood chamber	Super chamber
		
Hive cover/ Top cover	Hive frames	Dummy or division Board/ movable wall
		
Wooden bee feeder	Plastic bee feeder	Queen gate
		
Queen cage	Queen cell protector	Queen excluder

		
Plastic pollen trap	Wooden pollen trap	Hive tool
		
Bee veil	Gloves	Boots
		
Bee brush	Smoker	Decapping knife/ uncapping knife
		
Honey extractor	Travelling screen/net	Comb foundation frame
		
Comb foundation wax sheet	Queen cage	Embedder
		
Stingless bee hive	Greater wax moth	Lesser wax moth

		
Wax beetle	Yellow banded hornet	Bee hunter wasp
		
Bee eater	Ectoparasitic mite, <i>Varroa destructor</i>	Endoparasitic mite, <i>Acarapis woodi</i>
		
American foul brood	European foul brood	Thai sac brood
		
Nosema	Amoebic	Healthy bee (L) K-winged bee (R)
		
	<i>Apis dorsata</i> comb	<i>Apis cerana indica</i> comb
		
Overalls (Protecting wear)	<i>Apis florea</i> comb	<i>Apis mellifera</i> comb



Bee communication

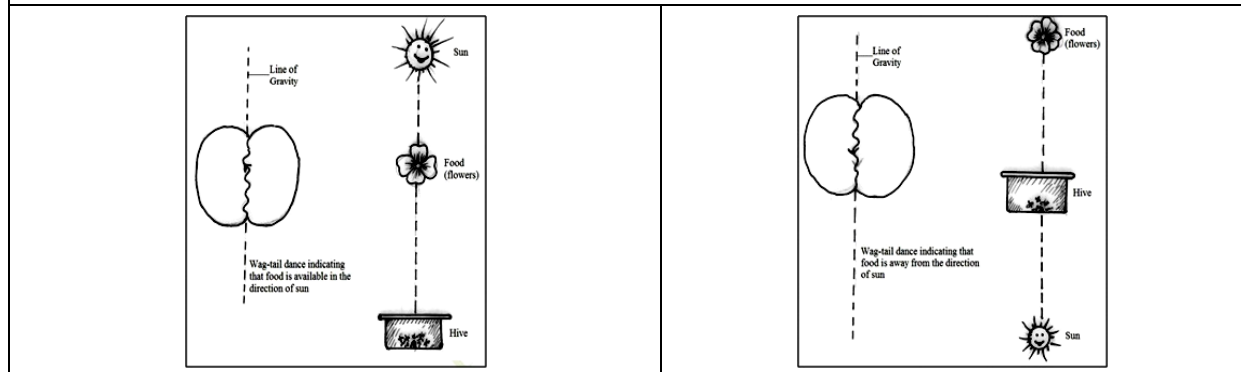


Fig. 1: Direction indication in wag-tail dance when food is in the direction of sun

Fig. 2: Dance when food is away from direction of sun

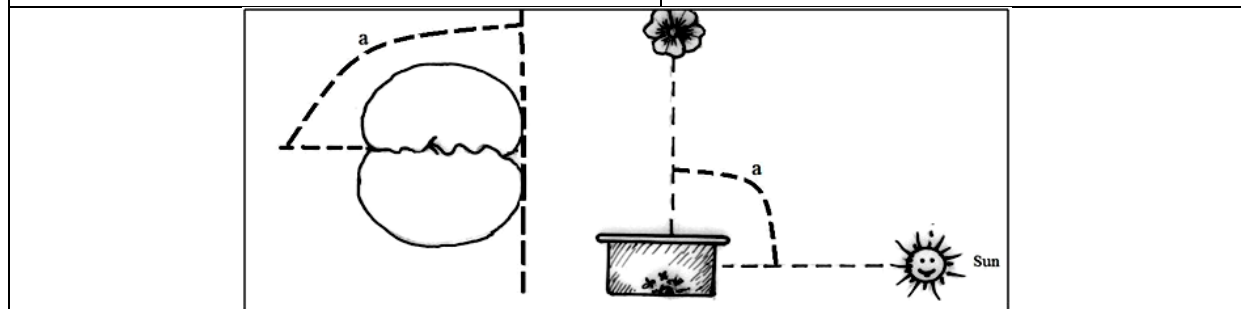


Fig. 3: If food is to the left of the sun, bee dances at an angle counter-clockwise to the line of gravity

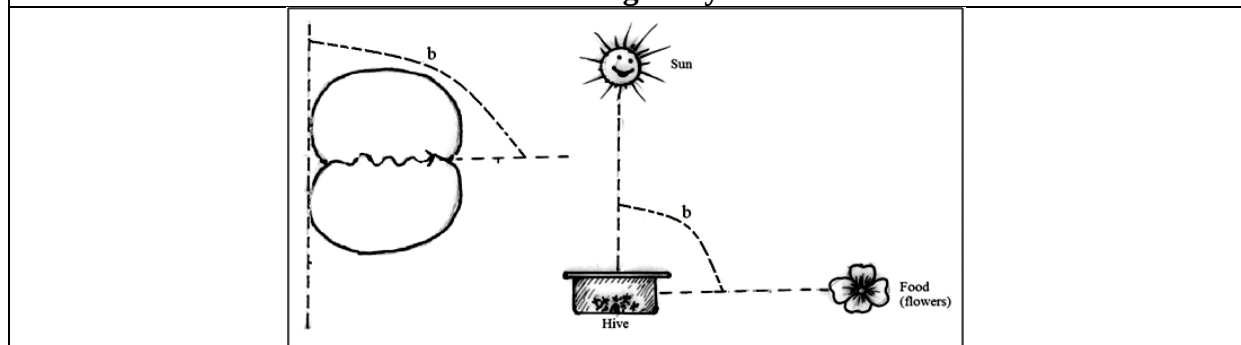
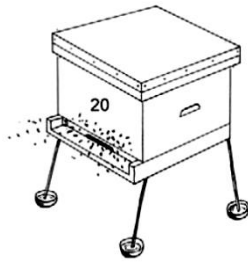


Fig. 4: If food is to the right of the sun, bee dances to the right of the line of gravity

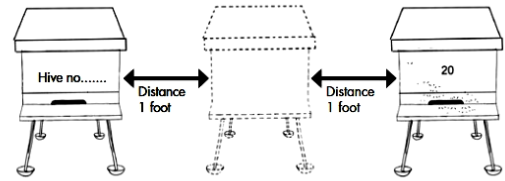
Methods for colony division



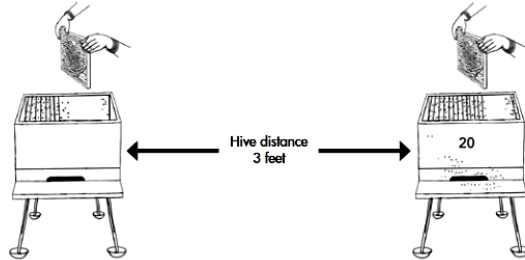
Step 1: Inspect the colonies



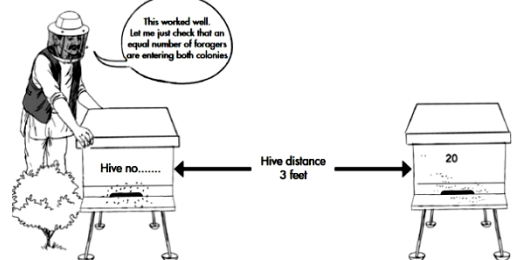
Step 2: Select the best mother colony



Step 3: Move the mother colony 1 ft (30 cm) to the left and place an empty hive 1 ft (30 cm) to the right of the previous mother colony position. The hives are a hive width plus 2 feet apart

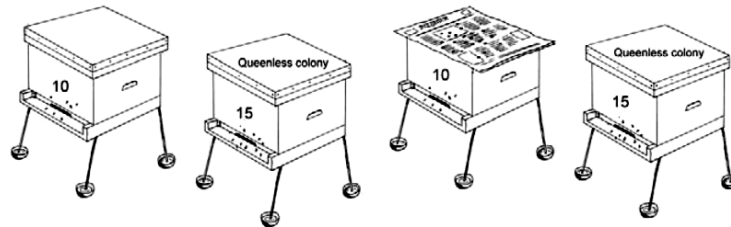


Step 4: Put 4 to 5 brood frames with the queen in the new hive



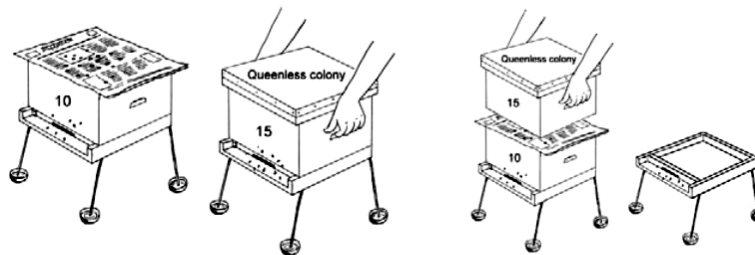
Step 5: Check the colony division is balanced and close the hives with the covers

Uniting honeybee colonies by newspaper method



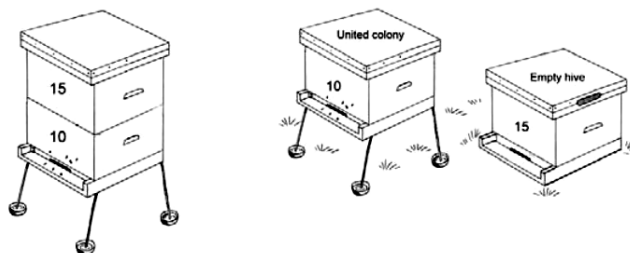
Step 1: Queen-right and queenless colonies moved close together

Step 2: Covers of queen-right colony removed and replaced with a sheet of perforated paper smeared with syrup or honey



Step 3: Queenless colony lifted from bottom board

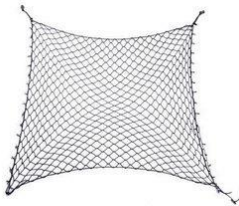
Step 4: Queenless colony placed on sheet of paper above queen-right colony

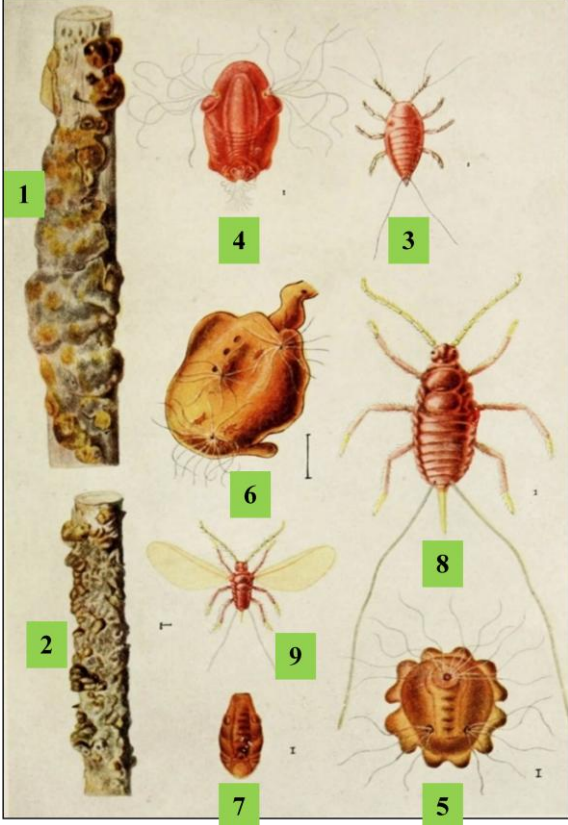


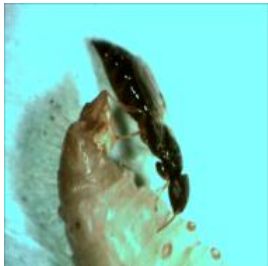
Step 5: Pheromones of colonies allowed to unite while bees chew the paper

Step 6: After 2 days bees and frames from upper chamber transferred to lower chamber and covers replaced on the united colony

			
Eggs	Larvae	Cocoons	Adult
Mulberry silkworm, <i>Bombyx mori</i>			
			
Eggs	Larvae	Cocoons	Adult
Eri silkworm, <i>Philosamia ricini</i>			
			
Mulberry cultivation		Castor cultivation	
			
Rearing house (Sericulture Unit)		Rearing stand (Tray method)	

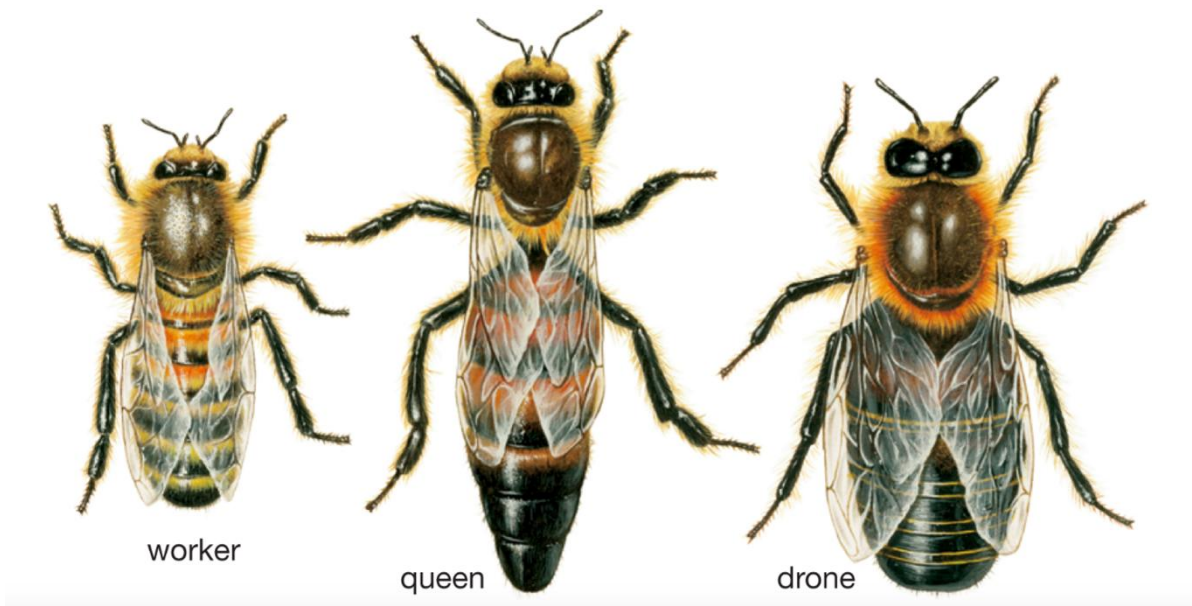
		
Ant well	Rearing tray	Paraffin paper
		
Foam rubber strips	Chopsticks	Feathers
		
Chopping board and Knife	Cleaning net	Mountages
		
Reeling machine	Rearing/feeding stands	Kharikas
		
Uzi fly	Dermestid beetle	Pebrine disease
		
Flacherie disease	Grasserie disease	Muscardine disease

		1. Healthy lac cells 2. Diseased lac cells 3. Crawler (40X) 4. Female cell (4 weeks after inoculation (35X)) 5. Female cell (13 weeks after inoculation (15X)) 6. Emergence of crawlers from female cell (4X) 7. Male cell (13 weeks after inoculation (15X)) 8. Wingless male (12X) 9. Winged male (40X)
Various stages of lac insect		
		
Semialata plant	Kusum	Brood lac
		
Palas	Ber	Inoculation of brood lac

		
Settlement of crawlers	Lac encrustation	Lac encrustation
		
Larva of <i>Eublemma amabilis</i>	Adult of <i>Eublemma amabilis</i>	Damage of <i>Eublemma amabilis</i>
		
Net covering of lac insect	Phunki	Scrapping of lac encrustation
		
Ichneumonid wasp	Braconid wasp	Chalcidoid wasp
		
Trichogramma wasp	Eulophid wasp	<i>Goniozus nephantidis</i>

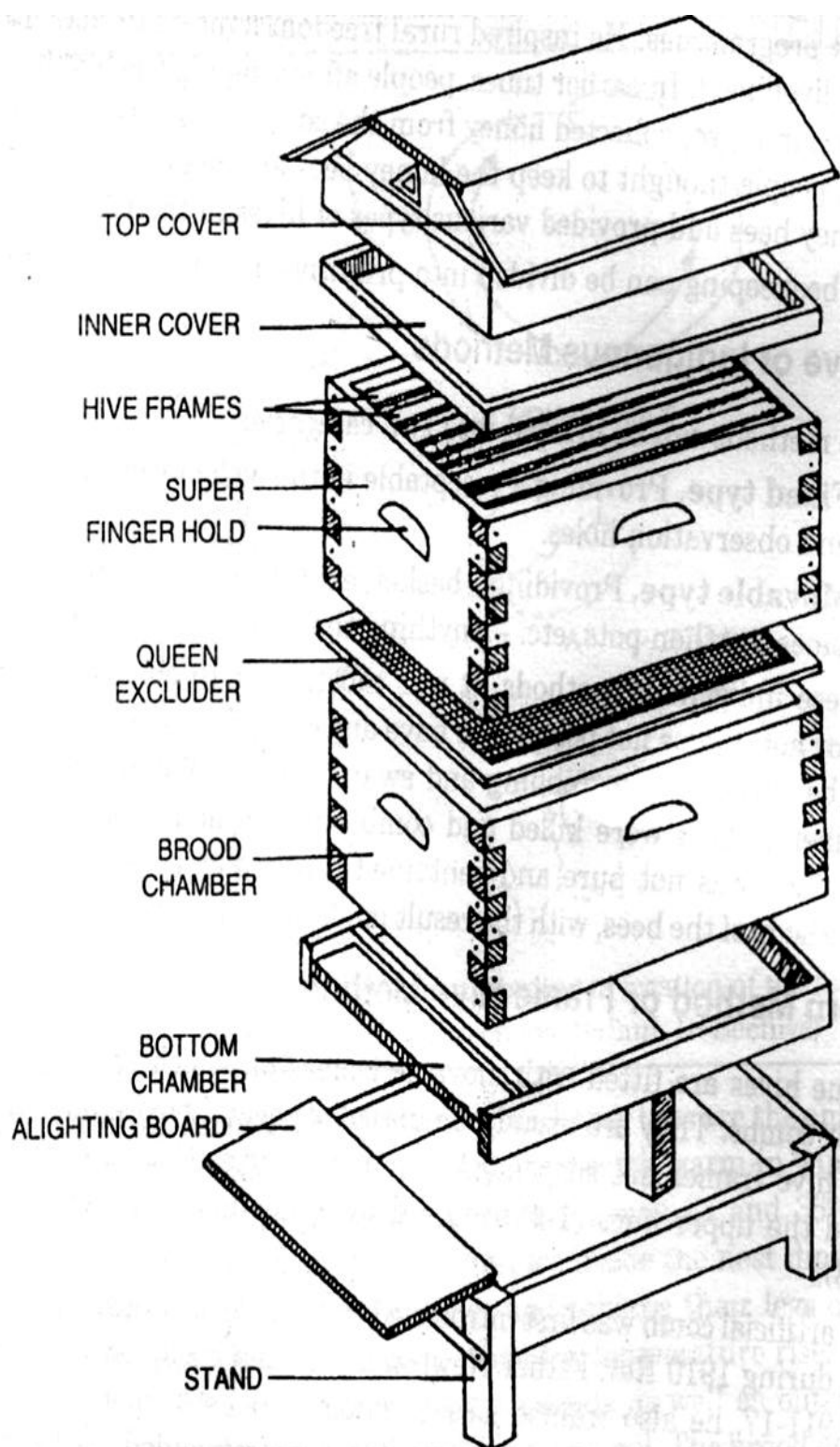
		
Tachinid fly	<i>Epiricania (Fulgoraecia) melanoleuca</i>	Dragon fly
		
Damsel fly	Preying mantid	Reduviid bug
		
Pentatomid bug	Giant water bug	Mirid bug
		
Ripple bugs	Ant lion	Green lace wing
		
Robber fly	Syrphid fly	Lady bird beetle
		
Ground beetle	Tiger beetle	Rove beetle

		
Wasp	Digger wasp	Red ant
		
Fig wasp	<i>Neochetina eichhorniae</i>	<i>Neochetina bruchi</i>
		
Oil palm pollinating weevil <i>Elaeidobius kamerunicus</i>	Mexican beetle <i>Zygogramma bicolorata</i>	Lantana weed killer <i>Cactoblastis cactorum</i>



Honey bee castes

Langstroth bee hive



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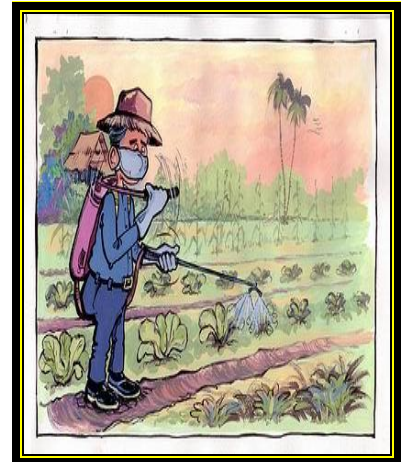


Study Material

PESTS OF FIELD CROPS AND STORED GRAIN AND THEIR MANAGEMENT

AG. ENTO 5.4 (1 +1)

FIFTH SEMESTER B.Sc.(Hons.) AGRICULTURE



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POLYPHAGOUS PESTS

1. TERMITE :

Family :

- (i) Kalotermitidae : Exclusively inhabit dead, dying and living wood, have no connection with the soil. *e.g. Neotermes* and *Cryptotermes*
- (ii) Hodotermitidae : Live in arid zones of India, attack grasses and stored grains, live and breed wholly underground. *e.g. Acanthotermes*
- (iii) Rhinotermitidae : Largely sub-terranean, some invade wood works in buildings. *e.g. Heterotermes, Rhinotermes, Coptotermes* and *Reticulitermes*
- (iv) Termitidae : Largest and economically most important, both under and above ground dwellers. *e.g. Odontotermes, Microtermes, Hypotermes, Nasutitermes*

Although about 270 species of termites from South Asia are injurious to economic plants, principal among them are ***Microtermes obesi* Holmgren** and ***Odontotermes obesus* (Rambur)**.

The termites are social insects and their colony organization is based on a caste system. In a colony, there are numerous workers, lots of soldiers, one queen, a king and a good number of complementary or the colonizing forms of true but immature males and females. The various castes and their duties are described as under.

A. Productive Castes

(1) Colonizing individuals :

- These are winged individuals of both sexes and are produced in large numbers during the rainy season.
- When the temperature and moisture conditions are optimum, they emerge from the parent colony and hover over street lamps early in the evening, usually after a shower of rain.
- The wings are meant of the nuptial flight only and when they have mated, the wings usually drop off.
- Most of the winged insects are eaten up by frogs, lizards and snakes.
- A pair that happens to escape may start a new colony in a crevice in the soil as the queen and the king of a colony.
- To start with , they themselves attend to the foraging and other duties which, later on, are performed by the workers.

(2) Queen :

- This is the only perfectly developed female in the colony.

- She develops either from colonizing individuals described or from the wingless forms present in an established colony.
- She attains a much larger size when developed from the former caste.
- Her reproductive system occupies almost the entire abdomen.
- She is a phenomenal 'egg-laying machine', laying one egg per second or 70,000-80,000 eggs in 24 hours.
- There is only one queen in a colony and normally she lives from 5 to 10 years.
- The queen is fed by the workers on the choicest food, and is housed in a special area referred to as the 'royal chamber' which is situated in the centre of the nest, at a depth of about 0.5 metre below the ground surface.

(3) King :

- A king develops from an unfertilized egg and becomes fully developed by consuming a superior diet.
- He is the father of the colony and is a constant companion of the queen, living with her in the 'royal chamber'.
- He is much smaller than the queen and is slightly bigger than the colonizing individuals.
- He mates with the queen from time to time and thus aid her in laying fertilized eggs from which the colonizing forms and workers develop.
- The king's life is much shorter than that of the queen and when he dies, he is replaced by a new one.

(4) Complementary castes :

- They are short-winged or wingless creatures of both sexes and lead a subterranean life.
- In the event of the untimely death of the king or queen in a colony, the complementary castes replace them.
- They are induced by the workers to undergo sexual development.

B. Sterile Castes

(5) Workers :

- The workers develop from the fertilized eggs but remain stunted as they reared on ordinary food.
- Numerically, they are the most abundant in a colony but are smaller than the soldiers. Except for the reproduction and defence of the community, practically all other duties are performed by the workers.
- They take care of the eggs and the young ones and remove them to safe places at the time of danger.

- They also tend and feed the queen, collect food and cultivate a fungus food in underground garden.
- When a new colony is established, the earlier broods of workers construct a hemispherical chamber for the queen and its is connected with innumerable galleries.
- In certain species, the workers also construct a high mound above the ground, which is known as the *termitarium*.
- Since the workers have to collect all the provisions for the colony, they are notoriously destructive.

Life cycle :

- In the rainy season when atmospheric conditions are favourable, the colonizing forms leave their parent colony.
- As they are weak fliers, they do not travel a long distance unless aided by wind.
- As a rule, a particular species swarms at about the same time of season. The members of swarm comprise individuals of both sexes.
- They are attracted to light where they mix with individuals of the neighbouring swarms.
- A great majority of them fall prey to many types of predators and only a few individuals survive in the end.
- Sooner or later the survivors fall down and cast their wings and mate before or after shedding them.
- Both the male and female participate in the early operations of forming a nest by excavating small burrows or galleries or nuptial chambers.
- In the beginning, only a few eggs are laid and are looked after by them and the newly hatched nymphs are fed by the parents themselves. They develop into workers and then take over all the brooding.
- During the first season, the reproductive castes are usually not produced. Gradually, the queen grows in the size and the number of eggs laid increases.
- The eggs hatch after one week during the summer and within 6 weeks the larvae develop to form soldiers or workers, as the case may be.
- The reproductive castes, when produced, mature in 1-2 years.
- The queen is capable of laying millions of eggs during her life, which is very difficult to estimate, but probably 6-9 years is the approximate span.
- The nests of many termites grow fungus gardens in the centre, near about the 'royal chamber'.
- The fungus grows into a comb-like structure and is fed to the royal pair and the larvae.

Host plants :

Since the termites are wood-feeding insects, they can eat away the roots of any plant.

Nature of damage :

- The damage is largely done by the workers who are responsible for feeding of the entire community.
- The large number of workers is responsible for the inflicting of the damage.
- The termites live on cellulose which they obtain from dead and living vegetable matter. Besides all kinds of crops, termite damage wood works in the buildings, furniture, bridges, poles, airfields, books in archives and clothes.

Sr.	Category	Commodities
1.	Agricultural Crops	Wheat, barley, oat, maize, millets, paddy, pulses, cotton, groundnut, sugarcane, castor, poppy, sunflower, vegetables, grasses
2.	Plantation Crops	Tea, coffee, rubber, coconut, cocoa, jute, sunnhemp
3.	Fruit trees	Mango, apple, ber, citrus, mulberry, guava, custard apple, cashew, pomegranate, peach, sapota, grapevine
4.	Other economic trees	Bamboo, eucalyptus, mahua, neem, oak, palm, chir pine, willow, semal, sal, teak, sheesham
5.	Garden plants	Chrysanthemum, rose, bougainvillea
6.	Ordinance stores	Wooden ammunition boxes, wooden cable and wire rope drums, tents, textiles, boots, saddler, other leather goods, matting stored timber.

Integrated Pest Management:

1. Collect and destroy leaves and stubbles of previous crop from the field.
2. Deep ploughing in summer, so it destroys the colony as well as termatorium of the termite.
3. Use well decomposed organic manure.
4. Before preparation of the field, add neem, castor or karanj cake in the field then irrigate the field and after one week sowing should be done.
5. Give irrigation in the field at regular interval; do not create water stress condition in the field.
6. **Fungi & Nematodes:** Preparations based on insect-attacking nematodes and the fungi *Beauveria bassiana* and two species of *Metarhizium*, however, are effective, especially when introduced into mounds. Fungi spores can act as repellents. A fungus *Metarhizium anisopliae* (Bio Blast) is another biological termiticide. Nematodes caused high mortality of *Reticulitermes flavipes* (Kollar) termites in laboratory tests.
7. **Encouraging predators:** Termites have many predators because they provide a source of protein. Insects that eat termites include spiders, beetles, flies, wasps and especially ants. Other predators including frogs, reptiles, birds and mammals such as bats and monkeys. Encouraging this kind of wildlife will help to reduce the number of termites.

8. **Use of botanicals :** Botanical pesticides possess an array of properties including insecticidal activity, repellency to pests, antifeedency, insect growth regulation, toxicity to agricultural pests. Plant parts and plant extracts can be used effectively. These can be removed from the plant and used as a natural insecticide by grinding up the relevant parts, placing in boiling water, stirring and leaving to soak. The mixture is then sprayed onto the infested crop.

Plant materials: Leafy extract of following plants can be used to control termite: *Azadirachta indica* (Neem), *Allium sativum* (Garlic), *Ocimum canum* (Green basil), *Carica papaya* (Papaya), *Jatropha curcas* (Ratanjot), *Argemone mexicana* (Mexican poppy), *Camellia sinensis* (Tea), *Santalum album* (Sandalwood) *Tagetes minuta* (Mexican marigold), *Tectona grandis* (Teak), *Tagetes erecta* (Marigold), *Ricinus communis* (Castor), *Calotropis gigantea* (Madar), *Cannabis sativus* (Hemp), *Curcuma amada* (Mango Ginger), *Datura alba* (Datura), *Eucalyptus globules* (Blue gum), *Lantana camara* (Lantana), *Musa paradisiacal* (Banana), *Pongamia pinnata* (Poongam), *Parthenium hysterophorus* (Carrot grass)

9. Search out the termatorium from the field and place one tablet of aluminium phosphide in it and close the opening with mud or drench it with chlorpyrifos 20 EC 20 ml in 10 litre of water.
10. In case of wheat, treat 100 kg of seeds with bifenthrin 10 EC 200 ml or chlorpyrifos 20 EC 450 ml or fipronil 5 SC 600 ml in 5 litre of water and place it on the ground floor for a night then use these seeds for sowing purpose on next day.
11. In case of irrigated wheat are recommended to apply cake before sowing and sow the seeds air dried for 12 hours after treating with any one of the following insecticides diluted in 5 litre of water for the management of termite.
1. Castor cake @ 1 ton/ha and fipronil 5 SC 500 ml/100 kg seeds
 2. Castor cake @ 1 ton/ha and chlorpyrifos 20 EC 400 ml/100 kg seeds
 3. Neem cake @ 1 ton/ha and fipronil 5 SC 500 ml/100 kg seeds
12. If seed treatment was not given in wheat and incidence of termite was observed in the field, so mix chlorpyrifos 20 EC 2.5 litre or fipronil 5 SC 1.6 litre + 100 kg sand + 5 litre water and spread these sand in the field then give light irrigation in the field.
13. In case of groundnut, treat 1 kg of seeds with quinalphos 25 EC or chlorpyrifos 20 EC 25 ml or imidacloprid 17.8 SL 5 ml and leave it for 3 to 4 hours for drying then use it for sowing purpose.
14. Before planting of sugarcane, give the sett treatment of malathion 50 EC 20 ml in 10 litre of water to it.
15. Apply chlorpyrifos 1.5% dust 30 kg/ha in the furrow of sugarcane field before planting.
16. In case of sugarcane, Drenching of bifenthrin 2.5 EC 20 ml/ 10 litre of water

Application of chlorantraniliprole 18.5 SC 5 ml/ 10 litre of water

Drenching of clothianidin 50 WDG 2.5 g/ 10 litre of water

2. LEAF MINER :

The different species of leaf miner are as under.

(1) American serpentine leaf miner : *Liriomyza trifolii* (Burgess)

Order : Diptera and Family : Agromyzidae

Host plants: Bean, beet, carrot, celery, cucumber, eggplant, lettuce, melon, onion, pepper, potato, squash, tomato, chrysanthemum, gerbera, gypsophila, marigold, castor

Description and Life cycle:

Leaf miners have a relatively short life cycle. The time required for a complete life cycle in warm environments is often 21 to 28 days, so numerous generations can occur annually in warm climates. The growth at a constant 25°C and reported that about 19 days were required from egg deposition to emergence of the adult. Development rates increase with temperature up to about 30°C; temperatures above 30°C are usually unfavorable and larvae experience high mortality. At 25°C the egg stage required 2.7 days for development; the three active larval instars required 1.4, 1.4, and 1.8 days, respectively; and the time spent in the puparium was 9.3 days. Also, there was an adult preoviposition period that averaged 1.3 days. The temperature threshold for development of the various stages is 6 to 10°C except that egg laying requires about 12°C.

Egg:

- Eggs tend to be deposited in the middle of the plant; the adult seems to avoid immature leaves.
- The female deposits the eggs on the lower surface of the leaf, but they are inserted just below the epidermis.
- Eggs are oval in shape and small in size, measuring about 1.0 mm long and 0.2 mm wide.
- Initially they are clear but soon become creamy white in color.

Larva:

- The larva is legless. Initially the larva is colorless, but becomes yellowish as it matures.
- Unlike in many flies, the larva of this insect does not taper strongly toward the head end.
- It also bears a pair of spiracles at the posterior end.

Puparium:

- The larva normally leaves the leaf mine and drops to the soil to pupate (or more technically, pupariate).
- The puparium is initially yellowish, then golden brown, but turns darker brown with time.
- This is oval and slightly flattened ventrally.
- It measures about 1.3 to 2.3 mm long and 0.5 to 0.75 mm wide.

- The puparium has posterior spiracles on a pronounced conical projection, each with three distinct bulbs, two of which are elongate.

Adult:

- Adults are small, measuring less than 2 mm in length, with a wing length of 1.25 to 1.9 mm.
- The head is yellow with red eyes. The thorax and abdomen are mostly gray and black although the ventral surface and legs are yellow.
- The wings are transparent.
- Adults live about 13 to 18 days and the oviposition occurred at a rate of 35 to 39 eggs per day, for a total fecundity of 200 to 400 eggs.
- The female makes numerous punctures of the leaf mesophyll with her ovipositor, and uses these punctures for feeding and egg laying.
- The males live only two to three days, possibly because they cannot puncture foliage and therefore feed less than females, whereas females usually survive for about a week.
- Typically they feed and oviposit during much of the daylight hours, but especially near mid-day.

Nature of damage:

- Punctures caused by females during the feeding and oviposition processes can result in a stippled appearance on foliage, especially at the leaf tip and along the leaf margins.
- However, the major form of damage is the mining of leaves by larvae, which results in destruction of leaf mesophyll.
- The mine becomes noticeable about three to four days after oviposition and becomes larger in size as the larva matures.
- The pattern of mining is irregular; although tending to be blotch-like near the end of the mine.
- The shape is influenced by the plant, so is not a reliable indicator of species.
- Both leaf mining and stippling can greatly depress the level of photosynthesis in the plant.
- Extensive mining also causes premature leaf drop, which can result in lack of shading and sun scalding of fruit.
- Wounding of the foliage also allows entry of bacterial and fungal diseases.

(2) Citrus leaf miner : *Phyllocnistis citrella* Stainton

Order : Lepidoptera and Family : Gracillariidae

Host plants: Citrus, orange, lemon, lime, tangerine, bael, atalantia, orange jasmine, pongam

Description:

- Adults are minute moths with a 4 mm wingspread.
- They have white and silvery iridescent scales on the forewings, with several black and tan markings, plus a black spot on each wingtip.

- The hind wings and body are white, with long fringe scales extending from the hindwing margins.
- In resting pose with wings folded, the moth is much smaller in appearance (about 2.4 mm).
- The head is very smooth-scaled and white, and the haustellum has no basal scales.
- This is most easily detected by its meandering serpentine larval mine, usually on the ventral side of the leaf.
- Larvae are minute (up to 3 mm), translucent greenish-yellow, and located inside the leaf mine.
- The pupa characteristically is in a pupal cell at the leaf margin.
- Adults generally are too minute to be easily noticed, and are active diurnally and in the evenings.

Life cycle:

- The eggs are laid singly on the underside of host leaves.
- Egg eclosion occurs within two to 10 days, whereupon larvae immediately enter the leaf and begin feeding.
- Larvae make serpentine mines on young leaves (sometimes also young shoots), resulting in leaf curling and serious injury.
- Leaf mines are usually on the ventral leaf surface, except in heavy infestations when both leaf surfaces are used.
- Usually only one leaf mine is present per leaf but heavy infestations may have two or three mines per leaf, and up to nine mines on large leaves have been found.
- As with similar leaf miners, larvae are protected within the leaf during their feeding cycle.
- Larvae have four instars and development takes from five to 20 days.
- Pupation is within the mine in a special pupal cell at the leaf margin, under a slight curl of the leaf.
- Pupal development takes six to 22 days.
- Adults emerge about dawn and are active in the morning; other activity occurs at dusk or night.
- Females lay eggs evenings and at night.
- The citrus leaf miner may help spread citrus canker because of leaf damage from the mine.
- Generations per year appear to be nearly continuous: six in southern Japan, nine to 13 in north central India and 10 in southern India.
- Development time totals about 13 to 52 days.
- Depending on foliage flushing cycles and weather conditions as many as 6 to 13 can be expected.
- Adults live for only a few days and a new generation is produced about every three weeks.

Nature of damage:

- The larvae form serpentine mines in the leaves and rarely fruit of their hosts.
- These mines are filled with a central line of frass.
- This characteristic helps separate this leaf miner from the [citrus peel miner](#).
- The citrus leaf miner larvae only infest the younger, flushing foliage.
- Adults lay their eggs on both the upper and lower surface of the leaves which are less than 1.27 cm (1/2 in) in length.
- Economic losses are reflected by the increased cost of protecting nursery and non-bearing citrus, as well as limiting sales of hosts to door-yard growers.
- Infestations can retard the growth of young trees.
- Heavy infestations may affect production on mature trees, but this has been demonstrated only on limes.
- In Florida, a real concern is that the citrus leafminer creates openings that permit citrus canker bacteria to infest the tree (Grafton-Cardwell et al. 2009).

(3) Groundnut leaf mine : *Aproaerema modicella* (Deventer)

Order : Lepidoptera and Family : Gelechiidae

Host plants: Groundnut, soybean, Lucerne, mung bean and to a small extent redgram. *Psoralea corylifolia* is an alternate host

Symptoms :

- The first sign of the presence of the larvae in groundnut and soybean crops is the appearance of brown mines, usually close to the midrib.
- The mines extend outwards from the initial serpentine shape to become blotches.
- Leaves become distorted within a few days.
- Three or four mines per groundnut leaflet will cause so much distortion that a leaf exposes as little as 30% of the potential photosynthetic area to the sun.
- When larvae are larger, into and beyond the third instar, they leave the mine and web together two halves of a leaflet or several leaflets.
- This and the subsequent feeding activity reduces the amount of photosynthetic area even further.
- The leaves of a heavily damaged field turn light brown and drop off the plants; they have a cornflake-like appearance.
- Moths are flushed up from a crop when someone walks through it.
- They rise to a level of about 50 cm and fly a few metres before resettling.
- Once their typical flight behaviour becomes recognized, farmers can identify an incipient infestation by the presence of moths.

(4) Pea leaf miner: *Chromatomyia horticola* (Goureau)

Order : Diptera and Family : Agromyzidae

Host plant: cruciferous plants, antirrhinum, nasturtinum, pea, linseed and potato

Life cycle:

- The pest is active from December to April or May and is believed to pass the rest of the year in soil, in the pupal stage.
- The adults emerge at the beginning of December and after matting, start laying eggs singly, in leaf tissues.
- The eggs hatch in 2-3 days and the larvae feed between the lower and upper epidermis by making zig-zag tunnels.
- They are full-grown in about 5 days and pupate within the galleries.
- The adults emerge from the pupae in 6 days and the life cycle is completed in 13-14 days.
- The pest passes through several broods from December to April-May.

Nature of Damage:

- The large number of tunnels made by the larvae interfere with photosynthesis and proper growth of the plants, making them look unattractive.

Management:

- Remove infected plant material
- Remove the plant debris/ weeds
- Clipping of infested leaves in the initial stage of the crop.
- Install yellow sticky trap @ 1/ 10 hills after germination in cucumber.
- Use mosquito net in the nursery stage to protect the seedlings from egg laying of female.
- Biological control : Parasitic wasp, *Diglyphus isaea* & *Dacnusa sibirica*
- Apply 1.0 to 1.75 kg fine ash of *Lantana camara* per 200 sq.m. plot.
- Spraying of Neem seed kernel extract (NSKE) 5% for the management of leaf miner.
- Spraying of spinosad 45 SC 3 ml/ 10 litre of water along with 400 g jiggery, first at appearance of the pest and subsequent two sprays at 15 days interval.
- In groundnut, spraying of deltamethrin 2.8 EC 10 ml or lambda-cyhalothrin 5 EC 5 ml in 10 liter of water.
- In Tomato and gherkins, spraying of cyantraniliprole 10.26% OD 18 ml in 10 litre of water
- In Tomato and gherkins, spraying of Chlorantraniliprole 8.8% + Thiamethoxam 17.5% SC 50-100 ml/plant after 8-10 days of transplanting

LOCUSTS

Locusts are grasshoppers that belong to the order Orthoptera, family Acrididae. Such species of grasshoppers that congregate in large numbers as larvae (nymphs) and swarm to fly long distances as adults destroying vegetation on their way are called locusts; those that do not have this ability are simply called grasshoppers. Thus all locusts are grasshoppers but all grasshoppers are not locusts. There are some 5000 species of grasshoppers (acridids) found in the world but only 9 are recognized as locusts of which 3 belong to the Indian sub-continent. These 9 locusts are as follows:

1. Italian locust, *Calliptamus italicus* : Occurs in Italy, France, Northern Africa, Iran, Southern Russia.
2. Moroccan locust, *Dociostaurus maroccanus* Thunberg : Occurs in Southern Europe, Northern Africa, Iraq, Iran, Afghanistan.
3. Red locust, *Nomadacris septemfasciata* (Serville) : Occurs in Tanganyika, Southern Africa.
4. Brown locust, *Locustana pardalina* (Walker) : Occurs in Southern Africa
5. South American locust, *Schistocerca paranensis* (Burmeister) : Occurs in Argentina to Mexico
6. Australian locust, *Chortoicetes terminifera* (Walker) : Occurs in Australia
7. Bombay locust, *Patanga succinta* (Linnaeus) : Occurs in India, Sri Lanka, Malaysia
8. Migratory locust, *Locusta migratoria* (Linnaeus) : Occurs in India, Europe, Africa, Pakistan, East and South Asia, Australia
9. Desert locust, *Schistocerca gregaria* (Forsk.) : Occurs in India, Pakistan, Arabia, North African countries

Among the 3 locusts belonging to the Indian sub-continent, *S. gregaria* is the most destructive.

(1) Bombay locust, *Patanga succincta* Linnaeus (Orthoptera : Acrididae)

- In India, the activities of this locust are generally confined to the area extending from Gujarat in the North to Tamil Nadu in the South.
- The adult is smaller than the desert locust, bears an acute (pointed) ventral (prosternal) tubercle, 8 eye-stripes and conspicuous yellowish stripes laterally on its pronotum.
- The fore wings (elytra) have oblique dark markings and the hind wings become rose coloured basally after the insect has spent a month as a fledgeling.
- It breeds during monsoon in the Western Ghats and has only one brood a year.
- Its plague occurred during 1835-45, 1864-66 and 1901-08.

(2) Migratory locust, *Locusta migratoria* (Linnaeus) (Orthoptera : Acrididae)

- This species occurs in India in Rajasthan and Gujarat.
- The distinguishing features are the absence of ventral tubercle and eye strips, hind wings are hyaline in the young and yellow in the old adult.
- Unlike Bombay locust, it breeds twice; winter-spring breeding occurs in Baluchistan (Pakistan) and summer-monsoon breeding in Rajasthan and Gujarat.
- It may, therefore, have many broods a year.
- The swarms of this species were observed in India in 1878 in Tamil Nadu, in 1954 in Bangalore and concentrated breeding occurred in Gujarat during September-October of 1959.

(3) Desert locust, *Schistocerca gregaria* (Forsk.) (Orthoptera : Acrididae)

This is the most destructive of all locusts. It invades 30 million square kilometer areas spreading over 60 countries from the west and north of Africa to Assam in India and in 50 per cent of this area, breeding can occur.

Identification :

- The desert locust is found in two phases, *i.e.* the solitary phase and the gregarious phase. Individuals having characteristics in between the two are often placed under the transient phase.
- The nymphs of the gregarious phase are yellow or pink, with distinct black markings, whereas the colour of the solitary hoppers varies according to the colour of the surrounding vegetation.
- The gregarious adults are pink on emergence, gradually turning grey and ultimately yellow, when sexually mature.
- The adults of the solitary phase remain greenish grey throughout their life.

Life-history :

- A single female may lay up to 11 egg-pods, each pod containing up to 120 eggs. A female normally lays 500 eggs in about 5 pods.
- Before egg laying, the female, with the help of her ovipositor, bores a hole into the loose sandy soil, 5-10 cm deep.
- Having laid a pod, she secretes a frothy material over the eggs, which hardens on drying and makes the pod water-proof.
- While laying eggs, the females may be sitting very close to one another and as many as 5,000 eggs may be laid in one square metre.
- The egg, resembling grain of rice, is lightly curved and 7-9 mm long.
- The duration of the egg stage depends upon the soil conditions, temperature and moisture.
- The eggs laid in February and March hatch in 3-4 weeks and those laid in May-September hatch in 12-15 days.
- The nymphs, at the time of emerging, break the egg-shell and creep out of the holes.
- The duration of the nymphal (hopper) stage lasts 6-8 weeks in spring and 3-4 weeks in summer.

Host plants : Locusts eat all kind of vegetation except a few namely, neem (*Azadirachta indica*), ak (*Calotropis procera*), dhatura (*Datura stramonium*), jamun *Psidium cuminii*, sheesham (*Dalbergia sissoo*) and anjeer (*Ficus carica*).

Damage :

- The locust is harmful in both the hopper and the adult stages.
- These gregarious and voracious feeders eat almost any vegetation. When in swarms, they can consume all the green vegetation and cause a famine.
- In addition to the damage to crops, orchards, forests, etc., the locust can be nuisance in houses, as these creatures climb over the walls, invade kitchens, store-rooms and even enter into beds.
- They fall into wells by the million and thus make water unfit for drinking.
- If an army of hoppers or adults marches on to the railway lines, all traffic is suspended because the crushed hoppers cause slippery rails.

Management : Management operation can be carried out against all stages of the locust, the most practicable and effective measures are against the nymphs.

- (a) **Eggs:** If eggs are laid in a well-defined area, a trench may be dug around it, so that the young nymphs on emerging drop into it and can be buried alive, filling the ditch with soil. If these trenches are heavily dusted with Malathion 5%, it may not be necessary to bury the nymphs.
- (b) **Nymphs:** The hopper stage is the most vulnerable and control measures are most effective before the second moult. The nymphs may be destroyed either with chemicals or by using mechanical methods:
- (1) The principal mechanical method of control lies in digging trenches in front of the moving army of nymphs and driving them into these trenches, with brooms or with twigs of trees and then, buried alive. The nymphs can also be guided to the trenches along metal or canvas barriers, 45 cm high. Two barriers, one on each side of the army of the marching hoppers, are so fixed that they converge on a narrow gap that leads to a trench in which they drop. The trench should be deep enough to accommodate a large number of hoppers, most of which would then die under the weight of their own fellow-creatures. Later, the trench can be filled with earth. In the early stages, a trench, 30-45 cm wide and 60 cm deep, is sufficient but when the hoppers are older, the width should be 75 cm and the depth more than 60 cm.
 - (2) At night when the hoppers rest on bushes, they can be burnt with flame-throwers.
 - (3) Poison bait : Wheat/ Rice bran + fenitrothion 500 g + jiggery 5 kg, if scattered in the early morning or in the evening, are effective. During day, the bait dries quickly so the hoppers do not eat it.
 - (4) Spraying or dusting of malathion is very effective.

- (5) Spraying the crop with neem seed kernel suspension (5%) has been found to *be* very promising.
- (6) A number of birds attack locusts and of these, the common mynah and the tiliar (starling) are the most important. During the locust cycle, if practicable, these birds should be protected.

(c) Adults :

- (1) The adults can be beaten to death with thorny sticks, brooms or can *be* swept together and buried underground in heaps.
- (2) Malthion 5 per cent, if dusted on crops, trees and the ground, is very effective.
- (3) Malathion 50 EC or Chlorpyrifos 20 EC @ 1 litre per hectare can also be sprayed on locusts, on the ground.
- (4) Malathion 50 EC is also effective when sprayed with an aeroplane on top of a flying swarm.

GRASSHOPPERS

1. Sporadic grasshopper, *Oxya nitidula* Walker (Orthoptera : Acrididae)

Distribution: Sporadic grasshopper is widely distributed in the Orient and is a pest of sporadic occurrence. In Punjab, it is serious in the low-lying areas of Amritsar, Gurdaspur and Hoshiarpur which are flooded occasionally.

Identification:

- The nymphs are shiny green and have a broad, black band extending from the base of the eyes to the wing pads.
- The legs are greenish-yellow and the full-grown nymphs measure about 1.5-2.5 cm in length.
- The adults are similar in body colour but are larger (about 2.5-3.0 cm) and have green wings.

Life-history:

- The pest is active from March to December and passes winter in egg stage in the soil.
- The over-wintered eggs hatch in March and the emerging nymphs feed on berseem (*Trifolium alexandrinum*), khabbal grass (*Cynodon dactylon*) and other available crops.
- They moult 6 or 7 times by June and are transformed into winged adults in 60-64 days.
- The adults also feed on various *kharif* crops and live for 40-49 days.
- They lay brown eggs in clusters on the underside of leaves of various food plants, particularly sugarcane.
- A female may lay 29-143 eggs, which hatch in 16-24 days.
- The nymphs of the second generation developing during July-August are transformed into winged adults in 46-57 days.
- These adults live for about 60-71 days and lay eggs in the soil instead of plants.

- Some of these eggs hatch in October and give rise to third-generation nymphs which never complete their development and eventually die of cold in December.
- A majority of eggs, however, do not hatch and remain in the soil till next March. Thus, the pest completes two broods in a year.

Host plants: The insects feed on various *kharif* crops, such as maize, sorghum, rice, berseem, bajra, sugarcane etc.

Damage: The nymphs and adults feed on various crops. When there is a serious infestation, the plants may be completely defoliated and the crops, such as berseem, may be wiped out.

2. Surface grasshopper, *Chrotogonus trachypterus* (Blanchard) (Orthoptera : Acrididae)

Distribution: This species of surface grasshoppers is widely distributed in the Orient and Africa. In India, it is common in the north whereas *C. oxypterus* occurs in the southern regions.

Identification:

- The adults are stoutly built, about 2.0 cm long and 8 mm broad, with a rough brownish appearance.
- There are two longitudinal rows of black dots on the underside of the white body.
- The nymphs are similar in body form but are smaller and have wing pads instead of wings.

Life-history:

- *C. trachypterus* remains active throughout the year but its activity is considerably reduced during winter when only eggs and adults are found.
- A female may lay 36-434 eggs in 2-15 egg pods, at a depth of 3-6 cm in the soil. There are generally 16-46 eggs in a pod.
- In summer, the eggs hatch in 19-33 days whereas in winter they hatch in about 5 months.
- The developing nymphs feed on grasses or other soft foods. They moult 5-7 times and are full-fed in 40-70 days.
- Adults are long-lived, the female for about three months and the male about 1.5 months.
- There are two complete generations in a year and sometimes the eggs laid in October also hatch giving rise to a third partial brood, which dies in the nymphal stage during the winter.

Host plants: The grasshoppers are polyphagous and, besides cotton and wheat, they feed on a number of other cultivated crops such as berseem (*Trifolium alexandrinum*), sugarcane, kharif fodders, barley, etc.

Damage: Both nymphs and adults feed on leaves by cutting germinating plants of cotton, wheat, etc. particularly in areas adjoining the waste-lands. Often the damaged fields have to be resown. Unlike *Oxya* sp., the attack by this grasshopper is more serious in low-rainfall areas.

Management:

- Deep ploughing to expose the hibernating stage of insect to sunlight and predatory birds.
- Crops should be seeded as early as possible. Older plants that are growing vigorously can

withstand more grasshopper feeding than younger plants, which are not well established.

- When numbers are low, they can be handpicked and squashed.
- Sabadilla or pyrethrin to knock down nymphs - first or second instar.
- Baits containing the protozoan *Nosema locustae* are used in some western states to kill nymphs of migrating grasshoppers in uncultivated breeding areas early in the season.
- Poultry, including chickens and guinea hens, are excellent predators but can also cause damage to some garden plants.
- Cyfluthrin or any synthetic pyrethroid commonly used as sprays for grasshopper control

CUTWORMS

The term cutworm or surface caterpillar is applied to the larvae of several species of noctuid moths which have, in common, the habit of biting through the stems of seedlings at ground level and eating the leaves or the entire seedlings. The various species of cutworms have a wide range of food plants, both cultivated and wild. The majority of cutworms found in India fall under the genera *Agrotis* and *Euxoa*. Of the recorded species, only four are widespread in the plants and have considerable economic importance. *Agrotis ipsilon* (Hufnagel) is the commonest and *Ochropleura flammata* (Denis & Schiffermuller) is occasionally abundant in India, the latter being particularly destructive in the north. *Agrotis segetum* (Denis & Schiffermuller) and *A. biconica* Kollar are also quite common in India, being more so in the south.

1. Gram cutworm : *Ochropleura flammata* (Denis & Schiffermuller) (Lepidoptera : Noctuidae)

Distribution : The gram cutworm is one of the most important pests of chickpea or gram in northern India, particularly in the Punjab, Haryana and in the sub-Himalayan region. Its distribution extends to Europe, Syria, Iran, Western Siberia and Pakistan.

Identification:

- The adult is a heavy bodied, grayish-brown or wheat-coloured insect which measures 5.0-6.2 cm in wing expanse.
- Its fore wings have characteristic markings and smoky patches.
- The caterpillars are dark grey or dull green and their skin is smooth and greasy.

Life history:

- The female moths lay yellowish-white eggs on under surface of leaves, on shoots, stems, or in the soil.
- A female lays up to 980 eggs in its life time. The eggs hatch in 4-7 days during summer and 10-14 days during winter.

- The larvae remain hidden in soil during the day time and feed at night on young shoots or underground tubers.
- They are full-grown in 4-7 weeks and then make earthen cells in the soil for pupation.
- The pupal stage lasts 12-15 days but during winter it extends up to 5 weeks.
- The life-cycle is completed in 7-11 weeks and there are generally two generations in a year.

Host plants: It is a polyphagous pest and besides gram, it feeds on the seedlings of many vegetables and other plants such as potato, cucurbits, peas, okra, wheat, tobacco, opium, poppy *etc.*

Nature of damage:

- This cutworm is a sporadic pest of major importance. In some years, 50 per cent of the gram crop may be destroyed.
- The caterpillars spend the day hiding near and about the plant bases. They remain in the top 5-10 cm of the soil near the plants that might have been cut the night before.
- At night, they come out and become active, cutting down the young plants of gram, potato, vegetable seedlings, *etc* just above or slightly below the surface of the soil.
- They seem to be very voracious eaters and they cut more plants than they can consume.

2. Greasy cutworm : *Agrotis ipsilon* (Hufnagel) (Lepidoptera : Noctuidae)

Distribution: This is a pest of worldwide occurrence and is found in America, Europe, North Africa, Syria, Japan, China, Indonesia, Australia, New Zealand, Hawaii, Sri Lanka, Myanmar and India. It has been reported from almost all the potato growing regions of northern India, forming a continuous belt from the Punjab in the west to Bengal in the east and Madhya Pradesh in the South.

Identification:

- The adult moth measures about 2.5 cm from the head to the tip of the abdomen and looks dark or blackish with some grayish patches on the back and dark streaks on the fore wings.
- The slightly yellowish caterpillar, on emergence is 1.5 mm long with a shiny, black head and a black shield on the prothorax.
- The full grown larva is about 4.2-4.5 mm long and is dark or dark-brown with a plump and greasy body.

Life History:

- The pest is active from October to April and probably migrates to the mountains for further breeding during summer.
- The moths appear in the plains in October and come out at dusk and fly about until darkness sets in.
- They oviposit at night and lay creamy-white, dome-shaped eggs in clusters of about 30 each, either on the undersurface of the leaves of food plants or in the soil.

- The number of eggs laid by a female varies from 199 to 344.
- Oviposition continues from 5 to 11 days and the duration of the egg stage varies from 2 days in summer to 8-13 days in winter.
- The newly hatched larvae feed on their egg shells and move like a semilooper.
- The larval stage varies from 30 to 34 days in February-April. The advanced-stage larvae may become cannibalistic.
- The caterpillars are found throughout the winter and become active at night when they cut off and fell the young plants. During the day, they hide the soil and pupate underground.
- The pupal stage varies from 10 days in summer to 30 days in winter. The moths usually emerge at night.
- The life-cycle is completed in 48-77 days and generally three generations are completed in a year.
- It is a cold weather pest and is active from October to March in the plants.
- It suddenly disappears with the onset of summer during April and is not traceable during the off-season, from April to August-September.

Host plants: This polyphagous pest has been reported feeding on gram, potato, tobacco, peas, wheat, lentil, mustard, linseed, maize, sugarcane, cucurbits, *bhang* (*Cannabis sativa*), vegetable seedlings and several weeds.

Nature of damage:

- The young larvae feed on the epidermis of the leaves. As they grow, their habit changes.
- During the daytime they live in cracks and holes in the ground and come out at night and fell the plants by cutting their stems, either below the surface or above the ground.
- The cut branches are sometimes seen to have been dragged into the holes where the leaves are eaten at leisure.
- The larvae may also bore into cabbage. Damage to the *rabi* crops may go as high as 37 per cent and to the potato crop may be as high as 80 per cent.

Management:

- Deep ploughing to expose the hibernating stage of insect to sunlight and predatory birds.
- Collect and destroy caterpillars mechanically as they may be curled near the base of young plants or just a few inches deep in the soil
- Encourage predatory birds to visit the fields by placing bird perches
- Intercropping with wheat or linseed or mustard reduce infestation
- Install the light trap @ 1/ha to attract the nocturnal adult insect.
- Force hibernating stages of the cutworms to the soil surface, e.g. by turning the soil or irrigating regularly, to expose them to scorching sunlight and predatory birds

- Place the heaps of grasses in the field during the evening time, and collect and destroy the hidden larvae of cutworm in the morning hours.
- Poison bait (Wheat bran 1 kg + Malathion 5% dust 2 g) @ 10 kg/ha in the evening on weed free soil.
- Broadcast *Bt* mixed bait (mix 2 g of *Bacillus thuringiensis* formulation with 1 kg of wheat bran) @ 10 kg bait /ha over the surface of new planting beds one week before planting. Cutworms already present in the soil will eat the baits instead of new seedlings.
- Broadcast insecticide (chlorpyrifos 20 EC) treated sand @ 3 litre per 10 kg sand/ha in the field before planting
- Treat soil with chlorpyrifos 10% G @ 20 kg/ha before planting

HAIRY CATERPILLARS

(1) Red hairy caterpillar, *Amsacta moorei* (Butler) (Lepidoptera: Arctiidae)

Distribution: The red hairy caterpillar is widely distributed in the Orient, including India. In India, it is more common in Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, Gujarat, Punjab, Madhya Pradesh and Uttar Pradesh.

Identification:

- The moths are stoutly built and have white wings with black spots.
- The outer margins of the fore wings, the anterior margin of the thorax and the entire abdomen are scarlet red.
- There are black bands and dots on the abdomen.
- The full-grown caterpillars are reddish-amber to olive green and the body is covered with numerous long hairs arising from the fleshy tubercles.

Life-history:

- The female moths lay light-yellow spherical eggs in clusters of 700-850 each on the under surface of the leaves of host plants.
- A single female may lay up to 1500 eggs, which hatch in 2-3 days.
- The young caterpillars feed gregariously and as they grow older, they march in bands destroying field after field of various *kharif* crops.
- The caterpillars grow through six stages and complete their development in 15-23 days.
- They enter the soil, shed their hair and make earthen cocoons at a depth of about 23 cm.
- Here they pupate and remain in this stage for many months till they emerge next year from the cocoons. In a given population, probably more than one generation is completed in a year.

Host plants: It is a polyphagous insect and feeds practically on all kinds of vegetation growing during the *kharif* season. Its attack is particularly serious on sunnhemp, cotton, groundnut, maize, sorghum, guara, mung, moth and sesamum.

Nature of damage: The young hairy caterpillars prefer to eat the growing points of plants. The older ones have no such discrimination and they feed voraciously on all vegetation resulting in severe defoliation. Field after field is devastated by the moving army of caterpillars.

2. Bihar hairy caterpillar, *Spilarctia obliqua* Walker (Lepidoptera: Arctiidae)

Distribution: The Bihar hairy caterpillar is a sporadic pest and is widely distributed in the Orient. In India, it is very serious in Bihar, Madhya Pradesh, Uttar Pradesh and Punjab.

Identification: The moth measures about 5.0 cm across the spread wing and is dull yellow. The full-grown caterpillars are profusely covered with long greyish hair.

Life-history:

- The female lays 410-1240 light green, spherical eggs in clusters on the underside of leaves.
- The eggs hatch in 8-13 days and during the first two stages, the tiny caterpillars feed gregariously, but afterwards they disperse widely in search of food.
- They grow to maturity through 7 stages, within 4-8 weeks. When full-grown, larva spins a loose silken cocoon in which pupation takes place in plant debris or in the soil.
- The pupal stage lasts 1-2 weeks in the active period and the moths live for about a week.
- The life-cycle is completed in 6-12 weeks and the pest passes through 3 or 4 broods in a year.

Host plants: The pest is polyphagous feeding on sesamum, mash, mung, linseed, mustard, sorghum, cotton, jute, groundnut, sunflower and some vegetables.

Damage: The caterpillars eat leaves and soft portions of stems and branches. In severe infestation, the plants may be completely denuded of leaves.

Management :

1. Deep ploughing to expose the hibernating stage of insect to sunlight and predatory birds.
2. Collection and destruction of egg masses and hand picking of larvae
3. The moths are strongly attracted to artificial light Therefore, light traps of electric or petromax lamps placed just above a broad flat basin full of kerosenized water, should be put on the night following the first shower of the monsoon and continued throughout the period of emergence for about one month.
4. Young larvae can be destroyed by pulling out the infested plants and burying them underground.

5. The dispersing larvae of hairy caterpillar from one field to another can be checked by digging trenches across the direction of their march, and prompt destruction of larvae.
6. Placing the twigs of Ipomoea, Jatropha and Calotropis to attract the migrating caterpillars and kill them mechanically.
7. Prepare small balls with 10 kg rice bran + 1 kg jaggery + 1 liter quinolphos broadcast in the fields preferably in the evening times.
8. Dusting of quinolphos @ 25-30 kg/ha would be effective in the control of young larvae.
9. Spraying of any one of the following insecticides by mixing with 10 litre of water.
thiodicarb 75 WP 10 g or
flubendiamide 480 SC 3 ml or
indoxacarb 15.8 EC 20 ml

PESTS OF PADDY

Rice is the staple diet of over half of the world's population “rice is life”, is grown on over 145 million ha in more than 110 countries, and occupies almost one - fifth of the total world cropland under cereals. Considering its important position, the United Nation designated the year 2004 as the “International Year of rice. As many as 80,000 rice accessions (cultivated and wild varieties) have been collected at the International Rice Germplasm Center of the International Rice Research Institute (IRRI). Ready to eat products, popped and puffed rice, instant or rice flakes, canned rice and fermented products are produced. Rice straw is used as cattle feed, used for thatching roof and in cottage industry for the preparation of hats, mats, ropes, sound-absorbing, strawboard and used as litter material. Rice bran oil is used in soap industry. Refined oil can be used as a cooling medium like cotton seed oil/ corn oil. Rice bran wax, a by-product of rice bran oil is used in industries.

The rice plant is subject to attack by more than 100 species of insects; 20 of them can cause economic damage. Together they infest all parts of the plant at all growth stages, and a few transmit viral diseases. In the early stages of the crop, common insects such as leaf folder, whorl maggot and armyworms cause damage. The major insect pests that cause significant yield losses.

1. RICE STEM BORER

Scientific name: *Scirpophaga incertulas* (Walker)

Family: Pyraustidae

Order: Lepidoptera

Distribution: The yellow stem borer of rice attacks only rice and has a wide distribution in all Asian countries.

Marks of identification:

- Eggs are creamy white, flattened, oval and scale-like and laid in mass and covered with buff-coloured hairs.
- The larva is white or yellowish-white with a dark brown head and well developed prothoracic shield.
- White silken cocoon is found inside the stem.
- Female adult is bright yellowish-brown forewing with a black spot possessing a tuft of yellow hairs.
- A male adult is smaller with pale yellow forewings without black spot

Life history:

- The female lays 15 - 18 eggs in a mass near the tip on the upper surface of the tender leaf blade and covers them with buff-coloured hairs and scales. A female lays about 2 - 3 egg masses and the incubation period ranges from 5 - 8 days.

- The larva becomes full-grown in 33 - 41 days and measures about 20 mm long. Before pupation, it covers the exit hole with thin webbing and then forms a white silken cocoon in which it pupates.
- The pupa is dark brown and measures 12 mm long. The pupal period varies from 6 -10 days and may get prolonged depending on the weather conditions.
- The entire life-cycle is completed in 50 - 70 days.

Nature of damage:

- The newly hatched larva enters the leaf sheath and feeds for two to three days and bores into stem near the nodal region.
- Larva feeds inside the stem causing drying of the central shoot called '**dead heart**' in young plant or drying of the panicle called '**white ear**' in older plants.
- Plant shoots can be easily pulled by hand.
- October-December has been found conducive for the multiplication of the insect.

Management:

- Removal and destruction of rice stubbles at the time of first ploughing after harvesting of crop decrease the carry-over next crop.
- Grow the resistant variety viz., Gurjari, Mahisagar, Narmada, IR-22, IR-26, GR-102.
- Application of carbofuran 3G or cartap hydrochloride 4G @ 1 kg/100 m² along with sand at 15 days after sowing in the nursery stage.
- Transplanting should be done during the 2nd fortnight of July.
- Clipping the tip of the seedlings prior to transplantation to eliminate egg masses.
- To attract the adult moth of stem borer, install one light trap per ha
- The field should be necessarily be scouted during the vulnerable crop growth stages for early detection of **dead heart** and **white ear**.
- Release of egg parasitoid *Trichogramma japonicum* thrice at weekly interval starting 28 days after transplanting @ 1 lakh egg parasitoids/ha/release followed by the release of *Trichogramma japonicum* at 35 and 42 DAT.
- Install 30 pheromone trap 30 days after transplanting and change the lure at every 3 weeks interval
- Harvest the crop up to the ground level and disturb the stubbles with plough immediately after the harvest to keep the borer population low in next crop.
- Apply cartap hydrochloride 4 G 25 kg or fipronil 0.3 G 15 kg or carbofuran 3 G 33 kg per ha at the initiation of infestation or 30 days after transplanting then after 15 days interval.
- Application of chlorantraniliprole 0.4 GR @ 4 kg/acre or spraying chlorantraniliprole 18.5 SC @ 3 ml/10 litre of water

- Spraying of flubendiamide 20 WG 2.5 g or fipronil 5 SC 20 ml or lambda-cyhalothrin 2.5 EC 12 ml or flubendiamide 4% + buprofezin 20 SC 18 ml for the control of stem borer in paddy field.

2. RICE LEAF FOLDER/ LEAF ROLLER

Scientific name: *Cnaphalocrocis medinalis* Guen.

Family: Pyraustidae

Order: Lepidoptera

Distribution: Occurs in all rice-growing areas of our country. It is active from October to January.

Hosts: Wheat, maize, sugarcane, sorghum and *Cynodon dactylon*

Marks of identification:

- Eggs are flat, oval in shape and yellowish-white in colour.
- The larva is pale yellowish greenish translucent.
- It is brownish-orange coloured moth is small and has two and one distinct dark wavy lines on the brownish fore and hind wings, respectively.
- Both wings have a dark brown to grey band on their outer margin

Life history:

- The eggs are laid singly or in pairs on the under surface of tender leaf blades. The incubation period is 4 - 7 days.
- The pale yellowish green larva becomes full grown in 15 - 27 days and pupates inside the leaf roll.
- Pupal period is 6 - 8 days.
- Total life-cycle varies from 25 - 42 days

Nature of damage:

- The larva rolls the leaf blade by fastening its edges and sometimes even fastening the leaf tip to the basal part of the leaf blade and feeds from inside by scraping.
- In a severely infested field the whole crop gives a sickly appearance with white patches. The infestation at boot leaf stage of the crop sometimes results in heavy loss of grain yield.

Management:

- Grow resistant variety Gurjari
- In the initial stage, when infestation the lower then collect the pupa and rolled up leaves with larva & destroy.
- Keep the bunds clean by trimming them and remove the grassy weeds.
- Avoid use of excessive nitrogenous fertilizers.
- Transplanting should be done during the 2nd fortnight of July.

- Initial stage of infestation, spray *Bacillus thuringiensis* or *Beauveria bassiana* or *lecanicilium lecanii* @ 20 g/ 10 litre of water.
- To attract the adult moth, install one light trap per ha
- Need based spraying of flubendiamide 20 WG 2.5 g or fipronil 5 SC 20 ml or lambda-cyhalothrin 2.5 EC 12 ml or flubendiamide 4% + buprofezin 20 SC 18 ml for the control of stem borer in paddy field.

3. RICE GREEN LEAF HOPPER

Scientific name: *Nephotettix nigropictus* (Stal.) and *Nephotettix virescens* (Distant)

Family: Cicadellidae

Order: Homoptera

Distribution: These insects are found distributed in all rice-growing areas in Asia and Africa. The insect is active during July – November in different regions.

Hosts: Some grasses

Marks of identification:

- Greenish transparent eggs are deposited in the midrib of leaf blade or sheath of rice or green grass. They are laid in batches of 10 to 15 arranged in a single row.
- The nymphs are soft-bodied, yellow-white in colour. Gradually the colour changes to green.
- Adults are 3-5 mm long, bright green with variable black markings, wedge-shaped with a characteristic diagonal movement. The male insect has a black spot in the middle of the forewings that are absent in females. The insect is active from July to September.

Life history:

- The female inserts the eggs in rows under the epidermis of leaf sheath in groups of 3-18 and period is 3-5 days.
- The nymphal period is 12-21 days.
- The adult period is for 7-22 days in summer.
- The life-cycle occupies about 25 days
- They complete 6 generations per year.
- The insects over-winters in the adult stage. The pest population is maximum in July-August and decrease markedly after heavy rain.

Nature of damage:

- Both nymphs and adults suck the plant sap and cause browning of leaves.
- The plants lose vigour and turn yellow.
- This insect is known to be vectors of virus disease of rice such as **Rice Yellow Dwarf** transmitted by *N. nigropictus*. **Tungro virus** by *N. virescens*.

Management:

- Grow medium resistant varieties viz., Gurbhari, Narmada, GR-7, GR-101, GR-102, Masuri and Sukhvel
- Transplanting should be done during the 2nd fortnight of July.
- Apply neem cake @ 12.5 kg/800 m² nursery as basal dose.
- Apply neem cake @ 12.5 kg/20 cent nursery as basal dose.
- Transplanting older seedlings (>3 weeks) reduces viral disease susceptibility transmitted by leafhoppers.
- Nitrogen should be applied as needed to avoid contributing to population or hindering plant recovery from plant hopper damage by applying insufficient nitrogen.
- Good weed control in the field and on the bunds removes the preferred grassy hosts of Green leaf hopper and promotes crop vigor.
- Crop rotation with a non-rice crop during the dry season decreases alternate hosts for diseases.
- Upland rice intercropped with soybean reduces the incidence of leafhoppers on rice compared to rice alone
- Scout the field for the presence of Tungro and Green leaf hopper. Check 20 hills while walking diagonally across a transplanted field.
- Spraying of acetamiprid 20 SP 2 g or flonicamid 50 WG 3 g or buprofezin 25 SC 20 ml or dinetofuran 20 SG 3 g or fipronil 5 SC 20 ml or imidacloprid 17.8 SL 5 ml or thiamethoxam 25 WG 5 g in 10 litres of water

4. BROWN PLANT HOPPER

Scientific name: *Nilaparvata lugens* (Stal.)

Family: Delphacidae **Order:** Homoptera

Distribution: Distributed throughout South and South East Asia where rice is grown.

Hosts: It is known only to feed on rice and the weed *Leersia hexandra* Sw., Poaceae.

Marks of identification:

- Eggs are laid in a group of 2 to 12 in leaf sheath, near the plant base or in the ventral midribs of leaf blades. White, transparent, slender cylindrical and curved eggs are thrust in straight-line in two rows.
- Freshly hatched nymph is cottony white, 0.6 mm long and it turns purple-brown, 3.0 mm long in the fifth instars.
- Adult hopper is 4.5-5.0 mm long and has a yellowish-brown to the dark brown body.

Life history:

- The female lays eggs in two rows on either side of the midrib of the leaf sheath. The eggs laid varies from 250 - 350. The incubation period is 6 - 9 days.
- The nymphal period is 10 – 18 days.
- The total life-cycle occupies 16 – 27 days

Nature of damage:

- Both nymph and adult are damaging the crop.
- It infests the rice crop at all stages of plant growth
- Due to feeding by both nymphs and adults at the base of the tillers, plants turn yellow and dry up rapidly.
- At early infestation, round yellow patches appear which soon turn brownish due to the drying up of the plants and this condition is called '**hopper-burn**'. *Nephotettix lugens* is a phloem feeder. It also acts as **vector of the virus diseases** like grassy stunt, wilted stunt and ragged stunt
- Very high infestation causes lodging of the crop resulting in yield loss ranging from 10 - 70 per cent.

Management:

- Grow medium resistant varieties viz., Gurmari, Narmada, GR-7, GR-101, GR-102, Masuri and Sukhvel
- Closer planting of 15 x 10 cm creates favourable microclimate in field for rapid development of hopper population. Hence, a spacing of 20 x 15 cm should be followed
- Alternate drying and wetting the field during peak infestation and draining out the standing water from the field 2-3 times check the population of the hopper to a large extent.
- The release of mirid bug @ 100 bugs or 50-75 eggs/m² at 10 days interval have been found effective for the control of brown plant hopper.
- Nitrogen application can be split to reduce Brown plant hopper buildup.
- Drain the water before use of insecticides and direct the spray towards the base of the plants.
- Avoid use of insecticides causing resurgence such as synthetic pyrethroids, methyl parathion, fenthion and quinalphos.
- Use of botanical pesticides : Neem oil 40 ml/ 10 litres of water or Neem seed kernel extract 5%
- Spraying of acetamiprid 20 SP 2 g or flonicamid 50 WG 3 g or buprofezin 25 SC 20 ml or dinetofuran 20 SG 3 g or fipronil 5 SC 20 ml or imidacloprid 17.8 SL 5 ml or thiamethoxam 25 WG 5 g in 10 litres of water

5. WHITE BACKED PLANT HOPPER

Scientific name: *Sogatella furcifera* Horvath

Family: Delphacidae **Order:** Hemiptera

Distribution: It has assumed the status of a serious pest of rice in many Asian countries particularly India, Myanmar, Cambodia, Sri Lanka, China, Pakistan, Vietnam and the Philippines. It is widespread in many parts of India.

Marks of identification:

- Cylindrical eggs are laid in groups when the rice plant is small but in the upper part of the rice plant when the plant is large.
- Nymph is greyish-white and turns dark grey when it nears maturity.
- The adult is a straw coloured, wedge shaped insect, with white back.

Life history:

- The female lays eggs generally on the leaf sheath. The eggs hatch in 3-5 days.
- The nymphs feed on leaves and are transformed into adults within 9-13 days.
- The life-cycle is completed in 12-18 days.
- The adult females live for about a week. There are several generations in a year.

Nature of damage:

- The nymphs and adults suck cell-sap from the leaf surface and tend to congregate on the leaf-sheath at the base of the plant.
- The leaves of attacked plants turn yellow and later on rust red.
- These symptoms start from the leaf tips and spread to the rest of the plant.
- The attacked plants ultimately dry up without producing ears.
- The insect also excretes honeydew on which sooty mould appears, imparting a smoky hue to the paddy fields.

Management:

- Same as brown plant hopper

6. RICE SKIPPER

Scientific name: *Pelopidas mathias* Fabricius

Family: Hesperidae **Order:** Lepidoptera

Distribution: India, South East Asia, China, Africa

Marks of identification:

- Eggs are laid on the leaves.
- The caterpillar is elongate, yellowish green with four white dorsal stripes, smooth with a constricted neck and red 'V' mark on the head, which is distinct.

- Pale green pupa has white longitudinal lines on it and is attached to the leaf blade by a silk girdle.
- The adult is a dark brown skipper butterfly with two white spots on the wings.

Life history:

- Adult butterfly has brown coloured wings and curved antennae.
- Eggs are laid singly on the leaf blades. Larva is pale green with constricted neck.

Nature of damage:

- Caterpillars have a tendency to remain inside the leaf by rolling it and making it like a tube
- Larva sticks together the two edges of the leaf by sticky white substance and feed outside leaving behind midrib.

Management:

- Flood the nursery to expose the hiding larvae to the surface and thus birds pick them up.
- Allow the ducks into the field to feed on the larvae.
- Drain the water and spray chlorpyrifos 20 EC 80 ml/ha during late evening.
- The eggs of rice skippers are parasitized by small wasps, big wasps and tachinid flies parasitize the larvae. They preyed upon by reduviid bugs and earwigs. The spiders feed on the adult stage during its flight.

7. RICE HORNED CATERPILLAR

Scientific name: *Melanitis leda ismene* (Thunberg)

Family: Alydidae = Coreidae **Order:** Hemiptera

Distribution: Throughout India

Marks of identification:

- Eggs are white, round laid singly on the paddy leaves.
- The larva is green with roughened skin flattened dorsally and has a dark brown head with a pair of red horn like processes and two yellow processes in the anal end. It feeds on the leaves.
- The pupa is dark green chrysalis hangs from the leaf and is attached to the leaf blade by its anal extremity.
- Adult is dark brown with large wings having a few black and yellow eye-like markings one on each of the forewings and six ocellar spots on hind wings.

Life history:

- The butterfly lay round white eggs singly on the leaves.
- The caterpillar is green, slightly flattened with two red horn processes on the head and two yellow processes in the anal end.
- It pupates in a greenish chrysalis, which suspends from the leaf.

- The butterfly is dark brown with large wings having a black and yellow eye like spot one on each of the fore wings.

Nature of damage:

- Larva feeds on leaf blades of rice.
- Leaves are defoliated from the margin or tip irregularly.
- Heavy infestation – only midribs are spared

Management:

- Expose the eggs to be picked up by birds after ploughing and trim the bunds.
- Dusting the crop with quinalphos 5% @ 25 kg/ha.
- Spraying DDVP 76 EC @ 10 ml or malathion 50 EC 10 ml per 10 litres of water.

8. RICE BLUE BEETLE

Scientific name: *Leptispa pygmaea* Baly

Family: Chrysomelidae

Order: Coleoptera

Marks of identification:

- Eggs are laid singly on leaves
- The grub is scarabaeiform, depressed and dirty white in colour
- The beetle is slightly rectangular, small, smooth and dark greenish blue.

Life history:

- The egg period is 4-5 days
- Grub development period is 10-12 days
- Pupal period is 3-4 days
- Adult period is 15-18 days
- Total life cycle is 32-40 days

Nature of damage:

- Both grubs & beetles feed on the surface of leaves of young paddy crop
- Eat the green portion of leaves in characteristic linear patches along veins
- Ultimately turn white and dry up

Management:

- Dislodge the beetle by dragging rope across the flooded field.
- Destroy the alternate host like Dharo, darbh, grasses.
- Summer ploughing & avoid tillering from stubbles.
- Collect adult and kill them.
- Apply Fenitrothion 0.05 %.
-

9. SPINY BEETLE/ RICE HISPA

Scientific name: *Dicladispa armigera* (Olivier)

Family: Chrysomelidae

Order: Coleoptera

Distribution: Bangladesh, Burma, Southern China, India, West Malaysia, Nepal, Pakistan, Sumatra, Thailand, West Iran.

Hosts: Rice

Marks of identification:

- Eggs are laid inside minute slits on the tender leaves generally toward the tip.
- The grub is whitish yellow and flattened. It feed inside the leaf tissue by mining. It pupates inside.
- The adult beetle is somewhat square shaped about 1/6 to 1/8" in length and width dark blue or blackish in colour with spines all over the body.

Life history:

- Adult is blue - black shiny beetle with spines on the thorax and elytra.
- It lays eggs singly on the leaf tip.
- Grub is minute, flat and yellow. It mines between the epidermal layers of leaf and pupates in leaf mines.
- Egg period: 4-5 days; Larval period: 7-12 days; Pupal period: 3-5 days.
- There are six generations / year.

Nature of damage:

- Both adults and grub feed on the leaf tissue between the epidermal membranes.
- The adults scrape the upper surface, leaving only the lower epidermis.
- Adult feeding damage shows white streaks along the long axis of the leaf.
- Grub produce irregular longitudinal white mines as they tunnel between the epidermal layers

Management:

- The pest is suppressed if the infested leaf tips are clipped off and destroyed, while transplanting.
- To prevent egg laying of the pests, the shoot tips should be cut.
- Leaf tip containing blotch mines should be destroyed.
- Manual collection and killing of beetles – hand nets.
- If the nursery beds are flooded, the beetles float and can be swept together with brooms & then destroyed
- Weeding of alternate host plants in fields, bunds & adjacent areas
- Application of Phorate 10G @ 1 kg in nursery
- In field – Monocrotophos 36 SL or Quinalphos 25 EC or Chlorpyrifos 20 EC

10. RICE CASE WORM

Scientific name: *Nymphula depunctalis* (Thunberg)

Family: Pyralidae

Order: Lepidoptera

Distribution: Rice growing tracts

Hosts: Rice

Marks of identification:

- Individual egg is circular, flattened, and measures 0.5 mm in diameter. It is light yellow and has a smooth surface. Mature eggs are darker and develop two purplish dots.
- Pale translucent green with orange head. It has filamentous gills on the sides of the body. The larvae are found hanging from the leaf and measures up to 15mm long.
- The pupa is cream in colour and about 5.5 mm long. Mature pupa is silvery white.
- Moth is small, delicate white with pale brown wavy markings. The adult moth is about 5 mm long with a wing expanse of 16 mm with pale brown wavy margins. It is bright white with light brown and black spots.

Life history:

- Female laid about 50 eggs singly or in clusters of 4 on the under surface of leaves of grasses. Egg hatch in 4-6 days.
- Larva feeds on leaves and becomes full grown in 18-22 days.
- It pupates inside the case which is attached to the base of the tillers and pupal period is 5-6 days.
- The life cycle is completed in 5 weeks.

Nature of damage:

- The caterpillar causes damage by feeding upon leaves.
- They lead semi-aquatic life floating in their tubular cases on the surface of water or attached to the stems at or above the water level.
- The early stage of the crop is damaged by pest. The leaf blades are eaten away completely leaving only the midribs.
- In case of severe attack, the tillers become stunted and loose their vigour and often the plants are killed.

Management:

- Destroy the alternate host weeds around the paddy fields
- Transplanting older seedlings restricts larval feeding period
- Draining the rice field for some days kills of the case worm larvae
- Dragging a rope along the rice plants across the field dislodges most of the cases which can be collected at the outlet of the drainage.
- Spraying of lambda cyhalothrin 5 EC 5 ml in 10 litres of water

- Encourage the activity of larval parasite : *Apanteles* sp., *Bracon* sp., *Hormius* sp.

11. RICE GALL MIDGE

Scientific name: *Orseolia oryzae* (Wood-Mason) Mani

Family: Cecidomyiidae

Order: Diptera

Distribution: It is present in Pakistan, South-east Asia and Africa. It is appeared in Uttar Pradesh for the first time during 1971. It is distributed throughout India. Five biotypes of gall midge have been observed. It is destructive in some parts of Kerala, Orissa, Andhra Pradesh, Madhya Pradesh and Bihar.

Hosts: Number of grasses such as *Paspaladium geminatum*, *Paspalum scrobiculatum*, *Panicum* spp., *Ischaemum ciliare*, *Cynodon dactylon* and *Eleusine indica*.

Marks of identification:

- Eggs are reddish, elongated and 0.5 mm in length, singly or cluster, on the leaves or on stem.
- Maggot is 1 mm long after hatching with pointed anterior end. It creeps down the sheath and enters the growing bud. An oval chamber is formed round the site of feeding.
- At the time of emergence the pupa wriggles up the tube with the help of antennal horn to the tip of the silver shoot and projects half way out.
- Adult fly is yellowish brown and mosquito like. The male is ash grey in colour. Adults feed on dewdrops.

Life history:

- The brown fly lays 100 - 300 reddish elongate tubular eggs singly or in groups of 2 - 6 on just below or above the ligules of leaf blade.
- The maggot feeds on growing point for 15 - 20 days.
- Pupates inside the gall. Pupal period is 2 - 8 days.
- The life cycle completed in 19 – 21 days but during winter it takes 32 - 39 days.
- They completes 5-8 generations per year

Nature of damage:

- The gall formed by this fly is popularly known as ‘silver shoot’ or ‘onion shoot’ or ‘anaikomban’ because of the formation of hollow pink or purple, dirty white or pale green cylindrical tubes bearing at their tips a green reduced leaf blade complete with ligules and auricles.
- It infests the rice even in the nursery but usually tillers are preferred.
- The loss in yield in a heavily infested crop may be up to 50 %

Management:

- Careful timing of planting can avoid damage; once past the tillering stage, the plant is not suitable as host.
- Considerable build-up of midge population on grasses near the rice crop can be avoided by removing the grasses.
- Removal and destruction of weeds that serve as alternate host plants.
- Spraying of NSKE 5%
- Application of chlorpyrifos 20 EC 20 ml or quinalphos 25 EC 20 ml per 10 litre of water.

12. PADDY SHEATH MITE : *Steneotarsonemus spinki* (Trasonemidae : Acarina)

- At vegetative phase, both nymphs and adults colonise midribs of leaves and lacerate tissues up to maximum tillering stage causing brown necrotic patches on midribs.
- At panicle initiation stage mites move to leaf sheath to feed causing brown necrotic lesions on leaf sheath. Maximum incidence occurs at boot leaf stage.
- At panicle emergence, mites enter florets, feed on ovaries and stamens causing sterile and discoloured grains in the panicle.
- Later these grains turn black invaded by saprophytic fungus.

Management:

- Spray propergite 0.05 % or dicofol 0.05% (two sprays) for the control of rice sheath mite

13. RICE EARHEAD BUG : *Leptocorisa acuta* Thunberg (Coreidae : Hemiptera)

The Rice bug is commonly known as Gundhy Bug, is widely distributed in India.

Host plants : Paddy , Maize, Millets, Sugarcane & Some grasses

Marks of Identification:

- Adults are slender, about 15-17 mm long and greenish brown. They have long legs and antennae with four joints (13-15 mm long).
- The newly hatched nymph is about 2 mm long and is yellowish green. However, as it grows, the green colour deepens.
- The grown up nymphs are very similar to the adults in colour and size, but they are wingless.

Nature of damage:

- Rice fields severely attacked by this pest emit a repugnant smell which gives to this pest the name 'gundhy' bug.
- The nymphs and the adults suck juice from the developing grains in the milky stage, causing incompletely filled panicles or panicles with empty grains.

- Black or brown spots appear around the holes made by the bugs on which a sooty mould may develop.

Life History :

- The females lay 24-30 round yellow eggs in rows on the leaves.
- The eggs hatch in about 6 or 7 days and
- the nymphs grow to maturity in six stages within 2 or 3 weeks.
- The adult bugs live for 33-35 days. Breeding takes place in winter also, but at a slower rate.
- The pest is essentially diurnal and is most active in the morning and in the evening, seeking shelter during the hotter parts of the day. Many generations are completed in a year.

Control measures

- The population can be suppressed by killing the bugs by using light traps, collecting the adults with nets and destroying the weeds to remove alternate hosts.
- Spraying the crop with chlorpyrifos 0.05% or imidacloprid 0.005% or acetamiprid 0.004%

14. PADDY WORMS : Chironomids & Oligochaetes

Found on the roots of Paddy, cause mechanical injury to the root system.

Management:

- Drain the water from the infested field and then apply carbofuran 3 % G or Sevidol 4 % G @ 18 kg/ha and 3 days after apply nitrogenous fertilizers.

15. Crabs :

Feeds on nursery and newly transplanted paddy. They also damage bunds & irrigation system by burrowing and causing leakage.

Control measures :

- Prepare Baits and Keep near the burrows.
Carbaryl 5 % dust - 1 kg
Cooked rice - 9 kg
Jaggery - 175 gram

16. RATS:

- The Rat uproot paddy nurseries to eat the seeds and later on they also cut down the plants. The damage continues in vegetative and reproductive phase till harvest.

Control measures :

- The most effective method of controlling rat is the use of poison baits.
- The bait is prepared by mixing one part of zinc phosphide with 39 parts of broken grains of wheat, smeared with vegetable oil. The mixture is distributed in the field at 10-15 mt. distances.

PEST OF MAIZE AND SORGHUM

1. MAIZE STEM BORER

Scientific name: *Chilo partellus* Swinhoe

Family: Crambidae **Order:** Lepidoptera

Distribution: Worldwide distribution

Hosts: Cereal crops

Marks of identification:

- Creamy white eggs are laid on leaves in a cluster.
- The larva is yellowish-brown with a brown head, many dark spots on the body and prothoracic shield.
- The adult moth is straw coloured with minute dots on forewings. Hind wings are white.

Life cycle:

- The eggs are laid on the underside of a leaf near the midrib in 3-5 rows, in groups of 50-100. The eggs hatch out in 7-10 days.
- The larval period is about 28-35 days.
- Pupation takes place in a small chamber in stem
- The adult period is about 7-10 days.

Nature of damage:

- It infests the crop a month after sowing and the damage persists up to the emergence of ear heads.
- Central shoot withering leading to “dead heart” is the typical damage symptom.
- Bore holes are visible on the stem near the nodes.
- Young larva crawls and feeds on tender folded leaves causing typical “shot hole” symptom.
- Affected parts of the stem may show internally tunnelling due to caterpillars.

Management

- Early sowing is recommended (June 15-30).
- Use of light trap to destroy the moths
- The stubbles should be ploughed up during winter and burnt to destroy the hibernating larvae.
- Destruction of crop residues and chopping of stems harbouring diapausing larvae could be very effective in reducing borer population.
- Dead hearts should be pulled out and used as fodder or buried in manure pits.
- Apply carbofuran granules (5 to 7 granules per plant) in the leaf whorls to control shoot fly and stem borer.
- Apply granular insecticides like carbofuran 3 G or cartap hydrochloride 4% G @ 7.5 Kg. /ha

at an interval of 20, 30, and 40 DAS @ 8, 12 and 15 kg. / ha, respectively.

- Spraying of dimethoate 30 EC 10 ml or thiamethoxam 12.6% + lambda-cyhalothrin 9.5% ZC 2.5 ml in 10 litres of water.
- Bio-control agents viz., *Trichogramma chilonis* (egg parasitoids), *Bracon chinensis* and *Apanteles flavipes*, (larval parasitoids) should be encouraged.

2. SORGHUM SHOOT FLY/STEM FLY

Scientific name: *Atherigona soccata* Rondani

Family: Muscidae

Order: Diptera

Hosts: Maize, Wheat, Broom corn, Small millet and grasses

Distribution: Europe, Africa and Asia

Marks of identification:

- Eggs are elongated, flattened and boat-shaped, laid singly on under the surface of the leaves
- Maggots are legless, pale yellow & tapering anteriorly
- The adult is similar to house fly but smaller in size

Life cycle:

- Female lays 40 eggs single, on the underside of leaves. The eggs hatch in 1-2 days.
- Maggot period is about 6-10 days
- Pupation takes place in the stem or in the infested stem,
- Total life span 17-21 days

Nature of damage:

- Attacks young crop when it is in 3 to 6 leaf stage.
- The maggot on hatching migrates to the upper surface of the leaf and enters between the leaf sheath and stem.
- After reaching the soil level, the maggot bores inside the stem and cuts the growing point resulting in a “dead heart” symptom.
- The infested plant produces side tillers. The attack is more severe during summer than *khariif* season.

Management:

- Sow sorghum immediately at the onset of monsoon rains to minimize shoot fly damage
- Sow crop in the first fortnight of July.
- Increase seed rate up to 12.5 kg/ ha and remove the shoot fly damaged seedlings at the time of thinning or raise nursery and transplant only healthy seedlings.
- Seed treatment with thiamethoxam 30 FS (3 ml/kg seeds)
- Pull out and destroy plants showing dead hearts at the time of thinning.

- Set up the low-cost fishmeal trap 12/ ha till the crop is 30 days old.
- Soil application of carbofuran 3 G 40 kg/ ha or phorate 10 G 17 kg/ ha in seed furrow at the time of sowing.
- Spraying of dimethoate 30 EC 10 ml or quinalphos 25 EC 20 ml or thiamethoxam 12.6% + lambda-cyhalothrin 9.5% ZC 2.5 ml in 10 litres of water.

3. GUJARAT HAIRY CATERPILLAR

Scientific name: Gujarat hairy caterpillar (*Amsacta moorei* Butler), Red hairy caterpillar (*Amsacta albistriga*) and Bihar hairy caterpillar (*Spilosoma obliqua* Walker)

Family: Arctiidae

Order: Lepidoptera

Hosts: Maize, Wheat, Broom corn, Small millet and grasses

Distribution: Europe, Africa and Asia

Marks of identification:

- The female moth lays creamy or bright yellow eggs in clusters on the under-sides of leaves of grasses on field boundaries and covers them with pale brown hairs.
- The larva is reddish-brown with a black band on either side of the body having long reddish-brown hairs all over the body.
- The pupa is brownish colour and pupates in an earthen cocoon.
- Adult: *A. moorei*: white wings with red line on the apical margin of forewings and black band on the abdomen. *A. albistriga*: forewings having a red line on anterior margin, whereas hind wings are white with black markings.

Life cycle:

- Female moth lay a large number of eggs in clusters on the underside of leaves. They hatch in 5-7 days.
- Larvae pass through six stages and full-fed in 2-3 weeks.
- Pupation takes place in silken cocoons in the plant debris lying on the ground and pupates inside. The pupal stage about one week in the summer, during winter about 20 days.
- Pest passes through several generations in a year.
- *Amsacta* sp. - One generation per year
- *S. obliqua* - Three generations in a year

Nature of damage:

- These hairy caterpillars scrap the undersurface of the leaf when they are in the neonate stage. The scrapped patches of the leaves look like thin papery.
- Full-grown larvae devour the entire foliage, flowers and growing points leaving behind petioles, veins and main stem of plants.

Management:

- Reduce the bund size
- Cleaning of bunds in the summer season
- Plough the field deep in the summer season.
- Grow sunnhemp as a small band around the field and apply quinalphos 1.5% or fenvalerate 0.4% dust.
- Collection and destruction of egg masses and handpicking of larvae.
- Use of light trap (one/ha) soon after the first shower of monsoon for collecting and killing of adult moths is very effective. The light trap should be operated from eight to twelve pm only.
- The dispersing larvae of hairy caterpillar from one field to another can be checked by digging trenches across the direction of their march and prompt destruction of larvae.
- Prepare small balls by using 10 kg rice bran + 1 kg jaggery + 1-litre quinalphos 25 EC and broad-cast it in the fields preferably in the evening time.
- Spraying of thiodicarb 75 WP, 20 g or chlorpyrifos 20 EC 20 ml or quinalphos 25 EC, 20 ml or spinosad 45 SC, 3 ml in 10 litres of water.

4. SORGHUM APHID

Scientific name: *Rhopalosiphum maidis* Fitch

Family: Aphididae **Order:** Hemiptera

Marks of identification:

- First instar nymphs are light green. The tips of head, antennae and legs are slightly darker than the body. Second instar nymphs are pale green. The head, abdomen and antennae are darker than the body and the legs are paler. The eyes are red. Constriction on the third antennal segment is distinct. At the third stage, the constricted third antennal segment is divided into two segments. The body is still pale green, but slightly darker on the sides. Legs are darker than the body. The head is a dark green colour
- Adults are winged (alate) or un-winged (apterous), elongate and measure 1/25 to 1/12 inch in length.
- They are yellow-green to dark olive green or bluish-green and often have a light powdery covering. Their colour tends to be darker during cool weather and could be a pale green during warm weather. Head, antennae and legs are black

Life cycle:

- Most aphids in temperate regions overwinter in the egg stage. Since this species is a tropical species overwintering eggs have not been observed.

- There are four nymphal stages. Nymphal development is completed in about 16 days at 58 F, 9 days at 68 F, 7 days at 77 F, and 5 days at 86 F temperature.
- The corn leaf aphid is most active in temperatures ranging from 62.6 and 80.6 F temperature.

Nature of damage:

- Nymphs and adults suck sap from leaves and tender ear-heads leading to mottled appearance with yellow patches, failure of grains to develop in ear-head and formation of sooty mould due to honeydew excretion on the plants.
- It transmits maize dwarf mosaic virus in sorghum leading to the death of young seedlings.

Management:

- Coccinellids, syrphids and chrysopids suppress the population in nature. However, need-based treatments with thiamethoxam 25 WG 5 g per 10 litres of water are recommended.

5. GALL MIDGE

Scientific name: *Contarinia sorghicola* (Coquillett)

Family: Cecilomyidae

Order: Diptera

Hosts: Grain sorghum and Johnson grass are the primary hosts, reported on and reared from 14 other kinds of grass.

Marks of identification:

- Eggs are minute, transparent and elongated in shape.
- Maggot is white in colour at the initial stage then yellowish pink in colour and legless
- The adult is small, mosquito-like, fragile with a bright orange abdomen and has one pair of transparent wings. Female is bigger than the male.

Life cycle:

- The adult fly is small, fragile with a bright orange abdomen and a pair of transparent wings.
- It lays eggs singly in developing florets resulting in pollen shedding.
- A female lays about 30-35 eggs at the rate of 6-10 in each floret. The incubation period is 3-4 days.
- The maggot has four instars with the duration of 8-10 days.
- Larvae are colourless, but, when fully grown, they are dark orange. Larval period 9 - 11 days.
- The larval stage undergoes diapause in a cocoon during December - January within a spikelet.
- Pupates beneath the glume. The pupal period 3 days.
- When the adult emerges the white pupal skin remains at the tip of the spikelet.
- A generation is completed in 14-16 days. The insect's rapid developmental cycle permits 9-12 generations.

Nature of damage:

- Maggot feed on developing grains.

- It damage ovary of the sorghum grain.
- In case of severe infestation, all the grains in an earhead are chaffy.
- By pressing of damaged grains, red liquid comes out from grains.
- More damage found on plant damage by shoot fly or stem borer.

Management:

- Collection & destruction of damaged and dry plants, burn that plants or destroy them by buried in the soil.
- Sowing of the same variety in one area and harvesting should be done early to reduce the infestation.
- Sowing should be done in the 1st week of September.
- At 50% flowering spray the following insecticides, profenophos 50 EC then 2nd spray apply at 10 days interval.

6. FALL ARMYWORM

Scientific name: *Spodoptera frugiperda*

Family: Noctuidae

Order: Lepidoptera

Host plants: More than **100 crops** including maize, paddy, sorghum, cotton, vegetable crops, wheat, cowpea, potato, soybean, sugarcane

Distribution: Now in all over Gujarat, particularly in maize growing region

Marks of identification:

- The eggs are yellowish-white in colour and cover with a tuft of hair but sometimes it is not covered
- Neonate larva is greenish-white in colour with blackhead.
- Five lines of brownish dots with small hair on the body surface.
- The face of the mature larva is also marked with a white inverted "Y" and the epidermis of the larva is rough or granular in texture when examined closely.
- Four black dots arranged in a square on the last abdominal segment.
- The adult male forewing is greyish brown with reniform indistinct spot, faintly outlined in black, with a small v-shaped mark; light brown orbicular spot, somewhat oval and oblique in shape and white patch at the apical margin of the wing.
- The adult female forewing is with a mottled colouration of grey and brown, with brown markings and without white patch near the apical margin of the wing as seen in the male.

Life cycle:

- Female lay 60 to 90 yellowish-white eggs below leaf surface and cover with a tuft of hair but sometimes it is not cover. Female lay about 1500 eggs in her life span.
- There usually are six instars in fall armyworm.

- Young larvae are greenish with a blackhead, the head-turning orangish in the second instar.
- Duration of the larval stage tends to be about 14 days during the summer and 30 days during cool weather.
- Pupation normally takes place in the soil, at a depth 2 to 8 cm.
- Duration of the pupal stage is about eight to nine days during the summer but reaches 20 to 30 days during the winter
- Adult life duration is estimated to average about 10 days, with a range of about seven to 21 days.

Nature of damage :

- Larvae cause damage by consuming foliage.
- Young larvae initially consume leaf tissue from one side, leaving the opposite epidermal layer intact.
- By the second or third instar, larvae begin to make holes in leaves and eat from the edge of the leaves inward.
- Feeding in the whorl of corn often produces a characteristic row of perforation in the leaves.
- Larval densities are usually reduced to one to two per plant when larvae feed in close proximity to one another, due to cannibalistic behaviour.
- Older larvae cause extensive defoliation, often leaving only the ribs and stalks of corn plants, or a ragged, torn appearance.

Management :

- Install one light trap per ha to attract the adult moth of fall armyworm.
- Collect and destroy egg mass as well as neonate larval mass
- Interculturing operations should be carried out to expose the pupal stage of this pest.
- Spraying of *Beauveria bassiana* or *Metarhizium anisopliae* @ 40 g/ 10 litres of water.
- Spray *Bacillus thuringiensis* @ 20 g in 10 litres of water.
- Spray NSKE 5% or Neem oil 40 ml in 10 litres of water.
- Spray Chlorpyrifos 20 EC 20 ml or Spinosad 45 SC 3 ml or Emamectin benzoate 5 SG 5 g or Chlorantraniliprole 18.5 SC 4 ml in 10 litres at weekly interval during evening hours

7. RED MITE: *Oligonychus indicus* Hirst. Tetranychidae : Acarina

Marks of Identification:

- Body divided into two distinct regions: Cephalothorax and Abdomen. They possess four pairs of legs and red in colour.

Host Plants:

- Sorghum, Brinjal, Bajra, Cowpea, Sugarcane

Nature of Damage:

- Adults scattered on lower side of the leaves and start weaving webs within which they lay eggs and form a colony.
- Initially infestation starts along the midrib from lower leaves, later spread gradually to whole plant.
- As a result of feeding, the pale yellowish/whitish patches on leaves appeared which coalesce to form large patches.
- In case of severe infestation the leaves appear as burnt which dry up and fall off.
- The photosynthetic activity is adversely affected. Sometimes the entire crop may dry up especially in neglected fields. In certain varieties viz., BP 53, Surat 1, Sona 108 and CSH 1, this mite caused reddish patches on under surface of leaves, which was locally known as “Ratdo” in South Gujarat.

Life History:

- Spherical white eggs are laid on the leaf surface. Egg stage lasts for 3-4 days.
- After hatching first stage is called as larval stage and having 3 pairs of legs.
- Larval period lasts for 2 days. After moulting 2nd stage is called as Protonymphal stage in which abdomen black in colour.
- Protonymphal stage lasts 2-4 days. 3rd stage is Dutonymphal stage in which whole body reddish orange in colour.
- Dutonymphal stage lasts 2-6 days. Adult is brick red in colour and lasts for 17 days.

Management

- Collection and destruction of heavily infected leaves.
- Spraying the crop with dicofol 0.03% or propergite 57 % EC @ 16-25 ml / 10 lit of water or milbectin 1 % 0.00045% 4.5 ml / 10 lit water @ 4.5 gm ai/ha or abamectin 1.9 % EC 22.5 to 45.0 g ai/ha or fenazaquin 10 % EC 0.01 to 0.02 % 10-20 ml/10 lit of water or difenthiuron 50% WP - 6-8 gram/10 lit

8. CATERPILLERS DAMAGING SORGHUM EARS:**A. The Web Worm: *Cryptoblaes gnidiella* Mill (Pyraustidae: Lepidoptera)**

Moth is small with dark grey forewings. Larva dark brown in colour. Larva feeds on milky and hard grains. Larva remain inside silken webs in earheads forms by excreta and silken threads. Eggs laid singly on grains. Egg period 3-4 days. Larval period 12-20 days. Pupation takes place in silken threads in ear heads. Pupal period 5-17 days. Adult longevity 2-8 days. Total life cycle completed within 23-24 days.

B. Semi looper: *Eublemma silicula* Swinh. (Noctuidae : Lepidoptera)

Adult is small brown moth. Eggs laid singly on grain. Egg period 4 days. Larval period 12-13 days. Pupation takes place within gallery. Pupal period 12 days. The Caterpillar feed on maturing grains and remain under a small dome shaped or elongated gallery formed from silk and fallen anthers.

C. Heliothis: *Helicoverpa armigera* Hb. (Noctuidae : Lepidoptera)

Adult is brown coloured moth with a 'V' shaped speck on forewings and dull black border on the hind wing. Larva is green with dark broken grey lines and dark pale bands. It shows colour variation of greenish to brown. Initially larva feeds on the developing ovaries and anthers offlowers and later on feeds on milky and soft dough stage of grain. The presence of chalky appearance indicates the damage of this pest.

Management for Sorghum Earhead Worms:

- Dusting the crop with carbaryl 10% dust @ 25-30 kg/ha or malathion 5% dust or profenophos 0.1 % or NPV 250 LE/ ha - two times

9. EARHEAD BUG: *Calocoris angustatus* (Miridae: Hemiptera)

Marks of Identification:

- The adult is a small, slender, greenish yellow bug, measuring 5-8 mm in length and over 1 mm in width.

Host range: Pearl Millet, maize, tenai, sugarcane and grasses

Nature of Damage:

- The adults and nymphs damage the earheads by feeding on them. They suck the juice from the grains when they are in the milky stage. The sucked out grains, shrink and turn black in colour and become chaffy. Older grain shows distinct feeding punctures that reduce grain quality.

Life history :

- The bug lays eggs under the glumes or in between anthers of florets, by inserting its ovipositor.
- The female lays 150-200 eggs which are cigar- shaped and measure about 1.5 mm.
- The eggs hatch in 5-7 days and the nymphs start feeding on developing grains in the milk stage. The nymphs pass through 5 instars and develop into adults in about 3 weeks

Management.

- Dust with carbaryl 10% at 12 kg/ha (or) quinalphos 1.5% 12 kg/ha synchronising during milky stage

PEST OF BAJRA AND WHEAT

1. SHOOT FLY:

Scientific name: *Atherigona approximate* (Muscidae: Diptera)

Host plants : -Bajra, Sorghum, wheat.

Marks of Identification : -

- Adult is greyish white fly and little hair observed on body.
- Maggots are legless and pointed from anterior part, light white or light yellowish in colour.

Nature of damage : -

- It attacks seedling of bajra and causing dead hearts.
- The emerging ears are some times damaged. The seed set is affected considerably resulting in chaffy grains in the mature crop.

Life History : -

- Eggs are laid singly on under surface of leaves or on stem or on young plants of Bajra.
- Egg period 1-3 days. Larval period 7-10 days.
- Pupal period 1 week. Pupation takes place in the stem or soil.

Management

- Bajra should be sown as early as possible after the onset of monsoon as late sown crop suffers heavily.
- Use Higher seed rate about 5 kg/ha and remove infested plants with maggots and burn it.
- Spraying the crop with neemark 0.3 % or triazophos 0.04 % or neem oil 0.5 % + Detergent powder or quinalphos 0.05 % or methyl-o-demeton 0.03 % @ 500-600 ml / lit. spray solution / ha or dusting of methyl parathion 2 % dust @ 20 kg / ha - 15 DAG

2. BLISTER BEETLE

Scientific name: *Cylindrothorax ruficollis* Oliv.(Meloidae : Coleoptera)

Marks of Identification : -

- The beetles are medium-sized, 1.25 to 2.5 cm long with dark bright metallic blue, green, black or brown in colour.

Nature of damage:

- The adult is only damaging stage. The adults feed on the pollen and flowers and cause considerable damage.
- As a result of feeding, reduce the setting of grains.

- When disturbed the beetles emit a fluid containing the oil principle, Cantharidin, which has irritant properties, through the openings in the apices of the femur which causes Blister. The larvae remain in the soil and feed on eggs of the grasshopper and work as a beneficial stage.

Life cycle:

- Each year blister beetles tend to have one generation.
- A female beetle can lay up to 4,000 eggs; however, many will not survive.
- The adults lay their eggs either in the soil or near a bee's nest so that when the larvae hatch in the spring, they can attach themselves to bees or grasshoppers and feed off of their eggs (sometimes referred to as bee lice).
- From this larva stage, they will later turn into a legless grub, and then into a fully-grown adult, which occurs through May to September or the typical growing season.

Habitat:

- Blister beetles feed on alfalfa and other blooming plants, which commonly place them in the field at the same time as harvest, mixing these toxic pests in with the forage and poisoning the livestock that eats it.
- Blister beetles also tend to be found in areas with frequent grasshopper outbreaks.
- While this beetle can damage a farmer's alfalfa crop, especially when the beetle presents itself in swarms, the main concern is the effect they have on livestock, especially horses.
- When consumed, cantharidin can aggravate the animal's urinary and gastrointestinal tracts, sometimes leading to fatalities.

Management:

- Spraying of lambda-cyhalothrin 5% EC 5 ml in 10 litres of water

3. PINK STEM BORER

Scientific name: *Sesamia inferens* Walker

Family: Noctuidae

Order: Lepidoptera

Marks of identification :

- The eggs are rounded, pale and yellowish-green in colour laid on leaf sheath.
- The caterpillars are pinkish in colour without any stripes.
- The adult moth is small, stout and straw coloured, measuring about 28 mm in wing expands.

Life cycle :

- The life cycle is completed in about 40-70 days, depending upon the climatic conditions.
- There are 4-6 generations in a year.
- The eggs are laid in clusters in several rows within the cover of the leaf sheath.
- The eggs are rounded, pale and yellowish-green in colour.
- The larvae after hatching bore into the stem and feed upon the tissues of the stem.

- A fully grown caterpillar is cylindrical with its head red-brown in colour and measures 20-25 mm in length.
- It pupates inside the stem itself.
- The egg stage lasts for about 7-10 days, larvae for 20-30 days and pupal stage for 8-10 days.

Nature of Damage:

- The damage to the wheat crop is mainly caused by the caterpillars.
- The caterpillars bore into the stem and feed upon the tissues of the central shoot.
- The infected plant produces 'dead heart' or 'white ear heads'.

Management

- The infected wheat plant should be uprooted and destroyed.
- After harvesting the crop the stubbles should be collected and destroyed.
- Rotation of crop.
- The egg is parasitized by *Telenomeus* spp and *Trichogramma minutum*.
- The larva is parasitized by *Apanteles flavipes*, *Bracon chinensis* and *Sturmiopsis inferens*.
- The pupa is parasitized by *Xanthopimpla* sps and *Tetrastichus aygari*.
- Application of quinalphos 1.5% dust
- The spray of quinalphos 25 EC 20 ml/ 10 lit of water or granules of carbofuran is effective in checking the destruction from this pest.

4. TERMITE

Scientific name: *Odontotermes* spp.

Family: Termitidae

Order: Isoptera

Host plants: Polyphagous

Distribution: Tropical and sub-tropical regions of the world

Marks of identification:

- These are social insects, live in termitaria, in distinct castes, workers, soldier, king and queen.
- Workers' are small (4 mm) and have a soft, white body and a brown head.

Life cycle:

- The queen produces thousands of eggs over the lifetime.
- After mating, the new queen starts laying eggs in about a week.
- Eggs are laid in a crevice by digging a hole in the soil or by excavating a tunnel in wood.
- Once the nuptial chamber is constructed the king and queen will mate.
- Initially, the queen lays only a few eggs which are looked after by her and the king.
- The eggs are normally laid singly.
- Incubation takes from 24 to 90 days.

- There are normally seven nymphal instars (stages) in established colonies but the number varies depending on temperature, age of the colony, size of the colony and relative humidity. The nymphs may grow into soldiers or workers.
- The worker's life span is one to two years.
- After a few years, sexuals are released from the colony, who will, in turn, form new colonies.

Nature of damage:

- The termite is endemic in red and sandy soils.
- All termites eat cellulose (e.g. from dead plant fibre) and many termites cultivate a fungus within the nest, which is a source of food (especially proteins) for the queen, king and the young.
- Wilting of plants in patches
- Termites penetrate and hollow out the taproot and stem thus kill the plant.
- Boreholes into pods and damage the seed.
- It removes the soft corky tissue between the veins of pods causing scarification, weakens the shells, making them liable to entry and growth of *Aspergillus flavus* that produces aflatoxins.

Management:

- Collect and destroy leaves and stubbles of the previous crop from the field.
- Deep ploughing in summer, so it destroys the colony as well as termatorium of the termite.
- Use well-decomposed organic manure.
- Digging of termitaria and destruction of the queen is most important in termite management
- Before preparation of the field, add neem, castor or karanj cake in the field then irrigate the field and after one-week sowing should be done.
- Give irrigation in the field at a regular interval; do not create water stress condition in the field.
- Preparations based on insect-attacking nematodes and the fungi *Beauveria bassiana* and two species of *Metarhizium*, however, are effective, especially when introduced into mounds. Fungi spores can act as repellents.
- Treat 100 kg of seeds with bifenthrin 10 EC 200 ml or chlorpyrifos 20 EC 450 ml or fipronil 5 SC 600 ml in 5 litre of water and place it on the ground floor for a night then use these seeds for sowing purpose on next day.
- In case of irrigated wheat are recommended to apply cake before sowing and sow the seeds air-dried for 12 hours after treating with any one of the following insecticides diluted in 5 litres of water for the management of termite.
 1. Castor cake @ 1 ton/ha and fipronil 5 SC 500 ml/100 kg seeds
 2. Castor cake @ 1 ton/ha and chlorpyrifos 20 EC 400 ml/100 kg seeds
 3. Neem cake @ 1 ton/ha and fipronil 5 SC 500 ml/100 kg seeds

- If seed treatment was not given in wheat and incidence of termite was observed in the field, so mix chlorpyrifos 20 EC 2.5 litre or fipronil 5 SC 1.6 litre + 100 kg sand + 5-litre water and spread these sand in the field then give light irrigation in the field.

PESTS OF FINGER MILLET AND RAGI

1. PINK STEM BORER *Sesamia inferens* Walker (Noctuidae : Lepidoptera)

As per wheat

2. CUT WORM *Spodoptera exigua* (Noctuidae: Lepidoptera)

- The moth is brown coloured with white hind wings. It lays eggs in groups in plants.
- Larva is nocturnal in habit. It is brownish green with wavy lines on the dorsal surface and yellow stripes laterally.
- The larvae feeding on leaves and defoliates the plant. The larval period is 10-16 days. It pupates in earthen cocoons in soil for 7-11 days.

Management.

- In nature, larvae are infected by entomopathogenic fungus, *Nomuraea rileyi* and parasitised by *Bracon* sp. Thiodicarb 10 g/10l or acephate 10 g/10 or chlorpyrifos 25 ml/10 l as foliar sprays are recommended.

3. RAGI ROOT APHID *Tetraneura nigriabdominalis* (Aphididae: Hemiptera)

- Pale greenish, plumpy aphids remains at the base of the plant and suck sap from roots of ragi plants in nursery as well as main field resulting in plants turn pale yellow and become stunted.
- Wilting and drying of plants in patches is the typical symptom. Activities of ants which move about at collar region of plant for honeydew indicate the infestation by aphids. Upon examination aphids are seen attached to roots when pulled. Collar region turns black.
- Mix dimethoate 30EC 3 ml in one litre of water and drench the rhizosphere of the infested and surrounding plants with solution to check the root aphid.

4. ROOT GRUB : *Holotrichia consanguinea* (Melolonthidae: Coleoptera)

As per groundnut

PESTS OF SUGARCANE

1. EARLY SHOOT BORER

Scientific name: *Chilo infuscatellus* Snellen

Family: Crambidae **Order:** Lepidoptera

Hosts: Sugarcane

Distribution: Tamil Nadu, Andhra Pradesh, Punjab, U.P., Bihar, West Bengal, Madhya Pradesh, Rajasthan and Maharashtra

Marks of identification:

- The eggs are white and flat, laid in batches.
- The caterpillar is white with five violet stripes on the dorsal side of the body with a brownish head. The crochets in the prolegs are crescentic or semi-circular.
- Pupa is light brown in colour.
- Adult is straw coloured fore wings and whitish hind wings with apical light buff areas.

Life cycle:

- Eggs are laid on the under surface of the leaves by the side of the midrib in three or more rows, one overlapping the other. Eggs are laid on the leaf sheath also.
- A moth may lay more than 200 eggs at a time and in each cluster 8 - 60 eggs will be found. The oviposition is at peak during May in March - April planted crop. The eggs hatch in 3 - 4 days.
- The larval stage lasts for about 35 days
- Pupates inside the stem and the pupal period lasts for 10 days
- The moths live only for 2-4 days
- Total life cycle occupies 44 - 49 days
- Insect behaviour: The caterpillars cut a hole on the side near ground level and enter the shoot and feed downwards. The affected tiller will decay emitting a foul smell.

Nature of damage:

- Dead heart in 1-3 month old crop, which can be easily pulled out, rotten portion of the straw coloured dead-heart emits an offensive odour.
- A number of bore holes at the base of the shoot just above the ground level can be seen.
- It is major pest in the early stage of the crop.

- If the attack is in early stage, the mother shoot dies completely and late attack induces profuse tillering.

Management:

- Systematic collection of egg masses and their destruction.
- Removal of dead hearts and their destruction.
- Adjusting the planting dates to avoid the peak oviposition. Minimum incidence is in November and December planting. Maximum incidence is in January and February planting.
- Set treatment with 0.1% malathion or chloripyriphos.
- Light earthing up of soil up to 4-6 week old crop to make the stem inaccessible to larvae followed by frequent irrigations.
- The release of egg parasites, *Trichogramma minutum*; *T. australicum* is reported to have given good control of this pest at many places (Chagallu sugar factory area).
- Application of carbofuran 3G @ 33 kg/ha or Phorate 10G @ 10 kg /ha at 30 day after sowing or spraying the crop with chlorantraniprole 18.5 SC @ 4 ml or chlorpyrifos 20 EC @ 25 ml or fipronil 5 SC 30 @ 30ml or monocrotophos 36 SL @ 30 ml per 10 liter of water.

2. INTERNODE BORER

Scientific name: *Chilo sacchariphagus indicus* (Kapur)

Family: Crambidae **Order:** Lepidoptera

Hosts: Sugarcane, pearl millet, sorghum, maize and paddy

Distribution: The insect is found throughout India. It is serious in Andhra Pradesh, Karnataka, Kerala, Tamil Nadu and Uttar Pradesh.

Marks of identification:

- Oval flattish, scale like eggs are laid in rows on the leaf.
- The larva is white with dark spots on the body and four light violet stripes on the dorsal surface. The dorsal median line is absent. The head is shiny yellowish brown. The crochets on the prolegs are circular.
- Pupa is brownish red in colour.
- The adult is a pale brown moth with a white hind wing.

Life cycle:

- Eggs laid in batches, each batches containing 9-11 eggs in rows, on the sheathing leaves. Maximum 400 eggs laid by female. The incubation period is 5-6 days.
- Larva become fully mature within 35 to 53 days
- Pupal period last for 8-10 days, pupate in leaf sheath
- Ault's survive for 3-4 days
- Total life cycle occupies 50-70 days. There are six brood in a year.

- Larva bore at the nodal region enter to stem. It's feeding caused tissue to turn red and the hole usually plugged with excreta

Nature of damage:

- Usually occurs on sugarcane late in its growing phase during June – December
- The young larvae feed on the leaf sheath by scrapping the tissues and later they bore internodes of the cane top resulting in the formation of dead hearts. Damaged internodes get hardened and reduced in length and girth.
- Losses to cane are more to its damage than to its quality. However, juice quality is affected if more than 10 per cent of cane is affected.

Management

- Same as Stalk borer

3. TOP BORER

Scientific name: *Scirpophaga excerptalis* Walker

Family: Pyraustinae

Order: Lepidoptera

Hosts: Sugarcane and wild *Sacchrum* spp.

Distribution: The insect has a wide distribution in India but is more serious in North India. **Marks of identification:**

- Egg is dull white elongated.
- The caterpillar is cream yellowish white, slender and soft. After entering the shoot it does not move out.
- Pupa is cylindrical in shape and pale yellow in colour.
- Moth is uniformly creamy white in colour. The first pair of wings of certain moths bears a black spot on each wing. Females have a crimson hairy tuft at the anal end.

Life cycle:

- Female lays about 250-300 overlapping eggs in cluster, usually near the midrib of leaves and covered with a brown tuft of hairs. Egg period is last for 7-12 days.
- Larval period lasts for 25 - 41 days
- Full grown larva pupates inside the stem tunnel and emerges after 12 - 21 days. The adult comes out through the hole made by the larva before pupation.
- Adult live for 4-5 days
- There may be 5-7 generations in a year, pest remain active from February to October
- The total life cycle lasts for 45 – 75 days
- The infestation is detected by the presence of reddish brown charred 'Dead heart' and shot holes in the leaves and galleries in the midrib. The formation of side shoots which give rise to bunchy top

Nature of damage:

- The neonate larva bores through the midrib and slowly reaches the central region. It feeds through the leaf whorl, enters the growing shoot from the top and feeds downwards.
- It occurs on sugarcane in the later stages of growth during June-December and may persist till harvest
- Tunnelling of midrib in a leaf, small holes in a parallel line in the freshly appeared leaves, dead heart which is reddish brown in the young crop (2 - 4 months old) and a bunchy top in a grown up crop are the characteristic symptoms. Sprouting of the eye buds affects the quality of the juice.
- Since the growth is restricted, the yield is also affected. It accounts for 20 - 30 per cent reduction in yield resulting in low juice quality and early maturity of the crop. The sucrose per cent in juice decreases by 2 units.

Management :

- Collection and Destruction of egg masses.
- Removal of infested plants along with larvae.
- Two Trichocard (*Trichogramma japonicum*) i.e. 50,000/ha at an interval of 15 days for 6 to 7 times i.e. 2,40,000 to 2,80,000 /ha.
- Soil application of carbofuran 3 % G @ 1.00 kg a.i./ha two times i.e. at the time of sowing or one month after sowing (at the time of earthing up) or phorate 10% G @ 1.00 kg a.i./ha three times i.e. 30, 90 and 150 DAP or
- Spraying the crop with chlorantraniprole 18.5 SC @ 4 ml per 10 liter of water.

4. STALK BORER

Scientific name: *Chilo auricilius* Dudgeon

Family: Crambidae **Order:** Lepidoptera

Hosts: Sugarcane, paddy, wheat, oat and *baru*

Distribution: Most destructive pest in northern area

Marks of identification:

- 200-300 scale like eggs overlapping in clusters of 60-70
- The full grown caterpillar is 25-30 mm long with a light bluish pink body and has dark brown head and five longitudinal violet dorsal strips.
- Adult: the moth is straw coloured and female has wing expanse of 22-30 and male has wing expanse of 20-25 mm. The forewings have golden spots and the hind wings are silvery white.

Life cycle:

- Eggs are laid in leaf sheaths or on the underside of leaves of late winter shoots and early ratoon sprouts.

- Eggs period about a week.
- The larva full grown in 3-6 weeks and passes through five stages.
- Pupal period about one week.
- Total life cycle is completed in 5-9 weeks.

Nature of damage:

- Larva is damaging to the crop.
- On hatching, larva feeds by scrapping the inner surface of leaf sheath. Later on, larva bores into the shoots and internodes of the canes. In early stage of crop growth, the damage results in dead hearts, very similar to those caused by *C. infuscatellus*.
- In grown up canes, bore holes may be seen on the internodes after removal of leaf sheath
- The damaged internodes show symptoms of reddening within and emit a rancid odour

Management.

- Grow resistant varieties in the area where the stalk borer is a serious pest.
- Do not use the cane-seed from the infested field.
- Spread of the pest to uninfested areas may be prevented by restricting the movement of infested canes
- The pest population can be suppressed by burning the trash in the fields after harvest and by removing and destroying the water-shoots over large areas during February-March. This practice also induces tillering and is useful,
- Do not ratoon a heavily infested crop; plough up the affected fields, collect the stumps and destroy them,
- At harvest, do not leave the water-shoots in the field,
- Staple *Tricho-cards*
- Spraying the crop with chlorpyrifos 20 EC @ 25 ml or monocrotophos 36 SL @ 30 ml per 10 liter of water.

5. ROOT BORER

Scientific name: *Emmalocera depressella* Swinhoe

Family: Crambidae **Order:** Lepidoptera

Host: Sugarcane, *sarkanda*, *baru* and Napier grass

Distribution: Very important pest in eastern area

Marks of identification:

- Eggs are scale like creamy white.
- Larva is creamy white with yellowish brown head and rather wrinkles body.
- Adult moth measures about 25 mm in wings span relatively active and measures 2-2.5 cm in length.

Life cycle:

- Creamy white scale like eggs is laid singly on the leaves, the stem or on the ground.
- Eggs are hatched in 5-8 days
- Larval period about four week with five stages
- Pupate inside the canes after making emergence holes just above the soil surface.
- Pupal period is 9-14 days.
- Adult period is 5-7 days.
- Total life cycle is completed in 6-7 days.

Nature of damage:

- On hatching, larva crawls to the base of the stem and enters the stem by making a hole just below the ground level.
- Larva bores out right across the underground portion of stem and hence central leaves of the attacked plant dries up forming a **dead heart** which cannot be pulled out easily.

Management.

- Pest can be suppressed by ploughing and burning the stubbles in the field.
- Avoid ratoon crop.
- The cane should be harvested below the soil surface killing the caterpillars.
- Apply phorate 10 G or carbofuran 3 G or quinalphos 5 G any of these @ 1.0 kg a.i./ha or neemark 15 G @ 3 kg ai/ha or sevidol 4 G @ 1.5 kg ai/ha or fipronil 0.3 % G @ 33 kg/ha applied to the soil at the time of earthing up for the effective control of sugarcane root borer or spraying the crop with fipronil 5 SC 30 @ 30ml per 10 liter of water.
- Biological Control :
- Two Tricho card i.e. 50,000/ha at and interval of 15 days for 6 to 7 times i.e. 2,40,000 to 2,80,000 /ha.

6. LEAF HOPPER

Scientific name: *Pyrilla perpusilla* Walker

Family: Lophopidae **Order:** Homoptera

Hosts: Sugarcane, wheat, rice, maize, oats and barley

Distribution: It is major pest of sugarcane in Punjab, Uttar Pradesh, Bihar and Maharashtra. Generally, it is a minor pest but sometimes assume a major form remaining parts of the country.

Marks of identification:

- The female bug lays greenish yellow eggs in clusters. The eggs are covered with white cottony, waxy filaments.
- Nymph is also covered with white wax and has a pair of long anal waxy filament.

- Adult is straw coloured, wings are slanting like roof of the front side, it has snout like prolongation and has prominent eyes.

Life cycle:

- Eggs are laid on the under surface of leaves and between the detached leaf sheaths and the stem, 10 - 15 eggs are found in a cluster and they hatch in about a week.
- The nymphs have two characteristic anal processes and feed on plant sap. They develop into adults in 50 – 60 days.
- The insects are generally found from August - September. The intermittent periods of drought during July - September, heavy manuring and irrigation and luxuriant growth help in its profuse multiplication.
- The broad and soft-leaved varieties are more susceptible to this pest.

Nature of damage:

- They suck the cell sap from the leaves and secrete honey dew which attracts the black fungus.
- Due to this feeding the leaves turn yellow and finally look withered and burnt with black encrustation.

Management

- Release of the lepidopteran ecto-parasitoid, *Epiricania melanoleuca* @ 4000 - 5000 cocoons or @ 4 - 6 lac eggs/ha checks its multiplication.
- In case of severe infestation without the occurrence of the ecto-parasitoid, spraying of thiamethoxam 25 WG 4g or flonicamid 50 WP 3g in 10 lit of water.

7. WHITEFLY

Scientific name: *Aleurolobus barodensis* Maskell and *Neomaskellia bergii* (Sign.)

Family: Aleyrodidae **Order:** Homoptera

Hosts: Sugarcane and *Sarkanda*

Distribution: Bihar, Gujarat, Haryana, Karnataka, Maharashtra, Punjab, Tamil Nadu, Uttar Pradesh and Andhra Pradesh

Marks of identification:

- About 60-65 creamy white conical eggs which are glued to the surface of the leaves.
- On emergence, the young nymphs are pale yellow and have three pair of legs. They gradually turn to shiny black, oval in outline, flattened, scale like in form remain sticking to the same spot on a lower side.
- Adults are small, delicate with pale yellow abdomen and dirty white wings

Life cycle:

- Eggs are fixed firmly on the leaf tissue on both the surfaces. The incubation period varies from 9 - 13 days.
- Three nymphal instars last for 4 – 7, 3 – 7 and 3 – 8 days, respectively. The fourth instar (pupal stage) lasts for 9 - 14 days. The last nymphal instar is the pupal stage from which through a T-shaped opening the adult emerges.
- In a year about nine generations are completed.
- The life-cycle is completed in 32 – 44 days.

Nature of damage:

- The sap drainage by nymphs result in the leaf gradually turning yellow and pinkish and ultimately the leaf dries up.
- The nymphs excrete large quantities of honey dew which accumulates on the affected leaves and the leaves appear black due to development of sooty mould interfering with photosynthesis. High infestation causes stunted crop growth and reduces juice quality.
- Severe whitefly infestation may result in reduction of cane yield up to 24 per cent and loss in sugar up to 2.9 units.

Management.

- Avoid ratooning especially in low lying and water logged areas.
- Detrash lower leaves containing the puparia.
- Spraying the crop with dichlorvos 76% EC @ 0.03% or acephate 75% SP @ 0.05% or quinalphos 25% EC @ 0.03% or triazophos 40% EC @ 0.05%

8. WOOLLY APHID

Scientific name: *Ceratovacuna lanigera* Zehntner

Family: Pemphigidae **Order:** Homoptera

Hosts: Sugarcane and bamboo, *Miscanthus sinensis*.

Distribution: Assam, Nagaland, Sikkim, Tripura, U.P., Bengal, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Kerala, Uttaranchal, Bihar and Gujarat

Marks of identification:

- Newly emerged nymphs are yellowish or greenish yellow in colour devoid of woolly filaments. Nymphs are found congregated at both the sides of the midrib on the lower surface of the leaves.
- There are four instars observed after which they become adults. White coloured woolly filaments are observed on the dorsal side of the 3rd and 4th instar nymphs and not on the 1st and 2nd instars. Adults are black in colour and they have two pairs of transparent wings and a pair of cornicles.

Life cycle:

- Female produced a maximum of 217 nymphs in 20 days. Nymphs completed four instars to become adults in 6 - 22 days.
- The life cycle of this aphid is completed in a period of one month depending on climatic condition and sugarcane varieties.
- Overlapping generations are observed in the field.

Nature of damage:

- Both the stages suck the cell saps from lower surface of the sugarcane leaves and suck the cell sap and excrete 'honey dew' which is dropped on the upper surface of the lower leaves.
- Honey dew encourages the growth of the fungus *Capnodium* spp. which results in black coating called 'sooty mould' on the upper surface of leaves affecting photosynthesis. Due to sap sucking, yellowish white spots develop on the leaves leading to drying of leaf edges and complete drying of leaves.
- Severe infestation causes mottling of leaves, stunted growth, and loss in sugarcane yield and sugar recovery.
- Losses up to 26 per cent in sugarcane yield and 24 per cent in sugar content have been reported.

Management

- Earthing up to destroy infested material, weed management
- Restricting movement of seed material from infested areas
- Biological control by neuropteran predator, *Chrysoperla carnea*; lepidopteran predator: *Diapha aphidivora* and
- Foliar spray with Acephate 75% SP and dimethoate 30% EC @ 2 gm or 2 ml per lit. water have been found effective against SWA.

MINOR PESTS

1. SUGARCANE SCALE INSECT

Scientific name: *Melanaspis glomerata* (Green)

Family: Diaspididae

Order: Hemiptera

Host: Sugarcane

Distribution: It is considered as a serious sugarcane pest in Maharashtra, Gujarat and in certain pockets of Andhra Pradesh, Madhya Pradesh, West Bengal and UP.

Marks of identification:

- Females multiply ovo-viviparously. The nymphs that hatch out from the eggs within the female's body come out through the genital aperture. They are called 'crawlers'. They settle after selecting suitable site for feeding

- Adult: Greyish black or brown circular scales, they cover the nodal region forming a thick encrustation

Life cycle:

- The female reproduce oviparously 100-250 crawlers. There are five larval instar and total life cycle of female varies from 34 to 62 days.
- The differentiation of sex could be determine in the third instar.
- The male passes through a definite pupal period ranging from 6-13 days and total life cycle varies from 19 to 36 days.
- The insect complete 9 generation in year.

Nature of damage:

- Grown up nymphs are round, grey to light black in colour and the adult female remain protected under leaf sheath and suck the sap from the stem and cause shrivelling up and stunting of canes. *Pharosymnus horni* and *Chilocorus nigritus* are the important predators of this pest.

2. MEALYBUG

Scientific name: *Saccharicoccus sacchari* Cockerell

Family: Pseudococcidae **Order:** Hemiptera

Host: Sugarcane

Distribution: It is found to be distributed all over the Australia

Nature of damage:

- The eggs are laid in masses at the lower nodes of young cane. Young crawlers are tiny, active and settle under the leaf sheath, remain protected there and suck up the sap from cane. They also secrete honey dew on which black sooty mould develops.

Management for mealy bug and scale.

- Selection of pest free setts for planting.
- Avoid ratoon crop.
- Detrashing the lower leaves after six months of planting to reduce the pest population.
- Before planting sugarcane setts should be treated with 0.1% Malathion 50 EC (20 ml).
- Soil application of carbofuran 3% G @ 600 gm a.i. /ha, starting from June and give five times at an interval of one month. OR
- Spraying the crop with monocrotophos 36 SL @ 30 ml per 10 liter of water starting from June and give four spray at an interval of one month.
- The predators of Scale are *Pharocymnus horni* and *Chilocorus nigritus*

Management of sugarcane pests:

- Light earthing up of the tillers at the early stages of the crop (month old) during May and June reduces the incidence of early shoot borer. A second earthing up month later reduces the borer attack considerably.
- Mulching with cane trash at the early stages also has been reported to reduce the incidence of early shoot borer and help in conserving moisture.
- Cutting the affected tillers close to the ground as possible and destroying them.
- Soil application of granules of cartap hydrochloride 4 G at 1 kg a.i. /ha at planting followed by another application on 45th day for late planted crop.
- Cartap hydrochloride 4 G 1 kg a.i. /ha as whorl application at 35th and 65th day is also found effective.
- Inundative releases of the egg parasitoid *Trichogramma chilonis* @ 50,000/ha from first month of planting at 7 - 10 days interval till one month prior to harvest.
- Installation of light traps for monitoring the pest
- Fertilizers and irrigation should be used as the recommendation
- At 30th, 45th and 60th day of crop growth spray granulosis virus of *Chilo infuscatellus* (10^{-7} – 10^{-8} inclusion bodies/ml) at 500 litre per hectare.
- Release of 125 gravid females of *Sturmiopsis inferens* (Tachinidae) per ha at 45th day of crop growth
- Inundative release of the egg parasitoid *Trichogramma chilonis* @ 50,000 parasitoid/ha/week from the 4th up to 11th month after planting affords protection.
- Use of resistant varieties are CO 285, 453, 513, 617, 853, 915, 1007, 1287, 6806 and COJ 46.
- The egg masses and also the infested portions of plants may be collected and destroyed during the brood emergence period
- Release of the ichneumonid parasitoid, *Gambroides javensis* Rohw. has been found to be promising in Tamil Nadu.
- Variety Co 419 is comparatively resistant to this borer. Other resistant varieties are CoS 767, CoJ 67 and Co 1158.
- Soil application of carbofuran at 2 kg a.i. /ha or phorate at 1 kg a.i. /ha for the third brood during first week of July is recommended.
- Discourage ratooning in low lying areas and avoid water logging. Remove lower leaves containing pupae periodically.

- Spray acephate 75 SP 12 g or monocrotophos 36 SL 14 ml or acetamiprid 20 SP 4 g or triazophos 40 EC 40 ml in 10 litre of water after removing infested lower leaves. At least two or more sprays will be required at fortnightly intervals.
- Paired or wider row planting of sugarcane
- Release of the natural enemies, *Dipha aphidivora* Meyr. Or *Micromus igorotus* in shade net cages (5 m x 5 m) @ 50/cage and allow them to develop and disperse by removing the cages.
- Release of *D. aphidivora* larvae @ 1000/ha and *M. igorotus* larvae @ 2500/ha.
- Need based application of dimethoate 30 EC 15 ml or acephate 75 SP 10 g in 10 litre of water in case of severe infestation without the presence of natural enemies

3. TERMITE

Scientific name: *Coptotermes Heimi* Wasmann; *Odontotermes Assmuthi* Holmgr; *O. Obesus* Rambur; *O. Wallonensis* Wasmann; *Microtermes Obesi* Holmgr; *Trinervitermes Biformis* Wasmann

Family: Termitidea

Order: Isoptera

Host: Cotton, sugarcane, wheat, groundnut

Distribution: It is found to be distributed worldwide

Nature of damage:

- Damaging stage: Workers
- Polyphagous and found throughout the world. More serious under prolonged drought conditions and in light textured soils viz., sandy and sandy loam soils
- The termites attack setts, shoots, canes and also stubbles
- The termites gain entry through the cut ends or through buds of the setts and feed on the soft tissue. The tunnel excavated is filled with the soil. This affects germination and thus the initial crop stand and ultimately the cane yield. The germination failure could be up to 60 per cent.
- In the stalks the termites feed on the inner tissues leaving the rind intact. The cavity formed is filled up with moist soil, having galleries, in which, they move about. The affected canes die.

PESTS OF COTTON

BOLLWORMS:

1. SPOTTED BOLLWORM

Scientific name: *Earias vittella* (Fabricius), *Earias insulana* (Boisduval)

Family: Gelechiidae **Order:** Lepidoptera

Hosts: Cotton, okra, Hollyhock, *Hibiscus* spp., *Abutilon indicum* and other malvaceous plants

Distribution: Worldwide

Marks of identification:

- The female moth lays spherical and sculptured bluish eggs
- The caterpillars of both the species have number of black and brown spots on the body and hence the name spotted boll worm. Full grown larva measures 14 mm in length
- Before pupation, the larva spins a dirty, white boat shaped silken cocoon
- Adult of *E. vittella* has pale whitish forewings with a broad greenish band (wedge shaped) in the middle while *E. insulana* has completely green forewings. The adult body length is about 1 cm while the wing span is about 2.5 cm.

Life cycle:

- Eggs are laid singly or in groups on tender parts of the plant viz., fresh leaves, fresh squares (flower buds) and flowers. On an average each female moth lays 60-80 eggs. Egg stage is about 2-10 days.
- The larval stage lasts for about 9 -25 days.
- Pupation takes place generally in fallen material, outside the boll, on plant surfaces and in cracks and crevices of the soil. Pupal period is about 6-25 days.
- During the winter only pupae are found hiding in plant debris.
- Adult life-span is 5-7 days.

Nature of damage:

- The spotted bollworm appears about 6 weeks after sowing and initially damages the tender shoot by boring into it resulting in “drying of central shoots” which withers and drops down later on.
- The larvae later bore into the flower buds, squares and bolls
- The larva inserts its head inside the boll and feeds by filling the boll with excreta.

- A larva may move out and feed on another bud or boll. The feeding causes severe shedding of early formed flower buds and bolls

2. AMERICAN BOLLWORM

Scientific name: *Helicoverpa armigera* (Hubner) Hardwick

Family: Noctuidae **Order:** Lepidoptera

Hosts: It is a polyphagous pest infesting gram, lablab, safflower, chillies, groundnut, tobacco, tomato etc.

Distribution: American bollworm has a worldwide distribution in all the cotton growing regions of the world.

Marks of identification:

- The spherical, yellowish eggs are laid singly on tender parts and buds of plants.
- Caterpillars are of varying colour, initially brown and later turn greenish with darker broken lines along the side of the body. Body covered with radiating hairs. When full grown, they measure 3.7 to 5 cm in length.
- The full grown caterpillar pupates in the soil in an earthen cell and emerges in 16-21 days
- Moth is stout, medium sized with brownish/greyish forewings with a dark cross band near outer margin and dark spots near costal margins, with a wing expanse of 3.7 cm.

Life cycle:

- Eggs are laid singly or in groups on tender parts of the plant viz., fresh leaves, fresh squares (flower buds), and flowers. On an average each female moth lays 60-80 eggs. Egg stage is about 2-10 days.
- The larval period lasts for 18-25 days
- The full grown caterpillar pupates in the soil in an earthen cell and emerges in 16-21 days
- Adult period is about a week.

Nature of damage:

- Young larva feeds on the leaves for some time and then attacks squares and bolls.
- Internal tissues are eaten severely and completely hollowed out.
- While feeding, the caterpillar thrust its head inside leaving the rest of the body outside
- Holes are bore at the base of the buds, which are hollowed out.
- Cotton varieties with hairy leaves are more susceptible to *Helicoverpa* damage.

3. TOBACCO LEAF EATING CATERPILLAR

Scientific name: *Spodoptera litura* Fabricius

Family: Noctuidae **Order:** Lepidoptera

Hosts: Besides tobacco, it feeds on cotton, castor, groundnut, tomato, cabbage and various other cruciferous crops etc.

Distribution: Worldwide

Marks of identification:

- Female lays about 300 eggs in clusters. The eggs are covered over by brown hairs.
- Caterpillar measures 35-40 mm in length, when full grown. It is velvety, black with yellowish – green dorsal stripes and lateral white bands with incomplete ring – like dark band on anterior and posterior end of the body.
- Moth is medium sized and stout bodied with forewings pale grey to dark brown in colour having wavy white crisscross markings. Hind wings are whitish with brown patches along margin of wing. Pest breeds throughout year. Moths are active at night.

Life cycle:

- Eggs lay in groups on tender parts of the plant viz., fresh leaves, fresh squares (flower buds) and flowers. On an average each female moth lays 4-5 egg masses. Egg stage is about 7-10 days
- The larval stage lasts for about 15-30 days. It passes through 6 instars
- Pupation takes place inside the soil; pupal stage lasts for 7-15 days
- Total life cycle takes 32-60 days. There are eight generations in a year.
- Adults lives about 7-10 days

Nature of damage:

- In early stages, the caterpillars are gregarious and scrape the chlorophyll content of leaf lamina giving it a papery white appearance
- Later they become voracious feeders making irregular holes on the leaves and finally leaving only veins and petioles
- During flowering and boll formation stage, the caterpillars also feed on the internal contents of bolls causing irregular holes

Management of bollworms (Spotted bollworm, *S. litura* and American bollworms):

- Plough the field after last picking
- Purchase the labelled packed seed
- Install 5 pheromone traps for monitoring the spotted bollworm, tobacco leaf eating caterpillar and American bollworms.
- In endemic area, raise castor as ovipositional trap crop for *S. litura*
- Raise African yellow flower marigold as ovipositional trap crop for *H. armigera*
- Keep heaps of grass/weed at evening in-between two rows and collect them early in the morning along with the larvae of *S. litura* and destroy them.

- Spray SNPV for the control of *S. litura* @ 250 LE/ ha on appearance of larval population.
- Spray HaNPV for the control of *H. armigera* @ 450 LE/ ha on the appearance of the population.
- Collection and destruction of bigger larvae of *S. litura* and *H. armigera*
- On the incidence of *S. litura*, spray neem based formulation 20 ml (1 EC) to 40 ml (0.15 EC) or NSKS @ 5 per cent.
- Spray *Bt* base insecticide @ 10 to 15 g per 10 litre of water.
- Prepare a poison baits (chlorpyrifos 20 EC 100 ml + wheat bran 10 kg + jaggary 2 kg + water 7.5 litre) and apply in the field for the control of *S. litura*
- Spraying of quinalphos 25 EC 20 ml, fenvalerate 20 EC 10 ml, emamectin benzoate 5 WG 5 g, spinosad 45 SC 3 ml, novaluron 10 EC 10 ml, chlorantraniliprole 18.5 SC 3 ml, flubendiamide 480 SC 3 ml, indoxacarb 15.8 EC 10 ml, thiodicarb 75 WP 20 g, lambda-cyhalothrin 5 EC 5 ml in 10 litre of water. Spray any of them and change the insecticide in subsequent sprays.

4. PINK BOLLWORM

Scientific name: *Pectinophora gossypiella*(Saunders)

Family: Gelechiidae **Order:** Lepidoptera

Hosts: Cotton, okra, hollyhock, *Abutilon indicum*, hibiscus and other malvaceous crops

Distribution: Worldwide

Marks of identification:

- Female lays flat-scale like whitish eggs singly on various parts of young shoots. However, half developed bolls are preferred when available.
- The freshly hatched larvae are white and turn pink as they grow older.
- Pupation occurs in flimsy cocoon in boll, often in seed hollowed out by larva.
- Moth is small about 5-6 mm in length and has wing span of 12.5 mm. Body is dark brown in colour with numerous small black spots on the wings. The first segment of the antenna bears 5-6 long stiff hairs and the palpi are pointed and curved upwards. The moths are active during night.

Life cycle:

- Eggs are laid singly and protected by calyx. On an average each female moth lays 60-80 eggs. Egg stage is about 2-10 days.
- The larval stage lasts for about 9 -25 days
- Pupation takes place generally in-between two seeds. Pupal period is about 6-25 days.
- The hibernating larvae live in double seeds for many months and after passing the winter, they emerge as moths

- Adult period is about a week.
- No. of generation per year: 4-6 generations are completed.

Nature of damage:

- The larvae do most spectacular damage to practically mature cotton bolls which they enter mostly at such a tiny stage of just hatched larvae that their entry holes get healed and in which they remain, devouring both seed and fibre forming tissues.
- The attacked bolls fall off prematurely and those mature do not open freely and do not contain good quality lint.
- On severe infestation, more than one larva also found in single boll and 75-100 per cent bolls are found infested.

Management:

- Dispose the cotton sticks properly or use them for preparing the organic compost.
- Collect the fallen squares, infested bolls and burn them
- Collect and destroy deformed or rosette squares or flowers along with larvae.
- Allow the sheep and goats to graze the unopened bolls after the last picking
- Ginning process should be completed before the new sowing of the cotton
- The wastage of cotton in ginning factories should be disposed properly
- Install the sex pheromone traps in the premises of the ginning units and also around the factory
- Install the pheromone traps for monitoring purpose @ 5/ ha
- On co-operative basis, install the pheromone traps @ 40/ ha for mass trapping starting from the end of the October up to the end of the season
- Spray the insecticides quinalphos 25 EC 20 ml or cypermethrin 10 EC 10 ml or deltamethrin 1%+ triazophos 35 EC (36 EC) 10 ml or monocrotophos 36 SL 10 ml or spinosad 45 SC 3 ml or betacyluthrin 2.5 SC 10 ml per 10 litre of water starting from the oviposition of the pest
- Select the early *Bt* cotton varieties for the sowing
- Grow refuge as per the norms (10 to 20%)
- Do not use the cotton sticks to give the supports to the cucurbitaceous crop.
- Follow crop rotation
- Spraying of any one of the insecticide after mixing in 10 liters of water. quinalphos 25 EC 20 ml or chlorpyrifos 20 EC 20 ml or profenophos 50 EC 10 ml or cypermethrin 10 EC 10 ml or cypermethrin 25 EC 4 ml or spinosad 45 SC 3 ml or emamectin benzoate 5 SG 3 gm or indoxacarb 15.8 EC 5 ml or thiodicarb 75 WP 10 gm.

5. COTTON LEAF ROLLER : *Sylepta derogata* Fab. Pyraustidae:Lepidoptera

Marks of identification :

- The moth having yellowish wings with brown wavy markings.
- The larva is glistering green with dark brown head and prothoracic shield.

Host plant : Cotton, okra, hollyhock, American cotton

Nature of damage:

- The larva feeds on the lower surface of the leaves when they are young. As they grow they feed on the edges of leaves and roll inwards up to the midrib in to a trumpet shape fastened by means of silken thread and feed on leaf tissues.
- The larvae remain inside the roll and feed on the margins of the leaf.

Life history:

- Eggs are laid on the under surface of the leaves along the midrib and bigger veins. The moth lays as many as 200 eggs.
- The egg, larva and pupal periods occupy 2-3, 15-18 and 7-8 days, respectively. T
- he larva moults six times before pupation. P
- upation takes place in leaves. The life cycle is completed in 25-53 days.

Management:

- Spraying the crop with phosalone 35 EC 25 ml or carbaryl 50 WP 10gm per 10 liter of water

6. COTTON SEMILOOPER: *Anomis flava* Fab. Noctuidae: Lepidoptera

Marks of identification :

- Fully grown larvae are pale yellowish green with five white lines running longitudinally on dorsal surface and with six pairs of black and yellow spots on the back. As they move, they bend the body, forming loops and hence the name Semilooper.
- Adults are reddish brown with forewings traversed by two dark zigzag bands while the hind wings are pale brown.

Host plant : Cotton, Okra, Hollyhock

Life history:

- Fecundity of the females is about 500-600 eggs. Incubation 4 to 5 days.
- Larval period 18-20 days.
- Pupal stage – 8-9 days. Total life cycle 20-35 days.

Nature of damage:

- The young larvae congregate in groups and move actively, feed on the leaf lamina making small punctures.
- The grown up larvae feed voraciously leaving only the midrib and veins. They feed by chewing the leaves from margin towards the leaf veins.
- The caterpillars occasionally feed on the tender shoots, buds and bolls.

Management: As per Leaf roller

Natural enemies: *Apanteles* Sp., *Trichogramma minutum*

SUCKING INSECT PESTS

1. APHID

Scientific name: *Aphis gossypii* (Glover)

Family: Aphididae **Order:** Hemiptera

Host: Polyphagous. Cotton, okra, brinjal, guava *etc.*

Distribution: Worldwide

Marks of identification:

- Nymphs are light yellowish green or brownish or greenish black in colour.
- Adult is small, soft, yellowish, green or greenish brown in colour. It is found in colonies of hundreds on the tender shoot and the under surface of tender leaves. They are characterized by the presence of two tubes like structures called cornicles, on the abdomen. They are wingless normally but winged forms are often found mostly in the beginning and towards the end of season. Wings are thin, transparent and held like a roof over the body. They reproduce both sexually and parthenogenetically.

Life cycle:

- Nymphs are colonizing on growing points, lower surface of leaves and tender shoots. There are four instars. Nymphal period is about 5-9 days
- Adult lives about 5-10 days.

Nature of damage:

- Both nymphs and adults suck the sap by remaining on the lower surface of the leaves. As a result, cotton leaves curled, faded and dried
- Due to the secretion of honeydew, black sooty mould is developed which hinder the photosynthetic activity of the plants. As a result, plant shows stunting appearance.

2. LEAFHOPPER

Scientific name: *Amrasca biguttula biguttula* (Ishida)

Family: Cicadellidae **Order:** Hemiptera

Hosts: Cotton, okra, potato, brinjal, castor, tomato, hollyhock, *Abutilon indicum* etc.

Distribution: They are distributed in all cotton growing regions of India

Marks of identification:

- The yellowish eggs are usually inserted full length into the spongy parenchymatous tissue between the vascular bundles and the epidermis (leaf veins).
- Nymphs are pale greenish in colour like the adults but are wingless and are found in large numbers on lower surface of leaves. The nymph moults five times and the nymphal period last for 7-21 days. The whole life cycle is completed in about two weeks to more than a month depending on environmental conditions. There are 8-10 overlapping generations.
- It is a small insect, varying from less than 1 mm to about 3 mm. Its adult stage is subjected to seasonal changes in colour. The adult is a wedge shaped insect about 3.5 mm in length. There is a black spot on each forewing and two small black spots on the vertex. Both nymphs and adults move diagonally, when disturbed.

Life cycle:

- The female lays about 15 eggs. The eggs hatch in 4-11 days
- Nymphs are active. They pass through six stages of growth in 7 – 21 days.
- Adult lives for 5 – 7 weeks
- The pest completes seven generations in a year
- Both nymphs and adults move diagonally, when disturbed

Nature of damage:

- At nymphal stage as well as adult, it inflict the same type of damage. It sucks the cell sap from the plant tissue
- During de-sapping the plant, it also inject a toxin through saliva into the plant tissue, resulting in hopper burn
- In susceptible varieties, the attack results in mottling accompanied by the curling of the entire lamina with brown necrotic patches. Thus, the entire photosynthetic activity of the plant is adversely affected.
- The pest causing up to 35 per cent reduction in yield

3. WHITEFLY

Scientific name: *Bemisia tabaci* (Gennadius)

Family: Aleyrodidae **Order:** Hemiptera

Hosts: cotton, cabbage, cauliflower, melon, potato, brinjal, okra and some weeds

Distribution: Worldwide

Marks of identification:

- The eggs are light yellow in the beginning but turn brown later on.
- Nymphs are oval shaped, scale like, greenish yellow with marginal bristle like fringes. The nymphs remain stationary once they settle down.
- Adult is minute insect measuring about 0.5 mm in length having white or greyish wings, a yellowish body and red medially constricted eyes.

Life cycle:

- A female lays about 70-100 stalked eggs singly on the under surface of leaves, mostly on the top and middle leaves of plant. Egg period ranges from 3-33 days.
- Nymphs moult thrice. Nymphal period lasts for 9-18 days.
- Pupal stage also observed. Pupal period is 2-8 days.
- Adults live 5-7 days.
- There are about a dozen overlapping generations in a year.

Nature of damage:

- Nymphs and adults suck sap from lower side of leaves. Due to sucking of leaves, chlorotic spots appeared which later coalesce and forming irregular yellowing of leaves which extends from veins to outer edges.
- The vegetative growth of plant is retarded and boll formation seriously hampered.
- Shedding of the bolls accentuated and interfered in proper opening of the bolls.
- Quality lint is also hampered and lowers the oil content.
- Due to honey dew excretion on infested parts, sooty mould is developed on leaves. It is also known for vector of cotton leaf curl virus (CLCV).
- The maximum infestation on cotton occurs during July. High temperature and low humidity are reported to be favourable for the multiplication of this pest.

4. THRIPS

Scientific name: *Thrips tabaci*(Lindeman)

Family: Thripidae **Order:** Thysanoptera

Hosts: Cotton thrips is a highly cosmopolitan form and is found on all kinds of vegetation. Onion and garlic, amaranthus, guava, solanaceous and cucurbitaceous plants, groundnut, chillies, mango, cabbage, okra etc.

Distribution: All over India

Marks of identification:

- The nymphs are resemble to the adults but are wingless and slightly smaller.

- The adult are slender, yellowish brown and measure about 1 mm in length. The females have long, narrow strap-like wings, which furnished with long hair along the hind margins (fringed wing).

Life cycle:

- Female lays 50-60 kidney-shaped eggs singly in slits which are made in leaf tissue with its sharp ovipositors. The egg hatches in 4-9 days.
- Nymphal period is about 4-6 days.
- Pupal period is lasts for 3-5 days
- Adult lives about 2-4 weeks

Nature of damage:

- Nymphs and adults suck the cell sap from leaves and flower buds.
- Margins of affected leaves get slightly curled up and the leaf blades show uneven surface
- When attack during flowering stage, the affected flowers may wither away
- It is a vector of yellow spot virus and spotted wilt virus. Long dry spell favours fast multiplication of this pest.

5. MITE

Scientific name: *Tetranychus telarius* (Linnaeus)

Family: Tetranychidae **Order:** Acari

Hosts: The mite is a polyphagous and is known to infest on 183 species of plants including cucurbits, brinjal and okra on which it is sometimes very serious.

Distribution: Worldwide

Marks of identification:

- Adult female body is oval and is variable in colour *i.e.*, red, green, amber or rusty green and with two large pigmented spots on the body.

Main characters:

- They are small creatures measuring 0.1 mm long.
- Body is divided into two prosoma and head and thorax are fused together and opisthoma (abdomen).
- Mouth parts- chelicerae and pedipalpi are adapted to grasping, piercing, sucking and tearing.
- Legs are two segmented with chelate or pedipalpi.
- Larva and nymphal stages possess three pairs of legs, while adults have four pairs of legs
- Respiration takes place by trachea which is connected with stigmata. In some cases, it may cutaneous
- Metamorphosis is simple.
- The male is smaller than female.

Life cycle:

- It is active from March – October and passes winter as gravid female. It lays 60-80 eggs. Egg period lasts for 2-6 days.
- Nymph is light brown in colour and has two eye spots and four pairs of legs and quite active. Nymphs grow to maturity in 2 stages within 4-9 days.
- Adult lives for about 9-11 days
- Total life cycle in active period takes 9-19 days

Nature of damage:

- Both nymphs and adults cause damage by feeding on the lower surface of the leaf underneath a web
- Mite infestation begins in the seedling stage and extends to harvest
- On close examination of the lower leaf surface, mites smaller than a pinpoint may be seen.
- The infested leaves rapidly curl up, become hard and crisp and ultimately shaded off
- Yellowish patches and silky webbing is observed on lower surface of the infested leaves
- Heavily infested leaves give metallic appearance and whole crop looks reddish brown. Bolls ripen prematurely and in serious infestation, shaded

Management of sucking insect pests:

- Sowing the crop as early as possible. The incidence of sucking pest is low in early planting of the crop.
- *Bt* seed in labelled pack is already treated with insecticides. Un-packed seeds should be treated with imidacloprid 70 WS 7.5 g or thiamethoxam 70 WS 2.8 g per kg of seeds. It protects early stage of the crop.
- Select the hairy leaf varieties for the sowing. There is low incidence of sucking pests in hairy leaf varieties than the glossy varieties.
- Raise maize (10% plants) in the field to conserve and enhance the activity of natural enemies in cotton.
- Maintain Entomophage Park in 100 to 200 m² area in the field. Do not spray in this park.
- On the incidence of leaf hopper/ whitefly/ aphid/ thrips/ mites, spray NSKS 5% (500 g NSK powder) or neem oil 50 ml or neem base formulations 20 ml (1 EC) to 40 ml (0.15 EC) in 10 litre of water.
- To spray *Lecanicillium lecanii* 2 x 10⁸ cfu/g (1% WP) @ 40 g /10 litre water) or *Beauveria bassiana* 2 x 10⁸ cfu/g (1% WP) @ 40 g /10 litre water) at fortnightly interval for three times starting from initiation of sucking pests for the effective biological control.
- Spray biopesticides viz., *Verticillium lecanii* (Potency 2 X10⁸ C.F.U/gm) 10gm/l and *Beauveria bassiana* (Potency 10⁸ spores/ml), 10ml/l.

- For the control of whitefly/ leaf hopper/ thrips, spray any one of insecticides thiacloprid 48 SC 5 ml, flonicamid 50 WG 3 g, diafenthiuron 50 WP 10 g, dinotefuran 20 SG 10 g, profenophos 50 EC 10 ml, fipronil 5 SC 20 ml, acephate 50% + imidacloprid 1.8 % (51.8 EC) 10 ml in 10 litre of water. Change the insecticides in subsequent sprays.
- On ETL of whitefly and thrips (5 or more than 5 per leaf), spray acephate 75 SP 10 g, triazophos 40 EC 20 ml, acetamiprid 20 SP 3 g, spinosad 45 SC 3 ml, deltamethrin 1% + triazophos 35% (36 EC) 10 ml, indoxacarb 14.5 % + acetamiprid 7.75% (22.2 EC) 10 ml in 10 litre of water. Do not repeat the same insecticides in forthcoming sprays.
- On ETL of aphid and leaf hopper (5 or more than 5 per leaf), spray monocrotophos 36 SL 10 ml or dimethoate 30 EC 10 ml or methyl-o-demeton 25 EC 10 ml or imidacloprid 17.8 SL 5 ml or thiamethoxam 25 WG 4 g or buprofezin 25 SC 20 ml, lambda-cyhelothrin 5 EC 10 ml or thiamethoxam 12.6% + lambda-cyhelothrin 9.5 % (22.1 EC) 10 ml in 10 litre of water. Change the insecticides in subsequent sprays.
- For the control of mites, spray fenpyroximate 5 SC 10 ml or propergite 57 EC 10 ml or fenazaquin 10 EC 10 ml oretoxasole 10 SC 10 ml or sulphur 50 WP 25 g in 10 litre of water.

6. MEALYBUG

Scientific name: *Phenacoccus solenopsis* (Tinsley)

Family: Pseudococcidae

Order: Hemiptera

Hosts: Cotton, tobacco, mustard, sorghum, tomato and several weeds like congress grass etc.

Distribution: Pakistan, India

Marks of identification:

- Eggs are usually laid on plant in ovisac beneath female body.
- The nymphs are pale yellow with reddish eye, which are later on covered with white powdery mass. *Phenacoccus solenopsis* is greenish black with short to medium sized waxy filaments around the body; two dark stripes on either side of the middle “ridge” of the body; long glassy rods on back; anal filaments about one-fourth the length of the body and absence of long tails. This species produces an egg mass or ovisac. Male adults having one pair of wings.

Life cycle:

- A female lays 150-600 eggs usually in ovisac. The eggs hatch in 6-9 days.
- Female nymph passes through four instars in 10-15 days.
- The longevity of the adult is about 7-14 days.
- The total life cycle is completed in 25-30 days.
- There are 14-15 generations in a year.

Nature of damage:

- Mealybug suck the cell sap from the fruiting parts, prefers shoots and leaves. Mature and young ones also suck sap from leaves, buds, petioles, internodes.
- Pest secretes honeydew like substances and as a result sooty mould is developed and hinders the photosynthetic activity of the plants.
- Due to the continuous feeding, flowers, buds, mature bolls and even leaves fall down. Growth of the plant is retarded.
- Incomplete boll opening and reduction in the fibre quality
- In case of heavy infestations, white masses of wax conceal the mealy bugs. Cotton plant infested during vegetative phase exhibit symptoms of distorted and bushy shoots, crinkled and/or twisted and bunchy leaves and stunted plants that dry completely in severe cases.
- Late season infestation during reproductive crop stage result in reduced plant vigour and early crop senescence
- Heavy infestation leads to total drying up of plants. The yield is 50 to 100 percent depending upon the severity of the infestation.

Impact of weather factors on mealybug:

- It is observed that population of mealybugs is increased as the dry spell is extended for longer time in monsoon.
- Further, as the monsoon is over, population of mealybug is built up.
- Heavy and continuous rain fall adversely affect the population of mealybug

Management of mealybug:

Before planting:

- Remove all alternate host plants/ weeds and burn them.
- Do not throw uprooted weeds/ host plants in water channel.
- Destroy ant colonies during land preparation.
- Apply quinalphos 1.5% or chlorpyrifos 2% dust @ 25 kg/ha in soil or apply chlorpyrifos 20 EC @ 2 litre /ha through irrigation.

During crop season:

- Make one meter band of chlorpyrifos 2% dust on soil around the crop area to check the entry of mealybug coming from the hedge plants and neighbouring fields.
- Locate ant colonies and destroy them by drenching chlorpyrifos 20 EC (25 ml in 10 litre of water) or apply chlorpyrifos 2% dust @ 25 kg/ha in soil. This operation can be carried out 2 or 3 times during the season looking to the severity of incidence.
- Uproot severely affected cotton plants at early stage of infestation, put them in gunny bag, take away from the field and burn them or bury them in a pit and spray with any one of the recommended chemical insecticide.

- Wash equipment's with a jet of water or spray with chemical insecticides before moving to another field of cotton.
- Monitor fields regularly and give spot application of recommended insecticides to avoid further spread of mealybugs from infested plants. Spot application helps in conservation of coccinellid beetles, parasites, wasps *etc.*, which are important natural enemies of mealybug.
- If the population of *Aenasius bambawalei* Hayat, a parasitoid of mealybug is noted, do not spray synthetic insecticides. Follow the neem based formulations.
- Spray *Lecanicillium lecanii* or *Beauveria bassiana* (2×10^8 cfu) 40 g or ml per 10 litre of water during high humid days in evening time.
- In case of severe infestation, spray insecticides viz., profenophos 50EC 10 ml or quinalphos 25 EC 20 ml or acephate 75 SP 20 g or chlorpyrifos 25 EC 20 ml or thiodicarb 75 WP 10 g or buprofezin 25 SC 20 ml in 10 litre of water; 2-3 times as per need in rotation. Add 10 g of any detergent powder in above spray solution. Apply insecticidal spray on the plants to the extent of slight runoff and change the insecticides in subsequent sprays.

After harvest:

- Do not allow the cattle/ sheep/ goat to graze infested fields.
- Remove all crop residues in previously infested fields and burn them.
- Store cotton sticks away from the fields and if possible, makes a barrier of insecticide (*e.g.* chlorpyrifos 2% dust) around the stacks.

OTHER INSECT PESTS:

1. RED COTTON BUG

Scientific name: *Dysdercus cingulatus* (Fabricius)

Family: Pyrrhocoridae **Order:** Hemiptera

Hosts: Cotton, okra, maize *etc.*

Distribution: All over India

Marks of identification:

- The eggs are spherical, bright yellow and are laid in clusters or in loose irregular masses of 70-80 eggs each.
- The young nymphs have flabby abdomen, but as they grow older, they become more slender and develop black markings on the body
- The bugs are elongated slender insects having crimson red with white bands across the abdomen. The membranous portion of their forewings, antennae and scutellum is black.

Life cycle:

- The eggs are laid below the surface of the soil on an average 465, of which 49 per cent are hatched out within 7-8 days
- There are 5 nymphal stages and the development is completed in 49-89 days. The first-instar nymphs remained underground until the first moult.
- Adult period is about 15-24 days.

Nature of damage:

- The nymphs and adults suck sap from tender leaves, petioles and shoots in early stages and then infest flower buds and immature bolls and bolls that have just opened. As a result, plants lose their vigour and bolls open prematurely with stained lint.
- The infested seeds get shrivelled, underdeveloped, become unfit for sowing and oil content gets reduced
- From the spot of injury on the bolls, a bacterium – *Nematospora gossypii* gains entry and spoils the lint. Some-times cannibalism exists in this insect.

Management:

- Since the pest feeds gregariously, the infested leaves or bolls can be shaken in water and drowned.
- Plough the field to expose the eggs
- Spraying of phosphamidon 40 SL 600 ml/ha

2. DUSKY COTTON BUG

Scientific name: *Oxycarenus hyalinipennis* (Costa)

Family: Lygaeidae **Order:** Hemiptera

Hosts: Cotton, Hibiscus, Bauhinia

Distribution: All over India

Marks of identification:

- Eggs are cigar shaped and whitish immediate to oviposition. They turn pale then to pink before hatching.
- Early instar nymph is about 2.5 mm long with its rostrum extending the abdomen. They are orange in colour when about to moult. After the first moult the nymphs become reddish brown then becomes darker after each moult.
- Adults are 4-5 mm elongated with pointed heads, dusky brown with dirty white transparent wings and black spots on forewings and having deep red legs.

Life cycle:

- The eggs are usually laid in the lint of half opened bolls, either singly or in small clusters of 3-18 each. The egg stage lasts for 5-10 days
- The nymphs, on emerging, pass through 7 stages, completing the development in 31-40 days
- There are 4-5 generations per year. The life cycle lasts for 36-50 days. The last generation undergoes an inactive, dormant phase (aestivation)

Nature of damage:

- Both nymphs and adults suck sap from immature seeds and stain the lint. The seeds do not mature and get damaged. Seeds become lighter in weight and lose their germination capacity.
- This is minor pest of cotton and its chief importance lies in the fact that the adults-nymphs get crushed at the time of ginning, thus staining the lint and lowering the market value of cotton.

Management:

- Spraying of phosphamidon 40 SL 600 ml/ha

3. MIRID BUGS : *Campylomma livida*, *Hyalopepsus lineifer*, *Creontiades biseratense*

Nature of damage:

- Both nymph and adult stages cause damage.
- Feeding on the terminal growth, squares, flowers and bolls of cotton plants with the piercing/sucking mouthparts cause excessive shedding of flowers, small squares and immature bolls.
- The feeding results in small, dark, sunken lesions on the surface of the boll and in severe cases deformed bolls are formed due to lack of fertilization of some ovules.
- This symptom is often referred to as "**parrot beaking**" of bolls.

Life history:

- The female mirid lays egg singly, preferentially on the leaf petiole.
- Eggs are cylindrical, slightly recurved and laterally compressed; shining white in colour, turning to yellow as it matures.
- Eggs hatch within 4 to 5 days.
- There are five nymphal instars, each of about 2 to 3 days duration.
- Adults are elongated, about 7-9 mm long, with long legs and antennae.
- Development from egg to adult takes about 15 to 18 days.
- The adults can live for 3 to 5 weeks and a female can lay up to 80 eggs in the life time.

PESTS OF SUNHEMP

1. SUNHEMP HAIRY CATERPILLAR *Utetheisa lotrix*, *Argina cribraria*, Arctiidae:

Lepidoptera

It is the most serious and specific pest of sunhemp.

Marks of identification:

- Moth of *U. pulchella* has pale white fore wing with red and black dots.
- *A. cribraria* has orange yellow fore wing with black spots ringed with yellow. The hind wings are orange with black spots on them.
- The caterpillar has yellow lines dorsally and dorsolaterally and black stripes and orange patches laterally and a brown head with long brown hairs on its body.

Life cycle:

- The female moth lays about 80-100 round, smooth yellow eggs on leaves singly or in small groups. Egg stage lasts for 3-4 days. Larval duration is 18-21 days Full grown caterpillar pupates in the soil and pupal stage is 6-8 days. The total life cycle takes 27-31 days.

Nature of damage:

- The just hatched larva either defoliates (vegetative stage) or bores into pods (in heading stage).
- The larvae feed on sun hemp and defoliate the plant. The damage will be more (serious in later stages), when they bore into pods and feed on the seeds. The symptoms are defoliation of plant, bored seed capsules.
- Larval parasitoid *Bracon brevicornis* suppress the population naturally.
- Foliar spray with methyl parathion 2 ml /l or dusting methyl parathion 2D 10 – 12 kg/ac are effective measures.

2. SUNHEMP STEM BORER *Laspeyresia tricenra* Eucosmidae: Lepidoptera

The caterpillars cause small gall like swellings on shoots and stem and because of this the fiber length is affected and there is profuse branching of infested plants. Insecticides recommended against sun hemp caterpillar are effective.

3. SUNHEMP FLEA BEETLES *Longitarsus belgaumensis* Chrysomelidae: Coleoptera

It is common in South India. Adult beetle bite holes on leaves. Spraying with monocrotophos 1.6ml/l in the evening hours is recommended.

PESTS OF PULSE CROPS

1. GRAM POD BORER

Scientific name: *Helicoverpa armigera* (Hubner) Hardwick

Family: Noctuidae

Order: Lepidoptera

Host plants: Chickpea, Pigeonpea, Urdbean, Lentil, Cowpea, Soybean, Greengram, Pea, Bean and other pulse crops

Distribution: Cosmopolitan in distribution

Marks of identification: As per cotton crop

Life cycle:

- Female lay eggs singly on tender parts of plants. A single female may lay as many as 741 eggs in 4 days.
- Egg hatch in 2-4 days in April to October (in summer) and 6 days in February (in winter).
- Larvae move from pod to pod and are full-fed in 13-19 days.
- Pupal period is about 8-15 days, but in winter duration is prolonged and pupated in soil.
- There are total 8 generation in a year.

Nature of damage:

- Young larva feeds on the foliage for some time and later bores into the pod and feeds on the developing grains, with its body hanging outside.
- Larva prefers to feed on the protein-rich seeds within the pod.
- A single larva may destroy 30-40 pods before it reaches maturity.

Management:

- Grow Helicoverpa resistant varieties like,
- Red gram: T 21, Bori, BDN 2, ICPL 332, ICPL 84060, ICPL 88039, PPE 45-2, ICP 19640, ICP 7035, MA 2, Pant A1, BSMR 1, JG 315 and JG 74 for central zone and ICCV 7
- Determinate (pods in clusters at top of the canopy) type of pigeonpea varieties are more susceptible to this pest. Hence, in-determinate varieties should be selected for sowing.
- Raise random planting of yellow flower marigold as ovipositional trap crop for pod borer, *H. armigera*.
- Intercrop of maize with pigeonpea for *Helicoverpa* infested areas of pigeonpea under rainfed condition
- Apply recommended insecticides on chickpea at ETL 15 larvae per 20 plants at fruiting stage to manage the population of gram pod borer *H. armigera* effectively and economically.
- Install 40 pheromone traps per hectare for mass trapping of moths (*H. armigera*) infesting pigeon pea and chick pea
- It is also advisable to install light trap to collect and kill the nocturnal pests.
- Install 40 bird perches per hectare in chick pea crop to attract the predatory birds.
- Follow bio-intensive module consisting of the first spray of HaNPV 250 LE per hectare at ETL of 10 larvae per 20 plants followed by second spray of NSKS 500 g per 10 litre of water after 15 days of first spray

- On initiation of pod borers, spray NSKS 500 g in 10 litre of water spray HaNPV 250 LE per hectare during evening hours.
- Spray of *Bacillus thuringiensis* powder 10 g or *Beauveria bassiana* (1×10^9) 40 g per 10 litres of water
- Spray applications of fenvalerate 20 EC 10 ml or lambda-cyhalothrin 5 EC 5 ml or acephate 75 SP 15 g or emamectin benzoate 5 SG 2 g or flubendiamide 480 SC 3 ml or indoxacarb 15.8 EC 10 ml or chlorantraniliprole 18.5 SC 3 ml in 10 litres of water on 50% plants having flowering for the control of pod borers.
- In vegetable purpose of pigeon pea, spray chlorpyrifos 20 EC 20 ml or NSKS 50 g in 10 litres of water for the management of pod borer.

2. PLUME MOTH

Scientific name: *Exelastis atomosa* (Walsingham)

Family: Pterophoridae

Order: Lepidoptera

Host plants: Pigeon pea

Distribution: India and world-wide

Marks of identification:

- Eggs are minute, oval and greenish.
- Larva shows greenish brown or green with spines/ hairs all over body.
- Pupa is fringed with radiating spines and hairs.
- Moth is delicate, light brown in colour with fringed wings. Forewings divided into two parts and hindwings into two parts. The wings are plumes narrow and long.

Life cycle:

- Female moth lay 17-19 eggs singly on tender parts of plants. Egg hatch in 2-5 days.
- Young larvae feed on the pods and become full-grown in 10-25 days.
- Pupation takes place outside the pod on its surface or entrance hole itself. The pupal period extends from 3 to 12 days.
- The life-cycle is completed in 17-42 days.

Nature of damage:

- Larvae first scrape the surface of the pod and finally make holes into them and feed on the seeds, reducing crop yield.
- Pin head size holes on pods

Management:

- Insecticides are the most commonly used restraint for this pest in pigeonpea
- Spraying of emamectin benzoate 5 SG 5 gm or flubendiamide 48 SC 3 ml in 10 litres of water at 50 % flowering stage.

3. POD FLY

Scientific name: *Melanagromyza obtusa* (Malloch)

Family: Agromyzidae

Order: Diptera

Host plants: Pigeon pea

Distribution: World-wide

Marks of identification:

- Eggs are in the skin of tender pods
- Maggot (larva) is greenish having brown lateral marking.
- Full grown maggot is 3.5 to 4 mm long, it is tiny legless and greenish white or pale white in colour.
- Adult is small metallic black fly.

Life cycle:

- The adult female fly thrusts its minute eggs into the shell of a tender pod, lay singly.
- Eggs hatch in 2-4 days.
- Maggot becomes full-grown in 5-10 days
- Pupation takes place inside damaged pods
- Pupal period is lasts for 4 to 13 days.
- The adult emerged out by cutting holes (window hole).
- The total life-cycle is completed in 11-27 days.
- There are several generations in a year.

Nature of damage:

- Maggot first makes galleries just below epidermis of seeds, enters into seed and feeds in developing seed.
- Feeding deeper into the seeds later on and make them unfit for consumption.
- Seeds are shriveled, striped and partially eaten.
- Dark brown encrustation on the pod wall is observed.
- Dry pods showing pin head size hole.
- It is major pest of pigeonpea causing up to 60 per cent damage to pods.

Management:

- Conserve natural enemies like *Euderus lividus*, *Eurytoma* sp., *Euderus agromyzae*
- Spray lambda cyhalothrin 5 EC 20 ml or Lufenuron 5.4 EC 10 ml in 10 litres of water.

4. BLUE BUTTERFLY

Scientific name: *Lampides boeticus* (Linnaeus), *Catochrysops Strabo* (Fabricus)

Family: Lycaenidae

Order: Lepidoptera

Host plants: Pigeon pea and other wild legumes

Distribution: Widely distributed in Asia

Marks of identification:

- Eggs are pale blue.
- Larva is 12 mm long, greenish having brown lateral marking. It is flat and slightly rounded and pale green with a rough skin.
- Full grown maggot is 3.5 to 4 mm long, it is tiny legless and greenish white or pale white in colour
- Adult is greyish blue with prominent black spots on the hindwings and a long tail.
- Ventral sides of wings have numerous stripes and brown spots.

Life cycle:

- Female lays eggs singly on buds.
- Pupation occurs in the soil or in plant debris.
- Five weeks required to complete one generation under field condition.

Nature of damage:

- The larvae chew leaves, buds, flowers and pods
- Larva bore hole on buds, flowers and young pods
- Presence of slug like caterpillar
- Honey dew secretion with black ant movements

Management:

- Avoid dense and close planting
- Avoid early or late sowing
- Regular soil digging cause death of larvae and pupae
- Collection and destruction of larva.
- Egg parasitoid, *Trichogramma* spp.
- Larval parasitoids, *Hyperencyrtus lucoenephila* and *Litrodromus crassipes*

5. SPOTTED POD BORER

Scientific name: *Maruca vitrata* (=testulalis)(Geyer)

Family: Pyralidae

Order: Lepidoptera

Host plants: Cowpea, Greengram, Blackgram, Lablab, Red gram, Soybean

Distribution: Tropical and sub-tropical region of world

Marks of identification:

- Eggs are light green colour.
- Larva is green with a brown head, short dark hairs and black warts on the body.

- Moth has white cross band on the dark brown forewings and a dark border on the white hindwings.

Life cycle:

- The eggs are laid small in cluster of 10/ 15 on leaves, buds and flowers. Newly hatched young larva enters in to the bud, flower or the pod and feed in-side.
- Pupation takes place in the web or on the soil surface in a silk cocoon.
- Moth shelters among the lower leaves.
- Total life cycle may completed within 3 weeks.
-

Nature of damage:

- Larva webs together the flowers/ buds and feed on them.
- Caterpillar also feeds on the seeds within pod, it resulting in appreciable loss in yield of seeds.
- Bore holes on the buds, flowers or pods. The entrance hole is plugged with excreta.
- Severe damage under high relative humidity.

Management :

- Spray of Neem seed kernel suspension @ 5% on initiation of the pest.
- Spray chlorantraniliprole 20 SC 3 ml or flubendiamide 48 SC 2 ml at the time of 50% flowering on plants for effective control.
- Spray flubendiamide 480 SC 3 ml or chlorantraniliprole 18.5 SC 3 ml per 10 litre at the initiation of flowering and subsequent two sprays at 15 days interval.

6. TUR POD BUG

Scientific name: *Clavigralla gibossa* Spinola, *Riptortus pedestris* (Fabricius)

Family: Coreidae

Order: Hemiptera

Host plants: Cowpea, Chickpea, Lab-lab, Red gram, Soybean, Kidney bean, Cluster bean

Distribution: Across the Asia

Marks of identification:

- Young nymphs are reddish and show prominent lateral spines on the prothoracic and abdominal segments.
- The adult bugs are greenish brown in colour, having a spinet pronotum and femur swollen at the apical end.
- The bugs are about 20 mm long.

Life cycle:

- The bug appear on crops in October. They mate several times.
- The eggs are usually laid on pods and less frequently on leaves or the floral buds in clusters of 5-25.

- On an average female lays 60 eggs during an oviposition period of 15 days.
- The eggs hatch in about 8 days and the newly-hatched nymphs move away from egg shell within 10-15 minutes and gathered on suitable feeding spots.
- They are gregarious in nature and are seen feeding in groups.
- The nymph takes about 17 days to complete its development after passing through five nymphal stages.
- The pest is active from the middle of October to the end of May and completes six overlapping generations during this period.

Nature of damage:

- Both adult and nymphs suck the cell sap from the stem, leaves, flower-buds and pods.
- As a result, pods show pale yellow patches and later on shrivel up.
- The grain inside remains small in size and yield reduced significantly.

Management:

- Collection and destruction of egg masses, nymphs and adults.
- Egg parasite: *Hadronotus intestine* Dodd - up to 55%.

7. ERIYOPHID MITE

Scientific name: *Aceria cajani* Channabasavanna

Family: Acarina: Eriophyidae

Host plants: Cowpea, Chickpea, Lab-lab, Red gram, Soybean etc.

Distribution: World-wide distribution

Marks of identification:

- The eriophyid mite is about 0.2 mm long and difficult to see without magnification (10X or more).
- They are light coloured, long and spindle shaped and deposit their eggs on young foliage.

Life cycle:

- Deposit their eggs on young foliage
- Egg period is about 3 to 4 days
- Proto and due to nymphal stages are passed in 2-3 days.
- Total life cycle is completed in 7-9 days
- Complete its generation within two weeks

Nature of damage:

- Plant develop light green chlorotic foliage
- Leaves will have mosaic pattern.
- Bronzing of leaves followed by defoliation with heavy infestation

- Early infection results in sterility mosaic virus (Acts as vector)

Management:

- Use resistant pigeonpea varieties.
- Spray dicofol 18.5 EC 15 ml or wettable sulphur 40 WP 80 g or fenazaquin 57 EC 10 ml in 10 litres of water or propargite 57 EC @ 10 ml or dicofol 18.5 EC @ 0.04%
- Avoid synthetic pyrethroids as they cause resurgence after repeated spray.

8. MEALYBUG

Scientific name: *Coccidohystrix insolita* Green

Family: Pseudococcidae

Order: Hemiptera

Host plants: Pigeon pea, Brinjal, Potato etc.

Distribution: Wide area distribution

Marks of identification:

- Nymph is green coloured
- Adult males are slender, delicate with pale yellow thorax, single pair of metathoracic wings and two long waxy anal filaments.
- The female is apterous, soft bodied, oval in shape with number of waxy filaments around the body which is covered with white mealy powder.
- Freshly emerged first instar nymphs are oval in shape, light yellow in colour and little convex dorsally with three pairs of well-developed legs.

Life cycle:

- Female lays numerous eggs in white ovisac.
- Male nymph moults for four times while female nymph moults three times to attain maturity.

Nature of damage:

- Nymphs & Adult both on lower surface of leaves and suck the cell sap due to which leaves turn pale and later on dry up.
- As a results, wilting of the affected portions resulting in the ultimate drying and death of the plants.
- In addition to this, both nymphs and adult female excreted honeydew on which the black sooty mould developed which adversely affected the photosynthetic activity of leaves.

9. GRAM CUTWORM

Scientific name: *Agrotis ipsilon* Hufnagel

Family: Noctuidae

Order: Lepidoptera

Host plants: Potato, Tobacco, Cotton, Cabbage, Beet root, Lady's finger, Cucumber, Pea, Barley, Oat, gram etc.

Distribution: World wide

Marks of identification:

- Eggs are yellow coloured.
- The caterpillar is dark grey or dull green in colour and has habit of coiling up at the slightest touch. Its skin is smooth and greasy.
- Adults are greyish brown and have dark or blackish grey patches on their forewings.

Life cycle:

- Female lays eggs in batches on the under surface of leaves and on the stem in clusters about 30 numbers.
- It lays about 200-300 eggs.
- The eggs hatch in 4-10 days.
- Young caterpillar become full-grown in 15-30 days. The grown up larvae is about 2.0 cm long.
- Pupation takes place in earthen cocoon in soil and emerges out adult moth in 15-30 days.
- The total life cycle is completed in 30-68 days.

Nature of damage:

- Caterpillar are active during night.
- During day time, they remain hidden in cracks in soil.
- They cut the young plants at the ground level and feed on tender leaves and shoots.
- The caterpillar cut and damage much more than they can eat.
- The larvae carry the cut portions of the plants to their hiding place and eat them during the day time.
- The infested crop appears as if grazed by cattle.

Management:

- Deep ploughing summer to expose hidden stage of this insect.
- Use well decomposed organic manure
- Adopt crop rotation
- Early sowing in the last week of October
- Collect and destroy caterpillars mechanically as they may be curled near the base of young plants or just a few inches deep in the soil
- Install bird perches
- Intercropping with wheat or linseed or mustard reduce infestation
- Do not grow tomato or okra nearby the field

- Grow marigold on bunds
- Install 1 light trap/ha to attract the adult moth
- If the infestation is observed in the field, give light irrigation in the field to minimize its infestation.
- Place the heaps of grasses in the field during the evening time, and collect and destroy the hidden larvae of cutworm in the morning hours.
- Poison bait (Wheat bran 1 kg + Malathion 5% dust 2 g) @ 10 kg/ha in the evening on weed free soil.
- Broadcast *Bt* mixed bait (mix 2 g of *Bacillus thuringiensis* formulation with 1 kg of wheat bran) @ 10 kg bait /ha over the surface of new planting beds one week before planting. Cutworms already present in the soil will eat the baits instead of new seedlings.
- Broadcast insecticide (chlorpyrifos 20 EC) treated sand @ 3 litre per 10 kg sand/ha in the field before planting
- Treat soil with chlorpyrifos 10% G @ 20 kg/ha before planting
- Spraying of deltamethrin 2.8 EC 10 ml in 10 litre of water

10. BEAN APHID

Scientific name: *Aphis craccivora* Koch

Family: Aphididae

Order: Hemiptera

Host plants: Cosmopolitan pest

Distribution: World wide

Marks of identification:

- Nymphs and adults are dark coloured with cornicles in the abdomen

Life cycle:

- This species can reproduce without mating.
- One generation in a week under optimum conditions.
- Individual adults can produce about 100 nymphs over a lifespan of up to 30 days.

Nature of damage:

- Aphids colonize on the young shoots, flowers and pods.
- Young leaves of seedlings become twisted under heavy infestation.
- Seedlings may wilt, particularly under moisture-stressed conditions.
- Bean leaf-roll virus is transmitted by this aphid.

11. JASSIDS OR LEAF HOPPERS

Scientific name: *Empoasca Kerri* Pruthi

Family: Cicadellidae

Order: Homoptera

Host plants: Pigeonpea

Distribution: World wide

Marks of identification:

- Nymphs and adults are dark coloured with cornicles in the abdomen

Nature of damage:

- Leaflets damaged by jassids are cup shaped and yellow edged and tips.

Management of pod borers:

- Do summer cultivation of fields
- Remove the off seasonal plants and weeds as pests may harboring on these plants
- Select pigeon pea varieties viz., GAUT-82-85, 82-104, 82-105; ICPL-70, ICPL-7035, GAUT-85-19, ICPL-87075 or ICP-151 for sowing as they are tolerant against the pod borers and pod fly.
- Pigeon pea ICPL-332, ICPL-84060 and ICPL-270 are mid-late varieties and infestation of *H. armigera* is less than the varieties T-15-15, BDN-2 and *Prabhat*.
- Determinate (pods in clusters at top of the canopy) type of pigeonpea varieties are more susceptible to this pest. Hence, in-determinate varieties should be selected for sowing.
- Raise random planting of yellow flower marigold as ovipositional trap crop for pod borer, *H. armigera*.
- Intercrop of maize with pigeonpea for *Helicoverpa* infested areas of pigeonpea under rainfed condition
- Apply recommended insecticides on chickpea at ETL 15 larvae per 20 plants at fruiting stage to manage the population of gram pod borer *H. armigera* effectively and economically.
- Install 40 pheromone traps per hectare for mass trapping of moths (*H. armigera*) infesting pigeon pea and chick pea
- It is also advisable to install light trap to collect and kill the nocturnal pests.
- Install 40 bird perches per hectare in chick pea crop to attract the predatory birds.
- Follow bio-intensive module consisting of the first spray of HaNPV 250 LE per hectare at ETL of 10 larvae per 20 plants followed by second spray of NSKS 500 g per 10 litre of water after 15 days of first spray
- On initiation of pod borers, spray NSKS 500 g in 10 litre of water
- Spray HaNPV 250 LE per hectare during evening hours for *H. armigera*.
- Spray of *Bacillus thuringiensis* powder 15 g or *Beauveria bassiana* (1×10^9) 10 g per 10 litre of water
- Spray applications of fenvalerate 20 EC 10 ml or lambda-cyhalothrin 5 EC 5 ml or acephate 75 SP 15 g or emamectin benzoate 5 SG 2 g or flubendiamide 480 SC 3 ml or indoxacarb

15.8 EC 5 ml or chlorantraniliprole 20 SC 3 ml in 10 litre of water on 50 per cent plants having flowering for the control of pod borers.

- In vegetable purpose of pigeon pea, spray chlorpyrifos 20 EC 20 ml or NSKS 50 g in 10 litre of water for the management of pod borer and pod fly.
- For the control of *H. armigera* in chickpea, spray NSKS 50 g at flowering on 50% plants, second spray of HaNPV @ 250 LE/ha (1.5 x 10¹² POB /ha) at pod formation on 50% plants and fenvalerate 20 EC @ 0.02% at 15 days after second spray.
- Spray pigeon pea crop twice with thiamethoxam 25 WG 4 g in 10 litre of water for the control of pod fly. The first spray should be applied at pod formation on 50 per cent plants and second at 15 days after the first spray.
- Spray 5 per cent leaf extract of *Naffatia* (*Ipomoea carnea*) or *ardusa* three times (add sticker @ 10 ml per 10 litres of spray fluid), first at vegetative stage, second at flowering on 50 per cent plants and third at pod formation on 50 per cent plants for the effective and economical management of pod borer, *H. armigera* in chickpea crop grown under conserved soil moisture.

Control of pod borer in other pulse crops:

- For the control of legume pod borer (*M. vitrata*) in mungbean, spray chlorantraniliprole 20 SC 3 ml or flubendiamide 48 SC 2 ml at the time of 50 per cent flowering on plants for effective control.
- Spray emamectin benzoate 5 SG 5 g or flubendiamide 480 SC 2 ml per 10 litre of water at the initiation of pest incidence for the control of pod borers in black gram.
- Pod borer (*M. vitrata*) infesting cowpea, spray flubendiamide 480 SC 3 ml or chlorantraniliprole 18.5 SC 3 ml per 10 litre at the initiation of flowering and subsequent two sprays at 15 days interval.

Management of sucking pests in pulses:

- Give the seed treatment in pulses like green gram, cowpea and black gram with imidacloprid 70 WS 7.5 g or thiamethoxam 70 WS 2.8 g per kg of seeds. It protect early stage of the crop against the sucking pests.
- For the control of sucking pests (aphid, leaf hopper, whitefly and thrips), spray any one of insecticides dimethoate 30 EC 10 ml, thiamethoxam 25 WG 3 g, thiacloprid 48 SC 5 ml, flonicamid 50 WG 3 g, diafenthiuron 50 WP 10 g, dinotefuran 20 SG 10 g, proflenophos 50 EC 10 ml, fipronil 5 SC 20 ml, acephate 50% + imidacloprid 1.8 % 51.8 EC 10 ml, acephate 25% + fenvalerate 3% 28 EC 10 ml in 10 litre of water.

- For the control of mites in pigeon pea, spray fenpyroximate 5 SC 10 ml or propergite 57 EC 10 ml or fenazaquin 10 EC 10 ml or etoxasole 10 SC 10 ml or sulphur 50 WP 25 g in 10 litre of water.
- For the control of mealybug in pigeon pea, spray profenophos 50 EC 10 ml or quinalphos 25 EC 20 ml or acephate 75 SP 20 g or chlorpyrifos 25 EC 20 ml or thiodicarb 75 WP 15 g or buprofezin 25 SC 20 ml in 10 litre of water; 2-3 times as per need in rotation. Add 10 g of any detergent powder in above spray solution. Apply insecticidal spray on the plants to the extent of slight runoff and change the insecticides in subsequent sprays.

Control of termites in pigeon pea:

- In hot spot areas, apply chlorpyrifos 20 EC 2-3 litre per hectare with irrigation before sowing of the crop.
- In standing crop, drench the chlorpyrifos 20 EC 20 ml per 10 litre of water with knapsack sprayer after removing nozzle around the plant after second day of irrigation.

PESTS OF OIL SEED CROPS

PESTS OF CASTOR

1. LEAF EATING CATERPILLAR

Scientific name: *Spodoptera litura* Fabricius

Family: Noctuidae

Order: Lepidoptera

Nature of damage:

- Freshly hatched caterpillars feed gregariously by scrapping the leaves from ventral surface leaving the upper surface intact.
- Later instar larvae feed voraciously and plants are completely defoliated and field looks as it is grazed by cattle.
- Since the pest is nocturnal in habit, it hides under the plants, cracks and crevices of soil and debris during the day time.

Management:

- Monitoring the pest with pheromone traps (4-5/acre) for timely management
- Collect and destroy the egg masses and caterpillars in the early stages of infestation
- Plough the field in summer after harvest of crop so as to expose the pupae to predators, parasitoids and birds.
- To control early stage larvae, spray neem seed kernel extract (NSKE) 500 g (5%) or chlorpyrifos 20 EC or quinalphos 25 EC 20 ml in 10 litre of water.

- As the grown up larvae move down to soil to hide during day time, poison bait (1 kg chlorpyrifos 20 EC 100 ml+ 10 kg of rice bran + 1 kg jaggary + 1 litre of water to make the bait in to pellets for one hectare) placement at base of the plants helps in killing the larvae.
- Application of Nuclear Polyhedrosis Virus (NPV) 250 LE/ha in required quantity of water in the evening time.
- For the control of later instar larvae, application of fenvalerate 20 EC, 5 ml or deltamethrin 2.8 EC, 5 ml in 10 litre of water is effective.

2. CASTOR SEMI LOOPER

Scientific name: *Achaea janata* (Linnaeus)

Family: Noctuidae

Order: Lepidoptera

Hosts: Castor, rose, pomegranate, tea, citrus, mango, *Cadiospermum helicacabum* etc.

Distribution: India, Pakistan, Sri Lanka, Thailand, Laos, Malaysia and Philippines

Marks of identification:

- Eggs are laid singly on ventral side of the tender leaves.
- Larva is a semilooper, grey brown or black with red, black, bluish or yellow with white stripes. Head is black and a red spot on the third abdominal segment and red tubercles in the anal region.
- Adult is a pale reddish brown moth with black hindwings having a median white spot on the outer margin. The wings are decorated with broad zig-zag markings, a large pale area and dark brown patches.

Life cycle:

- Eggs are laid on the tender leaves. Egg period is 2-5 days. One female can lay up to 450 eggs.
- Larval period is 15-20 days. It pupates in fallen leaves on soil, sometimes within folded leaves on plant itself. Pupal period is 10-15 days. There are 5-6 generations in a year.
- The moths are active at dusk.

Nature of damage:

- The caterpillars feed voraciously on castor leaves, starting from the edges inwards and leaving behind only the midribs and the stalks.
- With the excessive loss of foliage, the seed yield is reduced considerably.

Management:

- Deep ploughing and intercropping with cluster bean, cowpea, black gram or groundnut (1: 2 ratio proportions) reduce semilooper infestation and help in buildup of natural enemies (coccinellids and spiders) population.
- Hand picking of older larvae during early stages

- Apply neem seed kernel powder 500 g (5% extract) + neem oil 20 ml (0.2%) in 10 litre of water.
- Release egg parasitoid, *Trichogramma minutum* @ 2,50,000/ ha. Spray neem seed kernel powder (5% extract) 500 g per 10 litre of water.
- Spray *Bacillus thuringensis* var. *kurstaki* @ 1 kg g in 500-600litre of water/ha.
- Spray or dimethoate 30 EC, 10 ml in 10 litre of water.
- Spray quinalphos 25 EC, 20 ml (0.05%) or chlorpyrifos 20 EC, 2 ml (0.04%) or monocrotophos 36 SL, 1.5 ml (0.06%), if 4-5 semi-looper/plant are observed on 30 and 40 days old crop
- Spraying of *Bacillus thuringensis* @ 1 to 1.5 kg in 500 litre of water

3. HAIRY CATERPILLAR

Scientific name: Gujarat hairy caterpillar (*Amsacta moorei* Butler), Red hairy caterpillar (*Amsacta albistriga*) and Bihar hairy caterpillar (*Spilosoma obliqua* Walker)

Family: Noctuidae

Order: Lepidoptera

Hosts: Bajra, maize, sorghum, tobacco, castor, groundnut, mustard, pulse crops, soybean

Distribution: World wide

Marks of identification:

- The female moth lays creamy or bright yellow eggs in clusters on the under-sides of leaves of grasses on field boundaries and covers them with pale brown hairs.
- Larva is reddish brown with black band on either side of body having long reddish brown hairs all over the body.
- Pupa is brownish colour and pupates in earthen cocoon.
- Adult: *A. moorei*: white wings with red line on apical margin of forewings and black band on abdomen. *A. albistriga*: forewings having red line on anterior margin, whereas hind wings are white with black markings.

Life cycle:

- Female moth lay a large number of eggs in clusters on the underside of leaves. They hatch in 5-7 days.
- Larvae pass through six stages and full-fed in 2-3 weeks.
- Pupation takes place in silken cocoons in the plant debris lying on ground and pupates inside. Pupal stage about one week in the summer, during winter about 20 days.
- Pest passes through several generations in year.
- *Amsacta* sp. - One generation per year
- *S. oblique* - Three generations in a year

Nature of damage:

- These hairy caterpillars scrap the under surface of the leaf when they are in neonate stage. The scrapped patches of the leaves look like thin papery.
- Full grown larvae devour the entire foliage, flowers and growing points leaving behind petioles, veins and main stem of plants.

Management:

- Reduce the bund size
- Cleaning of bunds in summer season
- Plough the field deep in summer season.
- Grow sunnhemp as small band around the field and apply quinalphos 1.5% or fenvalerate 0.4 per cent dust.
- Collection and destruction of egg masses and hand picking of larvae.
- Use of light trap (one/ha) soon after first shower of monsoon for collecting and killing of adult moths is very effective. Light trap should be operated from eight to twelve pm only.
- The dispersing larvae of hairy caterpillar from one field to another can be checked by digging trenches across the direction of their march and prompt destruction of larvae.
- Prepare small balls by using 10 kg rice bran + 1 kg jaggary + 1 litre quinalphos 25 EC and broad-cast it in the fields preferably in the evening time.
- Spraying of thiodicarb 75 WP, 20 g or chlorpyrifos 20 EC 20 ml or quinalphos 25 EC, 20 ml or spinosad 45 SC, 3 ml in 10 litres of water.
- Spraying of dichlorvos 76 EC, 7-10 ml in 10 litre of water

4. SERPENTINE LEAF MINER

Scientific name: *Liriomyza trifolii*(Burgess)

Family: Agromyzidae

Order: Diptera

Hosts: Castor, groundnut, tomato, pointed gourd, pumpkin, bottle gourd, rapeseed, mustard, cucumber and 57 other host plants, including field crops, vegetables, weeds, forest trees and ornamental crops.

Distribution: It is well distributed in America, Europe, Middle East and African countries. It is also found in India, USSR, Taiwan and Japan.

Marks of identification:

- Eggs are laid singly in leaf epidermis, oval in shape and small in size, measuring about 1.0 mm long and 0.2 mm wide. Initially they are clear but soon become creamy white in colour.
- Maggots are bright yellow to yellowish green
- Pupation is taken place in soil. Pupa is initially golden brown but turns dark brown with oval shape.

- Adults are small with yellow head and red eyes. Thorax and abdomen are grey and black, ventral surface and legs are yellow. Wings are transparent.

Life cycle:

- Egg period is 2-5 days.
- Larval period is 4-10 days.
- Pupa period 4-10 days.
- Adults live about 13 to 18 days. Total life cycle completed in a 23-35 days.
- Egg laying capacity is 35 to 39 eggs per day with total fecundity of 200 to 400 eggs.

Nature of damage:

- Larvae feed by mining leaves resulting in destruction of leaf mesophyll.
- Mining is irregular. In castor, blotch mines turn brown, become brittle and drop off.

Management:

- Remove all plant debris and weeds from fields.
- Crop rotation with non-host crop.
- Spray neem seed kernel powder 500 g (5% extract) in 10 litre of water to kill early stage larvae.
- Prepare poison bait by using profenophos 40% + cypermethrin 4% (44 EC) 20 ml + 2.5 kg jaggery + sugarcane juice 100 ml in 10 litre of water. Soak 20 cm long piece of cotton string in poison bait. Put this string in plastic container having four holes and a small tomato plant grown in plastic cup.
- Hang such traps on castor plants for attracting and killing leaf miner.

5. CASTOR CAPSULE/ SHOOT BORER

Scientific name: *Dichocrosis punctiferalis* Guenee

Family: Pyraustidae

Order: Lepidoptera

Hosts: Castor, mango, sorghum, guava, peaches, cocoa, pear, avocado, cardamom, ginger, turmeric, mulberry, pomegranate, sunflower, cotton tamarind, hollyhock etc.

Distribution: India, Australia, Burma, Sri Lanka, China, Indonesia and Malaysia.

Marks of identification:

- Eggs when deposited freshly are translucent, pale white and flattish oval with rough surface. After one day of deposition of the egg, colour changes to light pink and become dark pink before hatching. The length and breadth of egg were 0.59 mm and 0.39 mm, respectively.
- Larva is pale greenish with pinkish tinge and fine hairs with dark head and prothoracic shield. Fully grown larvae measured about 20 to 24 mm in length and 3-4 mm in breadth.

- Pupa is brown, about 0.25 inch long and covered by a silken cocoon. Larva built cocoon off the plant.
- The moth is medium sized bright orange-yellow colour and has numerous black dots on wings.

Life cycle:

- Eggs are laid on top leaf axil, inflorescence, tender part of plant and capsules. The egg period is 6-7 days.
- Larval period is 10-13 days. Colour of larvae changes to complete pink before pupation.
- Pupation takes place inside the fruits in a silken cocoon, pupal period is 4-11 days.
- Adult period is 4-6 days.
- Life cycle completes in 25-33 days.

Nature of damage:

- The freshly hatched larva initially feeds on the greenish coat of capsule in between the wart
- The larva then bores the capsule destroying seeds inside. It webs together capsule along with excreta and frass
- The larva may also bore into tender shoots and attach inflorescence killing the terminal shoots.

Management:

- Collection and destruction of infested shoots and seed capsules.
- Spray dichlorvos 76 EC, 7 ml (0.05%) or chlorpyrifos 20 EC 20 ml (0.04%) in 10 litre of water.
- Spraying can be done at flowering and 15-20 days after first spray

6. JASSID

Scientific name: *Empoasca flavescens* Fabricius

Family: Cicadellidae

Order: Hemiptera

Hosts: Polyphagous

Distribution: Wide area distribution

Marks of identification:

- Nymphs are pale greenish almost translucent and walk diagonally.
- Adults are greenish yellow, wedge shaped with a pair of black spots on vertex and a black spot on each of the forewings.

Life cycle:

- Female inserts their eggs into leaf veins from lower side of leaf.
- Eggs hatch in 6-10 days
- Nymphal stage lasts for 7-21 days

- Adult stage lasts for 35-50 days, There are 7-8 generations in a year.

Nature of damage:

- Nymphs and adults suck the sap usually from the under surface of the leaves and inject toxin causing curling of leaf edges and leaves turn red or brown. In severe infestation leaves curl upward and looks like a cup.
- The leaves dry up and shed. Economic threshold level is 2-3 adults/leaf

Management

- Apply neem seed kernel powder 500 g (5% extract) or neem oil 20 ml (0.2%) in 10 litre of water.
- Spraying of dimethoate 30 EC 10 in 10 litre of water.

7. WHITE FLY

Scientific name: *Trialeurodes ricini* Mishra

Family: Aleyrodidae

Order: Hemiptera

Hosts: Pulses, vegetables etc.

Distribution: Cosmopolitan pest

Marks of Identification:

- Both the nymphs and pupa are yellowish in colour.
- The adult fly has white wings, yellow body and pale white legs and antennae. It is a tiny insect a little less than a millimeter in length.

Life cycle:

- Female lays shining white long eggs in small clusters or scattered about on the underside of tender leaves.
- The eggs hatch into nymphs which settle on the leaves.
- The life cycle is completed in 19-21 days during July, August and September.

Nature of damage:

- Both nymphs and adults suck sap from leaves which show sticky appearance and sooty mould is developed when white fly infestation is severe.
- High bloom and triple bloom cultivars are more susceptible.

Management:

- Predaceous spiders and coccinellids feed on the whitefly and a chalcid wasp parasitizes the puparia. These should be conserved to keep the incidence of the pest in check.
- Application of neem oil 50 ml (0.5%) in 10 litre of water at initial stage. Spraying of triazophos 40 EC 25 ml (0.1%) or acephate 75 SP 10 g (0.075%) or monocrotophos 36 EC 10 ml (0.04%) or chlorpyrifos 20 EC 20 ml (0.04%) in 10 litres of water.

8. THRIPS

Scientific name: *Scritothrips dorsalis* Hood

Family: Thripidae

Order: Thysanoptera

Distribution: World wide

Marks of identification:

- Adults are about 1.2 mm long with dark wings and dark spots forming incomplete stripes, which appear on the abdomen.
- The abdomen has hardened plates that traverse the body.
- The shaded forewings are light in colour with straight hairs.

Life cycle:

- Egg period is 2-7 days
- Two larval stages are completed in 8 to 10 days
- Pupal stage last for 2-3 days
- The eggs hatch between two to seven days, depending upon temperature. The two larval stages are completed in eight to ten days and the pupal stage lasts for 2-3 days

Nature of damage:

- Both adults and nymphs scratch surfaces of the leaves
- The terminal leaves crinkle and appear silvery
- If infestation is severe, plants remain stunted
- The injury results in development of dull yellowish green patches on the upper surface and leaves get curl

Management:

- Insecticides such as dimethoate 30 EC 10 ml (0.03%) or spinosad 45 SC 3ml 10 ml in 10 litre of water will give good control of thrips.

PESTS OF SESAME

1. LEAF WEBBER/ LEAF ROLLER/CAPSULE BORER

Scientific name: *Antigastra catalaunalis* (Duponchel)

Family: Pyralidae

Order: Lepidoptera

Hosts: Sesame and *Duranta*

Distribution: India, Africa, Europe, Malta, Burma, Bangladesh, Indonesia, Sri Lanka etc.

Marks of identification:

- Eggs are pale green and shiny and they hatch in 2-7 days.
- Larva is greenish in colour with black head having short white hairs, about 2 mm in length.
- Adult moth is medium sized reddish yellow forewings.

Life cycle:

- Female lay up to 140 eggs singly on the tender portions of plants at night.
- The eggs are shiny, pale-green and they hatch in 2-7 days, depending upon the season.
- On emerging, the young larva, which measures about 2 mm in length, feeds for a little while on the leaf epidermis or within the leaf tissue.
- Soon after, it binds together the tender leaves of the growing shoot with the help of silken threads and continues to feed in the webbed mass.
- The size of this rolled mass increases gradually as the caterpillar grows older.
- It becomes full-grown in about 10 days in summer, but the period may be prolonged 33 days in winter.
- The grown-up larvae creep to the ground and pupate in silken cocoons in soil.
- Sometimes, pupation also takes place in the plant itself.
- Pupal development is completed in 4-20 days, depending upon the season.
- In summer, a generation is completed in about 23 days but in the winter it takes about 67 days.

Nature of damage:

- The young larvae roll together a few top leaves and feed by remaining inside roll.
- In the early stage of infestation, the plant dies without producing any branch or shoot.
- In later stage of attack, infested shoots stop growing.
- At flowering, larvae feed inside the flowers and on capsule formation, larvae bore into capsule and feed on developing seeds.

Management:

- Use of light trap for attracting and killing the moths
- Spraying of *Beauveria bassiana* 40 g powder or neem seed kernel powder 500 g (5% extract) in 10 litre of water as soon as infestation starts
- Spraying of dichlorvos 76 EC, 7 ml (0.05%) or quinalphos 25 EC, 20 ml (0.05%) or chlorpyrifos 20 EC, 20 ml (0.04%) in 10 litre of water at 30, 45 and 60 days after sowing.
- Spraying of quinalphos 25 EC @ 20 ml in 10 litre of water.

2. HAWK OR DEAD HEAD MOTH (Sphinx moth)

Scientific name: *Acherontia styx* (Westwood)

Family: Sphingidae

Order: Lepidoptera

Hosts: Sesame, Potato, Brinjal and Jasmine

Distribution: India, Sri Lanka, Burma, Indonesia, Philippines and Malaysia.

Marks of identification:

- Eggs are globular and greenish when freshly laid but later on turn yellowish

- Larva is stout, greenish in colour with oblique strips with a prominent dorsal curved anal horn on 8th abdominal segments.
- Pupa is 50-60 mm in length. Rarely formed more than 10 cm below the surface of the soil, in a smooth-sided chamber. Very tolerant of extremes of moisture or dryness and due to the tolerance this is main over wintering stage.
- Adult is brownish giant hawk moth which has characteristic skull marking.
- On the thorax end violet yellow band on abdomen
- Forewings are dark brown and hindwings are yellowish with two black lines.

Life cycle:

- The moths lay globular eggs singly on the underside of the leaves. They are greenish white when freshly laid but turn yellow later on. Eggs are laid singly and incubation period is 2-5 days.
- The pale yellow larvae emerge in 2 to 5 days and start feeding on leaves. The larval period is usually long and may last two months or more.
- The pupal stage lasts for 2 to 3 weeks in summer and about 7 months in winter.
- The changes in colouration of the larvae and adults aid them in protective mimicry.
- There are 3 generations in a year. The winter is passed in the pupal stage in soil.

Nature of damage:

- The larvae feed voraciously on leaves and defoliate the plants.
- The insect is capable of inflicting heavy damage at times, but generally it is not a very serious pest in India.
- However, it draws our attention because of its peculiar characteristics.
- The moth sucks honey from honey comb.

Management:

- Use of light trap for the control of moths.
- Deep ploughing exposes the pupae for predation to insectivorous birds.
- Hand picking and destruction of caterpillars.
- Spraying of neem seed kernel powder 500 g (5% extract) in 10 litre of water at the initiation of infestation.
- Spraying of quinalphos 25 EC, 20 ml in 10 litre of water, if infestation is more.

3. LINSEED GALL FLY

Scientific name: *Dasyneura sesame* Grower & Prasad

Family: Cecidomyiidae

Order: Diptera

Host range: Sesame

Distribution: Andhra Pradesh, Madhya Pradesh, Bihar, Uttar Pradesh, Delhi and Punjab

Marks of identification:

- Maggots are whitish and legless. Its anterior portion is pointed and posterior portion is blunt. Adult fly is mosquito like fly.

Life cycle:

- The female lays 29-103 smooth, transparent eggs in buds, flowers or in developing capsules, either singly or in clusters of 3-5. The egg hatch in 2-5 days.
- Maggots pass through four instars in 4 to 10 days.
- The full grown maggots drop to the ground, prepare a cocoon and pupate in soil. The pupal period lasts for 4 to 9 days. A generation is completed in 10 to 24 days.
- There are four overlapping generations during the season.

Nature of damage:

- Fully grown larvae make a hole in the bud and damage the flower.
- Buds develop into galls and produce no fruits and seeds.
- When infestation is severe, the crop may be a total failure.

Management:

- The adult flies can be killed by using light traps.
- The flies are also attracted in day time to molasses or *gur* added to water.
- As the incidence of this pest is more on late sown crops as compared to normal sown crop, the practice of normal sown crops should be adopted, if possible.
- Spray of quinalphos 25 EC or chlorpyrifos 20 EC 20 ml in 10 litre of water.

4. GALL FLY

Scientific name: *Asphondylia sesame* Felt

Family: Cecidomyiidae

Order: Diptera

Host range: Sesame

Distribution: Tamil Nadu, Andhra Pradesh, Kerala, Madhya Pradesh, Gujarat, and Maharashtra states of India.

Marks of identification:

- Maggots are whitish, legless and with body tapering. Adult fly is mosquito like fly.

Life cycle:

- The female lays eggs singly in buds, flowers and developing capsules. The eggs hatch in 2 to 4 days.
- The larvae complete their development in 14 to 21 days and pupate inside the galls.

- The fly emerges from gall in 7 to 12 days.
- The life cycle is completed in 23 to 37 days.

Nature of damage:

- As results of feeding by maggots, the buds develop into galls and produce no fruits and seeds. When infestation is sever, the crop may be a total failure. However, some varieties are comparatively resistance to its attack.

Management:

- The infested buds should be removed and destroyed to reduce further incidence.
- *Pteromalus fasciatus* Thomas act as a larval parasite, conserve properly.
- Spray crop at bud initiation stage, dimethoate 30 EC, 10 ml in 10 litre of water.

5. LEAF HOPPER

Scientific name: *Orosius albicinctus* Distant

Family: Cicadallidae

Order: Hemiptera

Marks of identification:

- Adult is light brown colour

Nature of damage:

- Curling of leaf edges and leaves turn red or brown
- The leaves dry up and shed
- It transmits sesame phyllody disease

Management:

- Spraying of NSKE 5% or neem oil 50 ml (0.5%) in 10 litre of water.
- Spraying of monocrotophos 36 EC, 10 ml (0.04%) or imidacloprid 17.8 SL, 4 ml or thiamethoxam 25 WG, 4 g in 10 litre of water, if infestation is severe.

PESTS OF SOYBEAN

1. BIHAR HAIRY CATERPILLAR

Scientific name: *Spilosoma oblique* Walker

Family: Noctuidae

Order: Lepidoptera

Hosts: Soybean, castor, groundnut, mungbean, black gram, cowpea etc.

Nature of damage:

- Young larvae feed gregariously on chlorophyll mostly on the under surface of the leaves, due to which the leaves look like brownish-yellow in colour.
- In later stages, the larvae eat the leaves from the margin.
- The leaves of the plant give an appearance of net or web

Management:

- Reduce the bund size.
- Cleaning of bunds in summer season.
- Plough the field deep in summer season.
- Grow sunnhemp as small band around the field and apply quinalphos 1.5% or fenvalerate 0.4% dust.
- Collection of egg masses and destruction of it.
- Use of light traps soon after first shower of monsoon for collecting and killing of adult moth's one trap/ha is very effective. Light trap should be operated from dusk to midnight only.
- The dispersing larvae of hairy caterpillar from one field to another can be checked by digging trenches across the direction of their march and prompt destruction of larvae.
- Vegetative traps like jatropha or ipomoea prevent the migration of the grown up larvae.
- Prepare small balls with 10 kg rice bran + 1 kg jaggery + 1 litre quinalphos and broad-cast in fields preferably in the evening times.
- Dusting of fenvalerate 0.4% or quinalphos 1.5% dust @ 25-30 kg/ha is effective in controlling the young larvae.
- Spraying of thiodicarb 75 WP, 20 g (0.15%) or chlorpyrifos 20 EC, 20 ml (0.04%) or quinalphos 25 EC, 20 ml (0.05%) or spinosad 45 SC, 3 ml (0.014%) or methomyl 40 SP, 20 ml (0.08%) in 10 litres of water.

2. GRAM POD BORER

Scientific name: *Helicoverpa armigera* (Hubner) Hardwick

Family: Noctuidae

Order: Lepidoptera

Hosts: Okra, brinjal, cabbage, pigeon pea, gram, bajra, lucerne etc.

Nature of damage:

- The first instar larva feeds on the chlorophyll of young leaves and skeletonizes it.
- They feed voraciously on flowers and developing grains.

Management:

- Deep summer ploughing after harvest of crop
- Install pheromone traps @ 40/ha
- Install bird perches @ 50/ha
- Setting of light traps @ 1/ha to kill moth population
- Spraying of chlorpyrifos 20 EC, 20 ml (0.04%) or quinalphos 25 EC, 20 ml (0.05%) in 10 litre of water.

3. LEAF EATING CATERPILLAR

Scientific name: *Spodoptera litura* Fabricius

Family: Noctuidae

Order: Lepidoptera

Nature of damage:

- Freshly hatched caterpillars feed gregariously by scrapping the leaves from ventral surface leaving the upper surface intact.
- Later instar larvae feed voraciously and plants are completely defoliated and field looks as it is grazed by cattle.
- Since the pest is nocturnal in habit, it hides under the plants, cracks and crevices of soil and debris during the day time.

Management:

- Monitoring the pest with pheromone traps (5/ ha) for timely management
- Collect and destroy the egg masses and caterpillars in the early stages of infestation
- Plough the field in summer after harvest of crop so as to expose the pupae to predators, parasitoids and birds.
- To control early stage larvae, spray neem seed kernel powder (5% extract) 500 g or chlorpyrifos 20 EC, 20 ml (0.04%) or quinalphos 25 EC 20 ml (0.05%) in 10 litre of water.
- As the grown up larvae move down to soil to hide during day time, poison bait (chlorpyrifos 20 EC 100 ml+ 1 kg of rice bran + 1 kg jaggary + 1 litre of water to make the bait in to pellets for one hectare) placement at base of the plants helps in killing the larvae.
- Application of nuclear polyhydrosis virus (NPV) 250 LE/ha in required quantity of water at evening time.
- For the control of later instar larvae, application of fenvalerate 20 EC, 5 ml (0.01%) or deltamethrin 2.8 EC, 5 ml (0.0014%) in 10 litre of water is effective.

4. THRIPS

Scientific name: *Sericothrips variabilis* Beach

Family: Thripidae

Order: Thysanoptera

Host distribution: World wide

Host plants: soybean

Marks of identification:

- Eggs are white to pale yellow, slightly curved, tapering and approximately 0.3 mm long.
- First-stage larvae are delicate and cream-colored. Second-stage larvae are yellow and robust with pigmented eyes.
- Nymph is very tiny pinkish nymphs

- Black adult with fringe wing. Thrips are minute, slender-bodied insects ranging from 0.8 to 5 mm in length. Their wings, when present, are fringed with close-set long hairs.

Life cycle:

- Egg period is 8-12 days.
- Larval period is 11-16 days.
- Adult life span is 32-33 days.

Nature of damage:

- Both adults and nymphs scratch surfaces of the leaves and suck the oozing sap.
- The terminal leaves crinkle and appear silvery.
- If infestation is severe, plants remain stunted.
- The injury results in development of dull yellowish green patches on the upper surface and leaves get curl.

Management

- Insecticides such as phosphamidon 40 SL, 10 ml, dimethoate 30 EC, 10 ml (0.03%), acephate 75 SP and monocrotophos 36 EC, 10 ml (0.04%) in 10 litre of water give good control of thrips.
- Monocrotophos (320 ml) + neem oil (1 litre) + soap powder (1 kg) in 200 litre of water should be applied twice at 10 days interval.

5. WHITEFLY

Scientific name: *Trialeurodes ricini* Mishra

Family: Aleyrodidae

Order: Hemiptera

Host plants: Pulse, vegetables, castor, cotton, sesame, rose, etc.

Distribution: World wide

Marks of identification:

- Eggs are whitish-green with a smooth surface, oblong, approximately 0.2 mm long and 0.08 mm wide at the widest point.
- Larva is greenish-yellow with red eyes, elliptical. The first-instar larvae are approximately 0.26 mm long and 0.13 mm wide and slightly convex with a waxy fringe. The second-instar larvae are approximately 0.33 to 0.41 mm long and 0.19 to 0.25 mm wide with a narrow waxy band. The third-instars are 0.48 to 0.51 mm long and 0.30 to 0.38 mm wide.
- Pupa is yellow with red eyes; white waxy filaments at the margins; elliptical, thin and flat, but become thicker after 3 or 4 days. The males are much smaller. The physical characteristics of the host leaf surface induce variation in the morphology of the puparia.
- Adult is bright-yellow to cream body with white legs and wings. At rest the wings are held 'tent-like', at an angle over the body.

Life cycle:

- The female lays shining white long eggs in small clusters or scattered on the underside of tender leaves.
- The eggs hatch into nymphs which settle on the leaves and along with the adults suck the sap from the leaves.

Nature of damage:

- Both nymphs and adults suck sap from leaves which results in sickly appearance and sooty mould is developed when whitefly infestation is severe.
- There will be reduction in yield due to severe infestation.

Management:

- Predaceous spider and coccinellids feed on the pest and a chalcid wasp parasitizes the puparia. These predator and parasitoid should be conserved to keep the incidence of the pest in check.
- Spraying of triazophos 40 EC, 25 ml (0.1%) or acephate 75 SP, 10 g (0.075%) or monocrotophos 36 EC, 10 ml (0.04%) or chlorpyrifos 20 EC, 20 ml (0.04%) in 10 litre of water.
- Neem oil 50 ml (0.5%) in 10 litre of water at initial stage of infestation.

6. SOYBEAN APHID

Scientific name: *Aphis glycines* Matsumura

Family: Aphididae

Order: Hemiptera

Host: Soybean

Distribution: Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Mississippi, Missouri, etc.

Marks of identification:

- Nymphs are Black colour, oblong and have cornicles on the posterior part of the abdomen.
- Winged adults have a black head and thorax.

Nature of damage:

- They suck the plant sap from the stem, leaves and pods which cause reduction in yield.
- The infested leaves are wilted or curled.
- Plants remain stunted and there is reduction in seed yield.

Management:

- Dusting of cow dung ash and spraying of clay suspension (in small area and low incidence of sucking insects)

- Spray quinalphos 25 EC, 20 ml (0.05%) or monocrotophos 40 EC, 10 ml (0.04%), or dimethoate 30 EC, 10 ml (0.03%) in 10 litre of water at the crop age of 35-40 days and repeat after 15 days if needed

7. GIRDLE BEETLE

Scientific name: *Oberea (Obereopsis) brevis* Gahan

Family: Cerambycidae

Order: Coleoptera

Host plants: Soybean, lablab and cowpea

Distribution: India, Myanmar

Marks of identification:

- Larva is white, soft-bodied worm with a dark head.
- Freshly emerged adult is yellow, red-brown on the head, thorax and bases of elytra.

Life cycle:

- The ovipositing female beetle girdles the stem twice and make 3 punctures just above the lower ring before inserting single egg through hole in to the pith.
- The female beetle lays 7 to 13 eggs and they hatch in 4 to 5 days.
- The larval period lasts for 34 to 47 days.
- Overwintering takes place as the full grown larva within the feeding tunnel in a gall like chamber near the base of the plant in the girdle portion of the stem which has fallen out or under plant debris.

Nature of damage:

- Girdling of stems and petioles
- The stem is eaten by the larvae and a tunnel is formed inside the stem.
- The leaves of plant of infested portion are unable to get the nutrient and are dried up.
- In later stages, the plant is cut at about 15 - 25 cm above the ground.

Management:

- Deep summer ploughing
- Grow the crop onset of monsoon
- Optimum seed rate (70-100 kg/ha) should be used
- Intercropping with maize or sorghum should be avoided
- Crop rotation should be followed.
- Avoid excess nitrogenous fertilizers.
- Collect and destroy infested plant parts and egg masses.

- Remove the infested plant parts at least once in 10 days and bury them in compost pit and reduce the populations of girdle beetle
- Spraying of azadirachtin 0.15 EC @ 40 ml in 10 litre of water
- Spraying of triazophos 40 EC @ 750 ml in 500 litre of water
- Apply phorate 10 G @ 10 kg/ha or carbofuran 3 G @ 30 kg/ha at the time of sowing
- Spray monocrotophos 36 WSC, 10 ml (0.04%) or quinalphos 25 EC, 25 ml (0.05%) or triazophos 40 EC, 20 ml (0.08%) in 10 litre of water at the crop age of 30-35 days and second spray 15 days after first spray.

8. STEM FLY

Scientific name: *Melanagromyza sojae* (Zehntner)

Family: Agromyzidae

Order: Diptera

Host plants: Red gram

Distribution: Northern India

Marks of identification:

- Maggot is white in colour and remains inside the stem.
- Adult flies are shining black and about 2 mm long.

Life cycle:

- The female fly thrust its minute eggs into tender pods. They hatch in 2 to 4 days.
- Maggot becomes fully grown in 5 to 10 days.
- Pupation takes place inside the damaged pods and the pupal period lasts for 4 to 13 days.
- The life cycle completed in 11 to 27 days and several generations are produced in a year.

Nature of damage:

- After hatching from the egg yellowish maggots bore the nearest vein of the leaf.
- The maggots then reach the stem through petiole and bore down the stem.
- If the infested stem is opened by splitting, distinct zig-zag reddish tunnel can be seen with maggot or pupae inside it.
- The maggots feed on cortical layers of the stem, may extend to tap root and killing of the plant.

Management:

- Deep summer ploughing
- Avoid pre-monsoon sowing
- Use optimum seed rate and plant spacing

- Proper crop rotation
- Remove and destroy the damaged plant parts
- Soil application of phorate 10 G @ 10 kg/ha or carbofuran 3 G @ 30 kg/ha at the time of sowing will prevent early infestation by stem fly
- One or two sprays of dimethoate 30 EC, 10 ml (0.03%) or quinalphos 25 EC, 20 ml (0.05%) or chlorpyrifos 20 EC, 20 ml (0.04%) in 10 litre of water

PESTS OF GROUNDNUT

1. GROUNDNUT LEAF MINER

Scientific name: *Aproaerema modicella*

Family: Gelechiidae

Order: Lepidoptera

Host: Groundnut, soybean and red gram

Distribution: India, Pakistan, Srilanka, Myanmar and South Africa

Marks of identification:

- Eggs are shiny white and are laid singly on the underside of the leaflets.
- Larvae are green in colour with dark head and prothorax. The newly hatched larvae about 1.5 mm in length.
- Pupa is reddish brown coloured.
- Adult is brownish grey moth, 6 mm long with 10 mm wing span. Forewings with white spot on the costal margin

Life cycle:

- A female moth lays 150-200 eggs that hatch in 2-3 days.
- Total 6 larval instars are reported. The larval period is 4-17 days.
- Pupal period is 3-10 days. Pupation takes place in silken cocoons. They formed in webbed leaflets.
- Adult longevity is 5-6 days. Life cycle is completed in 20-25 days. There are several generations during a year.

Nature of damage:

- Young larvae initially mine into the leaflets, feed on the mesophyll and form small brown blotches on the leaf.

- Later stages larvae web the leaflets together and feed on them, remaining within the folds.
- Severely attacked field looks "burnt" from a distance

Management:

- Crop rotation with non-leguminous crops and intercropping with cowpea are reported to reduce the severity of attack.
- Light traps placed at ground level early in the season to collect and destroy the moths have been reported to reduce pest incidence.
- As the attack is severe under drought conditions, it can be reduced by irrigation.
- Spray deltamethrin 2.8 EC 10 ml or lambda cyhalothrin 5 EC 5 ml or quinalphos 25 EC 10 ml in 10 litres of water.

2. GRAM POD BORER

Scientific name: *Helicoverpa armigera* (Hubner) Hardwick

Family: Noctuidae

Order: Lepidoptera

Nature of damage:

- Small or large irregular feeding holes on the leaves.
- The young larvae feeds on the chlorophyll of young leaves and skeletonize it.
- They feed voraciously on flowers and developing grains.

Management:

- Deep summer ploughing after harvest of crop
- Install pheromone traps @ 40/ha
- Erect bird perches @ 50/ha
- Setting of light traps (one trap/ha) to attract and kill moth population
- Spraying of chlorpyrifos 20 EC, 20 ml (0.04%) or quinalphos 25 EC, 20 ml (0.05%) in 10 litre of water.

3. TERMITE

Scientific name: *Odontotermes* spp.

Family: Termitidae

Order: Isoptera

Host plants: Polyphagous

Distribution: Tropical and sub-tropical regions of the world

Marks of identification:

- These are social insects, live in termataria, in distinct castes, workers, soldier, king and queen.
- Workers' are small (4 mm) and have a soft, white body and a brown head.

Life cycle:

- The queen produces thousands of eggs over the lifetime.
- After mating, the new queen starts laying eggs in about a week.
- Eggs are laid in a crevice by digging a hole in the soil or by excavating a tunnel in wood.
- Once the nuptial chamber is constructed the king and queen will mate.
- Initially, the queen lays only a few eggs which are looked after by her and the king.
- The eggs are normally laid singly. Incubation takes from 24 to 90 days.
- There are normally seven nymphal instars (stages) in established colonies but the number varies depending on temperature, age of colony, size of colony and relative humidity. The nymphs may grow into soldiers or workers.
- The worker's life span is one to two years.
- After a few years sexuals are released from the colony, who will in turn form new colonies.

Nature of damage:

- The termite is endemic in red and sandy soils.
- All termites eat cellulose (e.g. from dead plant fibre) and many termites cultivate a fungus within the nest, which is a source of food (especially proteins) for the queen, king and the young.
- Wilting of plants in patches
- Termites penetrate and hollow out the tap root and stem thus kill the plant.
- Bore holes into pods and damage the seed.
- It removes the soft corky tissue between the veins of pods causing scarification, weaken the shells, make them liable to entry and growth of *Aspergillus flavus* that produces aflatoxins.

Management:

- Digging of termataria and destruction of the queen is most important in termite management
- Use well rotten organic manure
- Harvest the groundnut as soon as they are matured, early removal of the haulm from the field will reduce the chances of termite damage to pods.
- Clean cultivation
- Irrigate the crop frequently in summer groundnut
- Ploughing and frequent intercultural operations reduces termite damage
- Destruction of debris, termite nests and queen
- Apply chlorpyrifos 20 EC, 1.25 litre/ ha with irrigation water
- Seed treatment with chlorpyrifos 20 EC, 25 ml or quinalphos 25 EC, 25 ml/kg seed may reduce termite damage.

4. WHITE GRUBS

Scientific name: *Holotrichia consanguinea*, *Holotrichia serrata*, *Phyllognathus* sp., *Apogonia rauca*, *H. fissa*, *Maladera* sp., *Schizonycha ruficollis*, *Adoretus bicolor*, *A. deccanus*, *A. versutus*, *Adoretus* sp., *Anomala bengalensis*, *A. dorsalis* and *A. varicolor*

Family: Scarabaeidae

Order: Coleoptera

Host: Groundnut, soybean, maize, sorghum, bajra, cowpea, greengram, Blackgram, etc.

Distribution: Worldwide

Marks of identification:

- Eggs are white in colour and almost round in shape.
- Larva is young grubs are translucent, whitish yellow in colour, fleshy 'C' shaped.
- Pupa is approximately the same size as the adult, the pupa may be creamy white, pale yellow, or dark brown.
- Adult is dark brown beetle. Beetles emerge out of the soil within 3-4 days after the onset of rain.

Life cycle:

- The female beetles lay eggs singly up to depth of 10 cm after mating.
- The egg hatch in 7 to 10 days.
- The grub development completed in 8 to 10 weeks.
- After the monsoon, the full grown grub migrate to a considerable depth in the soil for pupation.
- The pupa is semicircular and creamy white and the pupal stage lasts about a fortnight.
- The beetles remain in the soil at a depth of 10-12 cm and come out for feeding at night.
- Adults formed in November remain in soil till next June
- Their population is maximum in the rainy season and there seems to be only one generation in a year.

Nature of damage:

- The grubs feed nodules, fine rootlets and may also girdle the main roots, ultimately kill the plant.
- At night, the beetles feed on foliage and may completely defoliate even trees like neem and banyan.
- Adults feed on leaves of neem, ber, drumstick, *babool*, grass hopper etc.

Management:

1. **At the time of sowing :**

- Deep ploughing the field in summer. It would help in exposing the beetles from the soil.
- After the first satisfactory rain, spray chlorpyrifos 20 EC 20 ml in 10 litres of water on the border trees of the field.

- Mechanically shaking of the branches of the trees situated on the border the field, then collect and destroy the beetles in kerosenized water.
- Set up light traps or bonfires to attract and kill the adults on receipt of summer showers.
- Seed treatment with quinalphos 25 EC or chlorpyriphos 20 EC @ 25 ml/kg seed.
- Application of phorate 10 G 10 kg/ha or carbofuran 3 G @ 30 kg/ha in furrow before the sowing of groundnut.
- Application of castor cake 500 kg/ha in furrow before sowing of the crop.
- Application of *Beauveria bassiana* or *Metarhizium anisopliae* 1.15 WP @ 5 kg/ha alongwith the castor cake (300 kg/ha) before sowing in the soil and 30 days after sowing .

2. In standing crop:

- When you observe the infestation of white grub in the field, give the chlorpyriphos 20 EC 4 lit/ha along with irrigation. If irrigation facility is not available, so drench the solution of chlorpyriphos 20 EC 50 ml/ 10 litres of water in the root zone of the groundnut plant or apply the mixture of Chlorpyriphos 20 EC 4 lit + water 5 lit + sand 100 kg nearby the stem of groundnut plant and then irrigate the field.
- Spraying of monocrotophos 36 SL 10 ml in 10 litres of water on the crop to manage beetles.
- Drenching of Fipronil 40% + Imidacloprid 40% WG 4.5 g/ 10 litres of water near by the stem of groundnut.
- After the harvest of the crop the infestation observe in the next wheat crop, so deep plough the field and apply granular insecticides viz., carbofuran or phorate.

5. GROUNDNUT APHID: *Aphis craccivora* Koch. (Aphididae:Hemiptera)

Marks of Identification:

- Adult aphid is an oblong soft bodied insect.Both winged and wingless forms are common. The body colour is dark brown to black. The wings are thin transparent and are held like a roof over the body.
- Nymphs smaller in size and brownish in colour.
- The insects are characterized by the presence of two tube like structures called "Cornicles" at the anal end of the abdomen.

Life history:

- Both winged (alate) and wingless (apterous) forms produce young ones viviparously and parthenogenetically. A single female produces 8 to 22 nymphs per day.
- Nymphs moults four time before reaching the adult stage. The life cycle is completed in 7- 9 days and there are many generations in a year.

Nature of damage:

- This Polyphagous pest prefers to feed on the young shoots causing leaf curling and stunted growth. In later stages, flowers and pegs are also affected hampering pod formation seriously.
- Both adults and nymphs suck the sap from all foliar parts and in severe cases crop looks withered and blighted. This pest alone is capable of reducing yield upto 40 per cent (Khan and Hussain, 1965).
- This insect has been reported to be the vector of rosette disease. (Kaushalya *et al.*, 1971). However occurrence of rosette in India has not been confirmed. (Feakin, 1973; Ghanekar, 1980).

Control measures:

- Use of sticky trap to know the initial population of aphid.
- Use of natural predator lady bird beetle.
- Spraying the crop with chlorpyrifos 20 EC @ 20 ml or methyl-o-demeton 0.03 % or Dimethoate 0.03 %

6. GROUNDNUT JASSID: *Empoasca fabae*, *Emrasca kerri* Pruthi (Jassidae : Hemiptera)

Several species of jassid attack groundnut but *E. kerri* is the most common.

Host plants: Castor, cluster bean, maize, soybean, green gram, black gram, cowpea and pigeon pea, cotton, Brinjal, okra, potato

Marks of Identification:

- The adult is wedge shaped insect and is pale green in colour.
- There is a black dot on each of the fore wings and two spots on the vertex. Eggs are elongate and yellowish white in colour.
- Nymphs are also pale greenish in colour like the adults but wingless. Insect is characterized by its habit of walking diagonally in relation to their body.

Nature of Damage:

- Both the adults and nymphs suck sap from leaves mainly from the undersurface. The feeding on leaves results in veins becoming shiny white and the tips turning yellow.
- The "V" shape yellowing at the tip of leaflets is characteristic of jassid injury.
- In case of heavy infestation margin turns reddish and curls. The growth of plant remained stunted which adversely affects the yield.

Life history:

- Female lays about 30 eggs singly inside the leaf veins which hatch about in 4 to 11 days.
- Nymphal period is 7-21 days depending upon the climatic condition, during which time nymphs moult 5 times.
- Total period of life cycle is about 2 to 4 weeks and there are several generation in a year.

Control measure:

- Same as aphid.

PESTS OF MUSTARD

1. MUSTARD APHID

Scientific name: *Lipaphis erysimi* Kaltenbach

Family: Aphididae

Order: Hemiptera

Host plants: Mustard, cauliflower, cabbage, radish, tomato, turnip, etc.

Distribution: Worldwide

Marks of identification:

- There are four nymphal stages (instars). The general appearance of each stage is similar except for increase in size during subsequent instars. The first, second, third and fourth nymphal stages last 1-2, 2, 2, and 3 days, respectively.
- Aphids are small, soft-bodied, pearl-shaped insects that have a pair of cornicles (wax-secreting tubes) projecting out from the fifth or sixth abdominal segment. Wingless female aphids are yellowish green, grey green or olive green with a white waxy bloom covering the body. The winged, female, adult aphids have a dusky green abdomen with dark lateral stripes separating the body segments and dusky wing veins. Male aphids are olive green to brown in colour. The aphid attacks generally during 2nd and 3rd week of December and continues till March.

Life cycle:

- This insect is most abundant from December to March when it infests various cruciferous oil seeds and vegetables.
- The pest breeds parthenogenetically and female give birth to 26 to 133 nymphs
- They grow very fast and full fed in 7 to 10 days
- About 45 generations are completed in a year.

Nature of damage:

- Both nymphs and adults suck the sap from leaves, buds and pods
- Curling may occur in infested leaves and at advanced stage, plants may wither and die.
- Plants remain stunted and sooty molds grow on the honey dew excreted by the insects.
- The infected field looks sickly and blighted in appearance

Favorable seasons

- The aphid attacks generally during 2nd and 3rd week of December and continues till March.
- The most favourable temperature is between 8 and 24° C.
- Relative humidity of 70 to 80 per cent is favorable for faster multiplication of aphid.
- Rainy and humid weather helps in accelerating the growth of insects

Management:

- Growing of tolerant varieties like JM-1 and RK-9501
- The crop should be sown before 20th October to escape the damage.
- Set up yellow stick trap to monitor aphid population.
- Destroy the affected parts along with aphid population in the initial stage.
- Conserve the natural enemies viz., Ladybird beetles (*Coccinella septempunctata*, *Menochilus sexmaculata*, *Hippodamia variegata* and *Cheilomones vicina*) are most efficient predators of the mustard aphid. Adult beetles may feed on an average of 10 to 15 adults/day.
- Several species of syrphid fly i.e., *Sphaerophoria* spp., *Eristalis* spp., *Metasyrphus* spp., *Xanthogramma* spp and *Syrphus* spp. are predating on aphids.
- The braconid parasitoid, *Diaeretiella rapae* is a very active and effective biocontrol agent causes mummification of aphids.
- The lacewing, *Chrysoperla carnea* predate on the mustard aphid colony
- Predatory bird *Motacilla cospica* is actively feeding over aphids in February-March
- A number of entomogenous fungi, *Cephalosporium* spp., *Entomophthora* and *Lecanicillium lecanii* infect aphids
- Spray the crop with dimethoate 30 EC, 10 ml (0.03%) or chlorpyrifos 20 EC, 20 ml (0.04%) or thiamethoxam 25 WG, 3 g in 10 litre of water.

2. MUSTARD SAW FLY

Scientific name: *Athalia lugens proxima* (Klug)

Family: Tenthredinidae **Order:** Hymenoptera

Distribution: Indonesia, Formosa, Myanmar and Indian Sub-continent

Host: Mustard, *toria*, rapeseed, cabbage, cauliflower, Knol-khol, turnip and radish

Marks of identification:

- Eggs are spherical, about 0.5 mm in diameter, light bluish green in colour.
- Larva is Greenish black with wrinkled body and has eight pairs of pro-legs. On touch the larva falls to ground and feigns death.
- Pupae look like sand particle and have salivary secretions; the pupal stage lasted 11-12 days
- Head and thorax of adult fly are black in colour. Abdomen is orange colour. Wings are translucent, smoky with black veins

Life cycle:

- The mustard saw fly breeds from October to March and the larvae rest in their pupal cocoon in the soil during summer

- The adults emerge from these cocoons early in October. They live for 2 to 8 days and lay 30 to 35 eggs singly, in slits made with saw like ovipositors along the underside of the leaf margin
- The egg hatch in 4 to 8 days and larvae feed exposed in groups of 3 to 6 on leaves during morning and evening
- Larva passes through seven stages and is full grown in 16 to 35 days.
- They pupate in water proof oval cocoons made of silk and emerge from them as adult in 11 to 31 days
- The pest completes 2 to 3 generations from October to March
- Total life cycle is completed in 31 to 34 days.

Nature of damage:

- Initially the larva nibbles leaves, later it feeds from the margins towards the midrib.
- The grubs cause numerous shot holes and even riddled the entire leaves by voracious feeding.
- They devour the epidermis of the shoot, resulting in drying up of seedlings and failure to bear seeds in older plants.

Management:

- Summer ploughing to destroy the pupa.
- Early sowing should be done.
- Maintain clean cultivation.
- Apply irrigation in seedling stage is very crucial for sawfly management because most of the larvae die due to drowning effect. Severe cold reduces pest load.
- Collection and destruction of larva of saw fly in morning and evening
- Conserve *Perilissus cingulator* (parasitoids of the grubs) and the bacterium *Serratia marcescens* which infect the larvae of sawfly
- Spray the crop with quinalphos 25 EC, 20ml (0.05%) in 10 litre of water.

3. PAINTED BUG : *Bagrada cruciferarum* (Pentatomididae : Hemiptera)

Host plants : It is the specific pest of rapeseed and mustard as well as other cruciferous pests.

Marks of identification :

- The adults are pretty looking bugs, black in colour with yellow and orange spots.
- Nymphs are black in colour with number of brown markings

Nature of damage :

- It is the serious pest of cruciferous plants and is more destructive at the seedling and pod formation stage. It is also a serious problem at the harvested crop in the threshing floors.
- Both nymphs and adults suck the sap from leaves and developing pods which gradually wilt and dry up.

- The young plants may wilt and die on the severity of attack and the pests migrate to larger plants where they cluster over the leaves and pods. In the threshing floor the pest suck the sap from dry pods.
- The nymph and adult bugs also excrete a sort of resinous material which **spoils the pods**.

Life cycle :

- Eggs laid singly on leaves and stems. On an average a female lays 32-400 eggs. The eggs have been reported to be laid on soil, leaves, stem and inflorescence and in debris and seed pods. The egg stage is - 3 days in June - 6-12 days in November and - 20 days in December. The nymphs pass through 5 moults to reach adult stage.
- The nymphal period is 12-18 days in June, 33-36 days in December. There are nine generations in a year.

Control measures :

- Spraying the crop with dichlorvos 76 EC @ 15 ml
- Treat the seed with imidacloprid 70 WS @ 7 gm per kg seed
- To avoid the losses in threshing ground harvested crop should be threshed and removed immediately after harvest.

PESTS OF SUNFLOWER

1. CAPITULUM BORER/ HEAD BORER

Scientific name: *Helicoverpa armigera* (Hardwick) Hubner

Family: Noctuidae

Order: Lepidoptera

Nature of damage:

Larva first attack petals, tender parts of plants and later on flower heads feeds on the developing seeds and make tunnel on the disk. Head borer is a responsible for causing 20-25 per cent loss in yield under normal conditions. However, sometimes the damage is so severe and loss goes up to 40-70 per cent.

Management:

- Deep ploughing of the field is helpful to kill the hibernating larvae.
- Release of egg parasitoid, *Trichogramma* sp @ 50,000 adults/ha at weekly interval keep the head borer at bay.

- Spray nuclear polyhedrosis virus (HaNPV) @ 350 LE/ha for the control of 1st and 2nd instar larvae
- On the incidence, spray neem based formulation 20 ml (1 EC) to 40 ml (0.15 EC) or NSKS @ 5 per cent.
- Spray *Bt* base insecticide @ 10 to 15 g per 10 litre of water.
- Spray quinalphos 25 EC 20 ml, fenvalerate 20 EC 10 ml, profenophos 40% + cypermethrin 4% (44 EC) 10 ml, emamectin benzoate 5 WG 2 g, novaluron 10 EC 20 ml, diflubenzuron 50 WP 10 g, chlorantraniliprole 18.5 SC 3 ml, flubendiamide 480 SC 3 ml, indoxacarb 15.8 EC 5 ml, thiodicarb 75 WP 20 g, fipronil 5 SC 20 ml, in 10 litre of water. Spray any of them and change the insecticide in subsequent sprays.

2. BIHAR HAIRY CATERPILLAR

Scientific name: *Spilosoma obliqua* (Walker)

Family: Arctiidae

Order: Lepidoptera

Nature of damage:

- Larva is voracious feeders on leaves and soft portion of the stem and branches and causes defoliation.

Management:

- The eggs are laid in cluster, these can be collected and destroyed manually.
- The leaves on which large numbers of first instar larvae feed gregariously can also be collected and destroyed mechanically
- Digging trench around the field and fill up the water. Apply quinalphos 25 EC 20 ml in 10 litre of water to prevent the migration of caterpillars from one field to another
- Light trap should be installed in the field and attracted moths should be destroyed
- Application of *Bacillus thuringensis* (*Bt*) @ 1.0 Kg/ha is found effective.
- Spot application of insecticides
- Spray quinalphos 25 EC @ 20 ml or indoxacarb 15.8 EC @ ml/10 litre water

3. CUTWORM

Scientific name: *Agrotis spp.*

Family: Noctuidae

Order: Lepidoptera

Nature of damage

Cutworm larvae can sever stems of young seedlings at or near ground level, thereby causing collapse of the plant. Sometimes the young plant is partially dragged into the soil where the larvae feed on it. Larvae may also climb plants and browse on or cut off leaves. Crop areas attacked by cutworms tend to be patchy and the destruction of seedlings in one area may cause cutworms to migrate to adjacent fields. Risk period is summer and spring – one generation per crop.

Management:

- Deep ploughing of the field should be done after harvesting of the crop in order to expose the pupal stage of pest.
- Treat the seed with chlorpyrifos 20 EC @ 12 ml/kg seed.
- Sow the seeds on slope of ridges (6-8 cm height)
- Make a heap of the grasses between the rows and collect the hidden cutworm larva with the heap.
- Apply chlorpyrifos 20 EC 4 litre per hectare in soil with irrigation water.

4. TOBACCO CATERPILLAR

Scientific name: *Spodoptera litura* Fabricius

Family: Noctuidae

Order: Lepidoptera

Nature of Damage

- Soon after hatching, early instar larvae feed gregariously by scraping the chlorophyll of Lamina leading to skeletonization
- Later on, they disperse, become solitary and nocturnal
- Also feed on the flower buds, flowers, calyx etc.

Management:

- Deep ploughing of the field is helpful to kill the hibernating larvae.
- Collect the egg mass and first instar larva
- Used castor as trap crop
- Spray nuclear polyhedrosis virus (SNPV)@ 250 LE/ha for the control of 1st and 2nd instar larvae
- Application of 5 per cent neem seed kernel extract at 10 days interval protect the crop from insect damage
- Spray quinalphos 25 EC 20 ml, fenvalerate 20 EC 10 ml, novaluron 10 EC 20 ml, diflubenzuron 50 WP 10 g, flubendiamide 480 SC 3 ml, indoxacarb 15.8 EC 5 ml, thiodicarb 75 WP 20 g in 10 litre of water. Spray any of them and change the insecticide in subsequent sprays.

5. LEAF HOPPER

Scientific name: *Amrasca biguttula biguttula* (Ishida)

Family: Cicadellidae

Order: Hemiptera

Nature of damage

- Both nymph and adult suck the sap from the under surface of leaves.
- Leaves become crinkled and cup shaped, growth gets stunted brownish red colour develops on the edge of leaves and the condition is known as “**hopper burn**”.
- Population is high in Aug- Sept

Management:

- Use of nitrogenous fertilizers should be as per the recommended dose to reduce incidence of leaf hopper.
- It is decided that Economic threshold Level for Leaf hopper on Sunflower is 3 nymphs/leaf
- Spray monocrotophos 36 SL 10 ml or dimethoate 30 EC 10 ml or imidacloprid 17.8 SL 5 ml or thiamethoxam 25 WG 4 g or in 10 litre of water. Change the insecticides in subsequent sprays.

6. WHITEFLY

Scientific name: *Trialeurodes* sp. / *Bemisia tabaci*

Family: Aleyrodidae

Order: Hemiptera

Nature of damage:

- Nymphs and adults suck sap and excrete honeydew. Black sooty mould fungus grows on the sticky honeydew and can interfere with photosynthesis if severe.
- Under very heavy infestations, plants vigour may be affected and in situations of severe moisture stress, leaf wilting may occur. In very rare instances, yield may be affected.

Management:

- Whiteflies can be effectively attracted and controlled by yellow sticky traps, which are coated with grease/sticky oily materials.
- For management of whitefly on sunflower treatment with imidacloprid 70 WS @ 5 g/kg seed or two spraying of Azadirachtin 1500 ppm @ 20 ml / 10 litre of water at 15 and 30 days after emergence is recommended.
- The parasitic wasps *Encarsia* spp. and *Eretmocerus* spp. are common in most cropping regions where whitefly persist, and can provide high levels of biological control.
- Spray acephate 75 SP 10 g, triazophos 40 EC 20 ml, acetamiprid 20 SP 3 g, in 10 litre of water. Do not repeat the same insecticides in forthcoming sprays.

PEST OF SAFFLOWER

1. CAPSULE FLY/ SAFFLOWER BUD FLY

Scientific name: *Acanthiophilus helianthi* (Rossi)

Family: Tephritidae

Order: Diptera

Hosts: Linseed, Safflower

Distribution: This pest has been reported from Andhra Pradesh, Madhya Pradesh, Bihar, Uttar Pradesh, Delhi and Punjab in India.

Marks of identification:

- Early stage maggots are transparent, with a yellow patch on the abdomen later become deep pink and about 2 mm length.
- The adults is small delicate, Mosquito like orange coloured insect.

Life cycle:

- The female lays 29-103 smooth, transparent eggs in the folds of 16-17 flowers on in tender green buds, either singly or in cluster of 3-5. The eggs hatch in 2-5 days.
- These larvae feed inside flower buds and eat the contents. They pass through four instars in 4-10 days and when full-grown, become deep pink and measure about 2 mm length.
- The pupal period lasts 4 to 9 days
- Total life cycle completed in 10-24 days
- There are four overlapping generation during the season.

Nature of damage:

- Damage is the result of feeding by maggots on floral parts including the thalamus.
- The infested buds begin to rot and an offensive smelling fluid oozes at the apices giving a soaked appearance to the buds.
- The pest causes reduction in the yield of safflower seed.

Management:

- The early removal and destruction of infested buds is helpful in checking the spread of the pest.
- The adult flies can be killed by using light traps
- The flies are also attracted in day-time to molasses or *gur* added to water
- As the incidence of this pest is more on the late sown crop as compared with the normal sown crop, the practice of normal sown crops should be adopted possible.
- Application of dimethoate 30 EC 10 ml or monocrotophos 40 EC 10 ml in 10 litre of water.

2. SAFFLOWER CATERPILLAR

Scientific name: *Perigea capensis* (Guen)

Family: Noctuidae

Order: Lepidoptera

Marks of identification:

- The full grown caterpillar is smooth, greenish with purple markings and humped on the anal segments.
- The adult are dark brown medium sized moth with heavy markings on the fore wings.

Life cycle:

- Female lays about 60 eggs singly or in small cluster on leaves and stem. Egg hatched in 4-5 days
- Larval period is about 2-3 days
- Pupation take place in soil is for 10-15 days

Nature of damage:

- The larvae fed on the leaves and defoliate the plants which lost their vigour and become stunted.

Management:

- Intercropping with non-host crop like wheat.
- Excessive application of nitrogen should be avoided.
- Spraying of quinalphos 25 EC 20 ml or fenvalerate 20 EC 10 ml in 10 litre of water.

3. APHIDS

Scientific name: *Uroleucon compositae* (Theobald)

Family: Aphididae

Order: Hemiptera

Hosts: Niger, Gingelly, Citrus, Parthenium, Datura, Moong, Chrysanthemum etc.

Distribution: Safflower more destructive pest all over the India.

Marks of identification:

- Nymphs are smaller reddish brown in colour.
- Adult is a quite large, black in colour with conspicuous cornicle.

Life cycle:

- Female produces 30 young ones by parthenogenesis.
- The aphid is active from December to April.
- It completes its life cycle in 11-16 days.
- It completes 4-5 overlapping generations in a crop season.

Nature of damage:

- During pre-flowering stage both nymphs and adults suck sap from tender shoots apices, peduncles, leaves and stem, excreting honeydew.
- Sooty mould develops.
- Plants become stunted and weak. Heads of both nymphs and adults on the stem are oriented toward soil.

Management:

- Early sowing of crop in first week of November
- If the attack is observed in the border rows take control measures
- Avoid excess use of nitrogen.
- Maintain 2 or 3 rows of Maize and Sorghum around the fields.
- Spray NSKS 5% (500 g NSK powder) or neem oil 50 ml or neem base formulations 20 ml (1 EC) to 40 ml (0.15 EC) in 10 litre of water or tobacco decoction (hot or cold water) 0.2% .
- Spray monocrotophos 36 SL 10 ml or dimethoate 30 EC 10 ml or imidacloprid 17.8 SL 5 ml or thiamethoxam 25 WG 4 g in 10 litre of water. Change the insecticides in subsequent sprays.

PESTS OF TOBACCO

A. NURSERY PESTS

1. MOLE CRICKET

Scientific name: *Gryllotalpa africana* Palisot de Beauvois

Family: Gryllidae

Order: Orthoptera

Host plants: All crops raised in the nursery

Distribution: All over the world

Marks of identification:

- Eggs are oval, milky white; when first before hatching, dark purple, 3-4 mm long, 1.8-2.0 mm wide
- Newly hatch nymph has a bluish - white prothorax and legs. Later instars are greyish black with white markings and the last nymphal stage is similar to adult and exhibits short wing pads.
- Adults' body blackish brown. Front legs are short and fossorial type.

Life history

- Incubation period is temperature dependent, varies from 15-40 days.
- Female lays about 100 grey colour eggs in hardened chamber in the soil.
- Nymph undergoes about 8 moults each at an interval of one month.

- Univoltine in nature

Nature of damage:

- The insect while burrowing in the soil excavates soil particles which cover the germinating seeds and tender seedlings and cutting the root.

Management :

- The pest can be managed effectively by one drenching of chlorpyrifos 0.04% 2 litre per bed of one m² one week prior after sowing.

2. ROVE BEETLE

Scientific name: *Bledius gracillicornis* Kraatz

Family: Staphylinidae

Order: Coleoptera

Host plants: All crops raised in the nursery

Distribution: America and North Mexico

Marks of identification:

- Egg are typically white, spherical, spheroidal or pyriform (pear-shaped)
- Larva is typically campodeiform.
- Depending on the species of rove beetle some will spin a cocoon in which they pupate. Pupae are oblong, pigmented, and sclerotized in the subfamily Staphylinidae, but exarate, white, and un-sclerotized in all the other subfamilies.
- Adult is small, black, moderately shining insect. Body is long, slender and abdomen frequently curved upward. Antennae are 10-11 segmented and either filiform or clubbed.

Life history:

- Rove beetles, like all other beetles species, go through four stages of development- egg, larvae, pupa and adult
- Adults lay egg in areas that are close in proximity to food sources so that when the larvae appear they don't have to travel far.
- Larvae typically hatch within 5-10 days and feed on the pupa of root maggots or other insects
- Depending on the species of rove beetle some will spin a cocoon in which they pupate and mature into adults while others will inhabit the shell of another insect's pupa to do so.
- Rove beetles typically live as adults for 20-60 days

Nature of damage:

- Beetle is soil inhibiting pest and very active in sandy and sandy loam soils.
- Beetle cause damage during germination of seeds in nursery.
- They create a characteristic burrows in soil, excavate soil particles which covers tender seedling and also disturb the root system.

- The damage becomes more serious at each watering or when it rains.
- The population of seedlings goes down drastically.
- The extent of loss is estimated to about 80%.
- The pest is active from July to September.

Management:

- The pest can be effectively managed by a drenching of chlorpyrifos 20 EC 2ml (0.04%) in 2 litre per bed of one sq. m.
- The treatment should be given once at one week after sowing of seeds. Drenching of 10 per cent neem leaf extract @ 2 litre /sq. m in the nursery at 7 days after seeding is also effective for rove beetle.

3. LEAF EATING CATERPILLAR

Scientific name: *Spodoptera litura* Fabricius

Family: Noctuidae

Order: Lepidoptera

Marks of Identification

- Female lays about 300 eggs in clusters.
- The eggs are covered over by brown hairs.
- Caterpillar measures 35-40 mm in length, when full grown.
- It is velvety, black with yellowish – green dorsal stripes and lateral white bands with incomplete ring – like dark band on anterior and posterior end of the body.
- Moth is medium sized and stout bodied with forewings pale grey to dark brown in colour having wavy white crisscross markings.
- Hind wings are whitish with **brown patches** along the margin of wing.
- Pest breeds throughout the year.
- Moths are active at night.

Life cycle :

- Eggs lays in groups on tender parts of the plant viz., fresh leaves, fresh squares (flower buds) and flowers.
- On an average each female moth lays 4-5 egg masses. Egg stage is about 7-10 days
- The larval stage lasts for about 15-30 days. It passes through 6 instars.
- Pupation takes place inside the soil; pupal stage lasts for 7-15 days.
- Total life cycle takes 32-60 days. There are eight generations in a year. Adult lives about 7-10 days

Nature of damage:

- Larvae feed gregariously on tender leaves by scraping the green matter.
- The grown up larvae feed voraciously on leaves and defoliate them.

- As the plant grows, the leaf portion consumed by the larvae appears as big holes.
- The seedlings become unfit for transplanting.
- The pest is also found attacking the transplanted tobacco.
- The crop of 2-3 weeks old is critical stage for the attack of this pest.
- The extent of loss varies from 80 to 100 per cent in nursery.

Management:

- Deep ploughing of nursery area 2-3 times in summer
- Growing castor around nursery at a distance of 1 m as an ovipositional trap crop.
- Collection and destruction of egg masses and newly hatched caterpillars from castor leaves.
- Install light trap @ 1/ha
- Set up pheromone traps at 2 traps/ha to monitor the adult (moth) populations.
- On appearance of the pest, spraying of Neem seed kernel suspension 2 per cent or Nuclear Polyhedrosis Virus (NPV) @ 250 LE/ha is effective.
- Application of *Bacillus thuringiensis* @ 0.750 kg/ha is found the most effective.
- Spraying of quinalphos 25 EC 20 ml or monocrotophos 36 SL 10 ml or chlorpyrifos 20 EC 20 ml or chlorpyrifos 50% + cypermethrin 5% 10 ml in 10 litres of water at 20 ml in 30 days after sowing of seeds. In severe condition, synthetic pyrethroids, fenvalerate 20 EC 10 ml (0.02%) in 10 litre of water is found effective.

IPM in transplanted crop:

- Collection and destruction of egg masses and caterpillars from leaves.
- Two weeks old transplanted crop is a critical stage for infestation. At this stage application of chlorpyrifos 20 EC 20 ml (0.04%) exhibited effective control.
- When there is high larval population use of fenvalerate 20 EC 10 ml (0.02%) in 10 litre of water is an effective remedy.
- Use of pheromone trap also helps in monitoring and minimizing the pest

B. PEST OF TRANSPLANTED CROP

1. TOBACCO STEM BORER

Scientific name: *Scrobipalpa heliopa* Lower

Family: Gelechiidae

Order: Lepidoptera

Host plants: Tobacco, brinjal, potato and solanaceous weeds

Distribution:

- Native Australia, now in Asia and Africa
- Malaya, Indonesia, Australia, New Guinea, Philippines

- India especially of FCV tobacco and *Natu* tobacco in Andhra Pradesh, FCV tobacco in Karnataka State and bidi tobacco in Gujarat.
- Serious pest of both nursery and main field

Marks of identification:

- Eggs are cigar shaped and pearly-white in colour.
- The caterpillar is brownish coloured with dark head, up to 1.2 cm long.
- The pupal chamber is constructed in the tobacco stem, only a circular patch of the epidermis being left to close it from exterior. The pupal period occupies about 10-11 day.
- The moth is small, active and pale brown in colour.

Life history:

- A female can lay on an average 50- 80 elongated eggs on leaf stalk and lower side of leaves. Eggs hatch in 4 days.
- The caterpillar becomes full grown in about 6-7 weeks and pupates inside the larval burrow/gall
- Pupal period is about 10 days as pupate inside the gall.
- Adults after emergence survive for 2-14 days
- The total life cycle extends over 4-5 weeks.

Nature of damage:

- Larvae enter the stem through **midrib** and make its way to the **base of the stem**.
- Feeds on **internal tissues**
- Characteristic **gall** is formed at the base of the stem
- Plant remain **stunted**
- Affected plants shows **stunting** and unusual **branching** of plant.
- It causes about **25%** damage in tobacco.

Management

- Use of healthy seedlings for transplanting
- Use of pheromone traps for reduction of male moth population
- Removal of suckers periodically
- Infestation of this pest starts from the seed bed area so spraying of quinalphos 25 EC 20 ml (0.05%) in 10 litre of water two times at an interval of 15 days in nursery and two sprays at 10 days interval in transplanted crops.
- Removal and destruction of stubbles from the field after harvesting of the crop may help in avoid carryover of infestation in next season.

2. WHITEFLY

Scientific name: *Bemisia tabaci* Gennadius

Family: Aleyrodidae

Order: Hemiptera

Management:

- Destruction of weeds and alternative hosts around tobacco nursery and fields.
- Use healthy seedlings for transplanting.
- In the early stage scattered infected plants should be removed and destroyed with great care that the insects which are on infected plants should not spread in the field on other healthy plants.
- Spraying of NSKE @ 5 per cent
- Application of systemic insecticides viz., dimethoate 30 EC 10 ml or monocrotophos 36 SL 10 ml in 10 litre of water gives effective protection.
- The insecticide should be applied twice at 15 days interval, first at 30 days after sowing of seeds in nursery. In field crop 2 to 3 sprays of above insecticides at 10 days interval commencing from 15 days after planting is recommended.
- It also acts as a vector for leaf curl virus disease in tobacco.

3. TOBACCO BUD WORM/CAPSULE BORER,

Scientific name: *Helicoverpa armigera*(Hubner) Hardwick

Family: Noctuidae

Order: Lepidoptera

Nature of damage:

- It is a major pest of seed production of tobacco crop.
- Larva feed on terminated buds, top leaves and capsule
- Mainly, it prefers to feed on capsule
- The damage capsules are hallowed out results in heavy loss of seed yield.
- The loss was determined to the extent of 88.5 kg/ha in variety Anand-119.

Management:

- Deep ploughing in summer
- Install pheromone trap/ light trap for monitoring the pest
- Microbial insecticide like *HaNPV* @ 250 LE/ha or *Bt* @ 1 kg/ha
- Spraying of quinalphos 25 EC 20 ml or monocrotophos 36 SL 10 ml or chlorpyriphos 20EC 20 ml or fenvalerate 20 EC 10 ml in 10 lit of water as and when necessary.
- Natural enemies' viz., *Nesidiocoris tenuis* and *Rhinocoris fuscipes* are the efficient predators, so they should be conserved.

4. CUT WORM

Scientific name: *Agrotis ipsilon* Hufnagel

Family: Noctuidae

Order: Lepidoptera

Host plants: Potato, barley, beet – root, gram, okra, linseed, Lucerne, millets, oats, peas, pulses, tobacco, wheat etc.

Distribution: China, Europe, Canada, Japan, South America and New Zealand. It is more serious in south India.

Marks of identification:

- Eggs are globular and creamy white in colour.
- Caterpillars are smooth, stout, cylindrical, blackish brown dorsally and grayish green laterally with dark strips. Larvae coil-up at slight touch.
- Pupae are reddish brown in colour.
- Moths are medium sized, dark grayish brown with reddish tinges and have grayish brown wavy lines and spots on forewings.

Life history:

- Moths appear soon after dusk, mate and lay eggs on moist soil, freshly ploughed fields are preferred for oviposition.
- A female lays on an average 300-450 eggs in 10-15 clusters, each consisting of 30-50 eggs
- The incubation period is 2-13 days. On hatching, the tiny larvae feed gregariously on foliage for few days.
- The larvae become full grown in 10-30 days and pupates in earthen cocoon in soil
- Pupal period 30-68 days depending upon the climate conditions

Nature of damage:

- The larvae come out from the soil during night hours and cut the stem at ground level. They cut many more plants than they can eat
- The affected plants are destroyed and dry up.
- Plants stand is badly affected due to the attack of the pest.

Management:

- Clean cultivation and frequent interculturing of the crop may help in exposing the hidden larvae to natural enemies as well as direct sunlight.
- In the early stages pick the caterpillar and destroy.
- The adult insects can be controlled by light traps.
- Heaps of green grasses or weed may be kept in the cutworm infested fields during evening hours so caterpillars will get the shelter in such heaps for day time.

C. STORAGE PESTS

1. TOBACCO MOTH:

Scientific name: *Ephestia elutella*, *Ephestia kuehniella*

Family: Pyralidae **Order:** Lepidoptera

Host plants: Tobacco, oilseed

Distribution: Worldwide, intolerant of hot conditions.

Marks of identification:

- Eggs are oval, ivory in color and 1/12 inch long
- Larvae are 15 – 20 mm, white to pink with black spots (base of hairs), with the rim of the abdominal spiracles evenly thickened.
- Pupal cases are whitish with a yellow to brownish colored pupa inside.
- Adult labial palps are short and curved upwards. The forewing (7 – 14 mm) is gray with darker markings. Labial palps short and curved upwards. Forewing (7-14 mm) grey with dark markings.

Life cycle:

- The female lays eggs on or near the tobacco products
- A female lay about 100 to 200 eggs are laid in clusters over a two-week period and larvae hatch 10 to 14 days larvae, feeding on the product and producing large webs of silk.
- The larvae move off the food to pupate in the storage packaging or in the storage structure
- Total development takes 82 to 206 days depending on the temperature
- They develop into adults in about two months under moderate temperatures, optimal development conditions are 40 days at 27 °C, 75 per cent R H. The insect appears three to four times per year.

Nature of damage:

- The caterpillar of tobacco moth is a pest on dried tobacco, especially on tobacco plants with high sugar and low nicotine content.
- Mostly damage to tobacco plant is caused by larval feeding.

Management

- Controlled atmosphere for infestation in the product
- Heat treatment for infestation in building
- The use of pheromone traps and inspections can determine location and degree of infestation.
- BULLET LURE® - Contains sex pheromone blend to attract male moths. Effective duration of attraction is 6-8 weeks.

2. CIGARETTE BEETLE

Scientific name: *Lasioderma serricorne* Fabricius

Family: Anobiidae **Order:** Coleoptera

Host plants: Tobacco, wheat flour, cereal bran, peanuts, cocoa beans, cottonseed, spices and even insecticides containing pyrethrum, meat and fishmeal, ginger, turmeric and chilies.

Distribution: Worldwide and sheltered environments in temperate areas

Marks of identification:

- Eggs are white oval and about 0.5mm long.
- Larva is scarabaeiform, yellowish white 6.2 mm long, legs fully developed.
- Adults' antennae long and segmented saw-like, Elytra smooth with fine hairs and red in colour, Beetle are small, robust, oval, light brown in colour with its thorax and head bent downward gives the insect a humped appearance.

Life cycle:

- The female lays up to 30 creamy white oval eggs on the surface of stored material and the incubation period is 9-14 days. The larval and pupal periods ranged from 17-29 days and 2-8 days respectively.
- Grubs are internal feeders, immobile when mature.
- Grub period is 5-10 days.
- Adults- active, short-lived and do not feed on commodity

Nature of damage:

- Both grubs and adults bore into tobacco products viz., cigarettes, cheroots and chewing tobacco
- Presence of circular pin head sized bore holes on processed tobacco is the typical symptom of attack.

Management

- Keep the premises very clean by removing and destroying waste tobacco pieces and dust
- The Godown should be free of cracks and crevices and properly white washed
- Well lighted with double doors windows and ventilators
- Screened with wire mesh (20 meshes to 2.54 cm) to prevent entry of beetle from outside
- Tobacco should be store at low temperatures (15 to 18° C)
- The twenty tablets of 3g of Aluminum phosphide per 1000 cubic feet with 96 hours exposure kill all the stages of the beetle
- Sanitation is critical: inspect all organic materials in the structure and dispose of infested materials.
- Insect growth regulators are effective for long-term management.
- Fumigants are sometimes used by licensed professionals in commercial warehouses.
- Insect monitoring traps are available for *L. serricornis*, which contain specific pheromones to attract male beetles, and help detect and monitor infestations.

- With phosphine dosage rates is one gram of phosphine (equivalent to a 3-gram table) per m³ for 5 days at 12–15 °C and 4 days at 16–20 °C and 3 days above 20 °C. For localized infestations the approach is to find the infested product, dispose of it, and treat around the area with a residual insecticide such as cypermethrin to kill off any remaining beetles.

STORED GRAIN PESTS AND THEIR MANAGEMENT

Following are the main sources of insect infestation:-

Field infestation:

Insects like *Bruchids* (Dhora) or *Sitotroga* spp. fly from stores to fields and lay eggs upon maturing grains/pods. These eggs hatch out to larvae in favourable conditions when grains reach the stores. This is termed as "**hidden infestation**."

Cracks and crevices:

When storage godowns containers are emptied, cleaning is not properly/thoroughly done. Some grains continue to lie in cracks and crevices. Insect present in the stores keep on feeding and multiplying during this period also. If fresh stocks are kept in such stores the same get infested. Insects from old stocks can crawl/fly to fresh stocks and infest them. This process is called "**cross infestation**".

Containers/Bags:

It has been a general practice, especially with the fanners, that they keep without cleaning the empty food grains bags for use in the next season. Eggs and larvae of insects remain hidden in the seams and mesh of the bags. During off season they feed on the grain fragments etc. while sticking to the bags. Whenever the grains are filled up in such bags, infestation reappears.

Trucks, trollies and bullock carts:

Food grains are harvested, threshed in the fields and then transported to the godowns by trucks, trollies, bullock carts, etc. These are very good sources of cross infestation. Insects which may be present in the joints or corners of the carriers migrate to the food grain lots and cause infestation.

- In India, post-harvest losses caused by the unscientific storage, insects, rodents, micro-organisms etc., account for about 10 per cent of total food grains.
- The major economic loss caused by grain infesting insects is not always the actual material they consume, but also the amount contaminated by them and their excreta which make food unfit for human consumption.
- About 500 species of insects have been associated with stored grain products. Nearly 100 species of insect pests of stored products cause economic losses
- Storage insect pests are categorized into two types viz., Primary storage pests and Secondary storage pest

	Scientific Name	Common Name	Order	Family

Primary pests:				
1	<i>Sitophilus oryzae</i> Linn. <i>S. zeamais</i> Mots. <i>S. granaries</i> Linn.	Rice Weevil Maize Weevil Granary Weevil	Coleoptera Coleoptera Coleoptera	Curculionidae Curculionidae Curculionidae
2	<i>Rhizopertha dominica</i> Fab.	Lesser Grain Borer	Coleoptera	Bostrychidae
3	<i>Trogoderma granarium</i> Everts	Khapra	Coleoptera	Dermestidae
4	<i>Callosobruchus chinensis</i> Linn. <i>C. maculatus</i> Fab.	Pulse beetle	Coleoptera	Bruchidae
5	<i>Sitotroga cerealella</i> Olivier.	Grain moth	Lepidoptera	Gelechiidae
6	<i>Corcyra cephalonica</i> Stainton.	Rice moth	Lepidoptera	Pyalidae
7	<i>Plodia interpunctella</i> Hubner.	Indian meal moth	Lepidoptera	Pyalidae
8	<i>Carda (Ephestia) cautella</i> Walker.	Almond or fig moth	Lepidoptera	Phycitidae

Primary storage pests: Insects that can damage sound grains are called as primary storage pests

Secondary storage pest: Insects that damage broken or already damaged grains

Secondary pests:				
1	<i>Tribolium castaneum</i> Herbst. <i>T. confusum</i> Jacq.	Red rust flour beetle Confused flour beetle	Coleoptera Coleoptera	Tenebrionidae Tenebrionidae
2	<i>Latheticus oryzae</i> Water house.	Long headed flour beetle	Coleoptera	Tenebrionidae
3	<i>Oryzaephilus surinamensis</i> Linn.	Saw toothed grain beetle	Coleoptera	Silvanidae
4	<i>Cryptolestes ferrugineu</i> C. <i>pusillus</i> Schon.	Rust red grain beetle (Flat grain beetle)	Coleoptera	Cucujidae

1. RICE WEEVIL *Sitophilus oryzae* (Coleoptera : Curculionidae)

Nature of damage:

- Damage is done by adults and larvae. Grains are hollowed out. Kernels are reduced to mere powder, *Sitophilus oryzae* and *S. zeamais* are known to attack in fields too.
- Adults cut circular holes. Heating takes place during heavy infestation, which is known as dry heating.

Identification:

- Size 3 mm. Weevils are beetles having characteristic beak or snout. Antennae elbowed and slightly clubbed. Hind wings present except in *S. granarius*.

- Colour ranges from reddish brown, chocolate to almost black. *Sitophilus zeamais* -largest amongst the three species.

Commodities attacked:

Wheat, rice, maize, jowar and paddy (rarely).

Life history and habits:

- Female makes a cavity and lays translucent white eggs and then plugs the hole with gelatinous secretion.
- Eggs are laid singly. Single female lays 150 to 250 eggs.
- The legless, fleshy and curved larva remains in the grain and pupates also inside the grain.
- Larval stage lasts for about 20 days.
- Pupal period is for 3-6 days.
- Adult lives for 3-5 months. Grain having moisture less than 10% is not attacked. The life cycle takes 26 days at 30°C and 75% R.H.

2. LESSER GRAIN BORER:*Rhyzopertha dominica* (Fab) (Coleoptera : Bostrichidae)

Commodities attacked: Paddy, rice, wheat and maize. It is able to attack paddy more easily than *S. oryzae*.

Nature of damage:

- Irregular holes (cf. weevils). In bagged storage irregular messy waste flour spots indicate infestation of this pest. Heating is very common.
- Both adults and larvae cause damage and are voracious feeders. As such grain kernels are reduced to mere shells.
- The damaged kernels remain engulfed in a film of waste flour.

Identification:

- Most characteristic feature is that the head is deflexed downwards to such an extent that it is almost hidden in a dorsal view.
- There is a prominent constriction between prothorax and elytra. Colour ranges from brown to blackish. Antenna has a large loose three segmented club. Size 3 mm.

Life history and habits:

- Eggs are laid on the surface or interstices of cereal grains singly or in clusters.
- Single female lays eggs up to 55.
- Entire life cycle takes 25 days under optimum conditions.

- Adults are good fliers but they are not capable of field infestation as the larvae are free living. This insect prefers dark, dingy stores. Infestation in bagged storage is not normally confined to periphery

3. **KHAPRA BEETLE:** *Trogoderma granarium* (Everts.) (Coleoptera : Dermestidae)

Nature of damage:

- Being a primary pest, it damages the grain starting with germ portion, surface scratching and devouring the grain.
- Actually it reduces grain into frass.
- Excessive moulting creates public discrimination, loss of market appeal due to insanitation caused by the cast skins, frass, and hair.
- Crowding of larvae leads to unhygienic conditions in warehouses. Damage is confined to peripheral layers of bags or 30-45 cms. in bulk storage.

Commodities attacked:

Wheat, maize, jowar, rice, pulses, oil seeds and their cakes.

Identification:

- Adult size 1.5 to 3 mm, convex, oval in shape with practically no distinct division of head, thorax and abdomen.
- Larvae are straw coloured and hair with dark brown hairy bands on each segment and typical posterior tuft forming a tail of long hairs. Size 4-5 mm.

Life history and habits:

- About 80-125 eggs are laid. Life cycle is completed in 25 days under optimum conditions with about 12 generations per year.
- Pupation takes place on the surface of the grain in bulk and overlapping edges of bags. Pupal period lasts from 5-8 days. Adults are short lived, i.e. for about 14 days and are harmless. Wings are present but never seen to fly. It is more confined to extreme dry climates like the Punjab/Haryana/U.P./MP, Rajasthan being less common in coastal areas. Quarantine and phytosanitary regulations are applicable in countries where it is not established yet as a pest of stored commodities.

4. **PULSE BEETLE:** *Callosobruchus maculatus* (Linn) (Coleoptera Bruchidae)

Nature of damage:

- Larvae eat up the grain kernel and make a cavity.
- Adults are short lived, harmless and do not feed on stored produce at all.

Commodities attacked: Practically all whole pulses, beans & gram.

Identification:

- Small, squat, active with long conspicuous serrate antenna, 3 mm in size.
- Colour is brownish grey with characteristic elevated ivory like spots near the middle of the dorsal side.
- Elytra do not cover the abdomen completely. Larvae is fleshy, curved, white, and creamy in colour, with black mouth parts.

Life history and habits:

- 80-100 eggs are laid singly, glued to the surface of the pod (in fields) or on grain (in stores). Hatching period is shortest in warm climate being approximately 5 days. Larva hatches out from egg, penetrates into the pod or grain.
- Larval stage lasts for 30- 50 days depending upon climate and variety of the legume.
- Pupation takes place in a pupal cell prepared beneath the seed coat.
- Pupal period lasts 4 days in summer and two weeks in winter.
- The life cycle takes 23 days at 30°C and 70% R.H.

5. FLOUR BEETLE: *Tribolium castaneum* (Herbst.)

Nature of damage:

- Both adults and larvae feed on milled products. Flour beetles are secondary pests of all grains and primary pests of flour and other milled products.
- In grains, embryo or germ portion is preferred.
- Heavy infestation causes stinking odour in flour, adversely affecting the dough quality. It is an important pest for mill machinery.

Commodities attacked:

- Broken grains/ mechanically damaged grains, germ portion and milled products.

Identification:

- Oblong, flat, 3-4 mm, brown in colour.
- The distinction between *T. castaneum* and *T. confusum* is that compound eyes are completely notched and antennae are not gradually thickened in the latter whereas in the former the notch is not complete and antennae have a clear 3 segmented club.
- The larvae are worm like with white creamish colour, faint stripes and two spine like appendages at the end segment. Length is up to 5mm.

Life history and habits:

- 400-500 eggs are laid in stored grain at random.
- Incubation period is 5-12 days
- Larval period is 3-12 weeks and 5 weeks at 30°C.
- Pupa remains loosely lying in the grain and is naked. Pupal stage lasts 5-9 days.

- Adults are live for a year or 1 1/2 years. Life cycle is completed in 34 weeks at 35-37°C at 70% R.B

6. **SAW TOOTHED GRAIN BEETLE: *Oryzaephilus surinamensis* (Linn)**

Nature of damage:

- Adults and larvae cause roughening of grain surface, and off odour in grain.
- Grains with higher percentage of broken, dockage and foreign matter sustain heavy infestation, which leads to heating of grain.

Commodities attacked:

- Rice, Wheat, maize, cereal products, oil seeds and dry fruits.

Identification:

- Narrow, flattened 2.5. to 3.0 mm long. Thorax having six teeth like serrations on each side. Antennae clubbed. Elytra cover abdomen completely.
- Larva is slender, pale cream with two slightly darker patches on each segment. It moves freely in grain.

Life history and habits:

- Female lays 300 whitish eggs loosely in cracks of storage receptacles or godowns. Incubation period is for 3-17 days, limited to 5 days at higher temperature
- Larval period is for 14-20 days.
- Pre-pupal and pupal period lasts for 7-21 days. At 30°C and 75% R.H.
- life cycle takes about 3 weeks. Maximum longevity of adult is 3 years. Generally it survives 6-10 months. Multiplication is quick in rainy season and coastal areas.

7. **FLAT GRAIN BEETLE: *Cryptolestes ferrugineus* (Olivier)**

Nature of damage:

- Both adults and larvae feed on stored products and are important pests of mills.
- Larvae feed on germ portion and even on dead insects.
- Adults are only scavengers, cause heating in grain and flour in case of heavy infestation. Temperature may reach 49°C.

Identification:

- Smallest amongst the stored grain insect pests. Size 1.5 mm to 2.0 mm, colour light to dark reddish brown, filiform antennae little more than 1/2 the size of body.
- Young larva is cigar like, 0.7 mm, yellowish white with two reddish brown spines at anal segment. It either remains in germ of grain or moves actively.

Commodities attacked:

- Rice, maize, wheat with excessive broken, different flours, groundnut particularly with high moisture and mouldy grain.

Life history and habits:

- White eggs are laid loosely in flour, grain or crevices, incubation period being approximately 5 days.
- Larval period at 35°C and 75% R.H. is for 21 days.
- Matured larva pupates in a gelatinous cocoon covered with dust particles.
- Adults live for 6-12 months.
- From egg to adult it takes 6 weeks but in summer may take nine weeks.

8. LONG HEADED FLOUR BEETLE: *Latheticus oryzae* (Water)**Nature of damage:**

- Secondary pest of food grains. Important pest of milled products. Both larvae and adults feed.

Identification:

- Colour is light brown with elongated body, 2-3 mm; resembles *Tribolium spp.* Antenna shorter than head, 11 segmented with 5 clubbed apical segments. Head is longer (cf. *Tribolium sp.*)

Commodities attacked:

- Cereals flours, packaged food, rice and rice products, grains with excessive dust, dockage and broken grains with high moisture contents preferred.

Life history and habits:

- Female lays singly 400 white, smooth, cylindrical eggs at random in grain and seams of the bags,
- Incubation period is for 7-12 days.
- Larval period is for 15-80 days depending upon temperature.
- Pupal period is for 5-10 days.
- Life cycle is completed in 25 days at 35°C and 70% R.H. There is practically no development at 25°C.

9. WARE HOUSE MOTH: *Ephestia (Cadra) cautella* (Walker)**Nature of damage:**

- Only larval stage is harmful. It mainly feeds on germ portion leaving the rest of the kernel undamaged.
- In bulk infestation, its damage is limited to peripheral top layers only. Web formation covers the bags, floor space and mill machinery thereby leading to clogging in mills.

Identification:

- Size 13mm, wings expanse 2-2.5 cms. Wings are dirty white to grayish in colour with indistinct black bands about 4 mm from the head.
- It rests with sloped wings over the body almost like the slanting roof of warehouses. Being nocturnal, rests in dark places during day time but in dark dingy godowns. It flies during day time also. Usually it is active at dusk and dawn when temperature and R.H. fluctuates occurs.

Commodities attacked: Wheat, rice, maize, jowar, groundnut, spices.

Life history

- The adults live for less than 14 days. They do not feed on grains. They are attracted towards moist surface and water.
- The entire cycle is completed in 25 days.

10. GRAIN MOTH: *Sitotroga Cerealella* (Olivier)

Nature of damage:

- It is a primary pest. Only larvae damage grains, adults being harmless.
- On hatching, caterpillar enters grain from a crack or abrasion on grain. It feeds inside and remains in a single grain only
- Grains are hollowed out. It attacks in fields and stores too.
- In stored bulk grain, infestation remains confined to upper 30 cms depth only Hole is circular with characteristic 'flap' or 'trap door'.

Identification:

- Moth dirty yellowish brown with wings completely folded over back in a sloping manner. Wing expanse 10-14 mm.
- Hind wings with sharp pointing apical end and bearing heavy fringe of bristles. Leaves dirty small specks on window panes and walls.

Commodities attacked: Paddy, maize, jowar, barley and wheat (rarely). It is not capable of attacking milled rice or other cereal products.

Life history and habits:

- Female lays singly about 100 white eggs in stores or fields on the surface of damp grains,
- Incubation period being 4-30 days depending upon climatic conditions..
- Larva undergoes 4 instars after about six days each at temperature 30°C and R.H. 76%.
- Matured larva spins a cocoon to pass the pupal stage also inside the grain for 7 days.
- It takes 32 days to complete the life cycle. There are 3-4 generations in a year.

11. INDIAN MEAL MOTH: *Plodia interpunctella* (Huebner)

Nature of damage:

- Primary pest, causes serious damage to ear and grain of maize, contaminates the grain with excrement, cast skins, webbings, dead individuals and cocoons; prefers to eat germ portion and hence grains lose viability.

Identification:

- Fore wing basal half silver white or grayish, outer 2/3 portion is reddish, copper bronze luster with irregular bands. Hind wings long silvery grey with silky fringes. Thorax is slightly darker with reddish scales.
- Full grown larval size is up to 13 mm, dirty white, skin is granular with hairy body.

Commodities attacked: Maize, cereals, dry fruits, groundnuts and cereal products.

Life history and habits:

- One female lays 39-275 eggs in life. Incubation period is 2-17 days depending upon the ecological conditions. Fresh larva is transparent approximately 1mm. in size.
- Larval period is 30-35 days but may prolong during low temperature.
- On an average pupal period is for 10 days.
- From egg to adult, it takes 26 days at 30°C and R.H. 70% but may take up to 300 days during winter.

12. RICE MOTH: *Corcyra cephalonica* (Staint)

Nature of damage:

- Larva is only responsible for damage. It pollutes food grains with frass, moults and dense webbing. In case of whole grains, kernels are bound into lumps up to 2kg.

Identification:

- Spot free uniformly pale buff brown colour. Wing expanse 25 mm. Fore wings with dark veins. Cocoons dense white and tough.
- Larvae with conical prolegs on abdominal segments and creamy white.

Commodities attacked:

- Rice, jowar, other millets, whole cereals, cereal products, dals, processed products of cereals, pulses, oil seeds, nuts, dry fruits and milled spices.

Life history and habits:

- Eggs are small, oval, and elliptical laid on walls, bags or on grain. Incubation period is for 3-5 days. moves and feeds actively.
- Average pupal period is 10 days. Adult is the biggest amongst food grain infesting moths.
- Adult lives for 7-15 days and does not feed on grains.

- In optimum conditions (temperature 28⁰C to 32⁰C and R.B. 75%) egg to adult takes 4-5 weeks.

13. **GRAIN LICE:** *Liposcelis divinatorius* (Muli), *Liposcelis transval lensis* (Enderlein)

Nature of damage:

- Infestation of this pest is only indicative of unhygienic, damp warehouses, where aeration is ignored and is usually associated with high infestation or mouldy conditions. Infestation of psocids persist even after fumigation when other pests are controlled, thus causing irritation or nuisance besides contamination. Otherwise these are scavengers affecting only germ portion in heavy infestation. Normally they thrive on insect fragments and broken grains.

Identification:

- Small active, pinhead sized. Pale grey or yellowish white in colour. With filiform antennae. They are more oblong than roundish (c.f.mites).

Commodities attacked:

- All starchy material. Grain with high moisture (inherent or acquired during storage due to wet/dry heating or insect infestation).

Life history and habits:

- About 7-60 eggs are laid which hatch into nymphs (similar to adults but smaller in size i.e. metamorphosis is incomplete). More common in coastal areas or rainy season.

14. **GRAIN MITE:** *Acarus siro* (Linn.)

Nature of damage:

- Important economic pest, it eats only germ portion and imparts taint to the cereals and cereal products known as 'mintiness'.

Identification:

- Very small just visible to eye particularly when moving with translucent shiny roundish body. Colour is pale straw to dark reddish brown.

Commodities attacked: Cereal grains, flour and other eatables.

Life history and habits:

- Female lays approximately 100 eggs. Eggs hatch into 6 legged larvae which moult into nymphs (hypopi).
- Under optimum conditions egg to adult takes 9-12 days at 23⁰C and R.H 70%.

15. **GROUNDNUT BRUCHID** *Caryedon serratus*

Identification:

- The adult is a brown beetle . Small translucent milky-white eggs can be seen attached to the pod wall.
- The larva burrows through the pod wall, and starts eating the seed. Fully grown larvae often leave the storage sack and pupate in large numbers at the bottom of the pile of sacks.

Nature of damage.

- The first sign of attack is the appearance of 'windows' cut into the pod wall by the larva.
- The larva burrows through the pod wall, and eats the seeds. Thus, groundnut seeds are too badly damaged for human consumption or oil expulsion.
- The used gunny bags prior to their re-use should be utilized after proper disinfestation treatment with prophylactic or curative chemicals depending upon the situation to avoid cross infestation with the sound insect free food grains.

Integrated management of stored produce pests

The control methods of stored produce pests can be categorized into preventive and curative measures.

Preventive measures

- Brush the cracks, crevices and corners to remove all debris in the godown.
- Clean and maintain the threshing floor/yard free from insect infection and away from the vicinity of villages.
- Clean the machines like harvester and thresher before their use.
- Made the trucks, trolleys or bullock carts free from infestation.
- Clean the godowns/ storage structures before storing the newly harvested crop to eliminate various bio stages of pest hiding.
- Provide a metal sheet upto a height of 25 cm at the bottom of the wood in doors to arrest the entry of rats.
- Fix up wire meshes to windows, ventilators, gutters, drains etc., to prevent entry of rats, birds and squirrels.
- Remove and destroy dirt, rubbish, sweepings and webbings etc from the stores.
- Close all the rat burrows found in godown with a mixture of broken glass pieces and mud plastered with mud/ cement.
- Plaster the cracks, crevices, holes found on walls, and floors with mud or cement and white wash the stores before storing of grains.
- Provide dunnage leaving gangway or alleyway of 0.75 to 1 m all around to maintain good storage condition.
- Store the food grains in rat and moisture proof storage structures.

- Disinfest the storage structures receptacles by spraying malathion 50 EC @ 3 lit 100 m before their use.

Curative measures

i) Ecological methods

- Manipulate the ecological factors like temperature, moisture content and oxygen through design and construction of storage structures/ godown and storage to create ecological conditions unfavourable for attack by insects.
- Temperature above 42⁰ C and below 15⁰ C retards reproduction and development of insect while prolonged temperature above 45⁰ C and below 10⁰ C may kill the insects.
- Dry the produce to have moisture content below 10% to prevent the buildup of pests.
- Kill the pests bio stages harbored in the storage bags, bins etc., by drying in the sun light.
- Store the grains at around 10 % moisture content to escape from the insects attack.
- Manipulate and reduce oxygen level by 1% to increase the CO₂ level automatically, which will be lethal to all the stages of insects.

ii) Physical methods

- Provide a super heating system by infrared heaters in the floor mills and food processing plants to obtain effective control of pests since mostly the stored produce insects die at 55 – 60⁰ C in 10 – 20 minutes.
- Modify the storage atmosphere to generate low oxygen (2.4% and to develop high carbon di oxide (9.0 – 9.5) by adding CO₂ to control the insects.
- Seed purpose: Mix 1 kg of activated kaolin for every 100 kg of seed and store/pack in gunny or polythene lined bags.
- Grain purpose: Mix 1 kg activated kaolin for every 100 kg of grain and store. To protect the pulse grains, mix activated kaolin at the above dosage or any one of the edible oils at 1 kg for every 100 kg of grain or mix 1 kg of neem seed kernel for every 100 kg of cereal / pulse and store.
- Do not mix synthetic insecticides with grains meant for consumption.

iii) Cultural methods

Split and store pulses to escape from the attack by pulse beetle since it prefers to attack whole pulses and not split ones.

- Store the food grains in air tight sealed structures to prevent the infestation by insects.

iv) Mechanical methods

- Sieve and remove all broken grains to eliminate the condition which favour storage pests.
- Stitch all torn out bags before filling the grains.

v) Chemical methods

- Treat the walls, dunnage materials and ceilings of empty godown with malathion 50 EC 10 ml/L or DDVP 76 WSC 7 ml/L at 3 L spray solution/10 sq.m.
- Treat the alleyways and gangways with malathion 50 EC 10 ml/L or DDVP 76 WSC 7 ml/L (1 L of spray fluid/270 m³).
- Spray malathion 50 EC 10 ml/L with @ 3 L of spray fluid / 100 m² over the bags. • Do not spray the insecticides directly on food grains.
- Use knock down chemicals like lindane smoke generator or fumigant strips pyrethrum spray to kill the flying insects and insects on surfaces, cracks and crevices.
- Use seed protectants like pyrethrum dust, carbaryl dust to mix with grains meant for seed purposes only.
- Use aluminium phosphide 56 % 3 tablets per ton or 150 gm /100m³ or 10 gm pouch per ton or methyl bromide 98 % w/w @ 24gms/m³ or ethelene dichloride + carbon tetrachloride 3:1 @ 300-400gm/m³(230-307ml)

STORAGE STRUCTURES

The functional requirements of storage facility are

- To protect the grain from excessive moisture
- To protect from insects and rodent infestation
- To protect their germination and nutritive qualities
- To protect from temperature favourable to both insects and mold development
- To provide convenience and safety while moving grain in and out of storage
- To furnish facilities for inspecting the grain with out removal from storage
- To provide means for conditioning the stored grain
- To permit fumigation when required

The main storage structures are

1. Bamboo structures
2. Timber structures
3. Paddy straw structures
4. Mud and / or brick structures
5. Underground or pit type structures
6. Earthen storage pots
7. Oil and coaltar drums
8. Thekka storage structures

NON INSECT PEST AND THEIR MANAGEMENT

MITES

- Mites belong to the order Acarina of the class Arachnida.
- They are the pests of both animals and plants.
- Plant pests belong to the families Tetranychidae (spider mites, so called because some of them weave webs on the plants), Tenuipalpidae (false spider mites), Tarsonemidae (tarsonemids), Eriophyidae (blister or gall mites) and Eupodidae (eupodids).
- Of these, the spider mites are the most important and prevalent. Some of these mites (*e.g. Tetranychus urticae*) produce considerable amounts of fine silken webbing on the plant surface but others produce little or no webbing.
- The presence of mites may go unnoticed because of their minute size.
- However, symptoms of attack are often apparent before the mites themselves can be seen. For control, it is important to be able to recognise mite injury at an early stage.
- Mites normally feed on the undersurface of the leaves but the symptoms are more easily seen on the uppersurface.
- Two kinds of symptoms are produced by mites.
- While feeding carried out by tetranychids produce blotchings on the leaf-surface,
- Tarsonemids and eriophyids produce distortion, puckering or stunting of leaves and other parts of the plant.
- Some species of eriophyids produce distinct galls or blisters.

The following are the main characteristics of this group.

- They are small creatures measuring 0.1 mm long.
- Body is divided into two
Prosoma-head and thorax fused together
Opisthosoma- abdomen.
- Two pairs of mouth parts- the chelicerae and pedipalpi are adapted to grasping, piercing, sucking and tearing.
- Legs are two segmented with chelate or pedipalpi.
- Larval possess three pairs of legs, while adults and Nymphal stages have four pairs of legs.
- Respiration takes place by tracheas which are connected with stigmata. In some cases, it may be cutaneous.
- Metamorphosis is simple.

Life cycle of mite

- In both male and female, development proceeds through the following stages: egg, larva, protonymph, deutonymph, and adult.
- The length of time from egg to adult varies greatly depending on temperature.

- spider mites complete their development in five to twenty days.
- Females generally lay an average of 38 eggs in total.
- Eggs are deposited on leaf undersides.
- larvae hatch in about 5 day under optimum conditions of 25-30°C and 45-55% RH.
- The larva has 3 pairs of legs, while the protonymph and deutonymph have 4 pairs
- The mite exhibits arrhenotokous parthenogenesis. Fertilized eggs will result in female offspring, whereas unfertilized eggs will produce male offspring.

Tetranychidae

1. *Tetranychus ludeni* (Zacher).

- This is a very important pest of many vegetable crops like cowpea, brinjal, bhindi, etc.
- It generally prefers to live on the underside of the leaves but as the population increases, it spreads over the entire leaf and eventually over the entire plant.
- Initially the leaves take a stippled appearance due to formation of pale yellow spots which finally become brown.
- Moderate population may reduce the yield while severe infestation could kill the entire plant.

2. *Tetranychus cinnabarinus* (Boisduval).

- This species has a world-wide distribution.
- Its infestation has been recorded on vegetables, fruits, cotton and ornamental plants.
- Brinjal, cotton and the lady's finger (bhindi) are the worst sufferers.
- The mite is more troublesome during periods of warm dry weather.
- As a result of its attack, leaves get covered with strands of webbing which affect photosynthesis and so the yield. Eventually, the leaves dry up and fall off. Growth, flowering and fruit setting in the plants are greatly affected.

3. *Tetranychys neocaledonicus* (Andre).

- It is one of the more serious pests of brinjal besides other vegetables.
- The mites in all stages remain confined to the undersurface of the leaves covered with their webs where dust particles get entangled.
- The continuous sucking from leaves produces yellow spots on them which ultimately turn brown.
- The leaves wither and fall, and the plants lose vitality which affects their yield.

4. *Eutetranychus orientalis* (Klein).

- This is a serious pest of fruits, ornamental and medicinal plants. They are generally found on the upper surface of the leaves.
- The affected leaves turn yellowish brown which afterwards dry up and fall off.
- The species is serious citrus, *Zizyphus* (ber), peach, fig and castor.

5. ***Eutetranychus hirsti* (Prichard Baker).**

- This is a serious pest of fig in whole of North India.
- Due to the infestation of these mites, light green patches are produced which turn yellowish green, then brown with rough and dry texture.
- Such leaves along with the fruits drop-off prematurely, often resulting in complete defoliation of the plants.
- The infested fruits get shrivelled, fail to ripen and ultimately fall off.

6. ***Panonychus citri* (McGregor).**

- It is an important pest of citrus.
- The infested leaves are speckled with whitish spots which later turn silvery or brown and drop prematurely.
- Fruits are also attacked which turn grey or yellow.

7. ***Oligonychus indicus* (Hirst).**

- It is a serious pest of sugarcane, arecanut, coconut palm and some cereals.
- When infested, the lower fronds of the leaves show burning discolouration.

8. ***Oligonychus coffeae* (Nietner).**

- It is a major pest of coffee, tea and also jute in both North-East and South India.
- Damage is caused by scraping of the surface of the leaves and sucking the sap. Attacked leaves become bronzed and fall.

9. ***Petrobia latens* (Miller).**

- During recent years, this species has emerged as a serious pest of wheat, barley and coriander in the drier regions of Madhya Pradesh, Rajasthan, Delhi, Haryana and Punjab.
- Heavily infested wheat crops show drying of leaves, chlorosis and formation of no or only shrivelled seeds.

10. ***Schizotetranychus andropogoni* Hirst.**

- It causes serious damage to sugarcane in Tamil Nadu and Andhra Pradesh.
- The damage is done by scraping the leaf-surface and sucking of cell sap that leads to withering. Plants in shade have larger populations of this mite.

11. ***Brevipalpus phoenicis* (Geijskes)..**

- It is an important pest of many fruits, ornamental and plantation crops.
- It causes first yellowing and then browning of leaves, brownish patches appear on the fruits as well, specially in guava. Sometimes, the fruits may split up.

12. ***Larvacarus transitans* (Ewing).**

- It is a serious pest of *Zizyphus* (ber) in Rajasthan.
- It causes soft minute galls on the twigs. Yield due to its infestation may go down by as much as 30 per cent.

Tarsonemidae

13. *Polyphagotarsonemus lotus* (Banks)..

- These are pests of chilli that cause great losses throughout the country, more particularly in Tamil Nadu, Andhra Pradesh, Maharashtra and West Bengal.
- It attacks tea and potato also. Infested leaves show crinkling and curling, often leading to defoliation.
- The yield is considerable reduced.

Eriophyidae

14. *Aceria guerreronis* (Keifer).

- This mite pest has been reported as a serious pest of coconut in Kerala and Tamil Nadu.
- The mites are seen in colonies in the perianth of developing nuts and live in the white tender portion covered by the inner bract of perianth and suck the sap from the tender meristematic mesocarp tissues.
- Maturing nuts up to nine months old harbour the mites.
- The feeding results in warts and numerous longitudinal fissures on the husk of developing nuts.

15. *Aceria mangiferae* (Sayed).

- This species is associated with the mango malformation disease.
- It causes floral and vegetation malformations.

16. *Aceria cajani* (Channa Basavanna).

- This mite has been associated with the sterility disease in pigeonpea.
- It is believed to be the carrier of a virus that causes this disease. It is a widely spread mite found all over the country.

17. *Calacarus carinatus* (Green).

- It is a major pest of tea both in the North and South India.
- Fields affected by this mite can be recognised from a distance by the bronzed, coppery-brown or smoky colouration of the leaves.
- Severe attack leads to suppression of the growth of the shoot and defoliation.

Management of Mite Pests

Cultural control. The following cultural methods can be adopted to keep mite populations down :

- Monoculture cropping should be avoided,
- Intercropping using non-host crops should be done,
- Destruction of mite-damaged parts particularly in the case of mango malformation and litchi erineum formation will minimise mite attack, and
- Clean culture.

Biological control,

- **Mites.** Some of the predatory mites provide an effective control over the phytophagous mites by voraciously feeding on them. Their examples are *Amblyseius longispinosus* and *A. alstoniae* (Phytoseidae), *Agistemus industani* (Stigmaeidae), and *Hemicheyletia balkeri* (Cheyletidae)
- **Insects.** The insects which are voracious feeders on mites are *Stethorus pauperculus*, the coccinellid beetles that cannot survive without mite (food); *Scolothrips indicus* and *Chrysopa* sp. also feed on mites.

Chemical control.

- Spraying the crop with dicofol 0.03% or propargite 57 % EC @ 10 ml or milbectin 1 % EC 5 ml or fenazaquin 10 % EC 10 ml or fenpyroximate 5% SC 10 ml or difenthiuron 50% WP 10 gram per 10 liter of water

SNAILS AND SLUGS

- Snails and slugs belong to the invertebrate phylum Mollusca (class Gasteropoda, sub-class Pulmonata). Both these animals are amphibious capable of living on land and water.
- Snails differ from slugs in having a spirally coiled shell over their body which in slugs is reduced and completely hidden under the mantle.
- The snails that do a lot of damage to our crops are the common garden snails, *Helix*, *Macrochlamys indica*, the green-house snail, *Opeas gracilis* and the giant African snail, *Achatina fulica*, the last named having migrated from Africa has established itself in the Andaman islands, coastal regions of Assam, Bengal, Tamil Nadu and Kerala. The common Indian slugs are *Limax* sp., *Laevicaulis alte*, *Arion* sp., etc.

Life-history.

- The common snail breeds in the spring and the summer. It makes a hole of 1.24 cm in diameter and 3 cm in depth in damp soil, in which it lays eggs in a loose mass of about 60.
- The eggs hatch within two weeks and the young snails start feeding upon tender plants.
- The shell increases in size with age and the snail is full-grown in about two years. Snails are seen at all hours, except during mid day when it is hot and dry.
- In winter, they stay in colonies and are found among rockeries, loose boards of fences, at the bottom of hedges, in rubbish heaps, etc.
- The slugs feed at night in damp places and destroy young shoots of various plants. Under dry conditions, their population is reduced considerably.

Damage.

- The snails live in humid environment under bushes, stones, pots, uncared wooden logs, etc.
- They are active from spring up to the onset of winter and hibernate/aestivate in very cold/very hot and dry months.
- They are nocturnal, carnivorous, pestiferous and scavengers feeding on the dead bodies of their kind and carrions in agriculture, they do a lot of damage to vegetables (ipomea, beans, lady's finger, cucurbits, etc.) and garden plants (violets, marygold, papaya),
- The damage being more serious in the seedling stage.
- African giant snails even damage plantation crops like arecanut, rubber buds and coffee.

Management,

- They could be handpicked and then killed,
- Snails and slugs can be managed by biological methods,
- Snails predatory on other snails are *Euglandina rosea* and *Gonaxis quadrilateralis* but they, are not found in India,
- larvae of Indian glow-worm, *Lamprophorus tenebrosus*, lacerate flesh and feed on the slime secreted by the snails; larvae of another insect belonging to dipteran family Sciomyzidae (genus *Tetanocera*) attack aquatic and terrestrial snails, slugs and their eggs; hermit crab *Coenobita* enter the shell of *Achatina* to feed on it and the millipede *Orthomorpha* secrete hydrocyanic acid that instantly immobilises the snails, and
- snails are known to suffer from a leukoderma like diseases; pathogens of this disease can be water extracted and sprayed on snail colonies to spread the same.
- Metaldehyde (5%), copper sulphate solution (1%) and insecticides (arsenates, persistent organochlorines, etc.) are employed as molluscicides of which metaldehyde spray or dust (sold as *Metadex*) in 5% dilution has been found to be the most effective.
- Since slugs secrete a lot of slime that prevent contact with the irritants, repeat treatment will be needed in their case.
- A bait of 30% bran + 2% metaldehyde proves a good killer for the slug, *Laevicaulis*; for *Achatina*, a mixture of cut pieces of papaya stem (or fallen yellow leaves) + 5% metaldehyde acts as good poison-bait (these snails are attracted to papaya stem pieces, its yellow leave or more strongly to marygold plants which singly or in mixture can be used as attractant; likewise freshly powdered lime sprinkled around the plants acts as a deterrent.

CRAB

- Crab burrow on the sides of the bunds and live. They cut the young paddy plants near the ground level and carry them to their burrows for feeding.
- They are active during night; as they are nocturnal.
- Besides their crop damaging activity, they prepare a series of burrow in the paddy

- Fields due to which water is not retained in the field.
- Thus, crab is major crustacean pest of paddy crop, it requires intensive control

Marks of Identification

- Eggs: The eggs are bright orange when first deposited, but become yellow, brown, and then dark brown before hatching.
- Larvae: First stage larvae, called zoeae, measure approximately 0.25 mm wide at hatching; development to this stage requires 31-49 days.
- Juveniles: The juvenile "first crab" is typically 2.5 mm wide (from tip to tip of the lateral spines of the carapace). Juveniles gradually migrate in to shallower, less-saline waters in upper estuaries and rivers, where they grow and mature
- Adult: Sexual maturity is reached after 18-20 post larval molts, at the age of 1-1.5 years. Males continue to molt and grow after they reach sexual maturity, but females cease to molt and grow when they mature and mate.

Management

- Application of FYM at the time of puddling reduces crab damage.
- Block the mud holes on the farm bunds and mix paste of Silk Cotton (*Bombax ceiba*) tree bark, *Embelia ribes* fruits and Asafoetida 2 kg each in 100 lit water in 1 ha.
- Crab burrows fumigated with the cyanogas dust.
- Poison baiting of 0.5% parathion with rice syrup at the rate of 80-100 ml per burrow is quite effective in controlling the crabs.

RODENTS

Rats (Order — Rodentia) are among the most destructive pests in paddy in the field causing about 5-10 per cent damage. A number of vegetables, groundnut, pulses, sugarcane, cotton, finger millet, sesame and tender coconuts in the field and also store grains in warehouses and store rooms are damaged by rats and mice. Besides feeding on these products, they destroy a substantial quantity by spillage and contamination with their droppings, urine, body hair *etc.* rats daily consume food equal to about 10 per cent of their body weight, damage about 20 times the amount they actually consume by their gnawing activity and by polluting the food grains. It has been estimated that there are about 2500 million rats in our country. It is easy to realize the amount of damage these animals, with such an enormous population coupled with an equally enormous rate of their multiplication are capable of inflicting upon many of our cultivated crops and crop produces in store houses.

IMPORTANT CHARACTERISTICS OF RATS:

1. **High reproduction rate:**

1.Length of life	:	12 – 18.months
2.Age at puberty	:	6-11 weeks
3.Breeding season	:	All round the year
4.Mating habit	:	Promiscuous
5.Oestrous cycle	:	4-6 days
6. Duration of Oestrous	:	9-20 hours
7.Gestation period	:	21 days (21-30 days)
8.Size of litter	:	4-6 per year
9.First Oestrous after parturition (delivery	:	48 to 96 hours (2-4 days)

2. **Colour blind:**

- Can distinguish between shades
- Clear vision is limited

3. **Subsist on a wide range of food:**

- Prefer fresh food and can thrive on garbage
- Cannot vomit

4. **Well-developed senses of hearing, smell and touch:**

- Sense of touch confined to: Long hairs above eyes and
- Guard hairs of the body
- Perceive sounds traveling through solid medium

5. **Excellent sense of balance:**

- Can run on pipe, Narrow hedges, Wire, cross one building to another on telephone wires

6. **Gnawing ability:**

- Known as "Gnawing Animals"
- Gnaw to gain entrance to food and to keep incisors pointed
- Gnaw@5 inches (12 cm)/year

7. **Climbing ability:**

- Can climb over wires, pipes, wall, tree **etc.**
- Can jump horizontally about 8 feet and drop from a height up to 14 feet.

8. **Excellent or Good swimmer:**

- Remain in water for 1 - 4 hours

9. **Home range (Travel route):**
 - Regular route between shelter, food and water
 - Prefer protected routes along walls and through rough grass.
10. Neophobia and Neophilia:
 - Neophobia: Reaction to new food
 - Neophilia: Reaction to new object
11. Subjected to poison shyness and bait shyness:
 - Can identify harmful and harmless food
12. Hoarding habit:
 - Hoard the materials like food grains, straw, tillers **etc.**
13. Burrowing habit:
 - Inhabit burrows
 - Two type of burrow (i) Simple (ii) Complex
14. Exploratory behavior (Investigatory ability):
 - Learning ability is very sharp
 - Check all aspect of environment and extend the home range

CLASSIFICATION OF RATS:

1. Domestic rats: Living with man: House rats (*Rattus rattus rattus*),
2. Commensal rats: Living on man near man but not with man (brown rat, *R. norvegicus*; House rat, *R. r. frugivorus*; large bandicoot rat, *B. indica*)
3. Field rats: Living on man but away from man: Long tailed bandicoot, *Bandicota bengalensis*; Indian field mouse, *Mus booduga*; Indian gerbils, *Tatera indica*;
4. Wild Rats: They live without man: Indian desert gerbil, *Meriones hurrianae*; Indian bush rat, *Golnda ellioti*

THE SPECIES OF RATS AND MICE HAVING ECONOMIC IMPORTANCE

Field rodents:

1. Indian mole rat / lesser bandicoot, *Bandicota bengalensis*
2. Soft furred field rat / grass rat, *Rattus (Millardia) meltada*
3. Indian gerbil rat / antelope rat, *Tatera indica*
4. Indian field mouse, *Mus booduga*
5. Brown spiny mouse, *Mus platythrix*
6. Coconut rat, *Rattus rattus wroughtoni*

Rodents in stores:

1. House mouse, *Mus musculus*

2. House rat / common rat, *Rattus rattus rufescens*
3. Larger Bandicoot / Bandicoot rat, *Bandicota indica*
4. Brown rat / Norway rat / sewer rat, *Rattus norvegicus*

1. MOLE RAT, *Bandicota bengalensis* (Gray)

- It is dark greyish brown in colour with a greyish white belly and a bare tail, head and body 15 to 23 cm and tail 15 to 18 cm long.
- It feeds upon grass, grains and tubers and damage to rice crop is considerable in Tamil Nadu.
- It makes large ramifying burrows in soil extending to a depth of 1 to 1.5 m and laterally 9 to 15 m; the burrow along its course is provided with many walls or earthen blocks for protection.
- There are 4 or 5 openings for the burrow, the entrances are protected by heaps of excavated soil.
- Separate chamber for bed, breeding and food storage are provided in the burrow.
- It usually lives alone in the burrow and generally reproduces thrice in a year synchronizing with rice harvest.
- In rice, it appears late in the cropping season and damages the crop most severely. In shot blade stage, it cuts tiller and the affected area is seen as circular patches in a field. The rat re-visits the same area next night and spread the damage.
- It cuts ear-heads and carries to its burrow and in a burrow up to 2 kg of hoarded grains can be noticed.

2. GRASS RAT, *Millardia meltada* (Gray)

- It is smaller in size, dark brown grey above and pale grey below with soft fur.
- Head and body is about 13 cm long and tail is 10 cm long. The burrows of the grass rat are similar to that of the mole rat excepting that they are smaller in length and diameter and that usually more than one adult rat occupies a single burrow.
- 1 to 12 young are produced per litter. It attacks rice in all stages and feeds upon young germinating grains, cuts and feeds on tender seedlings and also grown up plants in the shot-blade stage.
- It also damages green cotton bolls in black cotton soils.

3. INDIAN GERBIL RAT, *Tatera indica* (Hardwicke)

- It is reddish grey in colour with white underside and it equals the common house rat in size with about 18 cm long head and body and a hairy tail little longer than the head and body.
- It generally feeds on grains, grass, roots and fruits.

4. INDIAN FIELD MOUSE, *Mus booduga* (Gray)

- It is about 5 to 8 cm long with 5 cm long tail.
- It is brown in colour with a white belly
- It burrows in field bunds causing extensive damage to bunds and wastage of water

- It produce 3-9 young one per Utter.
 - It cuts and removes grain from rice crop.
5. **COMMON RAT, *Rattus rattus wroughtoni* Hinton**
- It is reddish or yellowish brown with a pure white belly.
 - It is destructive to tender coconuts.
 - It lives and breed inside nests specially constructed in the crown of the palms.
 - In closely planted garden, it can jump from palm to palm.
 - It bites holes through the husk and drink the sweet liquid; spoilt nuts fall down in large numbers.
6. **COMMON HOUSE RAT, *R. rattus rufescens* (Gray)**
- It is brownish grey with dark under surface and feed en all kinds of vegetables and animal foods.
 - It live in roofs of house and underground burrows.
 - Its damage is great in warehouse and storage godowns.
7. **BROWN SPINY FIELD MOUSE, *Mus platythrix* Bennett**
- It is a pest in dry land crops in Karnataka and experience a seasonal reproductive cycle of active breeding during June — February followed by sexual quiescence during March-May.
 - The pick reproductive activity **is** during September - November coinciding with pick prevalence of pregnancy.
 - The prevalence of rain fall, low temperature, short day length and high relative humidity prevalent during July onwards is conducive for reproduction due to availability of food.
 - Timing rodent control program during March -May in dry land crop is suggested.
 - In the north east hill region, *Rattus nitidus* (Hodgson) is an important crop pest.
 - In arid area of Rajasthan, Indian desert gerbil, *Meriones hurrianae* (Gerdon) and *Gerbillus leadowimurray* are pests in rainfed crops.

RECOGNIZING RODENT INFESTATION

There are twelve indicators of rodent activity:

- **Droppings** - Usually, the first clue of a serious rodent problem is their droppings **on** the kitchen counter, in kitchen drawers and cabinets, or in the pantry. Look for mouse droppings in utility closets, roof voids, garages, sub floors and basements. Mouse droppings are smooth with pointed ends, and are 3 - 5 mm long. Rat droppings are pellet-shaped, blunt at both ends, about the size of an olive pit, and shiny black. Roof Rat faeces approximately 12 mm long and Norway rat faeces approximately 18 mm long and they soon fade to grey-white. Droppings are randomly scattered, but normally close to rodent runways, feeding areas, or near shelter.
- **Tracks** - Rodent tracks can be observed in mud, dust or bare dirt. Often, rodent tails also leave a mark. In the house, mouse tracks can be seen on dusty surfaces. You can also check for

mouse tracks by dusting suspected areas with a light coating **of** unscented talcum powder or chalk dust. Wait a day and then shine a flashlight across the area. If there are small tracks in the powder, mice have been there.

- **Gnawing** - Rats must chew continuously to wear down their incisor teeth. Look for holes in walls or ceilings, and trails in sub floors, behind or under cupboards, counters, bathtubs, shower stalls, or near hot water heaters, ducted heater units **or**; boilers.
- **Burrows** - Burrows can be found along ditches, walls, or fences, and under buildings, rubbish, low vegetation, woodpiles or concrete slabs.
- **Runways** - Rats follow the same routes as they make their rounds foraging for food each night. In doing so, they leave 50 mm wide runways in the dirt or grass, usually next to buildings or fences.
- **Grease marks** - Greasy rub marks are caused by a rat's oily fur repeatedly coming **in** contact with walls or entrance holes.
- **Urine stains** - Urine stains are more easily observable under a black light.
- **Nests** - Mouse nests can be found in utility closets, roof voids, garages, **and** basements. They are usually made of cloth or shredded paper, lined with finely shredded material. Rat nests look like a loosely woven ball 10 cm to 15 cm **in** diameter.
- **Partially eaten food** - Mice leave behind partially eaten food. While rats eat most **of** the food they find, even they leave tell-tale signs, like shells or other in edibles. Live or dead rodents - People usually see mice only when they have been sitting stock still, such as when reading or watching television. Rats are nocturnal, but in areas having large rat populations some low ranked rats will forage during the day, because they have been denied access to food at night. If you see rats during the day, it is a sign of a substantial infestation.
- **Sounds** - While you may not be able to see them, you can probably hear rodents moving after dark. If your pet paws at a wall or cabinet it may be trying to get at a lurking rodent.
- **Odours** - Often you can smell rodent urine or their musky odour, especially in a poorly ventilated room

MANAGEMENT:

- Commonly used rodenticides should be applied in the active area of rats.
- Aluminium phosphide - a fumigant used to kill rats and mice
- Bromadiolone (0.005%), coumatetralyl (9.0375%) and warfarin - These are anticoagulants which act as rodenticides and they are mainly stomach poisons
- Sodium cyanide insecticide with respiratory action is also used as rodenticide.
- Zinc phosphide - Inorganic compound, highly toxic, Garlic like odour and taste and commonly used in baits

RODENT BAIT STATIONS

- Rodent Bait Station is the important constituent in chemical and mechanical control of

rodents. It is a rectangular metal box in which rodent bait or Glue trap is kept.

Advantages of Rodent Bait Station:

- Rodents have a habit of eating in dark places, so get attracted easily towards Bait Stations.
- Rodent Bait station is a labelled instrument and hence it becomes very easy to detect the places where rodenticide is kept.
- As the Rodent bait is kept under box it is not easily accessible to pets and children and hence safer for pets and children.
- Contamination or dilution of rodenticide can be avoided, and therefore the bait remains effective for a longer period.

BAIT TECHNIQUE

Commonly 2 per cent bait is used to kill rats. 2 per cent bait is prepared by mixing 2 gm zinc phosphide with 98g of bait. Either cooked rice or Wheat flour or Grain flour is used for preparing baits and along with this edible oil (mustard or groundnut oil) is added in small quantities as attractant. Pre baiting with only baiting material is quite essential for attracting the rats to eat. Rats have to be fed for a period of 5 - 7 days before they start dying.

BIRDS

Birds belong to the class Aves. Their body is covered with feathers. They have a unique characteristic of forelimbs modified as wings. Mouth is continued to form a beak and are homoethermous and grainivorous. About 0.85 per cent losses are caused due to birds in storage. The damage done by birds to food grains in fields and stores is appreciable both quantitatively and qualitatively. Average consumption by birds ranges from 8 to 25 gm per day. Besides eating grain in the fields and godowns, they are also responsible for spoilage, contamination with excreta, feathers and dead bodies. Some of them are responsible for spreading diseases. They also create nuisance and unhygienic conditions in warehouses.

Some of the important birds of agricultural importance:

Sr. No	Common name	Damage
1	Common pigeon, Blue rock-pigeon	Grainivorous, eat food-grains in grain <i>mandies</i> , godowns
2	House Sparrow	Principally grainivorous; lives or enters house and warehouses, eat grains in open / bag.storage
3	House Crow	Omnivorous feeding oh kitchen waste to dead animals and hence considered as the best scavenger
4	Rose ringed parakeet	Normally frugivorous, attacks ripening cereal crops and food-

		grains in open storage.
5	Common mynah	Damages food grains in fields and <i>mandies</i> but seldom enters ware-houses.
6	Baya/ Weaver bird	Pest of paddy grains
7	Spotted Munia	Feed on ripening paddy grains, other grass seed

Management :

Lethal and non-lethal methods of control can be used against different birds. In certain situations, farmers need to kill a few birds to scare others. Shooting involves a lot of labour, and mist nets are very costly and not easily available. Certain traps can be easily constructed for catching crows and other birds. Fumigation of nest holes and nest destruction for population reduction is also very labour intensive. Some chemicals have been found to be efficient poison baits against pest birds. Lethal control of birds does not always solve the problems. The killing of most of the bird species is illegal in India. Non-lethal control measures call for special attention and research on them should be intensified.

- Habitat manipulation: trimming trees, removal of shrubs on borders reduces roosting place where birds perch/ settle/ sleep.
- Netting arrangement of traps and nets for catching the bird.
- Scaring by beating empty drums, mechanical bird scarers, metallic ribbons, pyrotechniques (art of making fireworks), catapulting (to shoot from a hurl)
- Destruction of eggs and nests
- Growing bird resistant varieties like Ganga 3 in maize and red sorghum
- Using repellents like cupric oxide, methiocarb
- Use of chemosterilants like mestranol, ornitrol, avitrol etc.
- Chemical and physical bird repellents, camouflaging maize cobs etc.
- Various devices to scare or repel birds.
- Traditional methods like erection of scare crows, noise making devices like crackers and carbide guns tying polythene bags.
- Reflective ribbon or bird scaring ribbon is found to be more effective and easily adaptable by the farmers in the field for scaring the birds. It is a polypropylene metallic shining ribbon with red/yellow on one side and silver white on the other side and is prepared by cutting into strips of 10 to 15 meters length and 15 mm (1.5 cm) width. About 25 - 30 strips are fixed in an acre with the help of bamboo poles keeping just one foot above the crop level in north and south directions and slightly twisted to reflect the sunlight throughout the day. The inter distance between the two ribbons should be about 4 to 8 meters (depending upon the crop size and pest population). During sun shine the brightness and humming noise produced in the wind scares the bird from the field.

- Pruning of perching and breeding places, in addition to the manual destruction of nests losing the entrance of the nests will reduce their population.
- Planting of flowering/fruit bearing trees or shade trees could reduce losses on nearby crops once the parakeets become accustomed to being able to feed on these trees without being disturbed.
- Large acreage cultivation of sunflower crop reduces the bird damage.
- Spraying of neem kernel powder solution (10 g per litre of water) after seed setting stage repels the birds.
- Pre-recorded distress calls of parakeets (Bio-acoustic method) are amplified with the help of speaker will drive away the parrots from the field.
- Combination of two or three methods for effective pest management so that the crop is completely protected during its vulnerable stages.
- Netting is the best technique to reduce bird damage in small fruit plantings. It is relatively expensive compared to other methods and probably the most labour intensive. It is also the most durable.
- predator kite/helium balloon, Scarecrows (a device that is used to discourage birds such as crows from disturbing crops), Balloons, Owl or hawk models, animated owl model, crow model, field windmill, Eagle Eye bird scarer, Flashing lights, Hanging CDs on string etc.
- Spray of Methyl anthranilate and Sugar (many bird species cannot digest disaccharides).
- Fogging is a fine aerosol mist that irritates birds' eyes and mucous membranes without harming them, and has an unpleasant taste when attempting to preen their feathers. Fogging should be done early in the morning or late in the evening when the population counts are high. Sound scaring devices viz., horns, clanging, aluminum pie plates, shiny flashing metal objects, firecrackers and humming devices.

STUDY MATERIAL

PESTS OF HORTICULTURAL CROPS AND THEIR MANAGEMENT

Ag. Ento. 6.5 (1+1)

Sixth Semester



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PESTS OF VEGETABLES

Among major biotic constraints in vegetable production in India, tomato fruit borer (*Helicoverpa armigera*), brinjal shoot and fruit borer (*Leucinodes orbonalis*), chilli thrips (*Scirtothrips dorsalis*) and mite (*Polyphagotarsonemus latus*), fruit and shoot borer (*Earias* spp.) on okra, diamond back moth (*Plutella maculipennis*) on cole crops, fruit fly (*Bactrocera cucurbitae*) on cucurbits are important ones. Insect pests like serpentine tomato leaf miner, gall midge, okra stem fly and bitter melon leafhopper and mites are gradually attaining the major pest status in different regions of the country. Earlier gall midge known to be a minor pest is gradually becoming a regular problem in chilli, Capsicum and brinjal in the states of Andhra Pradesh, Karnataka and in brinjal in Chhattisgarh, whereas *Hellula undalis* on cabbage and red spider mite on okra, brinjal, cowpea, Indian bean, etc. and more recently mealy bug, *Phenacoccus solenopsis* on several vegetable crops, have intensified the severity of occurrence. On an average the extent of crop losses in vegetables due to insect pest infestation is 40 per cent that varies with the plant type, agro climatic conditions, damage potential of the pest involved and cropping season prevailing in different parts of the country.

❖ PEST OF BRINJAL

1. BRINJAL SHOOT AND FRUIT BORER

Scientific name: *Leucinodes orbonalis* Guenee

Family: Pyralidae

Order: Lepidoptera

Distribution: This pest of brinjal fruits and shoots is widely distributed in Malaysia, Myanmar, Sri Lanka, India, Pakistan, Germany and East Africa.

Host plants. Besides brinjal, it has also been recorded feeding on many other solanaceous plants and occasionally on the green pods of peas also

Marks of identification:

- The moth is white but has pale brown or black spots on the dorsum of the thorax and abdomen. Its wings are white with a pinkish or bluish tinge and are ringed with small hair along the apical and anal margins.
- The fore wings are ornamented with a number of black, pale and light brown spots. The moth measures about 2.0-2.2 cm across the spread wings.
- The caterpillars are creamy white when young, but light pink when full-grown. The measure about 1.8-2.3 cm in length.

Life history:

- The female moths lay 80-120 creamy white eggs, singly or in batches of 2-4 on the underside of leaves, on green stems, flower buds or the calyces of fruits.
- The eggs hatch in 3-6 days
- The larvae grow through 5 stages and are full-fed in 9-28 days.
- The mature larvae come out of their feeding tunnels and pupate in tough silken cocoons among the fallen leaves.
- The pupal stage lasts 6-17 days and the life-cycle is completed in 20-43 days during the active season.
- There are five overlapping generations in a year.

Nature of damage:

- The young caterpillars bore into tender shoots near the growing points into flower buds or into the fruits.
- The caterpillar when attack the terminal shoots, the growing-points are killed.
- Damage to the fruits, particularly in the autumn, is very severe and it is not uncommon to see the whole of the crop destroyed by the borers.

Management:

- Removal of previous year brinjal crop residue from farm before planting.
- Transplant brinjal crop in the first week of September.
- Before transplanting by dipping the seedling root in solution of Rynaxypyr 18.5 SC @ 0.5 ml for 3 hours.
- At the time of transplanting of brinjal in the main field intercropping of brinjal with coriander' fennel (2:1) or as border crop.
- Throughout the crop period with a sharp knife the damage shoots and fruits should be removed and destroyed by burning or burying deep in to the soil.
- Sex pheromone based IPM technology involving mass trapping through use of plastic funnel baited with pheromone @ 100 traps/ha, shoot clipping at weekly interval from 20 DAT and 4 sprays of NSKE (4%) at 15 days interval from flowering was found to be effective
- Give three applications of Gir Sawaj Mating Disruption Paste @ 400 g per application per hectare (uniformly distributed in 1000 dots between two branches), first at initiation of pest infestation and successive two application at an interval of 30 days
- Coinciding with initiation of flowering, five innoculativereleases, first release (@ 50,000 parasitized eggs/ha) or once (© 2,50,000 parasitized eggs-ha) along with weekly 2-3 application of NSKE 4% or *Bt* formulation © 500 g/ha should be made. Tricho cards with parasitoid eggs should be stapled on underside of the foliage of randomly selected plants covering whole plot.

- Need based application of synthetic chemical insecticides when the shoot-fruit damage reaches 5% (ETL) spraying of chlorantranilprole 18.5 SC @ 3 ml/10 liter or emamectin benzoate 5 SG @ 5 g/10 liter or lamda cyhalothrin 5 EC @ 6 ml/10 liter of water

2. BRINJAL LACE-WING BUG

Scientific name: *Urentius sentis Distant*

Family: Tingidae

Order: Hemiptera

Distribution: The lace-wing bug is distributed in the north-western parts of the Indian sub-continent and is common in the plains.

Hosts: Except for brinjal, it has not been recorded feeding on any other plant.

Marks of identification:

- The adult bugs measure about 3 mm in length and are straw coloured on the dorsal side and black on the ventral side.
- On the pronotum and wings, there is a network of markings and veins.
- The full-grown nymphs are about 2 mm long 1.35 mm broad. They are pale ochraceous, and are stoutly built, with very prominent spines.

Life history:

- The bugs lay 35-44 shining white nipple-shaped eggs singly in the tissues on the underside of the leaves.
- The eggs hatch in 3-12 days
- They grow through five stages and transform themselves into adults in days.
- The insect passes through 8 overlapping generations in a year.

Nature of damage:

- The young nymphs feed gregariously on the lower surface of the leaves, but the fully-developed nymphs are feeding and moving about individually on the lower surface as well as on the upper surface.
- The nymphs and the adults suck the sap from leaves and cause yellowish spots which, together with the black scale-like excreta deposited by them, impart a characteristic mottled appearance to the infested leaves.
- When the attack is severe, about 50 per cent of the crop may be destroyed.

Management:

- Apply 625 ml of diazinon 20EC or one litre of dimethoate 30 625 litres of water per ha.

3. HADDA BEETLES

Scientificname: *Henosepilachna dodecastigma*(Wiedemann) and *H. vigintioctopunctata*(Fabricius)

Family: Coccinellidae

Order: Coleoptera

Distribution: This pest is prevalent throughout India.

Hosts: The hadda beetles attack different solanaceous vegetables like brinjal, tomato and potato.

Marks of identification:

- *H. vigintioctopunctata* beetles are deep red and usually have 7-14 black spots on each elytron whose tip is somewhat pointed.
- Beetles of *Henosepilachna dodecastigma* are deep copper-coloured and have six black spots on each elytron whose tip is more rounded. The grubs of both the species are about 6 mm long, yellowish in colour and have six rows of long branched spines.

Life history:

- The female beetle lays yellow cigar-shaped eggs, mostly on the underside of leaves, in batches of 5-40 each.
- A single female can lay up to 400 eggs in her lifetime.
- The eggs hatch in 2-3 days. The grubs feed on the lower epidermis of leaves and are full-grown in 11-15 days.
- The pupae are darker and are found fixed on the stems and most commonly, at the base of the plants.
- The pupal stage lasts 5-7 days. The pest passes through several broods from March to October and its population is maximum at the end of April or in early May.

Nature of damage:

- Both the grubs and the adults cause damage by feeding on the upper surface of leaves.
- They eat up regular areas of the leaf tissue, leaving parallel bands of uneaten tissue in between.
- The leaves, thus, present a lace-like appearance. They turn brown, dry up and fall off, and the plants are completely skeletonized.

Management:

- Hand picking and destruction of the different stages viz., eggs, grubs, pupae and adults of the pest
- With appearance of the beetle in the field spraying of mixture of Neem oil @ 5% + *M. anisopllae* @ 5 g/l (1:1 ratio)
- With appearance of the beetle in the field, need based application of quinalphos 20 AF 1.5ml/l or Cypermethrin 25 EC @ 0.4 ml/l or triazophos 40 EC @ 2-2.5 ml/l of water. Spraying to be done preferably with power sprayer during the early morning or evening hours.

4. BRINJAL STEM BORER :

Scientific name: *Euzophera perticella* Rag

Family: Pyralidae

Order: Lepidoptera

Distribution: The stem borer is widely distributed in India

Hosts: Besides brinjal, it may also attack chillies, potato and tomato plants..

Marks of identification:

- The moths measure about 32 mm across the spread wings and have pale-yellow abdomens.
- The head and thorax are greyish, the fore wings are pale straw-yellow and the hind wings are whitish.
- The caterpillars measure about 20-22 mm in length, when full-grown.
- They are creamy white and have a few bristly hairs. Their bodies taper posteriorly.

Life history:

- This pest is active from March to October and passes the winter as a hibernating caterpillar in the stems of old plants.
- The overwintered larvae pupate at the beginning of March and emerge as moths in the second half of the month.
- The moths are lay cream-coloured scale like' eggs singly or in batches on the underside of young leaves or in the axils of young branches.
- Single female may lay 104-363 eggs in its life span of about a week. The eggs hatch in 3-10 days
- Larva pass through 4 or 5 stages and are full-fed in 26-58 days.
- When full-they make silken cocoons within the feeding galleries or in the cracks and crevices in the soil.
- After pupation, they transform themselves into adults in 6-8 days,
- The life-cycle is completed in 35-76 days and the pest has 5-6 overlapping generations a year.

Nature of damage:

- The young larvae feed for a few minutes on exposed parts of plants before boring into the stem where they feed on the pith by making longitudinal tunnels.
- The caterpillars feed exclusively in the main stem and have never been observed to bore into the fruits.
- As a result of their attack in the field, stray plants are seen withering and drying up.

Management:

- When the attack of this borer is serious, the ratooning of brinjal plants should be discontinued.
- The infested plants should be uprooted and burnt
- Application of neem cake @ 500 kg/ha or Carbofuran 3G @ 1 kg a.i./ha at the time of transplanting around the base of the plant

5. RED SPIDER MITE

Scientific name: *Tetranychus cinnabarinus*(Boisduval), *T. urticae* Koch

Family: Tetranychidae **Order:** Acari

Hosts: It is a polyphagous non-insect pest feeding on more than 150 host plants including vegetables like brinjal, ladies finger, cowpea, cucurbits, beans etc.

Marks of identification:

- These mites are soft bodied red in colour and colony forming.

Life history:

- Generally, spider mites are found numerous during summer months, multiply quickly and pass through a several generations in a very short period of time like aphids.
- Larva is six legged while nymphs and adults are eight legged like spider.
- Size varies from 0.5-0.6 mm
- Spider mite completes its life cycle within 9-14 days during active period.

Nature of damage:

- These mites normally inhabit the under surface of leaves and spin the webs.
- The plants often remain covered with dense webs under which both the developing stages and adults damage the crops by sucking the cell sap.
- Besides, dust particles get adhered to webs and retard normal physiological activities of the plant leading to reduction in plant growth and yield.
- The affected leaves turn yellow, dry up and finally wither away giving an unhealthy appearance.

Management:

- Removal and destruction of ratoon crops, weeds (*Partheniimetc.*) from the main field
- Removal and destruction of infested leaves during dry period
- Need based application of Fenazaquin 10 EC @ 2.5 ml-lit or Spiromesifen 22.9 SC @ 0.8 ml/1 or Flumite/Flufenazine 20 SC @. 0.6-0.8 ml/1 of water with appearance and repeated after 10-15 days when infestation is high.

6. WHITEFLY

Order: Scientific name: *Bemisia tabaci*Gennadius

Family: Aleyrodidae **Order:** Hemiptera

Hosts :*B. tabaci* is highly polyphagous and is known to feed on several vegetables including tomato, egg plant and okra, and on field crops and weeds.

Distribution: The whitefly is widely distributed in tropical and subtropical regions, and in greenhouses in temperate regions.

Marks of identification:

- Adults are minute insects with yellowish body covered with a white waxy bloom.
- Eggs are pear shaped, light-yellowish with short.
- Nymphs are greenish yellow, oval in outline, along with puparia on the undersurface of leaves.

Life history:

- The females mostly lay eggs near the veins on the underside of leaves. They prefer hairy leaf surfaces to lay more eggs.
- Each female can lay about 300 eggs in its lifetime. Eggs are small (about 0.25 mm), pear-shaped, and vertically attached to the leaf surface through a pedicel. Newly laid eggs are white and later turn brown.
- Egg period is about three to five days during summer and 5 to 33 days in winter
- The last nymphal stage has red eyes. This stage is sometimes referred to puparium, although insects of this order (Hemiptera) do not have a perfect pupal stage (incomplete metamorphosis).
- Nymphal period is about 9 to 14 days during summer and 17 to 73 days in winter (David, 2001).
- Adults emerge from puparia through a T-shaped slit, leaving behind empty pupal cases or exuviae.
- Pupation taken place on the leaf itself. Pupal period lasts for 6-8 days.
- Adults live from one to three weeks

Nature of damage:

- Nymphs and adults suck the plant sap while remaining on lower surface of leaves.
- Chlorotic spots appear on the leaves which later coalesce forming irregular yellowing of leaf tissue which extends from veins to the outer edges of the leaves.
- If the plant is shaken, a cloud of tiny moth-like insects flutter out but rapidly resettle.
- On hatching nymphs crawl a little, settle down on a succulent spot on ventral surface of leaf, and keep sucking sap.
- Affected parts become yellowish, leaves wrinkle, curl downwards and are ultimately shed. Honeydew excreted by nymphs attracts sooty molds which form black coating on leaves.

Management:

- Whitefly is a polyphagous insect; it has several host plants for feeding and survival ranging from cultivated crops to weeds. The field selected for brinjal or seedling production should be clean and not be located near any host plants and weeds.
- Grow brinjal seedlings in insect-proof (50–64mesh) net houses, greenhouses, or plastic houses.

- If the seedlings are produced under open field conditions, use yellow sticky traps at the rate of 1-2 traps/50-100 m² to trap the whiteflies. Hang the traps slightly above or at the canopy level for better trapping
- If 5-10 whiteflies are noticed per leaf, spray triazophos 2.5 ml or difenthiuron 50 WP 1 gm/l of water.
- Do not spray synthetic pyrethroids like Deltamethrin, Cypermethrin and Fenvalerate as it leads to resurgence.

7. APHIDS

Scientific name: *Myzus persicae*(Sulzer)

Family: Aphididae **Order:** Hemiptera

Distribution: Throughout India

Hosts:This is a cosmopolitan pest and highly polyphagous. It prefers to feed on cotton, cucurbits, okra, Spinach, tobacco, peach, plum, cherry, many ornamental shrubs and flowering plants.

Marks of identification:

- The young aphids are pale yellowish, green in colour with three dark lines on the back of the abdomen.
- The aphids that are found in great numbers on the leaves are apterous (wingless) forms which can be either oviparous or viviparous.
- The aphids can also occur in winged form and in these cases they spread the infestation from plant to plant and form new colonies.

Life history:

- Unlike many insects, most aphids do not lay eggs. They usually reproduce through parthenogenesis (development of embryo without mating with males) and are viviparous (give birth to nymphs directly rather than eggs).
- Aphids mostly are found in groups. Each female produces about 20 nymphs a day, which become adults in a week.
- The aphids have 4 nymphal instars and total nymphal period lasts 6 to 11 days.

Nature of damage:

- By constant feeding on the sap, of the plants, the leaves look sickly in appearance.
- The green peach aphids are outstanding among aphids for transmission of diseases.
- They cause more than 50 kinds of virus diseases, mostly the non-persistent type.
- Apart from direct damage they also excrete a sugary liquid commonly known as 'honey dew' whose presence on the leaves for a few days causes development of a black mould called the "sooty mould". The presence of mould on the leaves also disturbs the photosynthetic process of the leaves.

Management:

- Grow brinjal seedlings in insect-proof (50–64 mesh) net houses, greenhouses, or plastic houses to avoid early infestation.
- Remove the severely affected plants to prevent further spread of this pest.
- Remove alternate weed host in and around the brinjal field.
- The ladybird beetles (*Menochilus* sp. And *Coccinella* sp.) and green lacewings are efficient predators of aphids. Protect the population of these predators by avoiding the use of broad spectrum pesticides.
- Spray methyl-o-demeton 25 EC 2 ml/l or dimethoate 30 EC 2 ml/l, malathion 50 EC 0.1 per cent, 2 ml/l to the point of run-off twice at 15 days interval.

8. LEAF HOPPER

Order: Scientific name: *Empoasca devastans* Distant

Family: Cicadellidae **Order:** Hemiptera

Distribution: India, Bangladesh, China, Myanmar, North Africa, Pakistan, Philippines, Sri Lanka, and Taiwan

Hosts: Cotton, okra, potato, castor, hollyhock, and sunflower.

Marks of identification:

- The adult is wedge-shaped about 2 mm long and pale green in colour.
- The forewings have a black spot on their posterior parts.
- The nymphs are wingless, pale green in colour and are found in large numbers on the lower surface of the leaves.
- They have a characteristic way of walking diagonally in relation to their body.

Life history:

- The adult female lays about 15 to 300 eggs in the leaf tissues and the minute nymphs emerge out of the eggs in 4 to 11 days.
- The nymphal period varies from one to four weeks depending on the temperature. The nymphs moult five times.
- The adults may live for one to two months.
- The life cycle is completed in 14 to 30 days.
- About 11 generations have been observed in a year, the duration of each varying from 15 to 46 days, but there is considerable overlapping.
- The adults are generally long-lived and can tide over during adverse climatic conditions.

Nature of damage:

- The nymphs and adults pierce the plant tissues and suck the cell sap by their mouth parts.

- While sucking the plant sap, they also inject toxic saliva into the plant tissues, which leads to yellowing. When several insects suck the sap from the same leaf, yellow spots appear on the leaves, followed by crinkling, curling, bronzing, and drying, or “hopper burn”.
- Little-leaf, a virus disease is transmitted by *E. devastans* from diseased to healthy brinjal.

Management:

- Choose tolerant or resistant cultivars with hairy leaves, as the length and density of the trichomes (hairs) repel leaf hoppers. Grow Gujarat brinjal hybrid – 1 (GBH-1) found more tolerant for effective and economic control of different pests of brinjal.
- Brinjal planted at the end of October had the lowest incidence of the jassid
- Apply recommended doses of Nitrogenous fertilizers.
- Avoid the use of broad-spectrum pesticides to encourage the performance of natural enemies. Generalist predators such as ladybird beetles and green lacewings are highly efficient in preying on leafhopper nymphs and adults. Parasitoids such as *Anagrusflaveolus* Waterhouse and *Stethyniumtriclavatum* Enock are effective against leafhopper (Subba Rao 1968; Parker *et al.* 1995).
- Use neem-based bio pesticides at recommended doses. If commercial neem formulations are not available, neem seed kernel extract (NSKE) @ 5% can be sprayed.
- Spraying of systemic insecticides like Phosphomidon or Dimethoate @ of 2ml/l of water is very effective. Repeat it 2 to 3 times at the interval of 10 days.

❖ PESTS OF OKRA

1. SHOOT AND FRUIT BORER:

Scientific name: *Earias vitella*, *E. insulana*

Family: Noctuidae

Order: Lepidoptera

Distribution. These two species of bollworms are widely distributed in North I Africa, India, Pakistan and other countries and are serious pests of cotton

Hosts: Several malvaceous plants like cotton, okra, hollyhock, sunnhemp, China rose, etc.

Marks of identification:

	<i>E. vitelli</i>	<i>E. insulana.</i>
Larva	Brown, with longitudinal white stripes on dorsal side as against for	Cream coloured body with orange dots on prothorax
Adult	Medium sized, head and thorax ochreous white Forewings are pale with a wedge shaped green band in the middle	Adults are smaller than <i>E. vitella</i> Head and thorax pea green in colour Forewings uniformly silvery green.

Life history:

- The female moths lay 200-400 eggs at night, singly on flower buds, brackets and tender leaves of okra plants.
- The eggs hatch in 3-4 days and the caterpillars pass through 6 stages, becoming full-grown in 10-16 days.
- They pupate either on the plants or on the ground (during November - December) among fallen leaves and the moths emerge in 8-14 days in summer and 18-23 days in winter.
- The life cycle is completed (usually August to October) in 17-29 days.
- Several overlapping generations are completed in a year.

Nature of damage:

- Larva bores into tender terminal shoots in the vegetative stage and flower buds, flowers and young fruits in the fruit formation stage.
- The damaged shoots droop, wither and dry up.
- The infested fruits present a deformed appearance and become unfit for consumption. Bore holes - plugged with excreta

Management:

- Deep ploughing during summer to expose the pupae to scorching sunlight and predation by birds.
- Collect and destroy infested shoots, buds, flowers and fruits. Avoid cultivation of alternate hosts like *Hibiscus cannabinus*, *H. abelmoscus* and *Abutilon indicum*.
- Install pheromone traps with *Eariasvittellalures* @ 60 traps per ha. The traps should be installed 3 weeks after germination and at one foot height above the crop canopy covering the whole field uniformly. The lure should be changed after every 3 weeks.
- Release egg parasitoid *Trichogramma chilonis* @ 1, 00,000/ha. Release first instar larvae of *C. carnea* @ 1 lakh/ha.
- Spray *Bacillus thuringiensis* var. *kurstaki* 1% WP @ 50 g/10 litre water or NSKE 5% @ 500 g/10 litre water at fifteen days interval for three times or six releases of *Trichogramma chilonis* @ 50,000/ha at weekly interval starting from the initiation of shoot and fruit borer (*Earias vittella*)
- Spraying azadirachtin 0.03% WSP (300 ppm) @ 5.0 g/lit or azadirachtin 5% Neem Extract Concentrate @ 5.0 ml/10 lit or quinalphos 25 % EC @ 8.0 ml/10 lit of water
- Spraying of cypermethrin 25 EC @ 0.5-0.75 ml/1 L of water or emamectin benzoate 5 SG @ 0.5-0.5 g/1 L of water or lambda-Cyhalothrin 5 EC @ 1ml/1 L of water starting from 40 days after sowing. There after 10 days interval depending up on the severity of the pest damage **or**

- Seed treatment with imidacloprid @ 3 g/kg of seed, sprays of rynaxpyr @ 0.15 ml/1 L of water at 25 DAS, NSKE 4% at 35 DAS, emamectin benzoate @ 0.5 g/1 L of water at 45 DAS, Bt@ 1 ml/1 L of water at 55 DAS and NSKE 4% @ 5 ml/1 L of water at 65 DAS

OR

1. Seed treatment with imidacloprid 600 FS, 9.0 ml/ kg seeds using equal quantity of water before 12 hours of sowing.
2. Removal and destruction of the shoot and fruit borer affected shoots and fruits along with larvae at weekly interval.
3. Installation of pheromone traps of *Earias vittella* @ 60/ha at three week after germination and replace the lures every 21 days interval.
4. Spraying of chlorantraniliprole 18.5 SC, 0.006% (3 ml in 10 litre of water) at 25 DAS (30 g a.i./ha).
5. Spraying of NSKE 5% at 35 DAS.
6. Spraying of emamectin benzoate 5 SG 0.0025% (5 g in 10 litre of water) at 45 DAS (12.5 g a.i./ha).
7. Spraying of *Bacillus thuringiensis* var. *kurstaki* 5 WP(10 g in 10 litre of water) at 55 DAS
8. Spraying of NSKE 5% at 65 DAS.

2. OKRA FRUIT BORER, *Helicoverpa armigera* (Hubner) Hardwick (Lepidoptera : Noctuidae)

Marks of identification:

- Moth - Medium stout light yellowish brown in colour.
- Forewings are pale brown with a dark brown circular spot in the center.
- Hind wings are pale Smokey white with blackish outer border.
- Caterpillar – 3 to 5 cm long greenish with dark brown grey lines along with the sides of the body.

Life Cycle

- The female lay eggs singly on the tender parts of the plants.
- A single adult female can lay 300-500 eggs in 4-7 days.
- The incubation period of eggs is 3-6 days.
- The larval period is 13-18 days.
- The full grown larva pupates in soil.
- The pupal period last for 8-15 days.

Nature of damage:

- The young larvae on hatching feed on foliage for some times
- Circular boreholes on fruits
- Larvae bore into the fruits with their bodies hanging outside.

Management

- Collect and destroy the infected fruits and grown up larvae
- Grow simultaneously 40 days old American tall marigold and 25 days old tomato seedling at 1:10 rows to attract *Helicoverpa* adults for egg laying.
- Setup pheromone trap with Helilure at 15/ha
- Six releases of *T. chilonis* @ 50,000/ha per week coinciding with flowering time
- Release *Chrysoperla carnea* at weekly interval at 50,000 eggs or grubs / ha from 30 DAS
- Spray HaNPV at 1.5*10¹² POB/ha along with cotton seed oil 300 g/ha to kill larvae.
- Spray carbaryl 50 WP 2 g/lit or *B. thuringiensis* 2 g/lit
- Do not spray insecticides after maturity of fruits.

3. LEAF HOPPER:

Scientific name: *Amrasca biguttula biguttula* Ishida

Family: Cicadellidae **Order:** Hemiptera

Distribution: This is polyphagous pest widespread in the Indian subcontinent.

Marks of identification:

- Adults are pale green, wedge-shaped and move diagonally. Nymphs are translucent yellowish green in colour.

Life history:

- The females lay about 15 yellowish eggs on the underside of the leaves, embedding them into the leaf veins.
- The eggs hatch in 4-11 days and give rise to nymphs which are wedge-shaped and are very active.
- They suck cell-sap from the underside of the leaves and pass through six stages of growth in 7-21 days.
- On transformation into winged adults, they live for 5-7 weeks, feeding constantly on the plant juice.
- The pest completes seven generations in a year.

Nature of damage:

- Injury to plants is caused both by the nymphs and the adults which suck sap from the foliage and probably also due to the injection of toxins into the plant tissues.
- The attacked leaves turn pale and then rust-red.
- With change in appearance, the leaves also turn downwards, dry up and fall to the ground.
- Severely affected plants have stunted growth.

Management:

- Seed treatment with imidacloprid 70 WS or thiamethoxam 25 WG @ 5 g/kg of seed before sowing.
- Foliar spray of thiamethoxam 25 WG @ 3 ml/10 l or imidacloprid 17.8 SL @ 3 ml/10 liter of water at 25 days interval with the appearance of pest

4. WHITEFLY:

Scientific name: *Bemisia tabaci*

Family: Aleyrodidae **Order:** Hemiptera

Distribution: This pest is distributed throughout the northern and western regions of the Indian sub-continent and is a very serious pest of American cotton particularly in the dry areas.

Host: They feed on tomato, brinjal, ladies finger, cowpea, cucumber, pumpkin, chillies, etc

Marks of identification:

- In the winged stage, they are 1.0-1.5 mm long and their yellowish bodies are slightly dusted with a white waxy powder.

Life history:

- The females lay stalked eggs singly on the underside of the averaging 119 eggs per female.
- The eggs hatch in 3-5 days during summer, 5-33 days in winter. The nymphs feed on cell-sap and grow into three stages to form the pupae within 9-14 days in summer and in 17-81 days in winter. In 2-8 days, the pupae change into whiteflies.
- The total life-cycle is completed in 14-122 days and 12 generations are completed in a year.

Nature of damage:

- Both the nymphs and adults suck the sap and also secrete the honeydew on which black sooty molds develop that reduce the photosynthesis of the plants.
- Chlorotic spots on the leaves which later coalesce forming irregular yellowing of leaf tissue.
- Severe infestation results in premature defoliation.
- Vector of yellow vein mosaic virus.

Management:

- Seed treatment with imidacloprid 70 WS or thiamethoxam 25 WG @ 5 g/kg of seed before sowing
- Spraying of spiromesifen 22.9 SC @ 8 ml/ 10 liter of water with the appearance of the pest and second spray after 10 days after first spray
- Spraying of neem oil (2-3 ml/l) with a sticker (0.5 ml/l of water) or Need based spraying of imidacloprid 17.8 SL @ 0.3 ml/ 1 L of water or thiamethoxam 25 WG @ 0.4 g/l L of water or dimethoate 30 EC @ 1.5-2 ml/l L of water of water

5. RED SPIDER MITES:

Scientific name: *Tetranychus urticae* Koch

Family: Tetranychidae **Order:** Acarina

Nature of damage:

- Both nymphs and adults damage the plants. Large numbers of webs formed on the leaves under which the pest sucks the cell sap.
- The affected leaves dry up and finally wither away giving an unhealthy appearance. Webbing interferes with the plant growth and reduction in yield.

Management:

- Two sprays of spiromesifen 22.9 SC @ 8ml/ 10 liter of water first spray at appearance of mites and second after 10 days of the first spray or
- Spraying wettable sulphur 0.125% and dicofol 0.03% alternatively at 10 days interval. Cultivation in a plot on road side to be avoided.

6. APHIDS:

Scientific name: *Aphis gossypii* Glover

Family: Aphididae **Order:** Hemiptera

Distribution : The aphid is world wide in distribution and is known as a potential pest of cotton.

Host: Though it is a polyphagous pest infesting a variety of plants, it is of more significance on crops like lady's finger, brinjal, guava, gingelly, etc

Marks of identification:

- The adults are small, greenish brown and soft-bodied insects found in colonies on the tender parts of the plants and under surface of the leaves.

Life history:

- The adults exist in both winged and wingless forms.
- The alate as well as apterous females multiply parthenogenetically and viviparously. In a day, a female may give birth to 8-20 nymphs.
- The nymphs moult four times to become adults in 7-10 days.

Nature of damage:

- The damage is caused both by the nymphs and adults by sucking plant sap.
- Severe infestation results in curling of leaves, stunted growth and gradual drying and death of young plants.
- Black sooty mould develops on the honeydew of the aphids which falls on the leaves. Dry conditions favour rapid increase in pest population and the younger plants are more susceptible than the older ones.

Management:

- Seed treatment with Imidacloprid 70 WS or thiamethoxam 25 WG @ 5 g/kg of seed before sowing.
- Foliar spray of thiamethoxam 25 WG @ 3.5 gm/10 liter of water with the appearance of the pest and second spray after 10 days after first spray.

7.MEALY BUG:

Scientific name: - *Phenacoccus solenopsis*

Order: -Hemiptera **Family:** - Pseudococcidae

Marks of identification: -

- The adult female is yellowish in colour, oval in shape and covered with white mealy powder.
- The female adults are wingless; however, male adults are having one pair of wings.
- The nymphs are pale yellow with reddish eyes, which are later on covered with white mealy mass.

Life-history:-

- A female lays 300-700 eggs usually in an ovisac beneath her body.
- The eggs hatch in few minutes to 2 days.
- The newly emerged nymphs (crawlers) crawl out and start feeding on tender parts plants.
- The female mealy bug passes through three nymphal instars in 12-17 days.
- The male mealy bug passes through four nymphal instars in 14-18 days.
- The longevity of adult female is longer (14-19 days) as compared to male which is shorter (1-3 days).
- The total life cycle of female is completed in 25- 38 days whereas of male in 17-24 days.

Nature of damage:-

- Both nymphs and adults suck the sap from leaves, flower buds, petioles, twigs, fruits and even from the stem of the plants.
- The insect heavily sucks the sap from the plant and renders it weak, feeble and dehydrated.
- In severe cases development of sooty mould takes on honeydew produced by mealy bugs.
- The sooty mold reduces the photosynthetic ability of the plants.
- The fruits infested with mealy bugs reduces the marketability of the fruit.

Management:-

- To check the spread of mealy bug, remove regularly the weeds growing adjacent to road sides, pathways, water channels and waste lands.
- The hymenopterous parasitoid, *Aenasius bambawalei* is very effective against mealy bug; as high as 70-80 per cent parasitization has been reported in certain areas.
- Avoid spray of insecticides if parasitized mealy bug mummies are observed.

- Spraying of buprofezin 25 SC @ 1 ml/l or acephate 75 SP @ 1 g/l or malathion 50 EC @ 2 ml/l or chlorpyrifos 20 EC @ 2 ml/l or imidacloprid 17.8 SL @ 0.3 ml/l of water. Spray the chemicals first on plants around infested plants and then spot application on the infested plants.

❖ PESTS OF TOMATO

1. FRUIT BORER:

Scientific name: *Helicoverpa armigera* (Hub.)

Family: Noctuidae

Order: Lepidoptera

Hosts: It is a highly polyphagous and polymorphous pest infesting more than 400 agricultural and horticultural crops. Several vegetable crops like tomato, cabbage, cauliflower, ladies finger, cowpea, pea, field bean, chillies, brinjal, potato, etc. have been found to be infested by this pest.

Marks of identification:

- Moth - Medium stout light yellowish brown in colour.
- Forewings are pale brown with a dark brown circular spot in the center.
- Hind wings are pale smoky white with blackish outer border.
- Caterpillar – 3 to 5 cm long greenish with dark brown grey lines along with the sides of the body.

Life history:

- Adult female lays around 240-750 spherical eggs during its life cycle on the flower buds, flowers, tender fruits and growing shoots.
- Incubation period varies from 3-7 days. Larvae are greenish to variable colours with dark broken grey lines.
- Pupation takes place in an earthen cell.
- The total developmental period ranges from 25-40 days depending upon the temperature and the host.

Nature of damage:

- The neonate larvae initially feed on the foliage and later bore into the yellowish green fruits.
- Damaged fruits are unfit for consumption and also invite secondary infection by other organisms lead to rotting.
- During the feeding, larvae characteristically thrust its head into the fruit leaving the rest of its body outside.

Management:

- Deep summer ploughing by mould board plough or other means so that deep layer of the soil will be exposed to expose the larvae and pupae of the fruit borer to sunlight and predatory birds
- Planting of one row of 40 days old seedlings of marigold every after 16 rows of 25 days old seedlings of tomato.
- Hand picking and destruction of larvae from the marigold flowers OR Spraying of dichlorvos 76 EC @ 1 ml/l of water only on marigold on colonization of pest population on trap crop
- Sex pheromone traps (funnel tarp) should be installed just above the crop canopy.
- Six releases of *Trichogramma chilonis* @ 50000/ha/week coinciding with flowering time and based on ETL
- Spray HNPV (1.0x10⁹ POB/ml) @ 250 ml/ha (5 ml/ 10 l water) or *Beauveria bassiana* (1x 10⁸ cfu/g) @ 1.0 kg/ha (20 g/10 l water) or *Metarhizium anisopliae* (1 x 10⁸ cfu/g) @ 1.0 kg/ha (20 g/10 l water) 85 days after transplanting for suppression of fruit borer, *Helicoverpa armigera* (Hubner).
- Need based application when pest population reaches ETL or 1 larva/plant or 2% fruit damage. Spraying of chlorantranilprole 18.5 SC @ 0.35 ml/l or flubendiamide 20 WG @ 0.2 - 0.25 g/l or indoxacarb 14.5 SC @ 0.75 ml/l or novaluron 10 EC @ 1 ml/l or quinalphos 25 EC @ 2 ml/l of water etc.

2. SERPENTINE LEAF MINER:

Scientific name: *Liriomyza trifolii* Burgess

Family: Agromyzidae **Order:** Diptera

Host: It is one of the polyphagous agromyzids causing serious damage on several crops including okra, onion, cucurbits, beans, cowpea potato, brinjal and crucifers.

Marks of identification:

- Adult fly 1.5-2.0 mm long grayish black with yellow spot in the top of thorax and has plum red eyes.
- Larva - Legless (Maggots) orange yellow about 2 mm long.

Life history:

- Eggs are inserted singly below the leaf surface and hatching takes place within 2-5 days.
- After hatching, the larvae start mining into the leaves in a zig-zag fashion.
- Pupation occurs in the soil beneath the plant.
- Adult emergence takes place 7-15 days after pupation.
- Life cycle completes in 12-15 days.

Nature of damage:

- Damage by the pest occurs due to mining into leaves and petiole by the larvae.
- The photosynthetic activity of the plants is often greatly reduced.
- Severely infested leaves may dry and fall.

Management:

- Judicious use of nitrogenous application at recommended dose in pest endemic areas
- With the infestation of pest, removal and destruction of heavily infested old/lower leaves followed by application of NSKE 4% with sticker (0.5 ml/lit of water) whenever the incidence is noticed
- Before flowering and during severe infestation, spraying of Imidacloprid 17.8 SL @ 0.35 ml/1 of water during the early stage of the crops before flowering. OR Application of dichlorovos 76 EC @ 0.5 ml/1 of water in severe infestation during reproductive phase crop
- Spray spinosad 45 SC, 0.0135 per cent (3 ml/ 10 litre water; 67.5 g a.i./ha) or abamectin 1.9 EC, 0.0006 per cent (3 ml/ 10 litre water; 2.85 g a.i./ha) along with 400 g jaggery, first at appearance of the pest and subsequent two sprays at 15 days interval.

3. SOUTH AMERICAN TOMATO PINWORM:

Scientific name: *Tuta absoluta* (Meyrick)

Family: Gelechiidae

Order: Lepidoptera

Host: **Tomato** is the primary host of *T. absoluta*, but it has been reported on other secondary hosts like egg plant, potato), pepper), sweet pepper and tobacco and other solanaceous weeds

Marks of identification:

- Adults are about 1 cm long, with a wingspan of about 1 cm with mottled gray in color.
- The most important identifying characters is the filiform antennae (bead like antennae), silverfish-grey scales and characteristic black spots present in anterior wing.
- The larvae becoming greenish to light pink in second to fourth instars.

Life history:

- The life cycle of this insect begins when the adult insect lays its egg on underside of leaves, buds, stems and calyx of unripe fruits.
- Fecundity of 260 eggs per female
- Egg hatching takes place 4-6 days after egg lying
- The young larvae penetrate into tomato fruits, leaves or stems on which they feed and develop, thus creating conspicuous mines and galleries
- Fully grown larvae usually drop to the ground on a silk thread and pupate in the soil.
- Larval period is most damaging period which completed within 12-15 days.
- life cycle that can take from 24 to 76 days, depending on the environmental conditions

Nature of damage:

- Tomato plants can be attacked from seedlings to mature plants.
- The pest has been responsible for losses of 80-100% in tomato plantations in both protected cultivation and open fields.
- Yield and fruit quality are both considerably impacted by direct feeding of the pest as well as secondary pathogens entering host plants through wounds made by the pest
- After hatching, larvae penetrate apical buds, flowers, new fruit, leaves, or stems. On leaves, the larvae feed on the mesophyll tissue, forming irregular leaf mines which may later become necrotic.
- Larvae can form extensive galleries in the stems which alter the general development of the plants.
- Fruits are also attacked by the larvae, forming galleries which represent open areas for invasion by secondary pathogens, leading to fruit rot

Management:

- Massive trapping before planting,
- clearing the soil of crop residues,
- The application of imidacloprid in the irrigation water 8-10 days after planting,
- The application of either spinosad or indoxacarb if occasional individuals of *T. absoluta* are observed and
- Elimination of the remnants of the crop immediately after the last fruits have been harvested.
- In case of pheromone trap catches less than ten moths per trap per week control treatments are recommended to be carried out mainly with bio-rational products, such as *Bacillus thuringiensis* and *Azadirachtin*.
- In case of pheromone trap catches more than ten moths per trap per week control treatment are recommended to be carried out by combining bio-rational insecticides with synthetic chemical insecticides.

4. LEAF EATING CATERPILLAR– *Spodoptera litura* Fab.

Order – Lepidoptera **Family** – Noctuidae

Mark of identification –

- Adult – Moth are medium sized stout with forewings gray to dark brown in colour with wavy marking. Hind wings are whitish.
- Larva- Caterpillars are pale greenish brown and smooth with dark marking and prothoracic plate.

Life history:

- Egg – Laid in cluster on ventral side of tender leaves covered with brown hairs. Incubation period 3 to 5 days and winter 20 days.
- Larva – Larval period 20 to 28 days and winter 90 days.
- Pupa – Pupation takes place in soil in rough earthen cocoons.
- Pupal period - 7 to 11 days and may extend 30 days in winter
- Moth – Adult longevity in 10 to 24 days.
- Life cycle – Completed in 30 to 40 days during summer and 18 to 20 weeks in winter.

Nature of damage:

- The caterpillar, when young feed gregariously on leaves and juicy stems and become isolated at later stage of growth.
- During severe infestation entire crop may be defoliated overnight.

Management:

- Plough the soil to expose and kill pupae.
- Grow castor along border and irrigation channels as indicator or trap crop.
- Flood the field to drive out the hibernating larvae.
- Set up light trap at 1/ha or pheromone traps at 15/ha with Pherodin SL lure.
- Remove and destroy egg mass in castor and tomato. Hand-pick grown-up larvae and kill them.
- Collect damaged leaves and gregarious early instar larvae and destroy.
- Spray chlorpyrifos 20 EC 2000 ml/ha or dichlorvos 76 WSC 1000 ml/ha or phenthoate 50 EC 2000 ml/l or NSKE 5%.
- Spray the insecticides during evening hours.
- Prepare poison bait with rice bran 5 kg, jaggery 500g, carbaryl 50 WP 500g, water 3 l/ha and spread the bait in the evening hours.

5. WHITE FLY – *Bemisia tabaci* Gen.

Family – Aleoerodidae **Order** – Hemiptera

Mark of identification:

- Whitefly is small, about 1/32inch long and whitish yellow. The head is broad at the antennae and narrow toward the mouthparts.
- Nymph – Nymphs are oval scale like and greenish white in colour.

Life history:

- Reproduction is mostly oviparous through parthenogenesis. Only males emerge from unfertile eggs where as both sexes develop from fertilized eggs.

- Eggs - Laid on under surface of tender leaves. E. P. - 3 to 5 days in summer and may extended 5 to 33 days in winter
- Nymph - Nymphal period 9 to 14 days in summer and 17 to 81 days in winter season.
- Pupa – Pupation takes place on leaves pupation period 2 to 8 days.
- Adult – longevity 2 to 5 days in summer and winter 2 to 4 days.
- Life cycle – Completed on 2 to 15 weeks. Number of generations 12 per year.

Nature of damage:

- Nymphs and adults suck the cell sap from ventral surface. As a result of their feeding the affected parts become yellowish leaves wrinkled and curl downward and are ultimate shade.
- Besides the feeding damage these insects also exude honey dew which develops sooty mold. In case of severe infestation; black sooty mold interferes with the photosynthetic activity of plant resulting in stunted growth.
- This white fly also acts as vector transmitting ‘leaf curl’ virus disease causing severe loss. Such plant is necessarily to be uprooted and destroyed.

Management:

- Uproot and completely destroy the diseased leaf curl plants.
- Collect and destroy the damaged leaves along with eggs, nymphs, pupae and adults.
- Remove alternate weed host, *Abutilon indicum*
- Use yellow sticky traps smeared with sticky substances to attract and kill adults.
- Spray Fish oil rosin soap (FORS) 2% or neem oil 0.5% along with teepol 1 ml/l or methyl demeton 0.25% or phosalone 0.7%.
- Apply systemic insecticides in early stages of the plant growth and contact insecticides in the later stages for vector control.
- Apply insecticides in the early morning, as adults are less active.
- Encourage activity of parasitoids, *Eretmocerus masii* and predators, Coccinellids, *Brumus* and *Chrysoperla*.

6. THRIPS

Scientific name: *Thrips tabaci*

Family: *Thripidae* **Order:** Thysanoptera

Mark of identification:

- Thrips are tiny (1/16 inch), slender insects that vary in color from yellow or orange (most common color) to dark brown or black.
- Thrips overwinter in plant debris or on weeds such as winter annuals found in or around fields.

Nature of damage:

- Both nymphs and adults lacerate (cut) the leaf tissues and feed on the oozing sap. Usually young leaves are preferred, but buds and flowers also get infested.
- The infested leaves become shortened, curl upwards, and crinkle. Under severe infested conditions the leaves shed and hence plant growth is affected.
- Buds, when infested, become brittle, petals of the flowers become brown and drop off. Infested fruit have light brown scars.

Management:

- Seed treatment with imidacloprid @ 5 grams per kg seed.
- In the field, spray with imidacloprid @ 1 ml in 3-4 liters of water or fipronil @ 2 ml per liter.

❖ PEST OF POTATO**1. POTATO TUBER MOTH:**

Scientific name: *Phthorimaea operculella* (Zeller)

Family: Gelechiidae

Order: Lepidoptera

Distribution. The pest is distributed in all potato growing areas, hills and plains of Uttarakhand in particular, and very serious in Himachal Pradesh

Host plants. This pest is destructive to potato and also attacks tobacco, tomato, brinjal and solanaceous weeds.

Marks of identification:

- The adult is very small narrow-winged nocturnal moth, about 13 mm across the wings when spread.
- It is grayish brown with mottling of dark brown.
- The caterpillars are about 2.0 cm in length, pinkish-white or greenish with mottling of dark brown

Life history:

- A female, on an average, lays 150-200 eggs singly on the underside of Leaves or on exposed tubers.
- The larval stage in summer lasts 2-3 weeks and
- The mature larva pupates in a greyish silken dirt-covered cocoon, which is about 13 mm in length.
- The moths emerge in 7-10 days.
- They complete their life-cycle in about one month and there are usually 5-6 generations in a year.

Nature of damage:

- The larvae first produce blotch mines' on leaves but subsequently they work their way into the stems.
- The damage is caused by the caterpillars by boring into the tubers, eating away the pulp and destroying the eye-buds.
- In warm dry climates extensive damage may be done to the crop; but the potato tubers kept in cold stores escape damage.
- Later generations in the field infest the tubers also.
- In storage, 30 to 70 per cent of tubers are damaged by the larvae

Management:

- All the infested tubers should be removed and destroyed,
- Cold storage of tubers also helps in suppressing the pest.
- The pest can be checked by spraying 2.5 kg of carbaryl 50WP in 625 litres of water per ha or by dusting seed potato with 150 g of malathion 2 per cent per 100 kg. Repeat spraying 2-3 times at fortnightly intervals and do not dust the edible potatoes
- If potato tubers in the stores get infested, fumigation with carbon disulphide @ 2-3 litres per 100 m³ should be done.

2. APHIDS:

Scientific name: *Myzus persicae* (Sulzer), *Aphis gossypii* Glover, *Aphis fabae*

Family: Aphididae

Order: Hemiptera,

Distribution. The pest is distributed in all potato growing areas, hills and plains of Uttarakhand in particular, and very serious in Himachal Pradesh

Host plants. Peach (primary host), 'herbaceous hosts, asparagus, pepper, eggplant, okra, broccoli, cabbage, carrot, cauliflower, beans, lettuce, mustard, papaya, sweet potato, tomato and some weeds. These aphids also attack many ornamental plants such as carnation, chrysanthemum, flowering white cabbage, poinsettia and rose

Marks of identification:

- *Myzus persicae*(Sulzer): Commonly known as the green peach aphid. It is pale yellow green, dark green or pink in colour
- *Aphis gossypii* Glover: Generally known as cotton or melon aphid. Colour variable, ranging from pale yellow to brown or grey black or light to dark green.
- *Aphis fabae*: Commonly called as the common bean aphid. Variable in colour, from black to olive green.

Life history:

- The winged viviparous females start appearing on potato and other secondary host plants from middle of November onwards in the Indo-Gangetic plains.
- These forms reproduce parthenogenetically and give birth to living young ones.
- These pass through four nymphal stages or instars.
- Each instar is of about 1-5 days duration and one generation is completed in about 15 days.
- This type of asexual reproduction goes on for many generations on the secondary host plants

Nature of damage:

- Both nymphs and adults suck the sap from phloem of potato stems, leaves and roots using their stylets during which virus acquisition and inoculation occurs.
- It is assumed, that the aphid saliva prevents the plant cell from sealing the puncture with special proteins. These special proteins are a part of plant's normal defense mechanism.
- The insertion of their stylets in phloem can take 25 minutes to 24 hours from the insertion of the stylets.
- Aphids play a vital role in limiting disease free seed production by transmitting major potato viruses viz. *Potato virus Y* (PVY), *Potato leaf roll virus* (PLRV), *Potato virus A* (PVA), *Potato virus M* (PVM) and *Potato virus S* (PVS).
- Among various aphid species, *Myzus persicae* and *Aphis gossypii* acts as potential vectors of *Potato leaf roll* (PLRV) and *Y* (PVY).
- The losses in yield by the aphid transmitted viruses range between 40 to 85%.

Management:

- Infestation of the main aphid vectors on potato crop can easily be avoided/kept low by adjusting the planting dates in the Indo-Gangetic plains, where about 90 per cent of seed crop is grown, i.e. up to 15th October in North-Western plains, up to 25th October in central plains and up to 5th November in the North-eastern plains. Besides, chemical control of aphids is also adopted.
- Installation of yellow sticky traps @60/ha for monitoring and mass trapping of aphids.
- Removal of all weed hosts susceptible to viruses and for aphids especially those having yellow flowers, and volunteer (self grown potato) plants from within and around the vicinity of seed potato plots.
- The haulm cutting of seed crop should be done as soon as the aphid number crosses the critical level i.e. 20 aphids/100 leaves. In case of haulm cutting, care must be taken to prevent any regrowth of stumps before harvest.
- Before the aphids cross critical limit, one spray of imidacloprid 17.8% S.L @ 0.03% is recommended and same may be repeated at an interval of 12-15 days depending on the stage of crop and level of infestation.

3. WHITEFLIES:

Scientific name: *Bemisia tabaci* (Gennadius)

Family: Aleyrodidae **Order:** Hemiptera

Distribution. The pest is distributed in all potato growing areas, hills and plains of Uttarakhand in particular, and very serious in Himachal Pradesh

Host plants. Tomato, chilli, brinjal, capsicum, bhendi, cotton, tobacco, cucurbits, crucifers and a few weeds. *B. tabaci* is a pest of more than 600 host plants including vegetables, fibre crops, spices, ornamentals plants, and many weed plant species.

Life history:

- Whiteflies have six life stages viz., egg, four instars, and the adult.
- The female lay around 150-300 eggs singly on the underside of the leaf which hatch in 4-7 days.
- The nymphs become adults in 10-14 days.
- The adult lives for 10-20 days.
- The total life cycle is completed in 20-30 days under favourable weather conditions.
- The whiteflies can complete 11-15 generations in a year depending upon the weather conditions and plant species. However, on potato crop, three generations can be completed. Whiteflies also reproduce parthenogenetically.

Nature of damage:

- Whitefly causes severe damage to potato plants indirectly by transmitting the important viruses in the genus *Begomovirus* belonging to the family Geminiviridae in subtropics.
- Both nymphs and adults suck plant sap from the underside of the leaf during which virus acquisition and transmission takes place.
- Whiteflies are known to transmit *Tomato leaf curl New Delhi virus-potato* (ToLCNDV-potato) in potato since 2000

Management:

- Potato cv. Kufri Bahar is highly tolerant and can be planted in whitefly prone areas.
- Maintain field sanitation by removing and destroying the weeds, alternate hosts and crop residues of vectors and viruses.
- Place yellow sticky traps (15x30 cm²) just above the canopy height @ 60 traps per hectare at equidistance from each other for mass trapping.
- Trap crops such as cucumber (*Cucumis sativus*) can be used to provide temporary protection. Cucumber is a favoured host plant for whiteflies but a non-host for virus, and whiteflies are known to lose their viruliferous capacity after feeding for few days on this plant.

- Seed treatment with imidacloprid at 0.04% for 10 minutes and its foliar application at 0.03% at emergence with repeated application after 15 days is standard recommendation in seed potato crop.
- Foliar sprays of imidacloprid 17.8SL (0.03%) at 85% germination followed by Thiamethoxam 25WG (5gm/10 lit of water) after 10 days of the first spray.

4. LEAF HOPPERS:

Scientific name: *Empoasca fabae* (Harris), *Amrasca devastans* (Distant)

Family: Cicadellidae **Order:** Hemiptera

Host plants. Potato leafhopper is a polyphagous pest and primarily a pest of potatoes but can also attack brinjal, chilli, pepper, cowpea, tomato, beans, peanuts, and woody ornamentals, apples, grapes, castor and alfalfa.

Marks of identification:

- The adults are pale green and marked with a row of white spots on the anterior margins of the pronotum.

Life history:

- Females insert 200-300 transparent to pale yellow eggs into the veins and petioles of leaves with an average incubation period of 10 days.
- The nymphal and adult developmental periods are 15 and 30-60 days respectively.
- Leafhoppers could complete two generations on potato in a year.

Nature of damage:

- Both nymphs and adults suck sap from lower side of the leaves causing extensive damage by direct feeding on the plants
- There is yellowing, browning, cupping, curling, stunting and dwarfing of leaves which can be easily identified in the form of triangular mark of burn at the tip of the leaf.
- In potato, the leaf veins turn yellow, the leaf margins turn brown and brittle followed by drying of entire leaf.
- The severely infested field gives a burnt like appearance in a circular ring commonly known as "hopper burn".

Management:

- Judicious use of nitrogenous fertilizers and balanced plant nutrition checks the hopper multiplication.
- In seed crop, granular systemic insecticide, Phorate 10G@) 10kg/ ha can be applied at the time of planting or earthing up. This is followed by application of oxydemeton methyl 25 EC @ 1 ml/ litre or dimethoate 30EC @ 2 ml/litre.

5. CUTWORMS *Agrotis ipsilon* (Noctuidae: Lepidoptera)

Host plant: Being polyphagous, it feeds on a variety of crops, viz. pulses, vegetables, cereals, oilseeds, several weeds and many other agricultural and horticultural crops.

Marks of identification:

- Adults are medium to heavy bodied moths. *A. ipsilon* moth is dark brown to greyish brown with large areas of black on the forewings and thorax.
- Young larva is yellow in colour. The full-grown larva is dark or dark brown with a plump and greasy body

Life history:

- On an average, each female moth deposits 300 eggs in clusters of 15-35 each on the underside of the leaves or on the soil.
- The eggs, creamy white in colour and dome-shaped, hatch out in 12-13 days.
- There are five instars and full grown final instar caterpillars may be up to 50 mm long.
- The larval period lasts for about 12-35 days.
- Full grown caterpillars form earthen cocoon in the soil and pupate in them for about 10 days in summer and 30 days in winter.
- The total life cycle is usually completed in 45 to 75 days.

Nature of damage:

- Crop damage is caused by the caterpillars only. They feed at night on young shoot or underground tubers.
- In the early stages of the crop, the caterpillars cut the stem of the young plants near the ground and feed on the shoots and leaves.
- After tuberization, they feed by boring and nibbling into the tubers affecting both tuber yield and its market value.

Management:

- Hot weather ploughing in plains and autumn ploughing in hills reduce the population of immature stages.
- A number of birds, such as crow, mynah, starling etc. feed on insects that get exposed upon ploughing.
- Set up light trap @ 1/ ha. Pheromone traps @ 12/ ha to attract male moths
- Apply methyl parathion @ 25kg/ ha in soil before planting of the potato.
- Spray insecticides like chlorpyrifos 20EC @ 1 lit/ha or neem oil @ 3%.

❖ PEST OF SWEET POTATO

1. SWEET POTATO WEEVIL:

Scientific name: *Cylas formicarius*(Fabricicus)

Family: Apionidae **Order:** Coleoptera

Distribution: This weevil is a serious pest of sweet potato in India.

Host plant: Sweet potato.

Marks of identification:

- The adult weevils are small, 5.0-6.5 mm in length, bluish black in colour, with reddish brown prothorax and a long snout.
- The apodous grub is whitish with a brown head and is 8.22 mm long.

Life history:

- The female weevil lays 97-216 eggs in cavities made on the vines or the tubers.
- The eggs hatch in 3-7 days.
The larval development is completed in 21-26 days.
- The pupation also takes place either in the vine or in the tuber.
- The pupal stage lasts 7-11 days and the life-cycle is completed in 36-43 days. More than one generation are completed in a year.

Nature of damage:

- The weevils feed on leaves, vines and tubers, whereas the grubs bore into tender vines and tubers, making the latter unfit for marketing and consumption, Up to 60 per cent damage may be caused by the pest.

Management:

- No infested or rotting tuber should be left in the field after harvest of the crop,
- Remove previous sweet potato crop residues and alternate host, *Ipomoea* sp. and destroy them.
- Discourage growing sweet potato in the same field year after year.
- Use pest free planting materials
- Mulch with leaves of *Chromolaena doormats*, *Clerodendron fortuneatum* at 3 tonnes/ha at 30 days after planting (DAP)
- Use cut sweet potato tubers (100 g) as trap during 50-80 DAP at 10 days intervals.
- Set the traps at 5 m apart at 4 pm and collect and destroy adult weevils at 6 am next day
- Rake up soil and earth up at 50 days after planting
- Harvest immediately after maturity and destroy the crop residues.
- In godowns, treat the bag surface with malathion 5% or carbaryl 5 % dust.

- Spray 2.5 kg of carbaryl 50WP followed by 2.0 litres of malathion] 50EC in 625 litres of water per ha.

2. HAIRY CATERPILLAR: *Cretonotus gangis* (Arctiidae: Lepidoptera)

Distribution and status: Sporadic pest in sweet potato growing region in India

Host range: Polyphagous pest Lucerne, rice, maize, grasses, coffee, groundnut, Johnson grass and also feeds on pastures.

Marks of identification:

- Caterpillars are cylindrical, slightly tapering posteriorly and dark violet to black in colour. Meso and Meta thorax are light golden-yellow and head black, hairy with characteristic yellow stripe dorsally.
- Adults have shiny black head. Fore wings are straw coloured with pinkish tinge and a transverse black band at the center. Hind wings are whitish with few black dots at the margin.

Life history :

- It appears in July and continues till November.
- Eggs are round in shape and shiny creamy yellow in colour. A female lays 285 to 695 eggs in clusters arranged in rows closely set together.
- Incubation period is 4-5 days, larval period 22-32 days, pupal period 5-7 days.
- Adult period 12 days.

Nature of damage:

- These hairy caterpillars scrap the under surface of the leaf when they are in neonate stage.
- Later the scrapped patches of the leaves looks like thin papery
- Full grown larvae devour the entire foliage, flowers and growing points.

Management:

- Collection and destruction of egg masses and hand picking of larvae
- The barnyard millet (*Echinochloa frumentacea*.) may act as strong barrier
- Summer ploughing and poison baiting.
- Erection of light traps soon after the monsoon for 20-45 days and collecting and killing of adult moths are found to be very effective.
- The dispersing larvae of hairy caterpillar from one field to another can be checked by digging trenches across the direction of their march, and prompt destruction of larvae.
- Vegetative traps utilizing *Jatropha* (wild castor) or *Ipomea* prevent the migration of the grown up larvae.
- Prepare small balls with 10 kg rice bran + 1 kg jaggery + 1 liter quinolphos broad-cast in the fields preferably in the evening times.

- Dusting of carbaryl or quinalphos @ 25-30 kg/ha would be effective in the control of young larvae.
- Use of 200 ml dichlorovos 100 EC dissolved in 400 litres of water/ha may be used to control grown up caterpillars. or
- Spray Quinalphos or dimethoate 2ml or monocrotophos 2 ml /lit of water.

3. TORTOISE BEETLES: *Aspidomorpha miliaris*, *Cassida circumdata*, *Chirida ipunctata*

Family : Cassididae **Order:** Coleoptera

Distribution : Throughout Africa, Southern China, Southeast Asia becomes serious occasionally.

Host : Sweetpotato, *Ipomoea triloba*, coffee, beet, potato and various flowers.

Mark of identification:

- *Aspidomorpha miliaris*: Adult: Broad oval shaped, brownish-red in colour with black dots . Grub: Flattened with spiny processes covering their body. Dried excreta are seen on the anal process
- *Cassida circumdata* : Adult: Broad oval shaped, greenish-yellow in colour with green crescent mark in middle. Grub : Pale greenish in colour
- *Chirida bipunctata* : Adult : Small metallic green in colour with six black spots on elytra Grub : Pale greenish in colour

Life history:

- These metallic coloured beetles are active during monsoon.
- Eggs are laid on ventral leaf surface. Grubs are nocturnal in habit.
- Egg, grub and pupal stages last for 9 to 11, 15 to 20 and 4 to 6 days respectively.
- Pupation takes place in ventral surface of leaves.
- Life cycle is completed in 28 to 36 days.

Nature of damage

- Skeletonization of leaves by grubs. Later grubs and adults gnaw holes in leaf lamina.
- Grubs are green, flat with anal projection always carry debris on its back.

Management

- Removal of convolvulaceous weeds in the surrounding area may reduce their numbers.
- Conserve or encourage larval parasitoids *Tetrastichus* sp, predator *Stalilia* sp., (Mantidae).
- Chemical control of this pest is seldom necessary.

4. LEAF FOLDER: *Brachmia convolvuli* (Gelechiidae: Lepidoptera)

Distribution : It is regarded as a pest of several *Ipomoea* species.

Host : *Ipomoea triloba* and *I. aquatic*, weed *Mikania cordata* (Asteraceae).

Mark of identification:

- Adult is a small slender moth and grayish-brown in colour.
- Full-grown larva is slightly flattened and tapering towards both ends. Head is reddish-brown, glossy and flattened; thorax and two abdominal segments are velvety black and other segments are yellowish-white with a velvety black band.

Life history:

- Adult lays eggs in small groups at the base of radiating veins on the underside of leaves.
- The eggs are oval, yellowish white when newly laid and turn pinkish yellow.
- Egg period three days.
- White neonate larva feeds on leaves and becomes full grown in 14 days undergoing five instars.
- It pupates within leaf fold in 7 days.

Nature of damage:

- Young larva scrapes the tender surface tissues of leaves remaining in thin webbings.
- Later on leaves folded longitudinally and green tissues eaten resulting in drying of leaves. Folds are usually single, but sometimes two folds are made, or two leaves are joined together.

Management

- Use of insect-free planting materials.
- Conserve ichneumonid parasite, *Macrocentrus* sp. that attacks young larvae when they have not yet folded the leaf margins.
- If level of infestation warrants the use of chemicals, then contact-systemic insecticides can be applied.
- Collect and destroy folded leaves along with egg clusters, larvae and pupae
- Spray dichlorvos 76 SC 660 ml or carbaryl 50 WP 1.0 kg or phosalone 35 EC 750 ml in 500 L water per ha to control widespread infestation

❖ PEST OF CRUCIFEROUS CROPS

1. DIAMONDBACK MOTH:

Scientific name: *Plutella xylostella* (Linnaeus)

Family: Yponomeutidae

Order: Lepidoptera

Distribution: This pest is distributed world wide

Host plants. This is a serious pest of cauliflower and cabbage, but also feeds on many other cruciferous, solanaceous and liliaceous plants.

Marks of identification:

- The moths measure about 8-12 mm in length and are brown or grey, with conspicuous white spots on the fore wings, which appear like diamond patterns when the wings lie flat over the body.
- When full-grown, the larvae measure about 8 mm in length and are pale yellowish green with fine black hair scattered all over the body.

Life history:

- Yellowish eggs of the size of pin-heads are laid singly or in batches of 1-40 on the underside of leaves.
- A female may lay 18-356 eggs in her life-time.
- The eggs hatch in 3-6 days. They become full-grown in 14-21 days.
- Before pupating, the larva constructs a barrel-shaped silken cocoon which is open at both ends and is attached to the leaf surface.
- The pupal stage lasts 4-5 days and the moths may live for as long as 20 days.
- The life-cycle is completed in 15-18 days during September-October and
- there are several generations in a year.

Nature of damage:

- The newly hatched caterpillars bore into the tissue from the underside of leaves and feed in these tunnels.
- Third and fourth instar larvae feed from the underside of leaves, leaving intact a parchment-like transparent cuticular layer on the dorsal surface.
- Central leaves of cabbage or cauliflower may be riddled and the vegetables rendered unfit for human consumption.

Management:

- Avoidance of early and late planting of the crops in endemic areas
- Intercropping with tomato or carrot. This will reduce the DBM infestation as well as favour its natural enemies
- Conservation of the larval parasitoids of *Cotesia plutellae*, *Diadegma semiothis*

- Spraying of *Bacillus thuringiensis* var *Kurstaki* @ 1 kg/ha at least twice during primordial stage at 10 days interval.
- Need based application of Chlorantraniliprole 18.5 SC @ 6.1 ml/l or Chlorfenapyr 10 SC @ 1.5-2 ml/l or Fipronil 5 SC @ 1.6-2 ml/l or Flubendiamide 20 WG @ 0.1 ml/l or Indoxacarb 14.5 SC @ 0.5 ml/l of water.

2.CRUCIFER LEAF-WEBBER:

Scientific name: *Crociodolomia binotalis* Zeller

Family: Pyralidae **Order:** Lepidoptera

Distribution: It is a serious pest of cruciferous plants in India, Myanmar, Lanka, Kenya and Uganda.

Hosts: Cabbage, radish, mustard and other cruciferous plants.

Marks of identification:

- Moths are light brown with a wingspan of about 2 cm.
- Caterpillars are dark green with a light brown head, and dark and yellowish white stripes on the body.
- When full-grown, the larva measures 1.6-2.0 cm in length.

Life history:

- The moth lays eggs on the underside of leaves in masses of 40-100 each.
- The eggs hatch in 5-15 days. The larval stage is completed in 24-27 days in the summer and about 50 days in winter.
- When, full-grown, the larva descends to the ground and pupates in the after making an earthen cocoon. The adult moth emerges in 14-40 days and
- the life cycle is completed in 43-82 days. More than one generation may be completed in the season

Nature of damage:

- In the early stages, the larvae feed gregariously on leaf parenchyma. As they grow, they spread out and start webbing the leaves and feeding on them.
- The caterpillars cause considerable damage to the crops by webbing the leaves together and feeding on them.
- They also feed on flower buds and bore into the pods.

Management:

- Remove and destroy the webbed leaves with larvae within,
- Spray 940ml of malathion 50EC or 320 ml of dichlorvos 100EC in 625 litres of water per ha.

3. CABBAGE CATERPILLAR:

Scientific name: *Pieris brassicae* (Linnaeus)

Family: Pieridae

Order: Lepidoptera

Distribution: The cabbage caterpillar is world-wide and is found

Hosts: It is a serious pest of cabbage, cauliflower, knol-khol and it may also attack turnip, radish, sarson, toria (*Brassica campestris*) and other cruciferous plant

Marks of identification:

- It is a large 5.6-6.6 cm white coloured butterfly with black wing tips and 2 prominent black spots on the fore wings of females alone.
- The young larvae are pale yellow, and become greenish yellow later on.
- The head is black and dorsum is marked with black spots.
- The body is decorated with short hair. When grown, they measure 4.0-5.0 cm in length.

.Life history:

- The butterflies lay, on an average, 164 yellowish conical eggs in cluster of 50-90 on the upper or the lower side of a leaf.
- The eggs hatch in 11-17 days in November- February and 3-7 days in March-May.
- The caterpillars feed gregariously during the early instars and disperse as they approach maturity.
- They pass through five stages and are full-fed in 15-22 days during March-April and 30-40 days during November- February.
- The larvae pupate at some distance from the food plants, often in barns or on trees.
- Pupal stage lasts 7.7-14.4 days in March-April and 20-28 days in November-February
- The butterflies live for 2.5-12.5 days and the pest breeds four times during October-April

Nature of damage:

- The caterpillars alone cause damage.
- The first instar caterpillars scrape the leaf surface, whereas the subsequent instars eat up leaves from the margin inwards, leaving intact the main veins.
- Often, entire plants are eaten up.

Management:

- During the early stage of the pest attack. Hand picking and destruction of the caterpillars
- Foliar spray of *Bacillus thuringiensis* var *Kurstaki* @ 1 kg/ha
- Foliar spray of Malathion 50 EC @ 2 ml/l or Cypermethrin 10 EC @ 1.5-2 ml/l of water is beneficial

4. CABBAGE BORER:

Scientific name: *Hellula undalis* (Fabricius)

Family: Pyralidae

Order: Lepidoptera

Distribution: The cabbage stem borer is one of the serious pests of cruciferous crops, having a worldwide occurrence.

Hosts: The larvae attack cabbage, cauliflower, radish, knol-khol and beet-root.

Marks of identification:

- The adult moth is slender, pale yellowish-brown, having grey wavy lines on the fore wings.
- The caterpillar (1.2-2.5 cm long) is creamy yellow with a pinkish tinge and has seven purplish brown longitudinal stripes.

Life history:

- The female moths lay eggs singly but more often in clusters, on the under surface of the leaves or some other parts of the plant.
- The eggs hatch in 2-3 days. The caterpillars feed in the heart of the cabbage and become full-grown in 7-12 days, after undergoing four moultings.
- The full-grown caterpillar spins a cocoon among the leaves touching the ground or even inside larval burrows.
- The pupal period is about 6 days and the life cycle is completed in 15-25 days.

Nature of damage:

- The caterpillars first mine into the leaves. Later on, they feed on the leaf surface, sheltered within the silken passages.
- As they grow bigger, they bore into the heads of cauliflower and cabbage.
- When the attack is heavy, the plants are riddled with worms and outwardly the heads look deformed.

Management:

- Collection and mechanical destruction of caterpillars in early stage of attack helps to check the infestation,
- Since the attack is mostly in the nursery and on young plants in the field, spray 375 g of carbaryl 50WP in 150 litres of water per ha. Repeat spray at 10-day interval, pick all flowering

5. CABBAGE SEMI-LOOPER:

Scientific name: *Thysanoplusia orichalcea* (Fabricius) and *Autographa nigrisigna* (Walker)

Family: Noctuidae

Order: Lepidoptera

Distribution. These two species are widely distributed in north-western India.

Hosts: They are minor pests of cabbage, cauliflower and other winter vegetables. They are polyphagous and attack a number of plants, including groundnut and sunflower

Marks of identification:

- The adults of *T. orichalcea* are light palish brown with a large dark patch on each fore wing. They measure about 4.2 cm across the spread wings.
- The adults of *A. nigrisigna* are darker and have dark-brown and dirty-white patches on the fore wings.
- The caterpillars are plump and palish green.

Life history:

- They lay eggs on leaves of host plants and the caterpillars feed individually, biting holes of varying size according to the stage of their development.
- When full-grown, they pupate in the debris lying on the ground.
- The moths are very active at dusk on flowers in gardens and public parks, where they are seen in hundreds during the spring season.

Nature of damage:

- The caterpillars cause damage by biting round holes into cabbage leaves.
- On walking, they form characteristic half-loops and are often seen mixed with cabbage caterpillars.

Management: Same as in case of cabbage caterpillar

6. CABBAGE FLEA BEETLES:

Scientific name: *Phyllotreta cruciferae* (Goeze),

Family: Chrysomelidae **Order:** Coleoptera

Hosts: The common field crops like mustard, raya, taramira, toria and vegetables like radish, turnip, cabbage, cauliflower and knol-khol are severely damaged by adult beetles. Some winter flowering plants, namely dahlia, sweet sultan, antirrhinum and sweet peas also provide food for the beetles.

Distribution: The cabbage flea beetles attack almost all the cruciferous plants in Europe, erstwhile USSR, North and South America, Australia, Japan and India.

Marks of identification:

- The dorsum of the adult beetle, *P. cruciferae*, is metallic blue in colour, with a greenish hue.
- The body is elongate narrow in front but broad distally.
- The beetle is round at the anal end. The head is finely punctate and the antennae extend beyond the middle of elytra.
- The larva is dirty white in colour with pale white head and measures about 5 mm in length.

Life history:

- The female beetle lays 50-80 creamy white eggs singly in the soil around the host plants,
- The incubation period ranges between 5-10 days.
- The larva is very active and feeds on the tender roots of the host plant.

- It moults thrice during a total larval period of 9-15 days.
- The larva before entering into the pre-pupal stage wriggles out of the mined roots and prepares an earthen cell, 0.5 mm long, in the vicinity of the infested plants. There it pupates.
- The pre-pupal period is 2-4 days and the pupal stage lasts 8-14 days.
- There are 7-8 generations of this pest in a year.

Nature of damage:

- The adults mostly feed on the leaves by making innumerable round holes in the host plants.
- The stem, the flowers and even pods may also be attacked.
- The old, eaten away leaves dry up, while the young leaves are rendered unfit for consumption.
- A special kind of decaying odour is emitted by the cabbage plants attacked by this pest.

Management:

- Spray 2.5 kg of carbaryl 50WP in 250 litres of water per ha.

7. TOBACCO CATERPILLAR:

Scientific name: *Spodoptera litura* (Fabricius)

Family: Noctuidae

Order: Lepidoptera

Distribution: The tobacco caterpillar is found throughout the tropical and subtropical parts of the world. It is widespread in India

Hosts: Besides tobacco, it feeds on castor, groundnut, tomato, sunflower, cabbage and various other cruciferous crops.

Marks of identification:

- The moths are about 22 mm long and measure 40 mm across the spread wings.
- The fore wings have beautiful golden and greyish brown patterns.
- The caterpillars are velvety black with yellowish-green dorsal stripes and lateral white bands.

Life history:

- The female lays about 300 eggs in clusters. These clusters are covered over by brown hair and they hatch in about 3-5 days.
- Larva pass through 6 stages and are full-fed in 15-30 days.
- The full-grown larvae enter the soil where they pupate.
- The pupal stage lasts 7-15 days and the moths, on emergence, live for 7-10 days.
- The life-cycle is completed in 32-60 days and the pest completes eight generations in a year.

Nature of damage:

- The larvae feed on leaves and fresh growth. They are mostly active at night and cause extensive damage, particularly in tobacco nurseries.

Management:

Same as in case of cabbage caterpillar

8. CABBAGE APHID: *Brevicoryne brassicae*

Marks of Identification:

- Nymphs and adults yellowish green with wavy white filament over the body

Nature of Damage:

- Yellowing.
- Crinkling and cupping.
- Distorted primordial.
- Presence of white cast skin at the base of the plant.

Life cycle

- Aphids appear in November and remain active till April.
- A single female produces 5 to 10 young ones per day during February to May and 2 to 5 per day during July to January.
- Their activity goes down in extreme hot conditions of May-June.
- The life cycle is completed in 11 to 18 days during April to March.
- Under favorable conditions, 11 to 20 generations are completed in one year.
- A female produces on an average 7, 13 and 26 young ones during October to December, January to March and April to September, respectively.

Management:

- Destruction of infested foods with the appearance of the pest.
- Foliar spray of demeton-O- methyl 25 EC @ 300 g a.i./ha Or imidacloprid 0.005 %. Repetition of same at 15 days interval, if necessary.

9. MUSTARD APHID: *Lipaphis erysimi*

Marks of Identification:

- Aphids: Small, soft-bodied, pearl-shaped insects

Nature of Damage:

- Both nymph and adults suck the sap from leaves, buds and pods
- Curling of infested leaves and at advanced stage plants may wither and die
- Plants remain stunted and sooty molds grow on the honeydew excreted by the insects

Management:

- Set up yellow stick trap to monitor aphid population.
- Conserve the natural enemies viz., *Cocciniella septempunctata*, *Menochilus sexmaculata*,
- Spray dimethoate @ 2 ml /lit

❖ PEST OF CUCURBITACEOUS VEGETABLES

1. MELON FRUIT FLY:

Scientific name: *Bactrocera cucurbitae* (Coquillett)

Family: Tephritidae

Order: Diptera

Distribution: This is the commonest and most destructive fruit fly of cucurbits [throughout India. It is also found in Pakistan, Myanmar, Malaysia, China, Taiwan, Japan, East Africa, Australia and the Hawaiian Islands.

Host plants: In addition to melons, it has been found feeding on tomato, chillies, guava, citrus, pear, fig, cauliflower, etc.

Marks of identification:

- Adults are reddish brown with lemon yellow markings on thorax with spotted wings.
- The maggots are legless and appear as headless, dirty-white wriggling creatures, thicker at one end and tapering to a point at the other.
- A full-grown maggot is 9-10 mm long and 2 mm broad in the middle.

Life history:

- The adult females puncture fruits by its ovipositor to lay eggs, singly or in clusters of 5-12, inside the pulp.
- The eggs hatch in 1-9 days and the maggots bore the pulp, forming galleries.
- The attacked fruits decay because of secondary bacterial infection.
- The larvae are full-grown in 3 days during summer and 3 weeks during winter.
- The mature larvae come out of the rotten fruits and move away in jumps of 12-20 cm.
- After reaching a suitable place, they bury themselves about 5 mm deep in the soil and pupate.
- The pupae are barrel-shaped, light brown and they transform themselves into winged adults in 6-9 days in the rainy season and 3-4 weeks in the winter.
- There are several generations in a year.

Nature of damage:

- The maggots destroy fruits by feeding on the pulp.
- The damage caused by this fruit fly is most serious in melons and after the first shower of the monsoon,
- The infestation often reaches 100 per cent. Other cucurbitaceous fruits may also be infested up to 50 per cent

Management:

- Deep ploughing during summer and after the harvest of the crops
- Raking the soil around the vines
- The infested fruits to be collected and destroyed.

- Application of bait containing 10% molasses or jaggary along with Carbarvl 50 WP @ 2 g/l or Malathion 50 EC @ 2 ml/l of water. Such bait has to be installed 250 spots/ha. Spray at 4-5 days interval during reproductive stage
- During reproductive stage Install a cue lure trap @ 25-30 traps/ha
- Installation of cue-lure baited bottle trap at the middle of two sub-plots in the central row and bait spray @ molasses 10% + malathion 50 EC (0.2%) at 6 spots in two border rows in four corners at 5 days interval from flowering.

2. RED PUMPKIN BEETLE:

Scientific name: *Aulacophora foveicollis*(Lucas)

Family: Chrysomelidae **Order:** Coleoptera

Distribution: The red pumpkin beetle, is widely distributed in Asia, Australia, southern Europe and Africa.

Hosts: It is a serious pest of cucurbitaceous vegetables such as ash gourd, pumpkin, *tinda*, *ghia*, *tori*, cucumber and melon.

Marks of identification:

- The adult beetles are 6-7 mm long brilliant orange red and ventral surface is black, being clothed in short white hair.
- The grubs are creamy white, with a slightly darker oval shield at the back.

Life history:

- The beetles in their life span of 60-85 days lay about 300 oval yellow eggs singly or in batches of 8-9 in moist soil, near the base of the plants.
- The eggs hatch in 6-15 days and the grubs remain below the soil surface feeding on roots, underground stems of creepers and on fruits lying in contact with the soil.
- They are full-grown in 13-25 days and pupate in thick-walled earthen chambers in the soil, at a depth of about 20-25 cm. The pupal stage lasts 7-17 days and the beetles, on emergence, begin to feed and breed.
- The life-cycle is completed in 26-37 days and the pest breeds five times from March to October.

Nature of damage:

- The beetles are very destructive to cucurbitaceous vegetables, particularly during March-April when the creepers are very young.
- The grubs damage the plants by boring into the roots, underground stems and sometime into the fruits touching the soil.
- The beetles injure the cotyledons, flowers and foliage by biting holes into them.
- The early sown cucurbits are so severely damaged that they have to be resown.

Management:

- Deep ploughing during summer months after the harvest of the crops
- Seed treatment with thiamethoxam @ 3 g/kg seed followed by 3 sprays of NSKE 4% at 10 days interval from 20 DAS
- Dusting of Carbaryl 80 WP @ 1 kg ai/ha (during cotyledonous stage) or spraying of Dichlorvos 76 EC @ 1-1.5 ml/l of water.

3. SNAKE GOURD SEMILOOPER

Scientific name: *Anadevidia peponis* (F.)

Family: Noctuidae

Order: Lepidoptera

Distribution: The cabbage caterpillar is world-wide and is found **wb**— cruciferous vegetables are grown.

Hosts: It is a serious pest of cabbage, cauliflower, knol-khol and it may also attack turnip, radish, sarson, toria (*Brassica campestris*) and other cruciferous plant

Marks of identification:

- The brownish moth has shiny brown fore wings. The semilooper caterpillar with humped last abdominal segment measures 35-40 mm long. Its body is greenish with white longitudinal lines and black tubercles with thin hairs arising on them.

Life history:

- The female moth lays the white spherical eggs on the under surface of leaves. It pupates in a thin silken cocoon in leaf fold. Its life history occupies about a month

Nature of damage:

- It is a specific snake gourd and the larvae defoliate the plants considerably, if infestation is serious.

Management:

- The larvae when found in small numbers may be hand picked-and destroyed.
- Spray application of methyl parathion 0.05% controls the pest.

4. PUMPKIN CATERPILLAR

Scientific name: *Cryptographis indica* (Saunders)

Family: Crambidae

Order: Lepidoptera

Marks of identification:

- The adult moth is medium sized, wings being white with brown border and the abdomen of female bearing a tuft of orange hairs at tip.

Nature of damage:

- The caterpillars feed on flowers, leaves and fruits and cause considerable loss in yield

Management:

- Collection and destruction of the larvae
- Mynah (*Acridotherestrictis* L.) and cattle egret (*Bubulcus ibis* L.) are predaceous on larvae
- Spraying of *Btvar Kursiaki* @ 1 kg/ha

5. POINTED GOURD VINE BORER :

Scientific name: *Apomecyna saltator* Fabricius

Family: Cerambycidae **Order:** Coleoptera

Marks of identification:

- The adults always remained in hidden places and were less active.
- Females were brown and bigger in size, whereas males were black and small in size.
- The elytra covered the body and having seven white spots closely packed at two places with an appearance of triangular shape.
- Cream-coloured grubs

Life history:

- The egg was laid singly, 1 to 2 mm below the bark of vines, near the nodes.
- The freshly laid egg was smooth and whitish in colour but after four days turned yellow in colour.
- Average incubation period were 6.50 ± 1.15 days
- The larval stage passed through six instars.
- The average total larval period was 32.16 ± 3.36 days.
- Pupation took place in tunnel made by larva in the vine.
- Average pupal period was 8.44 ± 1.16 days.

Nature of damage:

- Borer first started its damage at nodal region and then larva bored into the main vines of plants causing swelling, oozing of sap and tunneling which became filled with glutinous waste material.
- Young plants died due to severe infestation

Management:

- Apply carbofuran 3 G @ 0.50 kg a.i./ha 3 MAP
- carbaryl 50 % W.D.P . paste @ 0.1 % three applications at an interval of 1 month starting from 3 MAP followed by the treatments of carbofuran 3 G @ 0.50 kg a .i./ha or chlorpyrifos 20 EC brushing @ 0.1 % 3 applications at an interval of 1 months starting from 3 MAP (19 .97 %).

6. STEM GALL FLY: *Neolasioptera falcata* (Cecidomyiidae: Diptera)

- Maggot feeds within distal stems of bitter-gourd, ribbed and smooth gourds causing formation of elongated galls in between nodes. Gall formation causes stunting of plants.
- Remove and destroy the affected shoots in the early stages of infestation.

7. STEM BORER /CLEAR WINGED MOTH: *Melittia eurytion* (Aegeriidae: Lepidoptera)

- It is a pest of snake gourd and occurs widely in India.
- Moth is clear winged with fan like tufts of hairs on hind legs.
- White larvae bore into the stems producing galls. Frass comes out of the gall through a hole made on it.
- Plants stunted with poor foliage. Pupal period 20-24 days in earthen cocoon in soil.

Management:

- Collect and destroy the damaged plant parts with larvae.
- Encourage activity of parasitoid: *Apanteles* spp.
- Spray any following insecticides malathion 50 EC @ 500 ml, dimethoate 30EC 500 ml, methyl demeton 25 EC @ 500 ml/ ha

8. LEAF MINER: *Liriomyza trifolii* (Agromyzidae: Diptera)

Refer Tomato

Management

- Two sprays, first at 40 days after sowing and second at 15 days after first spray of deltamethrin 2.8 EC, 0.0028% (10 ml/10 l water) or flonicamid 50 WG, 0.015% (3 g/10 l water)

❖ PEST OF LEGUMINOUS VEGETABLES

1. PEA LEAF MINER: *Chromatomyia horticola* (Goureau)

Family: Agromyzidae **Order:** Diptera

Hosts: Highly polyphagous pests, leguminous vegetables including beans.

Distribution: Widely distributed

Marks of identification:

- Larva is pale yellowish-brown with a series of lateral and sub-lateral black spots and specks.
- Flies are yellowish-brown, forewings have reddish-brown distinct and in distinct wavy lines and prominent White spots. There is black tuft of hairs nearer to thorax. Hind wings are white with dark brown apical area.

Life cycle:

- Female lays eggs singly in leaf issue and incubation period is about 2 - 3 days.

- Larval period is about 5 days. Pupated within the gallery and pupal period is completed in 6 days.
- The adult period lasts for 5 - 6 days.
- The insect completes one generation in about 13-15 days and passes through several generations during its activity period.

Nature of damage: .

- Maggot is the damaging stage. Maggot feeds between the lower and upper epidermis by making prominent whitish zig-zag tunnels. If the attacked leaf is held against bright sunlight, minute slender maggot can be seen feeding within the tunnels.
- The large number of tunnels interfere with photosynthesis and proper growth of the plants, making them unattractive.

Management:

- Remove infected plant material
- Remove the plant debris/ weeds
- Clipping of infested leaves in the initial stage of the crop.
- Install yellow sticky trap @ 1/ 10 hills after germination in cucumber.
- Use mosquito net in the nursery stage to protect the seedlings from egg laying of female.
- Biological control : Parasitic wasp, *Diglyphus isaea* & *Dacnusa sibirica*
- Apply 1.0 to 1.75 kg fine ash of *Lantana camara* per 200 sq.m. plot.
- Spraying of Neem seed kernel extract (NSKE) 5% for the management of leaf miner.
- Spraying of spinosad 45 SC 3 ml/ 10 litre of water along with 400 g jiggery, first at appearance of the pest and subsequent two sprays at 15 days interval.

2. PEA STEM FLY: *Ophiomyia phaseoli* (Iryon)

Family: Agromyzidae **Order:** Diptera

Marks of identification:

- The larvae (maggots) are creamy with dark mouthparts and reach 3 mm in length.
- Pupae are small, brown and cylindrical with rounded ends.
- Adults are small about 3 mm long and shiny black with clear wings.

Life cycle:

- The eggs are mainly laid into the leaves, in younger plants preferably into cotyledons.
- The egg period is about 2 - 3 days.
- The larva period is about 7 - 10 days.
- Pupation takes place inside the stem near the soil surface.
- Female adult lives for 10 days

Nature of damage:

- Larva (maggot) Is damaging the crop. On emergence of larva, first feed on leaf tissue then moves to the terminal stem.
- Maggot also bore into the stem thereby causing withering and ultimate drying of the affected shoot, thus reduce pod bearing capacity of plant.
- Adult is also damage leaf by puncturing it and injured parts turn yellow.
- Damage is more severe in on seedling than grown up plant.

Management:

- Remove and destroy all the affected branches during the initial stage of attack
- In case of wide spread incidence, spray the crop with diamethoate @ 0.03% or oxy- demeton methyl @ 0.025%
- Soil application of phorate 10G @ 10kg/ha is affective up to 40 days of sowing.

3. PEA POD BORER: *Etiellazinkenella* Treitschke

Family: Pyralidae **Order:** Lepidoptera

Hosts: Leguminous crops like pea, beans and pulses

Distribution: It is a cosmopolitan pest of worldwide distribution.

Marks of identification:

- The eggs are whitish and elliptical.
- The full grown larvae are pinkish with purplish tinge.
- The moths are grey in colour. Forewings have dark marginal lines and interspersed with scales. Hindwings are pale.

Life cycle:

- Moth lays eggs singly or in clusters on various parts of i.e. plant, including immature pods.
- The egg period is about 5 - 6 days.
- The larval period lasts for 7 - 10 days.
- The fully mature larva drop down and pupated in the soil and pupal period is about 10 days.
- The adult period is about 5-7 days.

Nature of damage:

- Newly emerged larvae feed on floral parts and subsequently they bore into the pods to feed on the seeds.

4. LEGUME POD BORER: *Maruca vitrata* (Geyer)

Family: Crambidae **Order:** Lepidoptera

Hosts: Pest infesting more than 40 host plants including cowpea, pigeonpea, and common bean

Distribution: World-wide distribution

Marks of identification:

- Larva is green with a brown head, short dark hairs and black warts on the body.
- Moths are medium sized with brownish black fore wings with conspicuous transverse white elongate marking, whereas, hind wings are translucent, pinkish white in colour.

Life cycle:

- Eggs are laid singly on the flowers, flower buds, pods, tender leaves and growing points.
- The egg hatches within 3-4 days and larval period lasts for 11-16 days.
- It pupates in the dry leaves or debris.

Nature of damage:

- Larva is damaging the crop. Larva damages flower and pods by webbing and feeding.
- The infested flowers do not develop into pods while pods become malformed.

Management:

- Spray of Neem seed kernel suspension @5% on initiation of the pest.
- Spraying of *Bacillus thurengiensis* var *Kursi* @ 1 kg/ha
- Spraying the crop with emamectin benzoate 5 SG @ 5 gm or indoxacarb 15.8 EC @ 15 ml or lambda cyhalothrin 5 EC @ 10 ml or spinosad 45 SC @ 1.5 ml or chlorantraniliprole 18.5 SC @ 3ml or flubendiamide 48 SC @ 2ml per 10 lit of water first at 50% flowering and second at 50 % pod formation stage

5. GRAM POD-BORER: *Helicoverpa armigera* (Hubner) (Lepidoptera : Noctuidae)**Marks of identification:**

- The moth is stoutly built and is yellowish brown.
- There is a dark speck and a dark area near the outer margin of each fore wing.
- The fore wings are marked with greyish wavy lines and black spots of varying size on the upper side and a black kidney shaped mark and a round spot on the underside.
- The hind wings are whitish and lighter in colour with a broad blackish band along the outer margin.
- The caterpillars are greenish with dark broken grey lines along the sides of the body.

Life-cycle.

- The females lay eggs singly on tender parts of the plants. A single female may lay as many as 741 eggs in 4 days.
- The eggs period is 4 to 6.
- Larval period is 13-19 days and
- The pupal period lasts 8-15 days.
- There may be as many as 8 generations in a year.

Nature of damage:

- Larva feed on the foliage, when young, and on the seed in later stages, and thus reduce yield.
- A single larva may destroy 30-40 pods before it reaches maturity

Management:

- Grow resistant varieties like, T 21, BDN 2, ICPL 332, ICPL 84060
- Install bird perches @ 50/ha to pick the larvae
- Set up pheromone traps @ 12 nos./ha
- The first spray of Neem Seed Kernel Extract @ 5% at flowering on 50% plants, second spray of HaNPV @ 250 LE/ha (1.5 x 1012 POB /ha) at pod formation on 50% plants and fenvalerate 20 EC @ 0.02% at 15 days after second spray.
- Spraying the crop with *Bacillus thuringiensis var. kurstaki* @ 20 gm per 10 liter water
- Spraying the crop with emamectin benzoate 5 SG @ 5 gm or indoxacarb 15.8 EC @ 15 ml or lambda cyhalothrin 5 EC @ 10 ml or spinosad 45 SC @ 1.5 ml or chlorantraniliprole 18.5 SC @ 3ml or flubendiamide 48 SC @ 2ml per 10 lit of water first at 50% flowering and second at 50 % pod formation stage

6. BLACK BEAN APHID, *Aphis craccivora* Koch.

- It is soft-bodied, black coloured sucking pest usually found in colonies on the growing points of the plants, tender fruits, flower buds etc.
- Both the nymphs and adults suck the sap from the plants and cause stunted growth of the plants and seeds shrivelled in the developing pods.
- They also produce copious amount of honeydew deposited on the plants and develop the sooty mould which hinder the photosynthetic activity of the plants.
- Beside these, they also transmit the viral diseases like bean yellow mosaic virus, bean common mosaic virus, etc.
- Reproduction noticed throughout the year by means of parthenogenesis.
- They are often attended by the symbiotic ants which favour them for dispersal and protection against natural enemies.
- Total life cycle completes in 9-13 days depending on the weather conditions.

Management:

- Collection and destruction of the infested shoots, buds, pods etc.
- Foliar spray of Oxvdemeton - methyl 25 EC @ 2 mM of water or Imidacloprid 17.8 SL @ 0.35 ml/t of water. If required second spray may be done after 15 days.

❖ PESTS OF AMARANTHUS

1. AMARANTHUS WEEVIL:

Scientific name: *Hypolixus truncatulus*

Family: Curculionidae **Order:** Coleoptera

Distribution: Widely distributed in India and neighbouring countries. It attacks both wild and cultivated crops and leafy vegetables with large leaves.

Marks of identification:

- Egg are Smooth, oval, pale yellow in colour, laid singly in stem.
- Grub are stout, curved, legless and white in colour whereas
- Adults are ash grey in colour with brown elytra and has a very long snout

Life history:

- Females lay eggs singly in each hole and cover holes with secretion.
- A female lays 30-34 smooth, oval and pale yellow eggs, egg period 4 to 10 days.
- A single stem contains 17-20 grubs in it. Grub stage lasts for 12 - 24 days.
- Full-fed grubs form a greyish-brown hard compact gall like chamber and pupate therein.
- On emergence, they remain inside the stem for 5 to 6 days, then cut epidermal membrane and emerge out.

Nature of damage:

- Grubs bite into stems, feed on pith region making irregular zigzag tunnels and fill with excreta.
- Stems split longitudinally. Plants dry completely.
- Adult feeds on tender leaves, makes circular holes in stems, branches and mid-ribs.
- Attack causes stunting of plants, twisting and swelling of branches and stem and suppression of shoot and leaf production.

Management:

- Collect and destroy wild amaranthus hosts in the vicinity of cultivated crop
- Collect and destroy affected plant parts along with grubs and adults
- Spray malathion 50 EC 2 ml/lit after the harvest of leaf

2. AMARANTHUS CATERPILLAR OR WEBBER :

Family: Pyraustidae **Order:** Lepidoptera

Scientific name: *Hymenia recurvalis*

Host: Amaranthus, beans, melons, spinach, coleus, *Luffa* spp., grasslands and pastures

Marks of identification:

- Larva is greenish with white lines and black crescents on thorax below the lateral lines.

- Adults are small, black coloured, moth with slender body. Wings dark brown in colour with white wavy markings

Life history:

- Spherical snow white eggs laid singly or in batches of 2 to 5, in grooves of leaf veins. Fecundity is 50 to 80 eggs.
- Fully fed, caterpillars drop down and pupate in soil.
- Incubation, caterpillar and pupal periods last for 3 to 4, 12 to 16 and 8 to 12 days respectively.
- Life cycle is completed in 3 to 4 weeks.

Nature of damage:

- Larvae scrape the epidermal and palisade tissues of leaves; web the leaves with silken threads resulting in drying of webbed leaves.

Management:

- Collect and destroy affected plant parts with caterpillars
- Set up light trap @1/ha to attract and kill the adults
- Spray malathion 50 EC 500 ml or dichlorvos 375 ml in 500 L of water per ha after the harvest of leaves and stems. Plan next harvest 15-20 days later

3. LEAF WEBBER:

Family: Heliodinidae **Order:** Lepidoptera

Scientific name: *Eretmocera impactella*

Marks of identification:

- Full-grown caterpillars are cylindrical, brownish yellow to brownish-grey in colour with a broad sub median dark stripe and black tubercles bearing several divergent longitudinal hairs.
- Moths are small, blackish with prominent yellow spots on fore wings.

Life history:

- Eggs are laid on leaves or on top shoots.
- Long brown pupae in white silken cocoons remain attached to leaves.
- Life cycle is completed in 3 to 4 weeks.

Nature of damage:

- Caterpillars web leaves with white silken threads and remain hidden in folds feeding from inside.

Management:

- Collect and destroy affected plant parts with caterpillars
- Set up light trap @1/ha to attract and kill the adults
- Spray malathion 50 EC 500 ml or dichlorvos 375 ml in 500 L of water per ha after the harvest of leaves and stems. Plan next harvest 15-20 days later

4. LEAF WEBBER: *Psara basalis* (Pyraustidae: Lepidoptera)

- Its habits, symptoms of damage and life history are similar to that of *Hymenia recurvalis*.
- Full fed caterpillars are greenish in colour. Adults are small with yellowish, white thorax and abdomen with brownish red forewing and dark brown hind wing.

5. TORTOISE BEETLE: *Aspidomorpha exilis* (Cassididae: Coleoptera)

- Eggs are laid singly on ventral surface of leaves. Grubs and adults feed by scrapping outer tissues of leaves.
- Pupation takes place on leaf surface. Life cycle is completed in 15 to 30 days.

❖ PEST OF SPINACH

1. SPINACH CROWN MITE:

Scientific name: *Rhizoglyphus* sp (Sarcoptiformes: Acaridae)

Nature of damage:

- Crown mites may damage sprouting seeds, seedlings before or after emergence, or older plants. •
- They feed primarily on newly expanding leaves at the heart of the plant. •
- Their ability to injure the crop decreases as plants get larger and as plants grow rapidly. •
- The damage appears as deformed leaves or as small holes in expanding leaves.
- Vector for plant pathogens - Pythium sp and Rhizoctonia sp

Management:

- Numerous predatory mites prey on crown mites in the field.
- Destruction of harvested fields and good sanitation of fields before planting may reduce mite populations.
- Effectiveness of rotations with nonhost crops has not been studied.
- Treatments with azadirachtin are acceptable for use on organically grown produce.

2. APHIDS:

Scientific name: *Aphis gossypii* Glover (Hemiptera: Aphididae), *Myzus persicae*

Mark of identification:

- The green peach aphid is dark green to yellow and have no waxy covering.
- Potato aphids have both pink and green forms.
- This aphid is much bigger than the green peach aphid, and the adult has much longer cornicles.

Nature of damage:

- Infesting tender shoots and under surface of the leaves.
- Curling and crinkling of leaves
- Stunted growth
- Development of black sooty mould due to the excretion of honeydew

Management:

- Release 1st instar larvae of green lacewing bug (*Chrysoperla*) @ 4,000/acre.
- Use of yellow sticky trap
- Spraying with tobacco decoction (1 Kg tobacco boiled in 10 l of water for 30 minutes and making up to 30 l + 100 g soap).

3. LEAF MINER: *Liriomyza huidobrensis*, *L. sativae*, and *L. trifolii*

- Adults are small black and yellow flies.
- Females puncture the leaf to feed on plant sap and to lay eggs within the leaf tissue.
- Eggs hatch within 2 to 4 days and the small white to yellow larvae tunnel within the leaf tissue.
- Pupate in the soil or in the leaf axils on plants.

Nature of Damage

- Punctures caused by females during the feeding and oviposition processes can result in a stippled appearance on foliage, especially at the leaf tip and along the leaf margins.
- However, the major form of damage is the mining of leaves by larvae, which results in destruction of leaf mesophyll.
- The mine becomes noticeable about three to four days after oviposition and becomes larger in size as the larva matures.
- The pattern of mining is irregular; although tending to be blotch-like near the end of the mine.
- The shape is influenced by the plant, so is not a reliable indicator of species.
- Both leaf mining and stippling can greatly depress the level of photosynthesis in the plant.
- Extensive mining also causes premature leaf drop, which can result in lack of shading and sun scalding of fruit.
- Wounding of the foliage also allows entry of bacterial and fungal diseases.

Management

- Remove infected plant material
- Remove the plant debris/ weeds
- Clipping of infested leaves in the initial stage of the crop.
- Install yellow sticky trap @ 1/ 10 hills after germination in cucumber.

- Use mosquito net in the nursery stage to protect the seedlings from egg laying of female.
- Biological control : Parasitic wasp, *Diglyphus isaea* & *Dacnusa sibirica*
- Apply 1.0 to 1.75 kg fine ash of *Lantana camara* per 200 sq.m. plot.
- Spraying of Neem seed kernel extract (NSKE) 5% for the management of leaf miner.
- Spraying of spinosad 45 SC 3 ml/ 10 litre of water along with 400 g jiggery, first at appearance of the pest and subsequent two sprays at 15 days interval.

4. SEED CORN MAGGOT, *Delia platura*

- The adult is a small, gray fly with black legs and scattered bristles on its body.
- It is less than 1/4 inch long.
- The larva is a typical fly maggot; legless and tough skinned with a pointed head and a rounded tail.
- It is white to yellowish white and about 1/4 inch long when mature.
- Both adults and larvae are almost identical to those of the onion maggot.

Nature of Damage

- Seed corn maggots damage newly planted seeds by feeding on seed contents often leaving empty shells and resulting in poor germination.
- Seedlings which do emerge are tall and spindly with few leaves.
- They rarely mature or mature late because of poor seed quality.
- Occasionally, seed corn maggots tunnel in seedling roots or stems.
- Either type of feeding allows entry of disease causing organisms.
- Damage is most likely in cold, wet springs and on land high in organic matter.
- Damage to spinach is by feeding in the terminal leaf clusters.
- Feeding is often followed in 2 or 3 days by invasion of decay organisms which cause a black discoloration of the leaves.
- Plants are seldom killed but suffer moderate to serious reduction in weight and are often rendered unfit for use because of quality impairment and contamination.

Management:

- Seed treatment has been reported as the cheapest and most effective treatment for the control of seed corn maggots.
- Granular insecticide can also be used effectively for the control of these maggots

5. SPINACH FLEA BEETLE

- Most adult flea beetles are very small ranging in size from 1/16 –1/8th inch long.
- The spinach flea beetle, an exception to this, is ¼ inch long.
- They vary in color from black, bronze, bluish, or brown to metallic gray, while some species have stripes.
- All flea beetles have large back legs which they use for jumping, especially when disturbed.

Nature of Damage

- Adult flea beetles cause the most damage by feeding on foliage, cotyledons, and stems.
- As flea beetles feed, they create shallow pits and small rounded, irregular, holes (usually less than 1/8th inch) in the leaves, resulting in a shot hole appearance.
- The damage is unique and similar for nearly all species.
- A heavy flea beetle attack can result in wilted or stunted plants.
- Transplants can generally withstand more damage than plants started from seed, although both can be severely injured if flea beetle numbers are high.

Management

- Proper weed control in and around planting sites.
- Remove old crop debris and other surface trash to deprive overwintering beetles of protective cover.
- If possible, plant crops as late as possible, when warmer temperatures will help plants outgrow flea beetle feeding damage.
- Floating row covers or other screening can exclude the beetles during seedling establishment. However, remove row covers before the flowering stage to allow pollinating insects access to the plants.
- Planting a trap crop may be successful in some situations. Plant a highly favored crop (e.g. radish) before you plant your main crop, in an effort to attract flea beetles away from the main crop.
- Spray Carbaryl, Malathion and Spinosad

❖ PEST OF YAM

1. MEALYBUGS *Rastrococcus* spp.

- Insects have a wide host range; often tended by ants which farm them for their sugary honeydew secretions.
- Flattened oval to round disc-like insect covered in waxy substance on tree branches; insects attract ants which may also be present; insect colony may also be associated with growth of sooty mold due to fungal colonization of sugary honeydew excreted by the insect

Management:

- Prune out heavily infested branches; mealybugs can potentially be controlled by natural enemies;
- chemical pesticides may decrease populations of natural enemies leading to mealybug outbreaks; horticultural oils or soapy solutions can be used to treat heavy infestations

2. WHITE SCALE INSECTS *Aspidiella hartii*

- The leaves and tubers are covered with small white scales from field to storage. Even though it won't effect yield sometimes foliage cause poor growth and tubers may show delay in germination or even stopped.
- Severe infestation may leads to tuber shrivel.

3. APHIDS: *Aphis gossypii*, *Pentalonia nigronervosa*

- Globular yellowish green to brown or black in colour.
- Aphids cause damage to young seedlings
- Nymph and adults suck the sap from leaves and stems of young vines.
- As a result, new growth is adversely affected.

Management

- Spray neem oil 0.5% (or) NSKE 5%.
- Conserve natural enemies like parasitoids and predators

4. RED SPIDER MITE: *Tetranychus sp*

- Nymphs and adults are red in colour.
- Eggs are laid on the ventral surface of the leaves and are whitish, spherical in shape
- Red spider mites are found to infest laminary base adjoining petiole
- Development of necrotic areas on the upper surface of the leaf lamina
- Feeding injury predisposes the plant for fungal infection in *D. floribunda* and *D. composita*.

Management

- Spray wettable sulphur 50 WP 2g/lit

5. YAM BEETLE, *Heteroligus meles* (Billberger) (Coleoptera: Dynastidae),

- Adult is about 23-33 mm in length, brown to black colour usually oviposite in moist and damp site
- Yam setts are attacked by the adults of *H. meles* shortly after planting.

- *H. meles* also feeds on tubers, making holes of 1–2 cm diameter prior to harvest, resulting in a low market value and a predisposition to fungal and bacterial infections in the field and during storage.
- Carbofuran 3G (at 47 kg/ha) applied at the time of planting significantly reduced the amount of damage by *H. meles*

❖ PEST OF COLACASIA

1. FLEA BEETLE: *Monolepta signata* (Alticidae: Coleoptera)

- Polyphagous pest, wide range of host plants like beet root, cabbage, cauliflower, chilli and radish.
- Adult is 3-4 mm long, reddish brown elytra with two big white spots on each elytron.
- Bite holes on leaves. In severe cases tuber development affected.
- Spray carbaryl 50 WP 1.0 Kg in 500 L of water per ha

2. HAIRY CATERPILLAR: *Pericallia ricini* (Arctiidae: Lepidoptera)

- The larva is robust, greyish black or blackish brown larva with red head and thick tuft of hairs arising from the body.
- The adult is greyish brown or black colour and black spots on wings. Hind wings are pink or red colour with black spots.
- The damage is caused by caterpillar. It feeds on leaves resulting in defoliation. Larvae nocturnal and feed voraciously at night.
- Spray malathion 50 EC 1.0 L or carbaryl 1.0 kg in 500 L per ha

3. SPHINX CATERPILLAR: *Theretra gnoma* (Sphingidae: Lepidoptera)

- Larva 80-85 mm long with green head and yellowish green body speckled with dark greensripes.
- Adult has greenish brown head and thorax with a white lateral stripe; abdomen brown with a black dorsal patch. Forewings are brown with one discal line parallel to outer margin. Hind wings are black.
- Caterpillars feed on leaves gregariously and cause defoliation.
- Hand picking and destruction of caterpillars in initial stage of attack. Spray carbaryl 50 WP 1.0 kg in 500 L water per ha

4. THRIPS: *Heliothrips haemorrhoidalis* (Thripidae, Thysanoptera)

- Silvery white patches and faecal globules on leaves. Nymph: Freshly hatched whitish; fully grown greenish brown. Adult: Dark brown.

❖ PEST OF MORINGA

1. POD FLY: *Gitona distigma* (Drosophilidae: Diptera)

Distribution: Serious pest of moringa in South India.

Host: Moringa

Mark of identification

- Adult is a small yellowish fly with red eyes. Wings extend beyond body and have a dark spot near the coastal margin.
- Full-grown maggots are cream coloured

Life history

- Activity is maximum from April to October and declines thereafter.
- Cigar shaped, sculptured and white coloured eggs are laid on the grooves of tender pod either singly or in groups of 3-4.
- Egg period 3-4 days, maggot period 18-25 days.
- Full-grown cream coloured maggots pupate in soil for 5-9 days.

Nature of damage

- Maggots enter into tender fruits by making small-bore holes at the terminal end.
- This causes oozing out of gummy fluid from fruits, which ultimately results in the drying of fruits from tip upwards.
- A maximum of 20-28 maggots are found in a fruit. Internal contents of the fruits rot.

Management

- As moringa pod flies are not attracted to methyl eugenol and fish meal, use attractants like citronella oil, eucalyptus oil, vinegar (acetic acid), dextrose or lactic acid to trap flies.
- Periodically collect and destroy all the fallen and damaged fruits by dumping in a pit and covering with a thick layer of soil to prevent carry-over of the pest.
- Frequently rake up the soil under the trees or plough the infested field to destroy puparia and a drench NSKE 5% at 2 L/tree at 50% fruit set.
- Spray dichlorvos 76 SC 500 ml or malathion 50 EC 750 ml in 500 - 750 ml of water per ha when pods are 20-30 days old and apply Azadirachtin 0.03 % 1.0 L during 50% fruit set and 35 days later.

2. BUD WORM: *Noorda moringae* (Pyraustidae: Lepidoptera)

Distribution: Major pest in South India

Host: Moringa

Mark of identification

- Adult is small in size with dark brown fore wings and white hind wings with dark brown border.
- Caterpillars are dirty brown with a prominent mid-dorsal stripe and black head and prothoracic shield.

Life history

- Adult lays oval, creamy white eggs in clusters or singly on flower buds.
- Full-fed caterpillars pupate in minute brownish cocoons, either in soil or on ground itself, below dried leaves and debris.
- Egg, larval and pupal periods occupy respectively 3-4, 8-16 and 6- 10 days.

Nature of damage

- Larvae bore into flower buds and cause shedding of buds up to 75%. Generally, infested buds contain only one caterpillar.
- Damaged buds seldom blossom; fall down prematurely. Activity is more during summer months in South India.

Management

- Plough around trees to expose and kill pupae
- Collect and destroy damaged buds along with caterpillars
- Use light traps to attract and kill adults @ 1-2 /ha
- Spray carbaryl 50 WP 1.0 kg or malathion 1.0 L in 500 - 750 ml of water per ha.

3. LEAF CATERPILLAR: *Noorda blitealis* (Pyraustidae: Lepidoptera)

Distribution: It is a sporadically serious pest of drumstick trees especially in South India.

Host range: Moringa

Marks of identification

- Adults are medium sized moths. Fore wings are uniformly dark in colour with a small white streak near the base. Hind wings are hyaline with broad black marginal band towards anal side.

Life history

- Eggs are laid in batches usually on ventral surface of leaves.
- Egg, larval and pupal durations last for 3, 7 to 15 and 6 to 9 days respectively.
- Pupation in soil.

Nature of damage:

- Caterpillars feed on leaf lamina, turning them into transparent parchment like structures.
- Peak period of infestation is during March to April and December to January.

4. HAIRY CATERPILLARS**a. *Eupterote mollifera* (Eupterotidae: Lepidoptera)****Mark of identification**

- Adults are large-sized moths with light yellowish-brown wings having faint lines.
- Full-grown caterpillars are brownish in colour and densely hairy. Hairs are irritating to touch.

Life history

- Moths appear with onset of monsoon and lay eggs in clusters on leaves and tender stems.
- Egg period lasts for 6 days.
- Larval and pupal periods last for 12 to 14 and 8 to 10 weeks respectively.
- Pupation takes place in soil. Only one generation/year.

Nature of damage

- Caterpillars feed gregariously by scraping bark and gnawing foliage.
- Severe infestation results in complete defoliation of the tree.

Management

- Collect and destroy egg masses and caterpillars
- Use light traps to attract and kill adults immediately after rains
- Spray chlorpyrifos 20 EC or quinalphos 25 EC 1.0 L in 500 -750 L of water per ha or fish oil rosin soap 25 g/L on the trunks and foliage, immediately after rain and 15 days later
- Spray chlorantraniliprole 18.5% SC, 0.006% (3.00 ml/10 litre water, 30 g a.i./ha) or emamectin benzoate 5% SG, 0.0019% (3.80 g/10 litre water, 9.50 g a.i./ha), first at appearance of pest and second after 15 days

b. *Metanastria hyrtaca* (Lasiocampidae: Lepidoptera)

Host range: Polyphagous pest and prefers several Citrus species.

Mark of identification

- Full-grown caterpillars are cylindrical in shape, greyish-brown in colour, stout and hairy.
- Stout, greyish-brown moths adults exhibit sexual dimorphism.
- Male moths have pectinate antennae and chocolate- brown patch in the middle of forewings.

Life history

- Eggs are spherical in shape and pale white in colour.
- Incubation, larval and pupal periods last for 9 to 12, 45 to 100 and 9 to 18 days respectively.
- Life cycle is completed in 75 to 110 days.

Damage symptoms

- Caterpillars are nocturnal in habit and feed gregariously and voraciously.
- During day, they remain crowded on shady side of tree trunks.

c. *Streblote (Taragama) siva* (Lasiocampidae: Lepidoptera)

Host range: Drumstick, rose (preferred host)

Mark of identification

- Full-grown caterpillars are pale ochreous–brown in colour with small black spots and long lateral tufts of ochreous hair.
- Moth has greyish-white head and thorax and whitish abdomen. Fore wings are beautifully coloured with reddish-brown spot ringed with white.
- Hind wings are white with slight fuscous on outer margin.

Management

- Collect and destroy caterpillars from the plants
- Use light traps to attract and kill adults
- Spray carbaryl 1.0 kg or malathion 50 EC 1.0 L in 500 -750 L of water per ha
- Spray chlorantraniliprole 18.5% SC, 0.006% (3.00 ml/10 litre water, 30 g a.i./ha) or emamectin benzoate 5% SG, 0.0019% (3.80 g/10 litre water, 9.50 g a.i./ha), first at appearance of pest and second after 15 days

5. LONG HORN BEETLES: *Batocera rubus* (Cerambycidae: Coleoptera)

Distribution: It is widely distributed all over the Indian sub-continent.

Mark of identification

- Grubs are stout, about 100 mm long, yellowish in colour with well-defined segmentation.
- Adults are medium sized beetles and yellowish–brown with white spots on elytra.

Life history

- Eggs are laid singly in cracks or crevices in the bark of the tree.
- Pupation takes place within the tunnels.
- Egg, grub and pupal periods last for 1 to 2, 24 to 28 and 12 to 24 weeks respectively. There is only one generation in a year.

Nature of damage

- Grubs make zig-zag burrow beneath the bark, feed on internal tissues, reach sapwood and cause death of affected branch or stem.
- Adults feed on the bark of young twigs and petioles

Management

- Clean affected portion of tree by removing all webbed material, excreta etc.
- Insert in each hole, cotton–wool soaked in monocrotophos 36 WSC 5 ml or any good fumigant like carbon disulphide, carbon tetrachloride, chloroform or even petrol and seal treated hole with mud.

❖ PEST OF CHILLIS

More than 20 insect species have been recorded attacking both leaves as well as fruits of chili. However, cotton whitefly and chili thrips cause considerable damage.

1. CHILLIES THRIPS

Scientific name: *Scirtothrips dorsalis* Hood

Family: *Thripidae*

Order: *Thysanoptera*

Distribution: The chillies thrips is a polyphagous pest and is widely distributed in India.

Hosts: It feeds on a number of plants including chillies, tomato, castor, sunflower, mango, cotton and citrus.

Marks of identification:

- The adults are slender, yellowish brown in colour, having apically pointed wings, and they measure about 1 mm in length.
- The females possess long, narrow wings with the fore margin fringed with long hairs.
- The nymphs resemble the adults in shape and colour but are wingless and smaller in size.

Life history:

- The female thrips lays 45-50 eggs inside the tissues of the leaves and shoots.
- The eggs hatch in 5 days.
- The larvae feed for 7-8 days and pupate in 2-4 days.
- The adult thrips lives for about 31 days.
- There are several over-lapping generations of this pest in a year.

Nature of damage:

- Damage is caused by the adults as well as by the nymphs.
- They suck the cell sap from tender regions and cause the leaves to shrivel.
- In case of severe infestation, there is malformation of leaves, buds and fruits, which may damage half the crop.
- The attacked plants are stunted and may finally dry up.
- The insect is also responsible for transmitting the virus causing leaf curl disease of chillies.

Management:

- Protection of the seedlings in the nursery with nylon net (200 mesh) for 25-30 days
- Seed treatment with imidacloprid 70 WS @ 7.5 g/kg of seed and before transplanting seedling should be dip for two hours in imidacloprid 17.8 SL @ 10 ml / 10 liter water or thiamethoxam 25 WG SL @ 10 ml / 10 liter water .
- Spray ready mix formulation of ethion 40 % + cypermethrin 5 % @ 0.045 % ordifenthion @ 0.05 % in addition to insecticides viz., imidacloprid @ 0.005 % and triazophos 0.04 % following ETL of 1 thrips per leaf or
- Alternate spray of triazophos @ 0.04 %, imidacloprid @ 0.005 % and acephate @ 0.075 % following ETL (1 thrips/leaf)

2. BROAD MITE:

Scientific name: *Polyphagotarsonemus latus* Banks

Family: Tarsonemidae

Order: Acarina

Marks of identification:

- They are white, transparent, very tiny, microscopic sized varies from 0.2- 0.25 mm

Life history:

- Each females lay around 20-25 eggs on the underside of leaves, tender stems, flowers and even on fruits.
- On chili, the developmental period from egg to adult is 3-4 days. Adult longevity is 10-15 days.

Nature of damage:

- It is a polyphagous, cosmopolitan, white, transparent, very tiny, microscopic mite and observed in large numbers on under surface of the leaves.
- Mostly mites are congregated towards terminal leaves of the plants.
- They suck the cell sap and cause typical " down ward curling" of the leaves like inverted boat and petiole elongation in older leaves.
- Edges of damaged young leave usually curl downward and the foliage often becomes rigid and appears bronzed or scorched.
- In severe infestation fruits become brownish with hard skin. Yield is drastically reduced.

Management:

- Immediately after infestation is noticed spraying of propergite 57 EC @ 3 ml/lit or spiromesifen 22.9 SC @ 1.5 ml/l or chlorfenapyr 10 SC @ 1.5-2" ml/l of water
- From transplanting onwards, seedling dip with Imidacloprid 1 ml and subsequent sprays of Buprofezin @ 1 ml/l, Fipronil @ 0.2 g/l, *Verticilliumlecanli*@ 5g/l, chlorfenapyr @ 1 ml/l and neem oil 1% from 25 DAT onwards at 10 days intervals each or

- Foliar application of milbectin 1 EC 0.0003%, 2.5 ml/ 10 liter water (1.25 g a.i./ha) or abamectin 1.9 EC, 0.0006%, 3 ml/10 litre water (2.85 g a.i./ha) found effective against thrips and mite infesting chilli.

3. FRUIT BORER: *Helicoverpa armigera*(Hub.)(Noctuidae : Lepidoptera)

Refer pest of tomato

4. WHITEFLY: *Bemisia tabaci*(Gennadius) (Hemiptera : Aleyrodidae)

Refer pest of tomato

5. STEM BORER: *Euzophera perticella* (Phycitidae: Lepidoptera)

Refer Brinjal

6. CUT WORM: *Agrotis ipsilon* (Noctuidae: Lepidoptera)

Refer Brinjal

❖ PEST OF ONION AND GARLIC

1. ONION THRIPS:

Scientific name: *Thrips tabaci*

Family: Thripidae

Order: Thysanoptera

Distribution. Onion thrips is world-wide and is found throughout India

Host plants. It is a major pest of onion and garlic. It also feeds on many other plants, including cotton, cabbage, cauliflower, potato, tobacco, tomato, cucumber, etc.

Marks of identification:

- The adults are slender, yellowish brown and measure about 1 mm length.
- The males are wingless whereas the females have long, narrow strap-like wings, which are furnished with long hair along the hind margins.
- Nymphs resemble adults but are wingless and slightly smaller.

Life history:

- The adult female lays 50-60 kidney-shaped eggs singly in slits which are made in leaf tissue with its sharp ovipositor.
- The eggs hatch in 4-9 days and the nymphs start feeding on plant juices by lacerating the leaf tissues.
- The nymphs pass through four stages and are full-fed in 4-6 days, after which they descend to the ground to pupate at a depth of about 25 mm.
- The pre-pupal and pupal stages last 1-2 and 2-4 days, respectively.
- Several generations are completed in a year.

Nature of damage:

- Both nymphs and adults suck plant sap and the leaves of attacked plants me curled, wrinkled and gradually dry up.
- The plants do not form bulbs nor do the flower set seed.

Management:

- Apply three sprays of dimethoate 30 EC 0.03% (10 ml/10 l of water) OR *Beauveria bassiana* 1.15 WP 0.0035% (Min. 2×10^6 cfu/g) + dimethoate 30 EC 0.015% (30 g + 5.0 ml/10 l of water) OR *Beauveria bassiana* 1.15 WP 0.007% (60 g/10 l of water) first at initiation of pest infestation and subsequent two sprays at ten days interval
- Apply schedule spraying of *Beauveria bassiana* 1.15 WP (Min. 2×10^6 cfu/g), first spray at initiation of pest infestation 0.0035% (30 g/10 l of water). Subsequent second 0.007% (60 g/10 l of water) and third 0.009% (80 g/10 l of water) spray at ten days interval for effective and economical management of thrips, *Thripstabaci* in garlic.
- Three sprays of spinosad 45 SC 0.0135% (3 ml/10 l of water) OR *Beauveria bassiana* 1.15 WP 0.0035% (Min. 2×10^6 cfu/g) + spinosad 45 SC 0.0068% (30 g + 1.5 ml/10 l of water), first at initiation of pest infestation and subsequent two sprays at ten days interval found effective in onion.

2. ONION MAGGOT:

Scientific name: *Delia antique* (Meigen)

Family: Anthomyiidae **Order:** Diptera

Marks of identification:

- The flies are slender, greyish, large-winged, rather bristly and about 6 mm in body length.
- The maggots are small, white and about 8 mm in length

Life history:

- The female lays elongate, white eggs near the base of the plant, in cracks in the soil.
- The eggs hatch in 2-7 days.
- The maggots crawl up to the plant, and enter the inside of the leaf sheath and reach the bulb.
- They feed there and become full-grown in 2-3 weeks.
- The maggots then crawl out of the bulb and pupate in the soil.
- After 2-3 weeks, the adults emerge and start the new generation.
- In the third generation, the pest often attacks the onions shortly before the harvest.
- It initiates the process of rotting of the onions in storage.

Nature of damage:

- After hatching the maggots crawl up to the plant, and enter the inside of the leaf sheath and reach the bulb.
- The maggots bore into the bulbs, causing the plants to become flabby and yellowish.
- They mine through the small bulbs completely, leaving only the outer sheath and thus causing a thin stand of the crop.
- The larger bulbs are attacked by several maggots at a time, making cavities.

Management:

- Apply 10 kg of carbaryl 4G per ha to the soil followed by light irrigation.
- Spray methy demeton 25 EC or dimethaote 30 EC 1.0 L in 500 – 750 L of water per ha.

3. EARWIG: *Anisolabis stali* (Forficulidae: Demaptera)

Distribution: Throughout India

Host: Onion, garlic, cabbage, cotton, sorghum and groundnut

Mark of identification:

- Adult is brown to black with forceps like caudal cerci and white jointed legs.

Life history:

- Adult female lays 21-139 eggs, egg period 14 days.
- Nymphs white in the early stage turn brown in the later stage, nymphal period 50 -54 days

Nature of damage:

- Nymphs bore into the bulb and make cavities which lead to withering of plants.

Management:

- Soil application of Carbofuran 3 G at 30 kg/ha on 20 DAS and earthed up.
- Basal application of FYM 25 t/ha or 250 kg/ha of neem cake

4. Tobacco caterpillar: *Spodoptera litura* (Noctuidae: Lepidoptera)

Refer tomato

5. Cutworm: *Agrotis ipsilon* (Noctuidae: Lepidoptera)

Refer potato

❖ PEST OF TURMERIC AND GINGER

1. RHIZOME SCALE:

Scientific name: *Aspidiotus hartii*

Family: Diaspididae **Order:** Hemiptera

Distribution. India, West Africa and West Indies

Host plant: Turmeric and ginger

Marks of identification:

- Scales are minute, circular, light brownish to grey with a thin pale membrane.

Life history:

- It reproduces either ovoviviparously or parthenogenetically
- Female lays about 100 oval, yellowish eggs under the scale.
- Egg period one day, nymphal period 30 days.
- Adult is yellow to deep yellow in colour.

Nature of damage:

- Both nymphs and adults infest rhizomes both in field and storage.
- The infested plants become weak, pale and withered in the field that results in shrivelling of rhizomes and buds.

Management:

- Apply well rotten sheep manure / poultry manure in two splits @ 10 tons/ha, first before planting and the second at the time of earthing up.
- Drench soil with dimethoate 30 EC or phosalone 35 EC @ 2 ml/L of water
- Soak seed rhizomes, in insecticide solution of either dimethoate 30 EC or phosalone 1.5 ml/L or dichlorvos 0.5 ml/L for 15 min. for storing.

2. SHOOT BORER:

Scientific name: *Dichocrosis punctiferalis*

Family: Pyraustidae **Order:** Lepidoptera

Nature of damage:

- The caterpillar enters into the aerial stem killing the central shoot which results in the appearance of 'dead heart'.
- For details on the bionomics and management refer castor.

3. RHIZOME MAGGOT: *Formosina flavipes*, *Chalcidomyia atricornis* (Chloropidae: Diptera)

Nature of damage

- Rhizomes and roots are tunneled extensively by the maggots resulting in rotting of rhizomes.

Management:

- Avoid using seed material from the infested fields.
- Spray methyl parathion 50 EC or dimethoate 500 ml in 500 -750 L water per ha
- Soak seed rhizomes, in insecticide solution of dimethoate 30 EC for 15 min. for storing

❖ PEST OF CORIANDER

The important pest of coriander is only whitefly.

1. COTTON WHITEFLY: *Bemisia tabaci* (Hemiptera: Aleyrodidae)

- The nymphs suck sap of the plants and adversely affect their growth.
- For bionomics and management. Refer tomato

2. APHID: *Hyadophis coriandri* (Hemiptera: Aphididae)

- Both nymphs and adults congregate colonise on ventral surface of leaves and suck cell sap.
- Due to copious production of honey dew, leaves give a glistening appearance in the beginning, but later covered with sooty mould fungus.
- Nymphs and adults are yellowish green.
- A single female produces 40 to 50 young ones and they take 8 to 12 days to mature.
- Life cycle is completed in 14 to 21 days during summer and 6 weeks in winter.

3. PENTATOMID BUG: *Agonoscelis nubila* (Hemiptera: Pentatomidae)

- Adult and nymphs suck the sap from leaves and stem. Heavily infested plants show stunting.
- Adults are yellowish. Life cycle is completed in 40 to 60 days.
- Spray dimethoate or quinalphos 1.5 ml/L

❖ PESTS OF CUMIN**1. MEALY PLUM APHID, *Hylaopterus pruni* Geoffroy (Aphididae: Hemiptera)****Mark of identification :**

- Aphid is rather light green but usually appears grey because of the black-white powdery substance that covers the body.

Life history:

- About 40 to 50 young ones are produced parthenogenically by single female. The young ones take 8 to 12 days to mature.

Nature of damage:

- Both nymphs and adults congregate in colonies on ventral surface of leaves and suck the cell sap.
- Due to copious production of honeydew, the leaves give a glistening appearance in the beginning, but later covered with sooty mould fungus.

Management:

- Timely sowing of crop.
- Spraying the crop with dimethoate 30 EC 0.03 % or methyl -o- demeton 25 EC 0.05 % or carbosulfan 25 EC 0.05 %
- Apply two sprays of *Beauveria bassiana* 1.15 WP (Min. 2×10^6 cfu/g) 0.007% (60 g/10 l of water), first at initiation of pest infestation and second at ten days interval
- Spray any one of the following insecticides, first spray at initiation of aphid and if required, second spray at 15 days after first spray.
 1. Flonicamid 50 WG, 0.015%, 3 g/ 10 litre of water.
 2. Clothianidin 50 WDG, 0.02%, 4 g/ 10 litre of water .
 3. Carbosulfan 25 EC, 0.04%, 16 ml/ 10 litre of water .
 4. Thiacloprid 24 SC, 0.024%, 10 ml/ 10 litre of water

2. STINK BUG, *Agnoscelis nubila* Fabricius (Pentatomidae: Hemiptera)**Nature of Damage:**

- Both nymphs and adults suck the cell sap from flowers and tender plant parts. Heavily infested plant may show stunting.
- Adults are yellowish in colour.
- Total life cycle completed in 40-60 days.

Management :

- Spraying the crop with dimethoate 30 EC 0.03% or methyl o demeton 25 EC 0.05%.

3. *Helicoverpa armigera* (Noctuidae: Lepidoptera)

Larvae feed on leaves, flowers and immature grains

❖ PESTS OF FENNEL

1. APHIDS, *Hyadaphis coriandri* Das (Aphididae : Hemiptera)

Host: Coriander

Marks of identification:

- The adult is dark dull yellow to green in colour. one pair of cornicles are present on abdomen.

Nature of damage:

- Both nymph and adult suck the cell sap from leaves stem and umbels as a result plant becomes weak and retarded.
- It secretes honeydew which favours the growth of sooty mould which inhibit photosynthetic activity of plant and quality and quantity of grain adversely affected.
- In severe infestation at early stage tender leaves growing points and flower stalk wither and dry up.

Life cycle:

- Female reproduce about 45 nymphs during the life span. There are 4 nymphal instars.
- Total nymphal period is 8 days. Longevity of adult 9 days.
- There are 10 generations during Feb. to April.

Management:

- Spraying the crop with dimethoate 30 EC 0.03 % or Imidacloprid 17.8 SL 0.006 % or Carbosulfan 25 EC 0.05%.

2. SEED MIDGE: *Systole albipennis* Walker (Eurytomidae : Hymenoptera)

- The pest attacks the grains in the field at maturity .
- The female midge lays eggs in the embryo of grain and developing larvae feeds remaining inside the grain.
- Larvae pupate inside the grain and adults emerge from the stored grains by making hole.

Management

- Spraying the crop with monocrotophos 36 SL @ 10 ml or acetamiprid 20 SP @ 2 gm or thiamethoxam 25 WG @ 3.5 gm or methyl demeton 25 EC 0.05% per 10 liter of water.

❖ **PEST OF FENUGREEK**

1. Cowpea aphid: *Aphis craccivora* Koch (Hemiptera: Aphididae)
2. Serpentine leaf miner: *Liriomyza trifolii* Burgess (Diptera: Agromyzidae)
3. Thrips: *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae)
4. Spotted pod borer: *Maruca testulalis* Geyer (Lepidoptera: Crambidae)
5. Mite: *Tetranychus cucurbitae* Rahman and Sapra (Arachnida: Tetranychidae)

❖ **PEST OF CURRY NEEM LEAF**

1. PSYLLID BUG: *Diaphorina citri* (Psyllidae: Hemiptera)
 - The tender shoot is often severely attacked by the psyllids
2. CITRUS BUTTERFLY: *Papilio demoleus* (Papilionidae: Lepidoptera)
 - The leaves are eaten commonly by the caterpillars.
3. LEAF ROLLER: *Tonica zizyphi* (Oecophoridae: Lepidoptera)
 - The larvae sometimes roll the leaflets in large numbers and cause appreciable damage.
4. BARK BORER: *Indarbela tetraonis* (Metarbelidae: Lepidoptera)

PESTS OF FRUIT CROPS

❖ PEST OF MANGO

There are a number of insect pests of this fruit and over 175 species of insects have been reported damaging mango tree but the most abundant and destructive at the flowering stage are the mango hoppers.

1. MANGO HOPPER

Scientific name: *Amritodus atkinsoni* (Lethiery), *Idioscopus clypealis* (Lethiery) and *I. niveosparus* (Lethiery)

Family: Cicadellidae

Order: Hemiptera

Distribution: The mango hoppers are widely distributed in India, Malaysia, Indonesia and Taiwan.

Host plants: Only mango of all varieties.

Marks of identification:

- It is a small, about 5 mm long, light greenish-brown wedge-shaped insect with small yellow and black marking, broad head and tapering body.
- The nymphs are pale yellow, elongated and more active.

Life history:

- The overwintering adults lay eggs by inserting the ovipositor in the shoot and flower stalks.
- A female deposits, on an average, 200 eggs within 4-7 days, the eggs hatch and the newly emerged nymphs are first seen at the end of February or in early March.
- They commence feeding on the inflorescence, quickly suck the cell-sap and excrete honeydew.
- The nymphs become full-grown in three stages in 8-13 days. The full-fed nymphs then moult and give rise to winged hoppers.
- The life cycle, from the time eggs are laid to the time the adults appear, takes 15-19 days and during the flowering season, two or more broods of the pest may occur.

Nature of damage:

- Mango hoppers are the most destructive pests of fruit trees.
- Injury to the inflorescence and young shoots is caused by egg laying and feeding.
- The voracious feeding nymphs are particularly harmful.
- They cause the inflorescence to wither and brown.
- Even if the flowers are fertilized, the subsequent development and fruit setting may cease.

- In thick and protected gardens where the atmosphere is humid, a sooty mould develops on patches of honeydew exuded by the nymphs.
- As the wind blows, young fruits and dried inflorescence break off at the axil and fall to the ground. The growth of young trees is much retarded and the older trees do not bear much fruit.
- Damage to the mango crop may be as high as 60 per cent.

Management:

- Do not go for high density planting as it provides favourable habitat for hopper multiplication,
- Do not encourage plants to put intermittent flushes by regular irrigation and split doses of nitrogenous fertilizers,
- Avoid waterlogged or damp conditions,
- In case of old dense orchards, prune some of the branches during winter to have better light interception,
- Application of bio-agents, *Metarhizium anisopliae* @ 1×10^8 cfu/ml or *Beauveria bassiana* @ 10^8 cfu /ml on tree trunk once during off season and twice at 7 days interval during flowering season. **
- Spray *Lecanicillium (Verticillium) lecanii* 1.15WP @50 g/10 l (1×10^8 cfu/g) or *Beauveria bassiana* 1.15WP (1×10^8 cfu/ml) @ 10 g/10 l with following schedule for effective management of mango hoppers. I at panicle initiation stage II spray 7 days after 1st spray III spray 7 days after 2nd spray IV spray at pea size stage V spray at marble size stage
- Use neem based formulations are advised to spray azadiractin based EC formulation at 0.0018 per cent or neem seed kernel extract at 5 per cent or neem oil at 0.5 per cent for the management of mango hopper
- Three to five sprays depending on pest intensity, first spray before flowering with 0.007 % cypermethrin 25% EC, second at panicle initiation stage with 0.07 % quinalphos 25% EC or 0.1 % carbaryl, subsequent sprays with imidacloprid 17.8 SL (0.0053%), thiomethoxam 25%WG or
- Spraying of imidacloprid 17.8 SL @ 5ml/ 10 liter water or thiamethoxam 25 WG @ 5ml/ 10 liter water or acetamiprid @ 5ml/ 10 liter water after appearance of 5 nymphs per inflorescence

2. MANGO MEALY BUG

Scientific name: *Drosicha mangiferae* (Green)

Family: Margarodidae **Order:** Hemiptera

Distribution: The mango mealy bug is widely distributed in the Indo-Gangetic plains from Punjab to Assam.

Hosts: Besides mango, it also attacks 62 other plants, including such trees as the jack-fruit, banyan, guava, papaya, citrus fruits and *jamun*.

Marks of identification:

- The wingless females are oval, flattened and have body covered with a white mealy powder.
- The males have one pair of black wings and are crimson red.

Life history:

- The eggs are generally deposited in April-May in soil up to 15 cm within silken purses. The dead body of the female is often found sticking to them. They hatch at the end of December or in January and, in a given locality, continue to hatch for about one month. Thus, the nymphs appear before the fresh growth of flowers on mango Trees.
- The young nymphs ascend the trees and congregate on the panicles where they feed on the cell-sap and pass through three stages.
- At the time of moulting the younger nymphs wander away from the original feeding places in search of suitable shelters such as cracks and crevices in trunks.
- The females mature after 15-35 days and lay eggs for 22-47 days during April-May.

Nature of damage:

- The nymphs and adult females are destructive and they suck plant juice, causing tender shoots and flowers to dry up. T
- The young fruits also become juiceless and drop off.
- The pest is responsible for causing considerable loss to the mango growers and when there is a serious attack, the trees retain no fruit at all.

Management:

- Remove weeds from orchards which act as additional hosts for mealy bug.
- Ploughing of orchards during summer exposes eggs to natural enemies and extreme sun heat,
- Nymphs should be prevented from crawling up the trees by applying 8 cm wide sticky bands with alkathene or plastic sheets around the trunk about one meter above the ground level during second week of December, (iu) The nymph found congregating below the lower edge of alkathene band should be killed mechanical" or by spraying them with 500 ml of methyl parathion 50EC in 250 litres of water per ha.
- Application of *Beauveria bassiana* (2g/L) or 5% NSKE around the tree trunk.
- Early instar nymphs of the mealy bug can be controlled by spraying of 0.05 % carbaryl from January to March.

3. MANGO STEM BORER

Scientific name: *Batocera rufomaculata* DeGeer

Family: Cerambycidae

Order: Coleoptera

Distribution: Mango stem borer has a wide range of distribution in north-western parts of the Indian sub-continent.

Hosts: Besides mango, it also attacks jack fruit, rubber, fig., eucalyptus,

Marks of identification:

- The adults are longicorn beetles, well built, large and pale greyish measuring about 5 cm in length and 2 cm in breadth.
- The beetle is provided with long legs and antennae and a dirty white band, extending from the head to tip of the body on each side.
- A number of dirty yellowish spots are present on the elytra.
- The full-grown larva is a stout, yellowish-white, fleshy grub, measuring about 6 cm in length.

Life history:

- The adults deposit eggs under the loose bark in a wounded or diseased portion of the trunk or a branch.
- The grubs are equipped with strong biting mouthpart and they penetrate into the stem or even the roots, feeding on woody tissues.
- Winter is passed in the grub stage in that very burrow.
- They again start feeding as soon as the weather warms up in spring and during the feeding process, they bore through the wood by cutting large galleries.
- The full-grown larvae then hollow out a cell for pupation.
- The larval stage probably lasts more than a year and the pupal stage lasts about one month.
- The life-cycle may be completed in 1-2 years.

Nature of damage:

- Although the borer is not very common, yet whenever it appears in the main trunk or a branch, it invariably kills the host.
- Though the external symptoms of attack are not always visible, the site can be located from the sap or frass that comes out of the hole.

Management:

- Insert swabs of cotton wool soaked in petrol or carbon bi-sulphide or chloroform or 0.13 % DDVP or 0.05 % Trichlorfan into holes & tunnels and seal the holes with mud.
- Cut and destroy the infested branches along with grubs and pupae.
- Insert the iron spike into the hole to kill the larvae, which is quite effective practicable when infestation is low.

- The mixture of Carbon bi-sulphide + chloroform + creosote (2:1:1) may be injected in the hole and then sealed with mud to kill the larvae.
- Application of Aluminum phosphide (3 gram tablet of celphos, quickphos or phostoxin) deep in the hole and sealing the opening with mud also kill the larva in the tunnel.
- Injecting hole with monochrotophos 36 % 5 ml + DDVP 76 % 5 ml in one liter of water immediately after treating the holes, seal the same with mud.

4. MANGO STONE WEEVIL

Scientific name: *Sternuchus mangiferae* (Fabricius)

Family: Curculionidae **Order:** Coleoptera

Distribution: This pest is widely distributed in Uttar Pradesh, Orissa, West Bengal, Assam, Tripura, Karnataka and Andhra Pradesh.

Hosts: Only mango

Marks of identification:

- This is a stoutly built, ovoid, dark brown weevil measuring about 6 mm.

Life history:

- The weevils lay eggs in the skin of ripening fruit. The wound caused by the ovipositor heals soon after and the fruit does not exhibit any outward sign of infestation.
- On a fruit 12-36 eggs may be deposited. On emergence from the egg the grub moves further inwards, eating its way through the unripe tissue until it bores into the embryo of the mango stone.
- When full-grown, the larva forms a cell inside the stone in which it pupates.
- The weevil cuts its way through the stone and the pulp comes out
- The generation is completed in 40-50 days, but the emerging adults become inactive and resume breeding only in the next season.
- Thus, there seems to be a single generation of this pest in one year

Nature of damage:

- The insect attacks mango varieties with a relatively soft flesh. The injury caused by the larvae feeding in pulp sometimes heals over but a certain number of fruits always get spoiled when the weevils make an exit through ripe or near-ripe mangoes.

Management:

- The pest can be suppressed by destroying all fallen fruits, weeviled mangoes and by disposing off refuse, stone, debris, etc.
- The weevil, being an internal feeder throughout its development, is not amenable to control with any of the insecticides.

5. FRUIT FLY

Scientific name: *Bactrocera dorsalis* (Hendel)

Family: Tephritidae

Order: Diptera

Distribution. The Oriental fruit fly or mango fruit fly, is the most serious of all fruit-flies and is widely distributed in India and South-east Asia. It has also been recorded in Malaysia, Indonesia, Taiwan, the Philippines, Australia and the Hawaii Islands.

Hosts: Apart from mango, the pest also feeds on guava, peach, apricot, cherry, pear, *chiku*, *ber*, citrus and other plants, totalling more than 250 hosts.

Marks of identification:

- The adult is stout, a little larger than the house fly, is brown and has transparent wings and yellow legs and dark rust-red and black patterns on the thorax.
- It measures 1.4 cm across the wings and 0.7 mm in body length.
- The legless maggots are yellow and opaque; when full-grown, measure 8-9 mm long and 1.5 mm across the posterior end.

Life history:

- The adult flies emerge in April and start laying eggs under the rind of the ripening fruits and vegetables of the season (such as guava, loquat, apricot, plum, brinjal, etc.) and later shift to mango.
- They lay 2-15 eggs at a time in clusters. A female lays, on an average, 50 eggs but under favorable conditions, 150-200 eggs are laid in one month.
- The eggs hatch in 2-3 days in March-April and 1-1.5 days in the summer, and 10 days during winter.
- As the maggots develop they pass through 3 stages in the ripening pulp and are full-grown in 6-29 days.
- They leave the fruit and move away by jumping in little hops. On reaching a suitable place, they bury themselves into the soil and pupate 8-13 cm below the surface.
- In 6-44 days, they emerge as flies and reach the ripe fruit for further multiplication.
- The life-cycle is completed in 2-13 weeks and many generations are completed in a year.

Nature of damage:

- The damage is caused both by maggots and adults.
- The adults feed on exudation of ripe fruits and honeydew of various insects. The punctures for egg laying made by the females attract fermenting microorganisms.
- The maggots destroy the pulp making it foul smelling and discoloured.
- The fruits develop brown rotten patches on them and fall to the ground ultimately.
- The infested fruits become unmarketable and at times almost all of them contain maggots.

Management:

- Avoid infestation of fruit flies by early harvesting of mature fruits,
- To prevent the carryover of the pest, collect and destroy all fallen infested fruits twice in a week.
- Plough round the trees during winter to expose and kill the pupae,
- Monitor the fruit fly population in orchards by using methyl eugenol traps.
- Spray 1.25 liters of malathion 50EC + 12.5 kg *gur* or sugar in 1250 liters of water per ha. and repeat sprays at 7-10 days interval if infestation continues,
- After harvest, dip the fruits in 5 per cent sodium chloride solution for 60 minutes to kill the eggs, if any and also to decontaminate them of insecticide residue if at all present.

6. LEAF WEBBER

Scientific name: *Orthaga exvinacea*

Marks of identification:

- Larva - Pale greenish with brown head and prothoracic shield.
- Adult - Brown moth with wavy lines on fore wings

Life history:

- Eggs are laid in clusters of about ten on buds and young leaves. After hatching the larvae forms a web around the leaflets and feed on the tender leaves.
- Pupation takes place inside the webs in silken cocoons.
- The last generation pupates in the soil around December-January
- The life-cycle completes in 3-4 weeks

Nature of damage:

- Infestations of leaf webber may begin as early as seedling stage and persist even during flowering and fruiting.
- Webbing of terminal leaves and tender shoots with several caterpillars found inside.
- Caterpillars initially scrap and feed on the terminal leaves within the web and give burnt appearance to leaves

Management:

- Webbed leaves should be removed mechanically along with larva and pupa and destroyed.
- Pruning of overcrowded branches and proper orchard maintenance.
- Encourage the activity of predators, carabid beetle *Panera lacticineta*, reduvid *Oecama sp*
- Spray carbaryl at 50 WP @ 0.1%, or quinalphos @0.05% when initial infestation is observed

7. SHOOT BORER

Scientific name: *Chlumetia transversa*

Marks of identification:

- Young caterpillars are yellowish orange with dark brown pro-thoracic shield.
- Full grown caterpillars (20-24mm) are dark pink with dirty spots.
- Adult moths are stout grayish brown in colour with wings having wavy lines and measure about 17.5 mm at expanded wings.
- Hind wings are light in colour

Life history:

- Female moths lay eggs on tender leaves.
- Young larvae after hatching enter the midrib of leaves and then enter into young shoots through the growing points by tunneling downwards.
- Four overlapping generations of the pest are found in a year and it overwinters in pupal stage.

Nature of damage:

- Tunneling from top-down wards of the tender terminal shoots.
- Stunting of seedlings with terminal bunchy appearance.
- Larvae of this moth bore into the young shoot resulting in dropping of leaves and wilting.
- Similar symptoms also noticed on panicles.

Management:

- Attacked shoots should be clipped off and destroyed.
- Effective control of the pest can be attained by spraying carbaryl (0.2%) or quinalphos (0.05%) at fortnightly intervals from the commencement of new flush. Two sprays at three weeks interval commencing from initiation of new flush of leaves may be required.
- Spray azadirachtin 1500 ppm @33 ml / 10 litres at the initiation of flowering and second at fifteen days after the first spray for the management of mango shoot borer.

8. LEAF GALL MIDGE, *Procontarinia matteriana*

INFLORESCENCE MIDGE, *Erosomyia indica*

There are four species of midges prevalent in India with three species attacking blossoms while one attacks the leaf.

Marks of identification:

- Larva - A maggot light yellowish in colour and moults three times
- Adult -a. *Erosomyia indica*: Yellowish fly
b. *Procystiphora mangiferae*: Light orange fly
c. *Dasineura amaramanjarae*: Orange red fly

Life history:

- Female laying eggs into the tissue of young leaves leaving a small reddish spot.
- The leaf tissue under the red spot becomes swollen and soft.
- Within seven days gall formation begins and reaches a maximum
- Midge damage on inflorescence diameter of 3-4 mm.
- From the underside of the leaf adults usually emerge leaving the pupal skin sticking out from the emergence hole

Nature of damage:

- Wart-like galls produced on leaves that reduce photosynthetic activity leading to leaf drop and lowered fruit production.
- Infested plant material and wind currents are responsible for its spread.

Management:

- Deep ploughing of orchard exposing pupae and diapausing larvae to sun's heat kills them.
- Monitor of larval population and follow effective control measures based on population.
- Spray thiomithoxam (0.05%) or dimethoate (0.05%) at bud burst stage.

9. BARK EATING CATERPILLAR

Scientific name: *Indarbela quadrinotata* Wlk., *I. tetraonis* M.o. and *I. dea* Swinhoe.

Family: Metarbelidae

Order: Lepidoptera

Hosts: Mango, guava, zizyphus, litchi, orange, pomegranate, baubinia, loquat, mulberry, guava

Marks of identification:

- The full grown caterpillar is dirty brown in colour and is about 35-45 mm in length.
- The moth is light grey in colour with dark brown dots and measures about 35-40 mm with expanded wings.

Life history:

- Female lays eggs below the bark or in between cracks.
- Eggs hatch in about 8-10 days and the larvae bore into the tree feeding on the bark for 9 - 11 months.
- There is only one generation per year.

Nature of damage:

- Young trees succumb to the attack. Caterpillars bore into the trunk or junction of branches make zig zag galleries.
- Presence of gallery made out of silk and frass is the key symptom.
- They remain hidden in the tunnel during day time, come out at night and feed on the bark.
- Under severe infestation, flow of sap is hindered, plant growth arrested and fruit formation is drastically reduced.

Management:

- Maintain a healthy orchard.
- Kill the caterpillars by inserting an iron spike into the tunnels.
- Clean hole and put emulsion of monocrotophos (0.05%) in each hole and plug them with mud.

❖ PEST OF SAPOTA

As many as 25 insect species have been reported to attack sapota trees, out of which sapota leaf-webber or chickoomoth is the most destructive.

1. LEAF WEBBER OR CHICKOO MOTH

Scientific name: *Nephopteryx eugraphella*

Family: Pyraustidae

Order: Lepidoptera

Host plants: Sapota and cured tobacco

Marks of identification:

- Neonate larvae initially they are pink and become yellow within 24 h and later turns into greenish in colour. Dorsal side of body is pink in colour while ventral side is green.
- Adult is grayish in colour. Fore wings are grayish with four black transverse wavy lines.
- Hind wings are membranous white. Both the wings are fringed at the outer margins.
- A brownish line is present near the outer margins of the wings. .

Life history:

- The female moths laying eggs singly or in batches of 2 or 3, on leaves and buds of young shoots.
- The eggs hatch in 2-11 days.
- The larvae feed for 13-60 days and complete development.
- They undergo pupation in the leaf-webs and this stage is completed in 8-29 days.
- The life-cycle is completed in 26-92 days

Nature of damage:

- The caterpillar generally feed on leaves but are often found on buds and flowers and sometimes on tender fruits as well.
- Generally larva make hole on basal portion of buds.
- The larvae web together a bunch of leaves and feed within on chlorophyll, leaving behind a fine network of veins.
- They also bore inside the flower buds and tender fruits which wither away and the larvae move on to the next bud or fruit.

Management:

- Damaged leaf webs along with larvae should be collected and destroyed.
- Two sprays of any of the following insecticides during peak flowering at 20 days interval for effective control of bud boring insects (*Anarsia achrasella* and *Nephopteryx eugraphella*) dichlorvos 0.03% (4 ml in 10 litres of water) or lambda cyhalothrin 0.005% (10 ml in 10 litres of water) or Mixture of profenophos (40%) + cypermethrin (4%) 0.044% (10 ml in 10 litres of water) or Mixture of chlorpyrifos (50%) + cypermethrin (5%) 0.055% (10 ml in 10 litres of water)
- Apply three sprays of either flubendiamide 39.35 SC @ 0.0096% (2.4 ml/10 litre) or emamectin benzoate 5 SG @ 0.0022% (4.4 gm/10 litre) at one month interval during fruiting stage.

2. CHIKU BUD BORER

Scientific name: *Anarsia achrasella*

Family: Galechiidae

Order: Lepidoptera

Marks of identification:

- Adult dark, ash grey in colour with fringed hind wings.
- First and second instar larva pale yellow but 3rd and 4th instar larva pinkish in colour. Full grown larva is 8-10 mm long.

Life history:

- Female lays 50 -60 eggs in axils of the tender leaves, singly or in batches of 10-20,
- Egg period 3 days.
- Larval period 14-16 days. Larvae pupate into the floral webbings, pupal period 7-10 days.
- Life cycle completed in 24-29 days.

Nature of damage:

- Generally larva makes the hole on upper portion of buds and feed inner content and makes the bud hollow (Feeding on ovary and petioles).
- After completing one bud, migrate to another bud.
- More than one larvae observed in a single bud.

Management:

- Damaged leaf webs along with larvae should be collected and destroyed.
- ETL 20 % damaged leaves & 10% damaged buds
- Two sprays of any of the following insecticides during peak flowering at 20 days interval for effective control of bud boring insects Dichlorvos 0.03% (4 ml in 10 litres of water) or Lambda cyhalothrin 0.005% (10 ml in 10 litres of water) or Mixture of profenophos (40%) +

cypermethrin (4%) 0.044% (10 ml in 10 litres of water) or Mixture of chlorpyrifos (50%) + cypermethrin (5%) 0.055% (10 ml in 10 litres of water)

3. FRUIT FLY

Scientific name: *Bactrocera dorsalis*, *B. zonata*)

Family: Tephritidae

Order: Diptera

As per Mango

4. SAPOTA SEED BORER

Scientific name: *Manilkara achras* (Mill) Forseberg, *Trymalitis margaritis* Meyrick

Family: Tortricidae

Order: Lepidoptera

Marks of identification:

- Moths are grayish coloured with white patches.
- The smaller larvae are whitish in colour which turns into dark pink colour with prominent brownish head.
- The full grown larva of about 12-15 mm in length comes out by making hole of about 2 mm in diameter mostly from lower side of the seed.

Life history:

- The female lays eggs which are white oval.
- The nymphs which hatch out are small but resemble adults in shape.
- The life cycle of this mite is completed in 10-12 days.

Nature of damage:

- The neonate larva bores into the fruit and finally enters the seed.
- A fine zigzag gallery can be seen on seed which indicates the presence of larvae inside the seed, while outer seed coat of such seed remain intact.
- The larva only feeds on endosperm of the seed and completes its larval period inside the seed.
- The full grown larva comes out by making hole of about 2 mm in diameter mostly from the lower side of seed. Thereafter, it prepares a tunnel, generally in lower half of the fruit and comes out.
- Thus, an exit hole of about 1 to 2 mm in diameter either round or oblong in shape on fruit indicates its damage and also exit of larva from such fruit.
- Generally, a single exit hole is observed on a fruit, however during severe infestation two holes can be seen on the same fruit. Pupation takes place in the leaf fold.
- Through the exit hole, secondary fungus develop inside the fruit and small black ants were also observed attracted to such fruits, which finally becomes unfit for consumption

Management:

- Spraying the crop with
 - Profenophos 50 % EC 15 ml or
 - Lamda cyhalothrin 5 % EC 10 ml or
 - Profenophos 40 % + Cypermethrin 4 % - 10 ml
 - In 10 lit of water during October- November.

❖ PEST OF CITRUS

There are a large number of insect pests of citrus which cause considerable damage to different parts of the trees. The insect's along with nematodes were responsible for citrus decline observed in various parts of India and other adjoining countries.

1. CITRUS PSYLLA

Scientific name: *Diaphorinacitri* Kuwayana

Family: Aphalaridae

Order: Hemiptera

Distribution: The citrus psylla is distributed throughout the Orient and has been reported from India, China, Taiwan, Japan, Myanmar, Sri Lanka, the East Indies and New Guinea.

Host plants. This pest it has been recorded on all species of citrus and a number of other plants of the family Rutaceae.

Marks of identification:

- Adult bugs are brownish in colour. 2-3 mm long and active in nature. Prefers to sit on the underside of the leaves. Rests in wings closed and abdomen raised position.
- The nymphs are flat, louse-like and orange yellow.

Life history:

- The female adults lay, on an average, 500 almond-shaped, orange and stalked eggs on tender leaves and shoots of citrus trees. The lower end of the *egg* stalk is embedded in plant tissue.
- The eggs are laid either singly or in groups of two or three and are arranged in straight line, there being as many as 50 eggs in one place.
- The eggs hatch in 10-20 days in winter and 4-6 days in summer.
- There are five nymphal stages and the development is completed in 10-15 days in summer and 34-36 days in winter.
- There are 8-9 overlapping generations in a year.

Nature of damage:

- Both the nymphs and adults suck the cell-sap in millions with the help of their sharp, piercing mouthparts.
- The vitality of the plants deteriorates, and the young leaves and twigs stop growing further.
- The leaf buds, flower buds and leaves may wilt and die.
- Whatever little fruit is formed in the spring, falls off prematurely.
- Moreover, the nymphs secrete drops of a sweet thick fluid on which a black fungus develops, adversely affecting photosynthesis.
- This insect is also responsible for spreading the greening virus.

Management:

- *Tetrastichus radiatus* is an important parasitoid of nymphs and is distributed in all the citrus groves.
- A number of lady bird beetles, viz. *Coccinellaseptempunctata*, *Menochilussexmaculatus* and *Brumoidessuturalis*, and *Chrysoperlacarnealarvae* also feed' on nymphs.
- Spray 1.70 litres of dimethoate 30EC or 1.25 litres of malathion 50EC in 1250 litres of water per ha during February-March (spring flush), May-June (before rainy season) and July-August (after rainy season).
- Spray Oxydemeton-methyl 25 EC @ 15 ml /10 liter of water

2. CITRUS WHITEFLY

Scientific name: *Dialeurodescitri* (Ashmead)

Family: Aleyrodidae **Order:** Hemiptera

Distribution: The pest is very widely distributed in America, India, Pakistan, Vietnam and China.

Hosts: Although is a pest of citrus, the insect prefers to feed on certain mciduous plants such as persimmon and *dharek* (*Melia azedarach*).

Marks of identification:

- The adult is a minute insect, measuring 1.02-1.52 mm, the males being smaller than the females. White colored waxy wings are present.
- The nymph is pale yellow, with purple eyes and its body s marginally fringed with bristles.

Life history:

- The female adults lay eggs singly on the underside of soft young leaves. The eggs are oval, pale yellow and rest on small stalks.
- A single female may lay 200 or more eggs during its life which may last from 7 to 10 days.
- It may take 10-20 days for the eggs to hatch.
- The young larva, on emergence, crawls about for a few hours and then inserts its proboscis into the succulent portion of a twig.

- The larvae remain there in a stationary state and transform themselves into pupae at the same spot.
- A nymph is full-fed in 25-71 days and then changes into a pupa.
- The pupal stage is of the longest duration during the hottest part of summer and the coldest part of the winter, when it lasts 114-159 days.

Nature of damage:

- The pest causes damage in the larval and adult stages. It sucks the cell sap from leaves which curl over and fall off.
- The honeydew excreted by the nymphs is a very good medium for the growth of a sooty mould, which interferes with photosynthesis.
- Thus, the trees infested with this pest deteriorate further.
- When the attack is severe, about 50 per cent of the crop may be destroyed.

Management:

- *Encarsia lahorensis* and *E. citifila* are the major parasitoids of this insect.
- A number of predators are recorded feeding on the eggs as well as nymphs of this insect, viz. *Brumoidessuturalis*, *Cryptognatha flavescens* and *Verania cardoni*; predatory thrips, *Aleurothrips fasciipennis* and a lacewing, *Chrysopa* sp.
- For effective management of flies, close planting, water logging or any other stress condition should be avoided.
- In case of localized infestation, the affected shoots should be clipped off and destroyed,
- Chemical control measures are same as mentioned under 'citrus psylla'.

3. CITRUS MEALY BUG

Scientific name: *Pseudococcus filamentosus* Cockerell

Family: Pseudococcidae

Order: Hemiptera

Distribution: The citrus mealy bug is more common in southern India than in the north.

Hosts: The mealy bugs are known to feed on a number of plants, often not closely related to citrus.

Marks of identification:

- The adult female is wingless, with a flattened body and short, waxy filaments along the margins.
- The nymphs are amber with a whitish waxy coating and filaments.

Life history:

- The females lay eggs in clusters on citrus plants, which are found in protective cotton-like masses.
- There may be 300 eggs or more in one mass. The eggs hatch in 10-20 days and

- The nymphs crawl out and start feeding by inserting their mouthparts in the lower surface of the leaves. A waxy white covering is soon formed on their bodies.
- A female nymph is full-grown in 6-8 weeks. The male nymphs spin cotton-like cocoons, two or three weeks after hatching, and pupate before transforming themselves into winged adults

Nature of damage:

- The insects feed on cell-sap and the plants become pale, wilted and the affected parts eventually die.
- The insects also excrete honeydew on which a black mould grows, which interferes with photosynthesis.
- In severe cases of infestation, the citrus flowers do not set fruit.

Management:

- For effective management of these coccids, orchard sanitation is extremely important.
- Weeds act as additional hosts and these must be removed
- The infested shoots should be pruned and destroyed,
- The coccinellid beetle, *Cryptolaemus montrouzieri*, should be released @ 10 beetles per plant, to control mealy-bugs. Inoculative releases of an exotic parasite, *Leptomastix dactylopii*, are also recommended,
- Chemical control measures are same as in case of citrus psylla.

4. CITRUS CATERPILLAR

Scientific name: *Papiliodemoleus* Linnaeus

Family: Papilionidae **Order:** Lepidoptera

Distribution: The citrus caterpillar or the lemon butterfly, is found in Africa, greater part of Asia as far as Taiwan and Japan. It has been reported all over India.

Hosts: It can feed and breed on all varieties of cultivated or wild citrus and various other species of the family Rutaceae.

Marks of identification:

- The adult is a large beautiful butterfly, 2.8 cm in length and 9.4 cm in wing expanse.
- Its head and thorax are black, there being a creamy-yellow coloration on the underside of the abdomen. Its wings are dull black; ornamented with yellow markings.
- The full-grown caterpillar is yellowish green, has a horn-like structure on the dorsal side of the last body segment, and is 4.0 cm long and 6.5 mm wide.

Life history:

- The butterflies lay eggs on tender shoots and fresh leaves, mostly on the undersurface.
- They hatch in 3-5 days.
- The larval life lasts 13-21 days.

- The larvae show preference for young and shiny leaves of citrus. The first four larval instars mimic the coloration of bird's dropping.
- The mature larva spins a supporting girdle around its body and pupates on a twig, a dry stick or any other raised structure.
- The pupal stage lasts about 8-11 days.
- The pest passes through three or four generations in a year.

Nature of damage:

- The young larvae feed only on fresh leaves and terminal shoots. Habitually, they feed from the margin inwards to the midrib.
- In later stages, they feed even on mature leaves and sometimes the entire plant may be defoliated.
- The pest is particularly devastating in nurseries and its damage to foliage seems to synchronize with fresh growth of citrus plants in April and August-September.
- Heavily attacked plants bear no fruits.

Management:

- Hand picking of various stages of the pest and their destruction especially in nurseries and new orchards helps to suppress the population of the pest,
- Spraying of entomogenous fungus, *Bacillus thuringiensis*, nematode DD-136 strain or neem seed extract (3%) also gives quite high mortality of caterpillars,
- In severe infestation, spray 2.0 kg of carbaryl 50WP or 1.45litres of quinalphos 25EC in 1250 litres of water per ha during April (after fruit set)

5. CITRUS LEAF MINER

Scientific name: *Phyllocnistis citrella* Stainton

Family: Phyllocnistidae **Order:** Lepidoptera

Distribution. This insect is widely distributed in the Orient, northern Australia and India, and is known to be a serious pest of citrus nurseries in Tamil Nadu, Madhya Pradesh, Assam, Uttar Pradesh, Punjab, Haryana and in Pakistan

Hosts: Apart from citrus, the insect also feeds on a variety of other plants such as pomelo, willow and cinnamon.

Marks of identification:

- The adult is a tiny moth, measuring 4.2 mm across the wings.
- On the front wings there are brown stripes and prominent black spots along the tips.
- The hind wings are pure white and both pairs are fringed with hairs.
- The full-grown larva measures 5.1 mm in length and is pale yellow or pale green with light brown well developed mandibles.

Life history:

- The moths lay minute, flattened, transparent eggs on young leaves or tender shoots, usually on the lower surface, particularly near the midrib.
- The eggs which are laid singly, generally two or three per leaf, hatch in 2-10 days, giving rise to legless larvae.
- Soon after emerging, the larvae mine into the leaf tissue and form galleries within which they remain confined for the rest of their immature life.
- Larvae are full-fed in 5-30 days, and when mature, they settle down in enlargements of the galleries near the leaf margin.
- By the time they spin cocoons for pupation, the leaves get twisted or folded over.
- The pupal stage lasts 5-25 days.
- The life-cycle is completed in 12-55 days and several overlapping generations are produced in a year.

Nature of damage:

- The damage is caused by the larvae due to their mining habit. The injured epidermis takes the shape of twisted silvery galleries.
- On older leaves, brownish patches are formed which serve as focii of infection for citrus canker.
- The attacked leaves remain on the plants for a considerably long time and the damage gradually spreads to fresh leaves.
- Heavily attacked plants can be spotted from a distance and young nurseries are most severely affected;
- The young plants of orange and grape fruit may not even survive.
- In larger trees, the photosynthesis is adversely affected, vitality is reduced and there is an appreciable reduction in yield.

Management:

- Spray on nursery plants 125 ml of fenvalerate 20EC or 250 ml of cypermethrin 10EC or 875 ml of decamethrin 2.8EC or 370 ml of monocrotophos 36SL in 250 litres of water per ha at fortnightly intervals,
- Spray of 2 per cent neem seed extract has also been found quite effective and safe,
- Chemical control measures in orchards are same as in case of citrus psylla.

6. FRUIT SUCKING MOTH

Scientific name: *Ophideres materna*, *O. fullonica*

Family: Noctuidae **Order:** Lepidoptera

Hosts: Citrus, mango, grapes and apple

Marks of identification:

- Caterpillar is cylindrical, stout bodied. It is semi looper with cryptic markings.
- Body is velvety dark brown. Measures 2.5 inch in length when fully grown. Prominent eye spot on the head region. Yellow or red spots laterally. A hump dorsally on the last abdominal segment.
- Adult moth is fairly very large. Measures about 2.5 to 3 inches.
- Fore wings are mottled, grey brown, dark chocolate. Pale greenish and white markings all over the wing.
- Hind wings are orange or yellowish ii color. A large, black “C” shaped curve in *O. fullonica*. *O. maternahave* marginal dark band mixed with white spots and a prominent black spot on the middle. Entire body is covered with orange colored scale

Life history:

- Round and translucent eggs laid on wild plants and weeds like *Tinosporacordifolia*, *Cocculuspendulus*, *C. hirsutus* in and around citrus orchard.
- Egg period two weeks,
- larval period 4 weeks with 5 instars.
- Pupates in a pupal case made from leaf pieces and soil particles. Pupa is thick and dark reddish brown with pupal period of two weeks.

Nature of damage:

- Larvae do not cause any damage to citrus crops.
- Adults are the damaging stage. Moths are nocturnal in habit. They get attracted by the strong aroma produces by the ripening fruits.
- They can fly over a longer distance in search of fruits. After settling using its proboscis searches for a suitable place for feeding. Inserts the proboscis into the rind of the fruit and sucks the fruit juice with a slow drilling action. Piercing action will be over within a minute. When juice becomes exhausted at a particular point it feeds on another part. Proboscis path is usually a straight line.
- More than one, or sometimes 50 punctures can be seen in a fruit.
- Due to insertion of proboscis wounds are formed in fruits. These punctured areas become soft. Causes the infection of fungus and bacteria.
- The wound area becomes brown and rotting occurs.
- Eventually the fruit falls from the tree and become unfit for consumption

Management:

- Removal of all wild creepers around orchards can be controlled by withholding irrigation disposing the fallen and decaying fruits.

- Creating smoke in the orchard by burning grasses, bagging of ripening fruits with polythene, setting light traps to attract the adult moths.
- Spray malathion 50 WP, poison bait: mixing malathion 60ml + molasses 2.25litres in 14 to 18 litre of water (one full bottle of such bait for 10 citrus trees)

7. CITRUS BLACK FLY: *Aleurocanthus woglumi*

Marks of Identification:

- **Nymphs** - are flattened, oval in shape and scale like in appearance.
- **Adult** - minute insect, shiny black with grey dusting on the body. Wings are extending beyond the tip of the abdomen.

Nature of Damage:

- The cell sap is sucked from the leaves - piercing stylet.
- Leaf curling. Leaves fall off immaturely.
- Honey dew secretion development of sooty mold fungus.
- Leaf turns to black in colour and affects photosynthetic activity of the leaves.
- Affected trees produce - few blossoms which develop into fruits.

Life cycle:

- A single female lay more than 100 eggs in spiral pattern on ventral side of leaves.
- There may be 15 to 22 eggs in a cluster.
- Ep: 7-14 days.
- Nymph: On emergence start feeding on cell sap.
- Pass through four nymphal instars.
- NP: 38 to 60 days.
- Pupate in leaf surface and this stage lasts 100 to 131 days.

Management:

- Collect and destroy the damaged plant parts along with nymphs, pupa and adults.
- Spray with triazophos 40 EC 0.05% - 12 ml or chloropyriphos 20 EC 0.05% - 25 ml in 10 lit of water.
- Spraying should be coinciding with new flush.
- Female lays eggs on lower surface of leaves in a form of three (15-22 eggs/whorl) whorls.
- The entire plant canopy should be drenched with the solution.
- Encourage activity of parasitoids, *Encarsia sp.*, *Eretomocerus serius* and *chrysoperla sp.*

8. CITRUS APHIDS :

Black aphid: *Toxoptera aurantii*,

Brown aphid: *Toxoptera citricida*

Aphididae : Hemiptera

Marks of Identification:

- The black citrus aphids are wingless, forms with very shiny black colour present only in mature females whereas immature form brown in colour.
- The wing forms can easily be recognized by a prominent black spot like stigma on each wing.
- The adult aphids measures 2.5 mm in length and has two short tube like structures on dorsal lateral side of the latter half of abdomen known as cornicles.

Nature of Damage:

- Feed on tender foliage and flowers.
- Transmit tristeza virus disease. Nymphs and adults suck the sap of leaves.
- Wilting and flower dropping. Infested leaves - cup shaped and crinkled. Growth of the plants is hindered.

Management:

- Use yellow sticky trap.
- Spraying crop with methyl-O-demeton 25 EC 0.025% - 10 ml or dimethoate 30 EC 0.03% - 10 ml or imidacloprid 17.8 SL - 3 ml in 10 lit of water.
- Use some coccinellid beetles and syrphid flies.

9. SCALE INSECT:

Aonidiella aurantii Maskell

Diaspididae : Hemiptera

Marks of Identification:

- The female scale insect is reniform (kidney) shaped, red in colour and measures 1.8 x 1.9 mm or 2 mm in size with distinct centrally located exuviae.
- The males are similar to female except after first moult it becomes elongated and possesses one pair of distinct purplish eyes.

Nature of Damage:

- The scale infests all the above ground parts of the tree.
- The reddish brown elongated and circular scales above 2 mm in size along with those of young ones completely cover the back stem of the plants.
- Nymphs and adults suck the cell sap of tender leaves.
- Feeding results in to the development of yellow marks on the leaves, twigs and fruits.
- Each mark indicate the point at which the scale insect have thrust its stylet.

- The branches soon loose chlorophyll turns scurfy grey and start dying.
- In case of heavy infestation leaves become pale and if young trees attacked, death results.
- It also excretes honey dew which hinders the process of photosynthesis.

10. COTTONY CUSHION SCALE: *Icerya purchasi* (Coccidae : Hemiptera)

Marks of Identification:

- Female can be identified by its conspicuous, white fluted cottony mass secreted by the insect itself.
- Adults are covered in white hair.
- White, ribbed masses that hold up to 800 red eggs.
- The adult male is a winged insect.
- The young crawler is light waxy yellow in colour later on turn to red with black legs and antennae.

Nature of Damage:

- Suck the cell sap of twig and branches by piercing their sucking tubes deep in to plant tissue.
- Beside insect excrete copious amounts of honey dew which accumulate in large amounts somewhat resembling like agglomerates of sugar crystals.
- Heavily infested twigs and branches turn brown and are killed within a short time.
- In certain cases entire trees may be killed whereas young trees dry up in few months.
- The trees cease to bear any fruits.

Management:

- Rubbing the branches with gunny piece followed by spraying with monocrotophos 36SL 10 ml or malathion 50 EC 0.05 %-10 ml in 10 lit of water along with detergent powder @ 20 gm. Spray dormant oil in late winter before spring.
- Spray horticultural oil, if needed, year round.
- Apply mixture of manure compost tea, molasses and citrus oil. Garlic-pepper tea also helps.
- Natural predators usually keep this insect in check.
- Dusting the crop with methyl parathion 2 % dust for the control ants which can give the scale a competitive advantage.
- Introduction of lady bird beetle, *Rodolia cardinalis* is the most perfect way of controlling this scale.

❖ PEST OF BANANA

1. RHIZOMEWEEVIL

Scientific name: *Cosmopolites sordidus* (Germar)

Family: Curculionidae

Order: Coleoptera

Distribution: This species although native to South-east Asia, has attained wide distribution on cultivated bananas of the world. Its present distribution, in addition to India and South-east Asia, covers parts of Australia, the Hawaii Islands, tropical and South Africa and tropical America.

Host plants. Banana rhizome.

Marks of identification:

- Grubs are legless, creamy white with red head having strong mouthparts, stout and distinctly curved.
- Adult weevils newly emerged are red brown which turns almost black after a few days, hard-shelled having a long-curved snout and about 10 to 16 mm long.

Life history:

- The female weevil bites a small hole in the corm, lays a single egg and continues this activity on other plants throughout the year.
- A female can lay 10-50 eggs during its life of a few months.
- The larvae emerge from the eggs in about a week and bore into the corm, where they feed, making a tunnel.
- When full-grown in 2-6 weeks, the larvae pupate in the same tunnel.
- The pupal stage lasts about a week.
- The adults, on emergence, remain in the soil for sometime, feeding on the underground parts of the plants. Later on, they visit the growing point for oviposition.

Nature of damage:

- The young grub tunnels into the base of suckers, roots and rhizome/corm.
- Presence of larval tunnels on the entire length of pseudostems.
- Yellowing and withering of leaves, reduced plant vigour, root destruction, reduced fruit production and are easily blown over by the wind.

Management:

- Practice clean cultivation with the suckers pruned periodically and infested clumps are removed and destroyed
- Crop rotation with non-host crops like paddy and sugarcane
- Ensure proper fertilization and weed removal
- Use of pheromone trap @ 16 traps /ha

- Application of bio control agents, *Beauveria bassiana* and *Metarhiziumanisopliae*, causes more than 90% mortality of the weevils
- Application of carbofuran 3G @ 40 g or neem cake @ 500 g/plant at planting and then at three months after planting.
- Sucker dipping in triazophos solution (2.5 ml/ 1 lit water) for about 20 minutes kills the eggs and grubs
- Remove the entire plants after harvest and treat the pit with carbaryl (1g/lit) or chlorpyrifhos (2.5ml/lit)

2. BANANA PSEUDO STEM BORER

Scientific name: *Odoiporus longicollis* (Olivier)

Family: Curculionidae **Order:** Coleoptera

Distribution: It is a serious pest of banana in North-east India.

Hosts: Banana

Marks of identification:

- The adult is a robust reddish brown weevil about 1.5-2.0 cm long.
- The grub is apodous, yellowish with reddish head.

Life history:

- The eggs are laid in small burrow in the rhizome or within leaf sheaths just above the ground.
- Eggs hatch in 3-5 days in summer and 5-8 days in winter
- The larva bores into pseudostem making tunnels within and cutting holes on its outer surface.
- The larval duration is 26 days in summer and 68 days in winter with five larval instars.
- It pupates in tunnel towards the periphery. The pupal period lasts 20-24 days in summer and 37-44 days in winter.
- The adult lives for a period of upto two years.

Nature of damage:

- Both the grubs and adults cause the damage.
- Grubs bore into the rhizome and make tunnels within it. Adults also tunnel within the stem, feeding on its internal tissues as a result of which the internal shoot is killed.
- Infested plants show premature withering, leaves become scarce, fruits become undersized and their suckers are killed outright.
- Presence of small pinhead-sized holes on the stem.
- Jelly exudation on the stem is the initial symptom of damage.
- Due to secondary infection of pathogens, rotting occurs and a foul odour is emitted.
- After flowering, when tunneling occurs in the true stem and peduncle, the fruits do not develop properly

Management:

- After harvesting the bunch, remove the pseudostem from ground level and destroy them in order to avoid it serving as a breeding site for the pest.
- Uproot and burn infested plants.
- Use Disc-on-stump or longitudinal Pseudostem traps @ 100/ha for trapping weevils.
- Swabbing with chlorpyrifos 2.5ml/l + adjuvant 1ml/l on the stem prevents infestation of banana stem weevil.
- When jelly exudation is noticed, inject 2ml triazophos solution (350 ml in 150 ml water). Two injections per plant at 2 and 4 feet above the ground level till flowering. The injection needle should enter only two or three leaf sheaths and should not touch the central core.

3. BANANA APHID

Scientific name: *Pentalonia nigronervosa* Coquerel

Family: Aphididae

Order: Hemiptera

Distribution: The pest is found in most of the banana growing areas in India.

Hosts: Apart from banana, it also attacks cardamom, large cardamom and *Colocasia antiquorum*.

Marks of identification:

- The aphid is brownish in colour and has black-veined wings.

Life history:

- The aphid lives in colonies within the leaf-axils, or tender leaves and at base of the culm at the ground level.
- Young ones are given birth by alate and apterous females by parthenogenetic development. An aphid is capable of producing 30-50 nymphs in its life time of 27-37 days.
- The nymph undergoes four instars of 2-3 days duration each.
- Total life-cycle is completed in 8-9 days.
- About 30 to 40 generations are completed during a year under South Indian conditions.

Nature of damage:

- Banana leaves are bunched into a rosette appearance with leaf margins becoming wavy and upward rolling thereby reducing the growth and vigour of plant.
- Severely infected plants do not produce bunches and act as a vector of bunchy top disease.
- Noticed in colonies on leaf axils and pseudo stem

Management:

- Adopt clean cultivation using healthy and pest free suckers
- Remove the affected plants and do not take up ratoon and inter crops
- Drench the petioles, furled leaves, whorls or young suckers with soapy water or insecticidal soap

- Spray dimethoate (75ml/100lit) or acephate (1.3g/lit) on infested plants and suckers
- Use of braconid wasps, *Lysiphlebiustest aceipes* as parasitoid
- Releasing of predators such as lady bird beetles and lace wings
- Application of bio control agent *Beauveria bassiana* in the banana fields

4. THRIPS

Scientific name: *Chaetanaphothrips signipennis*

Family: Thripidae

Order: Thysanoptera

Marks of identification:

- Egg: Kidney shaped, invisible to naked eye, laid just below the fruit or pseudostem surface.
- Larva: They are wingless creamy white, smaller but have the same shape as the adult.
- Pupa: Pupae are white like the larvae, can crawl, 1 mm in length.
- Adult: They are slender, creamy yellow to golden brown with delicate feathery wings and 1.5 mm long. Their wings have dark, eye-like spots at the base and are fringed; when the wings are folded, the adult appears to have a black line down its back.

Life history:

- Adult banana rust thrips reproduce sexually.
- After mating, females lay eggs in plant tissues where the thrips feed and hatch in 6-9 days.
- The newly hatched yellow nymphs feed for a few days before molting and after 8-10 days, mature nymphs migrate off the host plant into the soil and undergo pupation with the adult emerging in 6-10 days.
- The entire life cycle is completed in approximately 28 days.

Nature of damage:

- Distinctive reddish brown oval stains on the finger, which can extend the entire length.
- In severe cases peel splits and the exposed flesh quickly discolors

Management:

- At the time of shooting, cover the bunch firmly (without any space between polythene cover and bunch) with 100 gauge thickness polythene sleeve having 6 to 10% holes.
- Remove the male flower buds after opening of all hands.
- When the bud is in upright position, bud injection with imidachloprid 17.8EC @ 2ml chemical solution (0.2 ml of chemical dissolved in 500 ml of water) per bud using disposable syringe
- Spray the bunch with chlorpyrifos @ 2.5 ml/ litre of water/ acetamiprid 20SP (0.0025 %) i.e. 1.25 g/ 10 liter of water along with sticking agent (@ 0.5ml/litre of water, two times ie one at the time of opening of hands and second spray after all the hands opened.

- *Verticillium lecanii* (2×10^8 cfu/g) 3g/ lit + 1ml Milk + 1ml sticker or NSKE 5% + sticker can be taken up as second spray.

7. LEAF FEEDER: *Pericallia ricini* (Fabricius)

Marks of identification:

- **Larva** - Black with brown head having long brown hairs
- **Adult** - Grey coloured with dark spots on the pinkish hind wings

Nature of damage:

- Caterpillar scraping the chlorophyll content and windowing in unfurled leaves.

Management

- Hand picking and mechanical destruction of caterpillars in early stage of attack.
- Use burning torch to kill the congregating larvae
- Use light trap to attract and kill the adults
- Remove and destroy the rolled leaves with larvae and pupae of leaf rollers
- Spray chlorpyrifos 20 EC or quinalphos 25 EC 2ml/lit

8. LEAF EATING CATERPILLAR, *Spodoptera litura*

Marks of identification:

- **Egg:** Masses appear as golden brown.
- **Larva:** pale greenish with dark markings. Gregarious in early stages.
- **Adult:** Forewings are brown in colour with wavy white markings. Hind wings are white colour with a brown patch along the margin.

Nature of Damage

- Later on feed voraciously at night on foliage.
- Young larvae feed by scraping the leaves from ventral surface.

Management

- Hand picking and mechanical destruction of caterpillars in early stage of attack.
- Collect and destroy the damaged plant parts.
- Summer ploughing to expose the pupae.
- Use light trap @1/ha to attract and kill the adults
- Spray chlorpyrifos 20 EC or quinalphos 25 EC 2ml/lit
- Spraying of SlnPV 250LE/ha or Emamectin benzoate 10WSG 2-3gm/10 l of water.
- Field release of egg parasitoid *Telenomus spodoptera* or *T. remus*.

❖ PEST OF CASHEWNUT

1. STEM AND ROOT BORER

Scientific name: *Plocaederus ferrugineus* (**Linnaeus**)

Family: Cerambycidae

Order: Coleoptera

Distribution: This pest is the most important pest of the cashew tree in south India

Host plants: Cashew

Marks of identification:

- The grown up grubs are off-white in colour measuring about 7-10 cm in length.
- The adult is a medium-sized dark-brown beetle. When full-grown, the larva measures 7.5 cm.

Life history:

- The borer has one generation per year. The adult is a medium sized (25-40 mm long), reddish-brown long horned beetle. The female beetle lays 60-90 eggs.
- They prefer to lay eggs on old trees (> 4 - 5 years old) that have rough bark with more cracks, on trees either damaged by stem borers in the previous season or by physical actions like heavy pruning.
- The eggs are laid into the live tissues in the crevices of the loose bark in the trunk or exposed portion of the roots above the soil.
- The eggs are whitish, ovoid in shape measuring about 3 mm in length (looks like rice grain). The egg period varies from 4-7 days.
- The eggs hatch out as tiny grubs, which bore into the fresh tissues of the bark.
- The grubs feed inside the tissues for 4-7 months.

Nature of damage:

- Stem borer infection could be easily identified by the presence of small bore holes at the collar region.
- Extrusion of frass (like coarse dust powder) through the holes at the collar region. Oozing of gum at the base of cashew tree trunk.
- The grubs that hatch out bore into the bark and feed on the sub-epidermal and vascular tissues.
- Extensive tunneling in the stem and root region and the tissues are tunnelled in irregular fashion.
- As a result of damage the supply of water and nutrients is arrested by which the leaves turn yellow and are shed and finally leads to the death of the tree. Affected trees also tilt on one side due to loss of anchorage, if the injury is severe on anchoring roots.

Management:

- Monitor regularly for the presence of the frass near the base of the trunk.
- Mechanically remove the grubs from infected trees in the initial stage of infestation

- Inject 0.36 per cent monocrotophos by the padding method.
- Soak / drench the bark of the infested trees with O.SL of 0.1 per cent chlorpyrifos, one meter above the ground and also by drenching the soil/ root zone in a radius of 0.5m around the stem with SLOf the same insecticide to kill the grubs/ pupae in the root zone.
- Repeat the Injection of all infested trees with monocrotophos after 15-20 days.
- It is very important to adopt the phytosanitary measures like removal of dead trees infested with CSRB and bury or burn the same to avoid further spread of infestation.

2. TEA MOSQUITO-BUG

Scientific name: *Helopeltis antonii* Signoret

Family: Miridae

Order: Hemiptera

Distribution: It is a major pest of cashew in Kerala, Karnataka, Goa, Maharashtra and Tamil Nadu.

Hosts: Neem, guava, cocoa, mahogany, cinchona, cotton, apples, grapes, drumstick, black pepper and jamun.

Marks of identification:

- Adult bug has black head, red thorax, and black and white abdomen with a knobbed process mid-dorsally on the thorax.

Life history:

- Single female bug lays, on an average, 50 eggs. The incubation period of the egg is on an average 5-7 days.
- The adult usually feeds during early hours (6-10 am) and makes about 150 feeding punctures per day.
- A nymphal period is of 10-15 days with 5 instars.
- The female bug lives for about 7 days, while the longevity of male is 9-10 days. The life-cycle is completed in 25-32 days.

Nature of damage:

- Both nymphs and adults of this mirid bug suck sap from the tender flushes, young shoots, inflorescence, panicles, growing young nuts and apples.
- Occurrence of dark brown patches on green tender stem of young shoots and inflorescence rachis.
- Feeding on tender leaves causes crinkling and curling. Affected shoots show long black lesions.
- The immature nuts infested by this pest develop characteristic eruptive spots and finally shrivel and fall off.
- Heavily infested trees show scorched appearance, leading to the death of shoots and growing tips.

- Severely affected branches may lead to the secondary infection by fungus (*Botrydiplodia theobromae*) causing die back disease.
- Each nymph/adult during its life time damages at least three tender shoots/ panicles.

Management:

- For efficient management of mosquito bug, it is essential to check the build up of the pest population on cashew as well as on the alternate hosts such as guava, neem, cocoa, drum stick, mahogany and black pepper in the vicinity of cashew plantations.
- Spray , lambda-cyhalothrin 5 EC @ 0.003 % and 2.0 kg of carbaryl 50WP at the time when new flush and panicles appear.
- The eggs of the mosquito bug are naturally parasitized by *Telenoums* sp. and *Erythmelus helopeltidis*. Spiders such as *OxyopesSchireta*, *Phildippus* patch and *Hiyllus* sp. are efficient predators and feed on nymphs and adult mosquito bug.

3. FRUIT AND NUT BORER: *Thylocoptilapanrosama* M.(Pyralidae: Lepidoptera)

- It is a pinkish dark actively moving caterpillar.

Nature of Damage

- Caterpillar bores into the tender apples and nuts.
- Nuts are damaged in case of severe infestation.
- The caterpillars attack the fruits at all stages and cause the shrivelling and premature fall of nuts.
- The young larva of *T. panrosema* move to the joints of nut and apple, scrape the epidermis and then bore into them.
- In later stages, they bore into tender apples and nuts and feed on them.
- The borer affected nuts do not develop, become shrivelled and dried up resulting in premature fall of nuts and apples.
- Usually, the borers tunnel near the junction of apples and nuts, and the entry holes are plugged with excreta.

Life Cycle

- The adult is a medium sized moth with dirty black fore-wings and pale dark hind wings, with a wing span of about 15-20 mm in length.
- There are 5 larval instars which are completed in 15-23 days.
- The fully grown larvae drop to the ground and pupate in earthen cocoons. The pupal period lasts about 8-10 days.

Management

- This pest can be effectively controlled by spraying of Novaluron 10%EC
- Spray carbaryl 50 WP 0.1% (@ 2g / lit) at the time of fruit setting.

- In newly established orchards, there is a tendency for the cashew grafts to produce new flushes continuously during the first three to four years.
- Therefore, it may be necessary to give off-season sprays to control foliage pests such as tea mosquito, leaf miner, leaf webber, etc.
- In the subsequent years when the plants attain good growth three rounds of spraying during flushing, flowering and fruiting periods are to be given.
- It is necessary to use different chemicals for each of the sprays to ensure that the pests do not develop resistance by the continuous use of the same chemical over the years.
- For effective control of pests, spraying should be taken up only during cool hours of the day, that is, between 7 AM and 10 AM in the morning and 3 PM and 6 PM in the evening.
- While spraying the chemicals it should be ensured that spray is not directed against the wind.

4. FLOWER THRIPS *Selenothrips rubrocinctus* Giard. (Thripidae:Thysanoptera)

Mark of identification

- The nymphs commonly known as red-banded thrips are distinguished by their greenish yellow colour and recognized by bright red bands across the first and last abdominal segments, while the adults possess a highly polygonally reticulate body with needle-like terminal antennal joints and broad wings with dark strong stiff setae. Adults are dark brown

Nature of Damage

- Adult and young thrips are seen in colonies on the lower (abaxial) surface of leaves and suck the sap.
- As a result of rasping and sucking activities, the leaves of infested young trees become pale-brown and crinkled with roughening of upper surface. In severe cases, there will be shedding of leaves and even stunting of growth.
- In most of the young plants, thrips are found to appear on the foliage and cause heavy damage, particularly in summer months. The population increases during the dry season from December to January to a peak in April-May and then rapidly declines during wet season.

Life Cycle

- The eggs are inserted singly in the epidermis of the leaf and each is covered with a drop of excremental fluid which dries to form a black disc like pellicle.
- The nymphs emerge in about 10 days, wander freely and carry a drop of excremental fluid at the apex of the abdomen which is carried upraised and is lowered at intervals to deposit the droplet which gives a small brown stain when it dries up.
- The nymphs feed for 10 days, involving a mono-feeding, pre-pupal instar lasting for a day and non-feeding pupal instar for further 2-3 days.

- Winged dark-brown adults emerge which have mandibular and maxillary stylets similar to those of nymphs.
- The female can oviposit soon after emergence and may produce upto 50 eggs during her life of about a month

Management

- Spraying suitable insecticides at the time of emergence of tender shoots and panicles is very effective for its control.

5. LEAF AND BLOSSOM WEBBER *Lamida monocusalis* Walker (Pyraustidae: Lepidoptera)

Mark of identification

- Males of *L. monocusalis* are dark, while the females are olive green.
- The caterpillar is dark green in colour with yellow longitudinal bands and pinkish dorsal lines. Full grown larva measures 24.0 to 27.0 mm in length and the larval period is 16 to 24 days with 5 larval instars.

Nature of Damage

- Leaf and blossom webber attack new flushes and inflorescences.
- The caterpillars of this pest web the shoots and inflorescences together, remain inside and feed on them. Subsequently the webbed portion of the shoots and blossom dry up.
- Hence, it is called shoot and blossom webbing caterpillar.
- The galleries of silken webs reinforced with castings and scraps of plant parts are indicative of the presence of caterpillars inside the webbed portion. The incidence is found severe mostly on young trees.

Life Cycle

- The eggs are laid singly or in small groups of 3-5 on the leaves during night, more usually on the ventral surface and occasionally on the tender shoots, finely glued on to the surface.
- Freshly laid eggs are yellowish green in colour, ovoid, some what flat on the surface, but three broad pink bands appear across the surface a day later.
- The total number of eggs laid by a female varies from 18 to 83. The incubation period lasts 4 to 7 days.
- Pupation takes place in cocoons in the leaf webs.
- The pre-pupal period lasts 1-4 days and the pupal period 9-14 days.
- Males have peculiar habit of resting on the dorsal side of the leaves with the tip of the abdomen raised and bent upwards. Life cycle is completed in 37 days on cashew and 41 days on mango.

Management

- Spraying carbaryl 50 WP 0.1% (@ 2g / lit) or chlorpyrifos 20 EC 0.05% (@ 2.5 ml / lit) at flushing period will control this pest effectively.

6. MEALYBUG *Ferrisia virgata* Cockerell (Pseudococcidae: Heteroptera)

- The nymphs and adults of mealy bugs suck large amount of sap from the tender plant parts results in withering of growing shoots, inflorescence and developing fruits.
- It can be seen on the lower surfaces of tender leaves, twigs, inflorescence panicles and fruit peduncles.
- Besides causing direct damage, the bugs excrete copious amount of honey dew on which sooty mould develops which impairs normal photosynthetic activity.
- Heavy nut yield loss observed under severe outbreak conditions.

Life cycle:

- They are soft bodied, and covered with milky white coating on the body.
- They have reproductive potential of laying 100-300 eggs in masses covered with cottony white mealy filaments.
- The eggs are amber in colour and within a day they hatch into crawlers. Nymphal period lasts for 26-45 days. Adult lives for 15-20 days. The total life period is 45-65 days.

Management

- Continuous monitoring and early detection of infestation are essential to manage this pest.
- The cashew plantation and neighboring areas should be free from weeds and alternate hosts.
- The infested portion of the plant parts like leaves, inflorescence and twigs with mealy bug colonies should be pruned and destroyed.
- Fallen leaves under the tree canopy should be collected and burnt to avoid further spread of the pest.
- Spray of dichlorvas 76 WSC 0.2% (2.5ml / lit) or methyl parathion 50 EC 0.05% (@ 1ml / lit) or dimethoate 30 EC 0.05% (@ 1.75ml / lit) in combination with fish oil resin soap @ 20 g per liter of water reduces bug incidence effectively.

❖ PEST OF POMEGRANATE

Pomegranate is attacked by several insect pests among which pomegranate butterfly is the most serious.

1. POMEGRANATE BUTTERFLY

Scientific name: *Virachola isocrates* (Fabricius)

Family: Lycaenidae

Order: Lepidoptera

Distribution. This insect is widely distributed all over India and the adjoining countries. In India, it is commonly found in Uttar Pradesh, Bihar, Orissa, Himachal Pradesh, Haryana, Punjab, Rajasthan, Madhya Pradesh, Andhra Pradesh, Karnataka and Tamil Nadu.

Hosts: It is a polyphagous pest having a very wide range of host plants including *Aonla*, apple, ber, citrus, guava, litchi, loquat, mulberry, peach, pear, plum, pomegranate, sapota and tamarind.

Marks of identification:

- The adult butterflies are glossy-bluish violet (males) to brownish violet (females) in colour with an orange patch on the forewings. The wing expanse is 4-5 cm.
- The full-grown caterpillars (1.7 - 2.0 cm) are dark brown in colour and have short hair and whitish patches all over the body.

Life history:

- The female butterfly lays shiny white, oval shaped eggs singly on the calyx of flowers and on small fruits.
- The eggs hatch in 7-10 days and the young larvae bore into the developing fruits.
- They feed there for 18-47 days till they are full-grown.
- Then they pupate inside the fruit but occasionally may pupate outside even, attaching themselves to the stalk of the fruit.
- The pupal stage lasts 7-34 days. There are four overlapping generations in a year.

Nature of damage:

- The caterpillars damage the fruit by feeding inside and riddling through the ripening seeds of pomegranate.
- The infested fruits are also attacked by bacteria and fungi which cause the fruits to rot.
- The affected fruits ultimately fall off and give an offensive smell.
- This pest may cause 40 to 90 per cent damage to the fruits.

Management:

- Remove and destroy the affected fruits.
- Clip off calyx cup immediately after pollination followed by two applications of neem oil @ 3 %.

- Before maturity, bag the fruits with butter paper.
- At flowering stage, spray NSKE 5% or neem formulations 2 ml/l.
- Spray deltamethrin 2.8 EC (1.5 ml/litre of water) at fortnightly interval from the stage of flowering to fruit development.
- Spray malathion 50 EC 0.1% or azadirachtin 1500 ppm @ 3.0 ml/l at 15 days intervals commencing from initiation of flowering up to the harvesting subjected to the presence of fruit borer.

2. TAILED MEALY BUG, *Ferrisia virgata*

Marks of identification

- Nymph: Yellowish to pale white.
- Adult: Females apterous, long, slender covered with white waxy secretions, pair wax filaments at caudal end.

Nature of Damage

- Premature dropping of fruit

Management

- Collect and destroy the infested plant parts.
- Remove alternate hosts.
- Triazophos 40 % EC 0.05% 12 ml + neem oil 50 ml or phosalone 35 EC 0.075%- 21 ml + neem oil 50 ml or methyl demeton 25 EC 0.03 % - 10 ml or dichlorovos 76 % 5 ml + fish oil rosin soap 250 g in 10 lit of water.
- Release *Cryptolaemus montrouzieri* beetles @ 10/tree.

3. WHITEFLY: *Siphoninus phillyreae*

Marks of Identification

- Adult - Powdery white, active during early morning hours.
- Nymph - short glass like rods of wax along the sides of the body.

Nature of Damage

- Nymphs and adults suck the sap from leaves
- Honey dew - development of sooty mould fungus
- Yellowing of leaves.
- Dropping of affected leaves.

Management

- Field sanitation
- Removal of host plants
- Installation of yellow sticky traps

- Spray neem oil 3% or NSKE 5%
- Release of predators viz., Coccinellid predator, *Cryptolaemus montrouzieri* and lace wing fly, *Mallada astur*
- Release of parasitoids viz., *Encarsia haitierrsis* and *E. guadeloupae*

4. APHID, *Aphis punicae*

Marks of Identification

- Pale green, winged and wingless aphids.

Nature of Damage

- Nymphs and adults suck the sap from leaves, shoots and fruits
- Yellowing of leaves
- Wilting of terminal shoots.

Management

- Collect and destroy the damaged plant parts
- Use yellow sticky trap
- Spray application of dimethoate 25 EC or methyl demeton 30EC at 2ml/lit for effective management this pest
- Release first instar larva of *Chrysoperla carnea* @ 15 / flowering branch (four times) at 10 days interval from flower initiation during April

❖ PEST OF CUSTARD APPLE

1. TAILED MEALYBUGS

Scientific name: *Ferrisia virgata* (Cockerell), *Maconellicoccus hirsutus* (Green)

Family: Pseudococcidae

Order: Hemiptera

Host: It is a polyphagous pest causing serious damage to a number of economic crops including aonla, banana, citrus, guava, grapevine, jackfruit and pomegranate.

Marks of identification:

- The egg is buff to light yellow in colour and oval to cylindrical in shape having round end.
- Female is apterous, soft bodied, elongate oval in shape and deep brown in colour with a pair of prominent caudal filaments at posterior end and body is covered with a number of waxy filaments.
- Adult males are slender, delicate, and elongate in shape and smoky brown in colour with a single pair of mesothoracic wings and two long waxy anal filaments.

Life history:

- Female lays 100 to 300 eggs in 3 to 4 weeks. The egg masses remain under the females till the young ones hatch out. Incubation period is about 3 to 4 hours.
- The development period of male and female nymphs varies from 31 to 57 and 26 to 47 days, respectively.
- Longevity of males is only 1 to 3 days while that of females extends from 36 to 53 days.

Nature of damage:

- The infestation of this pest first appears on the seedlings grown up in the orchard.
- They infest leaves, shoots, buds and mainly fruits and suck the cell sap there from. As a result heavily affected developing fruits are reduced in size or get dropped.
- These insects also secrete honeydew on which a non- parasitic fungus, *Capnodium* species grows very rapidly, covering the fruits and plant parts with sooty mould. This black coating in turn interferes with the photosynthetic activity of the tree and as a result, its growth and fruiting capacity are adversely affected. The honeydew also attracts the ants which help in dissemination of the pest from tree to tree. Infested mature fruits also reduce their market value.

Management:

- To prevent the carryover of the pests, collect and destroy all the fallen infested fruits periodically and cut the branch portion being attached between tree and also ground level.
- Remove the seedlings and weeds, supporting the initial infestation, from the orchard.
- Plough around the trees during summer to expose and kill the hibernated insect to natural enemies and sun heat.
- Apply methyl parathion 2 per cent dust in the raked soil around the tree trunk to destroy the emerging crawlers.
- Spray carbaryl 0.2 per cent or methyl parathion 0.05 per cent on stem to kill the climbing crawlers.
- Remove and destroy the affected fruits and twigs to minimize the pest population.

2. FRUIT BORER:*Heterographis bengalella* (Pyralidae : Lepidoptera)

- Black coloured caterpillar
- Caterpillar bore into the fruits and make tunnel inside. Feed on the internal content of the fruits. Affected fruits fall to ground.
- Collect and destroy the damaged fruits. Spray malathion 50 % EC 0.1% - 20 ml in 10 lit of water two times once at flower formation and second at fruit set.

3. FRUIT FLIES

Scientific Name: *Bactrocera dorsalis*, *Bactrocera zonata*, *Bactrocera diversa*, *Bactrocera corectus*

Order:Diptera**Family:**Tephritidae

Distribution:

India, Pakistan, South East Asia, Malaysia, Indonesia, Formosa, Philipines, Australia, China, Hawaii, Islands. China and Taiwan.

Host Range:

Mango, Guava, Peach, Apricot, Cherry, Pear, Ber, Citrus, Banana, Papaya, Avacodo, Passion Fruit, Coffee, Melon, Jackfruit, Strawberry and pomegranate.

Marks of Identification

- The fly is brown or dark brown in colour with transparent wings having grey spots and yellow legs.
- The young maggot is dirty white, translucent and measures 1.5 mm x 0.3 mm.
- The full grown maggot is 8-9 mm long and 1.5 mm broad, the maggot is yellow at a later stage and the head of the cephalic segment is pointed anteriorly.
- The pupa is cylindrical in shape and 4-5 mm long and 2 mm broad. The colour varied from dull deep reddish yellow to ochraceous.

Nature of Damage

- Female fly lays eggs under the rind of the developing fruits by puncturing it with the ovipositor.
- On hatching maggots bore in to the fruits and feed on its pulp. The infested fruits start rotting and fall down pre maturely.

Life Cycle

- The adult female fly inserts the ovipositor deep and then the eggs are deposited.
- Once the Oviposition is completed the ovipositor is withdrawn and a puncture spot is left.
- The eggs are laid in clusters and each cluster has 2-15 eggs. The incubation period 2-3 days. Larval period 6-29 days.
- The pre-pupal period 18 hrs to 2 days.
- The pupal period lasts from 6-44 days.
- The life cycle is completed in 2- 13 weeks and many generations are completed in a year

Management

- Sanitation in the orchard is most important.
- Collection and destruction of the fallen fruits.
- Racking the soil around the tree to expose and kill the pupae.
- Apply methyl parathion 2 % dust in the racked soil around tree trunk to destroy the emerging fruit flies.

- Spraying the crop with 0.1 % fenthion during the month of May when there is severe infestation of pest.
- Methyl eugenol work as male sex attractant.
- The fruit fly population builds up February to March reaching to its peak in June.
- Use methyl eugenol and fenthion (1:1) to attract and kill the male fruit fly during this period.
- Four to five sprays are required for one hectare.
- Grow the black *Tulsi* in or around the orchard and spray fenthion 0.1 % on it at a fortnight interval to attract and destroy the male fruit fly.
- For effective control of this pest this operation should be done on co-operative basis.

❖ PEST OF AONLA

1. AONLA LEAF ROLLER:

Scientific name: *Caloptilia (=Gracillaria) acidula*

Marks of identification:

- Larva – cylindrical, yellow with thin, scattered hairs
- Adult – small, brownish moth

Nature of damage:

- Slender green larvae mine part or whole of the leaflets of compound leaves.
- Leaflets turn pale brown or dark brown.
- Upper epidermis separated from the lower.
- Intervening space filled with black excreta.
- Folded portion is skeletonized & dries up. In severe attack, the leaflets are twisted up to form cocoons.
- If the branch disturbed, all larvae leave their mines

Management:

- Clean cultivation.
- Collection and destruction of infested plant parts along with leaf roller Spraying of dimethaote 0.03% and quinalphos 0.025% were found effective against leaf roller.

2. APICAL TWIG GALL MAKER (Gall forming caterpillar)

Scientific name: *Betousa stylophora* (Swinhoe), *Hypolamprus stylo*

Nature of damage:

- The new growth of branches suffer damage temporarily as result of feeding by the sluggish caterpillar which form gall at the apical of the growing tip the blackish larvae while

- feeding secrete some metabolites which induce the some typical gall resembling “snake chamber fluts”
- The growth of heavily affected branches is temporarily arrested. However apices of these galls normal growth of twig are restored in subsequent year. With not much reduction in bearing the larvae form a single gall to complete development which is very slow.

Management:

- Over crowding of branches should be discouraged.
- Galled shoots should be pruned and destroyed along with the pest after harvest.
- In case of regular occurrence of this pest, spray chlorpyrifos (0.05%) in the beginning of the season. It may be repeated at fortnightly intervals, if needed.

3. AONLA FRUIT BORER: *Deudorix isocrates*

- Larva bores into the fruit in different phases. Young larva-tender fruits.
- Grown up larva- attack matured fruits.
- Infested tender fruits turn brown initially, and become black later.
- Matured fruits start decaying from one side, which gradually spreads all over, before they fall off.

Management

- Collection and destruction of damaged fruits.
- Remove alternate hosts- pomegranate, guava, sapota, tamarind.
- Release *T. chilonis*- 10 days interval -4 times.
- Inundative release of *Trichogramma chilonis* @ 15 cc/ha. Ovipositional deterrent- Neem oil 3% or NSKE 5%

4. FRUIT PIERCING MOTH: *Othreis materna*, *O. fullonica* and *O. ancilla*

Marks of Identification

- Caterpillar is cylindrical, stout bodied, semilooper with cryptic markings on velvety dark brown body and measures 2.5 inch in length when full grown.
- It has prominent eye spot on head, yellow or red spots laterally and a hump dorsally on the last abdominal segment.
- The forewings of adult moths are mottled – grey brown, dark chocolate, pale greenish with white markings all over the wings.
- The hind wings are orange or yellowish in colour with a large, black “C” shaped curved spots in *O.fullonica* whereas *O.materna* possess orange lower wings having marginal dark band mixed with white spots and a prominent black spot in the middle.
- The entire body is covered with orange coloured scales.

Nature of Damage

- The pest unlike other pest causes damage in adult stage whereas the caterpillars can be said to be beneficial since they destroy wild creepers not useful to mankind.
- The moth is nocturnal in habit and comes to the fruits at dusk. The moth gets attracted by the strong aroma emitted by the ripening fruits and is noticed to fly over long distance in search of fruits.
- The moth alights and settles on the fruits, starts searching the surface on fruit with the apex of its proboscis.
- After getting suitable surface observed moth drives its proboscis through the rind of fruit with a slow drilling action.
- Piercing action is normally over in less than a minute and then sucking begins.
- As the juice becomes exhausted at a particular direct path of the proboscis have been pierced and sucked.
- The path of proboscis is always in a straight line.
- If no satisfactory site is reached by the first insertion the proboscis is withdrawn and again inserted at a fresh site.
- There may be one or more than one, sometimes up to 50 such punctures are seen in a single fruit.
- The moths at night can be identified by their shining eyes and glistening wings.
- The moths continue feeding throughout the night and leave the fruits early in the morning.
- The adult moth causes damage by sucking the juice from the ripe fruits but the green fruits also not spared from attack.
- As a result, the area around the puncture becomes soft and through the wound caused by their proboscis fungal and bacterial infection takes place at the site of attack.
- The puncture becomes brownish and the area surrounding the puncture becomes pale and later on the fruits turn yellow.
- In the end such fruits fall down immediately or within a short period of about a week.
- The fallen fruits get rotted and become unfit for human consumption.

Management

- Removal of all wild creepers belonging to family Menispermaceae around the orchards and their destruction will prevent moth from breeding.
- The pest can be checked by withholding the irrigation and exposing the roots of the trees which will check January flowering.
- The attack of the pest can be avoided by not taking rainy season crop.
- Disposing of the fallen and decaying fruits which form a powerful factor for attacking the pest to the orchard site from long distances.

- When fruit ripen, the moths can be derived out of orchards by creating smoke by burning dry grass or leaves.
- Ripening fruits of costly varieties may be bagged with about 300 gauge alkathene or polythene bags.
- Since the moths are very much attracted towards lights placing of strong lights over cold kerosenized water will help in reducing their population.
- Baits containing fruit juice, fruit extracts or vinegar stimulate moths towards it; hence placing of fruit juice, crude sugar with poison in wide mouthed bottle and hanging them from tree will attract the moths and at same time kill them immediately.
- The insecticide like malathion 50 % WP and parathion 1 % can be used as poison. The poison baits can be prepared by mixing lead arsenate 56 gms, molasses 2.25 litres in 14 to 18 lit. of water or mixture of gur 1 kg, vinegar 60 gms, and lead arsenate in 10 litre of water. One full bottle containing such bait is sufficient for 10 citrus trees of medium size.

5. BARK EATING CATERPILLAR: *Indarbela tetraonis*, *Indarbela quadrinotata* Walker

Order: Lepidoptera

Family: Merarbelidae

Marks of Identification

- Freshly hatched larvae are dirty brown while the full grown larvae have pale brown bodies with dark brown heads.
- The adults are pale brown moths with rufous head and thorax.
- The forewings are pale rufous (reddish brown or brownish red) with numerous dark rufous bands.
- The hind wings are fuscous (dark gray or grayish brown)
- On hatching the larvae bore into the bark or main stem.
- The larvae remain within the bored holes during day and come out at night to feed on the bark.
- They feed sheltered under the silken galleries.
- The attacked trees show the presence of winding silken galleries full of frass and fecal matter on the bark surface extending from the bored holes downwards.
- Generally, one larva is seen in each hole but in case of severe infestation 15 to 30 larvae may be interference with the translocation of cell sap and thus, arresting of tree growth is noticed with the resultant reduction in its fruiting capacity.

Management

- Keep the orchard clean to prevent the infestation of this borer.
- Kill the caterpillars mechanically by inserting an iron spike into the holes made by these caterpillars.

- In case of severe infestation, clean the affected portion of the trunk or main stem and insert into the hole swab of cotton wool soaked in a 0.05 per cent emulsion of dichlorvos and seal the hole with mud paste for killing the larva in tunnels.

6. MEALY BUG: *Ferrisia virgata* (Pseudococcidae : Homoptera)

Marks of Identification

- The egg is buff to light yellow in colour and oval to cylindrical in shape having round end, measured 0.34 mm in length and 0.17 mm in width.
- Female is apterous, soft bodied, elongate oval in shape and deep brown in colour with a pair of prominent caudal filaments at posterior end and body is covered with a number of waxy filaments.
- Adult males are slender, delicate, and elongate in shape and smoky brown in colour with a single pair of mesothoracic wings and two long waxy anal filaments.
- The freshly hatched adult female measured 1.96 mm in length and 2.34 mm in breadth with wing expansion.

Nature of Damage

- The infestation of this pest first appears on the seedlings grew up in the orchard.
- They infest leaves, shoots, buds and mainly fruits and suck the cell sap there from.
- As a result heavily affected developing fruits are reduced in size or get dropped.
- These insects also secrete honeydew on which a non- parasitic fungus, *Capnodium* species grows very rapidly, covering the fruits and plant parts with sooty mould.
- This black coating in turn interferes with the photosynthetic activity of the tree and as a result, its growth and fruiting capacity are adversely affected.
- The honeydew also attracts the ants which help in dissemination of the pest from tree to tree. Infested mature fruits also reduce their market value.

Management

- To prevent the carry over of the pests, collect and destroy all the fallen infested fruits periodically and cut the branch portion being attached between tree and also ground level.
- Remove the seedlings and weeds, supporting the initial infestation, from the orchard. Plough around the trees during summer to expose and kill the hibernated insect to natural enemies and sun heat.
- Apply methyl parathion 2 per cent dust in the raked soil around the tree trunk to destroy the emerging crawlers.
- Spray carbaryl 0.2 per cent or methyl parathion 0.05 per cent on stem to kill the climbing crawlers.
- Remove and destroy the affected fruits and twigs to minimize the pest population.

- Drip irrigated orchards are more affected than the flood irrigated so it is advised to give heavy flood irrigation once at the flowering stage to destroy the emerging crawlers.
- Foliar application of the triazophos 0.05 per cent or chlorpyrifos 0.05 per cent or quinalphos 0.05 per cent should be done as and when pest appears on tree.

❖ PEST OF BER

1. FRUIT FLY:

Scientific name: *Carpomyia vasuviana* Costa

Family: Tephritidae

Order: Diptera

Host: It is a specific pest of ber both wild and cultivated varieties

Marks of identification:

- The adults, smaller than the housefly, are brownish colour with brown longitudinal strips on the thorax.
- Wings are pale, transparent with grayish brown spots.

Life history:

- The pest is active during winter and hibernates in the soil from April to August in pupal stage.
- At the age of one month, the flies make cavities in the skin of fruit and lay 12 to 18 singly or groups of 2 to 4 eggs, 1 mm below the skin.
- The eggs hatch in 2 to 3 days and the maggots feed on the flesh of the fruit, making galleries towards the center.
- The larvae are full grown in 7 to 10 days and they come out of the fruit by cutting one or two holes in the skin.
- They move away, making jumps of 15 to 26 cm and reach a suitable place to pupate generally 6 to 15 cm below the soil surface.
- The pupal stage lasts 14 to 30 days and the shortest life cycle, from egg to the emergence of the adult, is completed in 24 days.
- There are 2 to 3 broods in a year.

Nature of damage:

- The female flies puncture the ripening fruits and lay their eggs inside the epidermis.
- On hatching maggots feed on freshly and juicy pulp.
- The infested fruit turn dark brown, rotten near the stones and emit a strong smell.
- One maggot is sufficient to destroy the entire fruit.

Management:

- Collect and destroy the fallen infested fruits at alternate days.
- Rake the soil around the trees during summer to expose the pupae to sun heat and natural enemies.
- To escape egg laying on fruits, do not allow the fruits to ripe on the tree, harvest at green and firm stage.
- Install methyl eugenol traps in ber orchards to trap and and kill the male fruit flies.
- Three sprays of monocrotophos 0.04 per cent or fenthion 0.05 per cent or alternate spray of monocrotophos 0.04 per cent, fenthion 0.05 per cent and carbaryl 0.1 per cent or remaining two sprays of fenthion 0.05 cent at an interval of 15 days for the control of fruit fly. The first spray should be applied when ber fruit attains peanut size.
- The insecticides, malathion 0.07 per cent, neemark 0.1 per cent dichlorvos 0.03 per cent and quinalphos 0.05 per cent are also found effective against fruit fly.

2. BER FRUIT BORER:

Scientific name: *Meridarchis scyroides* Meyrick

Family: Metarbelidae **Order:** Lepidoptera

Hosts: Jamun and olive

Marks of identification:

- The caterpillars are pale yellow during earlier stages, later these become pinkish to radish in colour while
- adult moths are dark brown.

Nature of damage:

- On the hatching the caterpillars bore in to the fruits, feed on pulp and fill the cavity with faecal matter

Management:

- Collect and destroy the fallen infested fruits periodically to prevent carry over of the pest.
- Rake the soil around the tree during summer to expose and kill the hibernating insect to natural enemies and sun heat.
- Three sprays of Monocrotophos 0.04 per cent or fenthion 0.05 per cent or fenvalerate 0.01 per cent is recommended for the control of fruit borer at 15 days interval. First spray should be applied when ber fruit attains peanut size.
- The insecticides malathion 0.07 per cent, neemark 0.1 per cent, dichlorvos 0.03 per cent and quinalphos 0.05 per cent are also found effective against this pest.

❖ PEST OF GUAVA

1. GUAVA FRUIT FLY:

Scientific name: *Bactrocera diversus*

Family: Tephritidae **Order:** Diptera

Hosts: Guava, Tomato and other commercial fruits.

Marks of identification:

- Similar to oriental fruit fly, but smaller and with a darker, mostly black thorax.
- Adult -about 7 mm long, , thorax ferrugineous without yellow middle stripe, legs yellow,.
- Adult smoky brown with greenish black thorax having yellow marking with hyaline wings (expanse: 13 - 15 mm), abdomen conical in shape and dark brown in colour.

Life history:

- Eggs laid on soft skin of fruits and egg period 1-4 days.
- Maggot pale cream, cylindrical, 5-8 mm in length, larval period 4-5 days.
- Maggot pupates in soil, pupal period 7 - 13 days.

Nature of damage:

- Maggots bore into fruits and feed on soft pulp.
- The infested fruits show small cavities with dark greenish punctures and when cut open, the wriggling maggots are seen inside.
- The infestation causes rotting and dropping of fruits.

Management:

- Collect and destroy fallen and infested fruits.
- Summer ploughing to expose pupa.
- Use methyl eugenol lure trap (25/ha) to monitor and kill adults
- Bait spray combining molasses or jaggery 10g/l and one of the insecticides, malathion 50 EC 2 ml/l or dimethoate 30 EC 1ml/l, two rounds at fortnight interval before ripening of fruits
- Field release of parasitoids such as *Opius compensatus*, *Spalangia philippinensis*, parasitoid wasp *Diachasmimorpha kraussi*
- Bagging of fruits (whereby the individual fruits are wrapped in paper to protect infestation by fruit flies) and trapping with various baits

2. TEA MOSQUITO BUG:

Scientific name: *Helopeltis antonii*

Family: Miridae **Order:** Hemiptera

Host plants. Guava, cashew, tea, moringa, neem and others

Marks of identification:

- Nymph and adult: Reddish brown, elongate bug with black head, red thorax. black and white abdomen.
- A knobbed process on mid-dorsal thorax.

Life history:

- Female inserts 32 eggs into epidermis of tender shoot, axis of inflorescence and tender fruits,
- Egg period 7-8 days, eggs elongated and slightly curved with a pair of filaments.
- Nymphal period 14-16 days.
- Life cycle completed in 22-25 days.

Nature of damage:

- Adults and nymphs feed on petioles tender shoots and leaf veins causing necrotic lesions, coalesce to form patches.
- On foliage, brownish-black necrotic patches appear and resin exudes from feeding punctures.
- Blisters and scales / rusty corky growth /scab formation on fruits,
- Widespread drying of shoots, inflorescence and flowers and shedding of fruits is witnessed.

Management:

- Undertake pruning to regulate the shade to facilitate proper penetration of sunlight inside the canopy.
- Spray monocrotophos 36 WSC @ 2.5 L in 1500 – 2000 L water per ha at new flush formation.
- Spray carbaryl 50 WP @ 2.5 kg in 1500 – 2000 L water per ha + Urea 3% at flower initiation again at fruiting time.

3. FRUIT BORER (CASTOR CAPSULE BORER, SHOOT AND CAPSULE BORER)

Scientific name: *Dichocrocis punctiferalis*

Family: Pyraustidae **Order:** Lepidoptera

Marks of identification:

- Larva - Pale greenish with pink tinge and fine hairs with dark head
- Adult - Medium sized bright orange yellow moths with black spots on

Life history:

- Eggs are laid in between the warts of young fruits and flower buds and rarely on leaves and shoots
- Pupation in silk-cocoons inside the fruits or stem.
- Life cycle-25-33 days

Nature of damage:

- Newly emerged larvae scrape on leaves ,buds and flowers,

- While second instar Larva bores in to shoot or fruits within which it lives in silken galleries full of frass.
- Feeds on internal contents (pulp and seeds)
- Dry up and fall off without ripening

Management:

- Collect and destroy damaged fruits.
- Clean cultivation as weed plants serve as alternate hosts.
- Use light trap @ 1/ ha to monitor the activity of adults.
- Insecticides: malathion 50 EC 0.1% two rounds, one at flower formation and next at fruit set.

4. FRUIT BORER (POMEGRANATE BUTTERFLY)

Scientific name: *Virachola isocrates* (Fabricius)

Family: Lycaenidae

Order: Lepidoptera

Hosts: It is a polyphagous pest having a very wide range of host plants including Aonla, apple, ber, citrus, guava, litchi, loquat, mulberry, peach, pear, plum, pomegranate, sapota and tamarind.

Marks of identification:

- The adult butterflies are glossy-bluish violet (males) to brownish violet (females) in colour with an orange patch on the forewings. The wing expanse is 4-5 cm.
- The full-grown caterpillars (1.7 - 2.0 cm) are dark brown in colour and have short hair and whitish patches all over the body.

Life history:

- The female butterfly lays shiny white, oval shaped eggs singly on the calyx of flowers and on small fruits.
- The eggs hatch in 7-10 days and the young larvae bore into the developing fruits.
- They feed there for 18-47 days till they are full-grown.
- They pupate inside the fruit but occasionally may pupate outside even, attaching themselves to the stalk of the fruit.
- The pupal stage lasts 7-34 days.
- There are four overlapping generations in a year.

Nature of damage:

- The caterpillars damage the fruit by feeding inside and riddling through the ripening seeds
- The infested fruits are also attacked by bacteria and fungi which cause the fruits to rot.
- The affected fruits ultimately fall off and give an offensive smell.
- This pest may cause 40 to 90 per cent damage to the fruits.

Management:

- Bagging of fruits before maturity will help in checking damage,

- Collection and destruction of fallen infested fruits prevents build up of the pest,
- Insecticides: malathion 50 EC 0.1% two rounds, one at flower formation and next at fruit set.
Release *T. chilonis*- 10 days interval -4 times Inundative release of *Trichogramma chilonis* @ 15 cc/ha
- Ovipositional deterrent- Neem oil 3% or NSKE 5%

5. BARK EATING CATERPILLARS;

Scientific name: *Indarbela tetraonis*

Family: Metarbilidae **Order:** Lepidoptera

Hosts: Mango, guava, citrus, Loquat, pomegranate, litchi

Marks of identification:

- The full-grown larvae is light brown or dirty brown with strong biting mouth parts.
- The moth is stout, pale brown with rufous head and thorax.
- The fore wings are pale brown with numerous brown spots and bands / streaks, while the hind wings are smoke-grey coloured and fuscous
- Males are slightly smaller than females.

Life history:

- Egg laying in clusters of 15-25 on the bark near cracks and crevices.
- Larvae feed on the bark for some distance which they cover up with dark ribbon like wood chips and excreta pellets.
- At advanced stage, they bore in to the wood making short tunnels in which they hide during day time and come out at night to feed on the bark.
- They become full grown in Dec. where after they overwinter and pupate in Apr.

Nature of damage:

- Young trees may succumb to the attack.
- Caterpillars bore into the trunk or junction of branches.(bore hole damage)
- Presence of gallery made out of silk and frass.
- Caterpillars remain hidden in the tunnel during day time come out at night and feed on the bark.

Management:

- Remove and destroy dead and severely affected branches of the tree.
- Remove alternate host, silk cotton and other hosts.
- Swab Coal tar + Kerosene @ 1:2 or Carbaryl 50 WP 20 g / l of water on the basal portion of the trunk up to 3 feet height.
- If infestations are severe then apply the copper oxychloride paste on the trunk of the tree.

6. SPIRALING WHITEFLY:

Scientific name: *Aleurodicus dispersus*

Family: Aleyrodidae **Order:** Hemiptera

Hosts: It is found on 128 plants including guava, cassava, cotton, chillies, tomato, brinjal, bhendi, papaya, crotons and weeds such as *Euphorbia*, *Corchorus*, *Eclipta*, *Vernonia*, *Vicoa*, *Acalypha*, *Alternanthera*, *Amaranthus*, *Convolvulus*, *Abutilon* etc.

Marks of identification:

- Nymphs are short glass like rods of wax along the sides of the body.
- Adults are larger than many of the whitefly species and white in colour with waxy coating on the body. Eyes are dark reddish brown. Fore wings are with three characteristic spots.

Life history:

- Eggs are laid in a spiralling pattern (concentric circles) on the under surface of leaves.
- Egg period lasts for 5-8 days.
- Nymphal period is 22-30 days. Adult longevity is for 13-21 days.
- Total life cycle is completed in 40-50 days.

Nature of damage:

- Adults and nymphs congregate heavily on the lower surface of leaf, suck the sap and cause pre-mature leaf drop, chlorosis, yellow speckling, crinkling and curling.
- Honey dew secretion also leads to the development of sooty mould fungus.
- The copious white, waxy flocculent material secreted by all the stages of the pest is readily spread by wind and thus cause public nuisance

Management:

- Field sanitation
- Removal of host plants
- Installation of yellow sticky traps
- During heavy infestation - application of triazophos 40EC at 0.06%
- Spray neem oil 3% or NSKE 5%
- Release of parasitoid *Encarsia haitierrsis* and predators viz., *Cryptolaemus montrouzieri*

❖ PEST OF PAPAYA

1. WHITE FLY:

Scientific name: *Bemisia tabaci*

Marks of identification:

- Egg - pear shaped, light yellowish
- Nymph - Oval, scale-like, greenish white

- Settle down on a succulent part of leaves.
- Adult - White, tiny, scale-like adults.

Nature of damage:

- Nymphs and adults suck the sap from undersurface of the leaves. Yellowing of leaves.

Management:

- Field sanitation
- Removal of host plants
- Installation of yellow sticky traps
- Spray application of imidacloprid 200SL at 0.01% or triazophos 40EC at 0.06% during heavy infestation.
- Two sprays of acetamiprid 20 SP 0.006% (3 g/10 l of water) OR thiamethoxam 25 WG 0.01% (4g/10 l of water), first at nymphs and adults infestation and second at 15 days after first spray
- Spray neem oil 3% or NSKE 5%
- Release of predators viz., Coccinellid predator, *Cryptolaemus montrouzieri*
- Release of parasitoids viz., *Encarsia haitierrsis* and *E.guadeloupae*

❖ PEST OF GRAPE

1. STEM GIRDLER *Sthenias grisator*

Mark of identification

- Grub - Head is dark brown colour, pair of strong mandibles.
- Adult – Medium sized, grey coloured with a white spot in the center of each elytra.

Nature of damage

- Wilting of branches and then the entire vine.

Management

- Remove loose bark at the time of pruning to prevent egg laying
- Collect and destroy damaged plant parts
- Swab trunk with carbaryl 50 WP 2g/ lit
- Spray application of quinalphos 25 EC 0.05% or carbaryl 50 WP 0.1%, first round immediately after pruning and repeat it 2-3 time

2. FLEA BEETLE: *Scelodonta strigicollis*

Marks of Identification

- Adult - Reddish brown, shiny with six spots on elytra
- Grub – brown in colour and black colour head

Nature of damage

- Caused two type of damages
- Larvae and adults feed on the upper and lower leaf surfaces – leaf injury
- Adult feed on swollen grape buds
- Chew holes in the sides of the newly developing grape buds
- Small holes on tender leaves by adult
- Root damage by grub

Management

- Remove the loose bark at the time of pruning to prevent egg laying
- Shake vines to dislodge adult beetles
- Collect into trays containing kerosenated water and destroy them
- Insecticide: phosalone 35 EC 0.07% after pruning

3. MEALY BUG: *Ferrisia virgata*

Marks of Identification

- Nymph - Yellowish to pale white.
- Adult - long, slender covered with white waxy secretions

Nature of damage

- Premature dropping of fruit.

Management

- Debark vines and branches and apply methyl parathion paste
- Collect damaged bark, leaves, twigs and stems
- Use sticky traps on fruit – bearing shoots at a length of 5 cm
- Insecticides
 - Dimethoate 30 EC plus kerosene oil at 150 ml plus 250 ml in 100 ml of water
 - Apply quinalphos dust in the soil at 25 kg/ ha to kill ants
 - Release exotic predator, *Cryptolaemus montrouzieri* @ 10 beetles/vine

❖ PEST OF COCONUT DATE PALM

The coconut and other palm trees are attacked by specific pests like rhinoceros beetle, red palm weevil, black headed caterpillar and also by a number of polyphagous insects like white grub. Slug caterpillars occasionally major pest status. Black headed caterpillar is severe in coastal regions.

1. BLACK-HEADED CATERPILLAR

Scientific name: *Opisina arenosella* Walker

Family: Xyloryctidae

Order: Lepidoptera

Distribution: This is one of the most important pests of coconut palm in Kerala as well as along the western coast of India, Sri Lanka and Myanmar

Host plants. Coconut and other plams

Marks of identification:

- Caterpillar is greenish brown with dark brown head and prothorax, and a reddish mesothorax. It has brown stripes on the body.
- The moth is ash grey. It is medium-sized, measuring 1.0-1.5 mm, with a wing expanse of 2.0-2.5 cm.

Life history:

- A female moth lays 125 scale like eggs in small batches on the underside of the tips of the old leaves.
- Freshly laid eggs are creamy white and turn pink on completion of embryonic development. The incubation period lasts about 3-5 days in summer and 10 days in winter.
- When full- grown in about 40 days, the larva transforms itself into a brownish pupa inside the gallery.
- Within about 12 days, a whitish moth emerges and starts the life-cycle all over again

Nature of damage:

- The larva feeds on green matter and simultaneously constructs a silken gallery in which it feeds and voids frass.
- As a result of the numerous galleries made by the feeding caterpillars, the foliage dries up.
- Infested trees can be recognized from the dried up patches in the fronds.
- In case of severe attack due to large scale drying of leaflets, the whole plantation presents a burnt up appearance from a distance, resulting in a considerable reduction in yield.

Management:

- Release the larval (*Bethylid*, *Braconid* and *Ichneumonid*) and pupal (*Eulophid*) on (chalcid) parasitoids and predators periodically from January, to check the build up of the pest during summer.
- Among the larval parasitoids, the bethylid *Goniozus nephantidis* is the most effective in controlling the pest. The optimum level of release is 1:8 of host-parasitoid ratio. The parasitoid should be released @3000/ha under the coconut trees when the pest is in the 2nd or 3rd instar larval stage. Parasitoid release trap may be used to release the parasitoid at the site of feeding. Parasitoids should not be released in the crown region since they will be killed by predators like spiders and reduviid bugs.
- Remove and burn all affected leaves/leaflets.
- Spray malathion 50 EC 0.05% (1ml/lit) to cover the undersurface of the leaves thoroughly in case of severe epidemic outbreak of the pest in young palms.

- Root feeding for the control of coconut Black headed caterpillar:
- Select a fresh and live root, cut sharply at an angle and insert the root in the insecticidal solution containing monocrotophos 36 WSC 10 ml + water 10 ml in a 7 x 10 cm polythene bag. Secure the bag tightly to the root with a cotton thread. Twenty four hours later, check whether there is absorption. If there is no absorption select another root. These methods should not be resorted to as a routine practice and it is suggested only for cases of severe epidemic outbreak of the pest and when the survival of the tree is threatened.

2. RHINOCEROS BEETLE

Scientific name: *Oryctes rhinoceros* (Linnaeus)

Family: Scarabaeidae **Order:** Coleoptera

Distribution: The rhinoceros beetle is one of the most important pests of the coconut in all coconut growing states of India. It is found throughout South-east Asia, the Philippines and southern China.

Hosts: Coconut and other palms such as date-palm, sago-palm, palmyra, etc

Marks of identification:

- Grub is stout, sluggish, white “C”-shaped with pale brown head and found at a depth of 5 to 30 cm.
- The adult beetle is stout, black or reddish black, about 5 cm long and has a long horn projecting dorsally from the head in male; in the female the horn is short.

Life history:

- The oval, white, seed-like eggs are laid 5-15 cm below the soil surface in decaying organic matter.
- The early stages of the beetle are generally passed in manure pits and decomposing vegetable matter, chiefly in the dead palm trunks.
- The female lays 100-150 eggs, 5-15 cm below the soil surface in decaying matter.
- The eggs hatch in 8-18 days and the grubs start feeding on the decaying matter found in the vicinity.
- The larvae pass through three instars to complete their development in 80-130 days.
- Pupation takes place in chamber at a depth of about 30 cm and the beetles emerge after 10-25 days. They remain in the pupal cell for about 11-20 days before coming out of the soil and, on emergence, they are soft-bodied creatures.
- Soon, they fly to the nearest palm-tree and start the attack. They lay eggs after 20-60 days. The adults can live for more than 200 days.
- Generally, one generation is completed in a year.

Nature of damage:

- The damage is done by adults alone since grubs feed on decaying matter.

- The beetles throw out a fibrous mass while feeding in the burrows made in the young fronds.
- The injury is seen as a series of holes on the fronds when they open out.
- As a result, the growing point is soon cut off and the tree dies.
- The damage caused by this beetle is more serious on young trees.

Management:

- Destroy and dispose all dead trees
- Avoid manure pits in the vicinity of coconut gardens
- Rake and turn up the decaying manure to expose the developing grub, egg and pupae to sun drying and predation. Then apply the fungal culture of *Metarrhizium anisopliae* to manure pits during cooler months of October - December.
- Once in three months, drench the manure pits with carbaryl 50 WP 1 g/lit
- Soak castor cake @ 1 kg/5 lit of water in wide mouthed mud pots and keep them in the garden to attract and kill adults. Replace the slurry once in 30 days.
- The crown region may be properly cleaned during harvests and the adults may be hooked out using a long wire.
- Light traps may be set up to attract the adults during monsoon months and following rains during summer.
- The top-most three axils may be filled with a mixture of sand + Neem Seed Powder (2:1) once in three months (150 g/tree)
- Use aggregation pheromone traps Rhinolure @ 1/ha. Instal the trap at five feet from the ground level.
- Treat the breeding places with 2.0 kg of carbaryl 50WP in 250 litres of water per ha.

3. RED PALM WEEVIL

Scientific name: *Rhynchophorus ferrugineus* (Olivier)

Family: Curculionidae

Order: Coleoptera

Distribution: The pest is distributed in India, Pakistan, Bangladesh, Sri Lanka, Malaysia, the Philippines and New Guinea. It is one of the most destructive pests of coconut palm in Maharashtra, Assam, Kerala, Tamil Nadu, Mysore and Orissa.

Hosts: Coconut and other palms.

Marks of identification:

- Light yellowish grub without legs
- This weevil is reddish-brown, cylindrical, with a long curved snout.
- The male has tuft of hairs along the dorsal surface of the snout, whereas the female is without it. The full grown grub is yellowish.

Life history:

- The mother weevil scoops out a small hole with its snout in the soft tissues of the trees or in the existing wounds, in the crown or trunk and lays an oval, whitish *egg*.
- A weevil may lay up to 200-500 eggs in its life span of 3-4 months.
- The eggs hatch in 2-5 days
- The larval period ranges from 2 to 4 months.
- The grub changes into a pupa after spinning a cocoon.
- The weevil emerges from this cocoon on the completion of the pupal stage in about 14 days.
- The adults remain within the case for 11-18 days out of life-span of 50-113 days, the male surviving for a longer period than the female.
- The adult is capable of flight and is diurnal in habits.

Nature of damage:

- Few small holes with protruding chewed fibrous material and oozing out of a brown liquid from such holes, present in the tree trunk, indicate the early infestation by the pest.
- In the advanced stage of attack the central shoot shows sign of wilting and a large mass of grubs, pupae and adults of the insect could be seen inside the trunk at the affected portion.
- In the grown up trees the crown region alone is infested.

Management:

- The dying and already damaged palms should be destroyed and as far as possible inflicting mechanical injuries on trees should be avoided.
- Inject emulsion of dimethoate 30EC @ 400 ml or carbaryl 50WP @ 250 g in 25 litres of water into the live holes and plaster them with mud after application of chemicals.

4. COCONUT ERIOPHYID MITE:

Scientific name: *Aceria guerreronis*

Family: Eriophyidae

Order: Acari

Marks of identification:

- The mite has worm like body with the two pairs of legs and can be identified by the pattern on the dorsal shield and genital cover flap.
- The mouth parts comprise needle like chelicerae which are used to puncture cells and suck the contents.
- The mites are very minute in size and are not visible by naked eye.
- The size of this measures to 200-250 microns in length and 20-30 microns in width.

Life history:

- The female lays eggs which are white oval.
- The nymphs which hatch out are small but resemble adults in shape.

- The life cycle of this mite is completed in 10-12 days.

Nature of damage:

- The mites are seen in colonies in the perianth of developing nuts and live in the white tender portion covered by the inner bract of perianth and suck the sap from the tender raeristematic mesocarp tissues.
- Maturing nuts up to nine month old harbour the mites.
- The feeding results in warts and numerous longitudinal fissures on the husk of developing nuts.

Management:

- **Nutrients (per tree / year)** Urea 1.3 kg, super 2.0 kg, potash 3.5 kg, neem cake 5 kg, borax 50 g, gypsum 1 kg, MgSO₄ 500 g, FYM 50 kg
- **Root feeding**
Root feeding with carbosulfan 15 ml + 15 ml water / tree at 45 days interval or fenpyroximate at 10 ml/tree
Note: Before root feeding, pluck nuts. After root feeding, next harvest should be done 45 days later.
- **Spray** - Fenpyroximate 5 EC 1.0 ml/L of water
- IPM package in coconut consisting application of 50 kg FYM + 5 kg neem cake + 500 gm magnesium sulphate + 50 g borax + 500:320:1200 gm NPK (in two splits) + crown spraying with Azadirachtin 1500 ppm (thrice in a year) /palm/year to harvest the higher number of healthy nuts and low incidence of eryophide mite.

5. TERMITE: *Odontotermes obesus*

Mark of identification:

- Adults: Cream coloured, tiny insects resembling ants with dark coloured head

Nature of damage:

- Termites are likely to cause damage to transplanted seedlings particularly in the earlier stage. (wilting of seedlings)
- Base of trunks plastered with runways made of soil and fibers

Management:

- Locate termite mounds in or near the coconut nursery or garden and destroy.
- Adoption of field sanitation by disposal of organic matter in nursery soil and covering germinating nuts with a layer of river sand.
- Spray Chlorpyrifos @ 3ml/lit of water, Neem Oil 5% or NSKE 20% to preserve plaited coconut leaves from the termite attack.
- Apply calcium at the base of the trunk for control of termite attack.

- Swabbing with neem oil 5% once on the base and upto 2 m height of the trunk for effective control

❖ PESTS OF ORNAMENTAL PLANTS

India has made noticeable advancement in the production of flowers. During 2006-07, the country produced 886000 metric tonnes of loose and 27.23 million cut flower. Various species of thrips, aphids, leafhoppers, scale insects, mealy bugs, leaf-miners, caterpillars, cutworms and chaffers attack the common ornamental plants including rose, chrysanthemum, hibiscus, hollyhock, sunflower, iris, jasmine, etc.

1. ROSE APHID

Scientific name: *Macrosiphum rosaeiformis* Das

Family: Aphididae

Order: Hemiptera

Distribution: This aphid has been recorded in Punjab, Delhi, Karnataka, Andhra Pradesh and the Nilgiri Hills.

Marks of identification:

- The non-winged rose aphid has an elongated body measuring 2.5-2.6 mm, large red eyes, black cornicles and a yellowish green tip of the abdomen

Life history:

- Nymphal development is completed in 11-14 days of the non-winged forms and 14-19 days of the winged forms, the growth being the quickest in March.
- The aphid multiplies most rapidly in late spring but cannot withstand the summer heat. Consequently, its population declines.

Nature of damage:

- The aphid sucks cell sap from the tender leaves, buds and twigs. It is particularly injurious to tender buds, resulting in the disfigurement and withering of flowers.
- Each aphid makes several punctures, producing wounds, which leave their mark as the flower opens.
- A black fungus may also develop on the honeydew excreted by these insects, giving an ugly appearance to the plant.

Management:

- Spray 500 ml of malathion 50EC or methyl demeton 25EC in 500 litres of water per ha.
- The treatment may be repeated at the reappearance of the pest.

2. RED SCALE *Aonidiella aurantii*

Marks of identification:

- Reddish brown waxy scale found on lower portion of old stem.
- Female wingless comparatively large

Nature of damage:

- Both adults and young nymphs suck the sap from stem and mature shoots and cause harm to plant vigour.
- Infested shoots have reddish brown encrustation, bear few small flowers and in case of severe infestation the entire plant become dry.

Management-

- Selection of planting material free from scale infestation.
- Cutting and burning or burying of heavily infested shoots is very effective.
- Soil application of Carbofuran (1.0 kg a.i.) followed by application pongamia oil (10 per cent) to infested shoots, immediately after pruning provides effective control.
- Spray chlorpyrifos (0.05 per cent) is very effective.

3. ROSE THRIPS *Rhipiphorothrips cruentatus*

Marks of identification:

- Nymphs are reddish and adults are dark brown or black in colour

Nature of damage:

- The thrips attack starts with the new flush after pruning on open cultivated rose.
- Blackish brown adults and reddish nymphs of thrips found underside of tender leaves and beneath sepals and petals of buds and flowers.
- Female lays eggs in leaf tissues, newly emerged nymphs cause damage to foliage by rasping the tissue and sucking the cell sap that oozes out.

Management-

- Spraying of acephate (0.1%) is very effective in controlling this pest.
- Raking up of soil during winter and drenching with chlorpyrifos (0.1%) kills inactive stages of thrips.

4. TWO SPOTTED SPIDER MITE *Tetranychus urticae*

- The mite is very active in March to May when hot and dry conditions prevail.
- Cream coloured nymphs and red coloured adults with two black spots are found in colonies on lower side of mature leaves covered by webs.
- In case of severe infestation, they spread to entire plant which includes buds and flowers.

- The mites scrape tissues and suck the sap resulting in discolouration, yellowing, drying and dropping of attacked leaves.

Management-

- Proper ventilation, clean cultivation and frequent watering to bring down temperature keep the pest under check.
- Cutting and burning of heavily infested shoots should be done.
- Spray of dicofol (0.05 per cent) or wettable sulphur (0.3 per cent) controls mite problem roses.

5. JASMINE LEAF WEBWORM

Scientific name: *Nausinoe geometralis* (Guenée)

Family: Pyraustidae **Order:** Lepidoptera

Distribution: This pest is widely distributed in West Africa, India, Pakistan, Sri Lanka, Myanmar, Java, Taiwan, China and Australia.

Marks of identification:

- The moths are brown with hyaline patches on the wings. Their abdomen is purplish brown, which is interspersed with lateral patches of lighter shades on each segment.
- The young caterpillars are light yellow in colour but as they grow they become darker.

Life history:

- The female lays 15-20 eggs singly on the leaf lamina. The eggs are greenish yellow in colour- which hatch in 3-4 days.
- The larvae become full-grown in 12-15 days after passing through five instars.
- The larvae spin extensive webbings in the shaded portion of the plant around the leaves on which they feed and pupate within that area.
- The pupal stage lasts 6-7 days and the life- cycle is completed in 22-24 days during July-August.

Nature of damage:

- During the rainy season, the caterpillars attack leaves of the plant mostly in the lower bushy and shaded portions. During the dry and sunny weather the terminal shoots are attacked.
- The leaves are webbed in an open and loose manner. The silk threads are seen as a cobweb, on the surface of leaves.
- The larvae skeletonize the leaves by eating away the parenchyma.
- As a result of the gregarious attack of the caterpillars, the vitality of the plant is reduced

Management:

- Spray 500 ml of dimethoate 30EC in 500 litres of water per ha.

6. JASMINE BUDWORM

Scientific name: *Hendecasis duplifascialis* Hampson

Family: Pyraustidae

Order: Lepidoptera

Marks of identification:

- The moth is pale white.
- The larva is yellowish green in colour with a distinct black head and prothoracic shield.

Life history:

- The freshly laid eggs are round, creamy and glued to the flower buds. The eggs hatch in 2.6-3.5 days and the larva passes through five instars.
- The total larval duration varies from 11.5 to 17.0 days depending on the jasmine species.
- The pupal stage lasts 6.5-9.0 days and the life cycle is completed in 21-29 days

Nature of damage:

- The larva bores into immature bud and feeds on the internal contents.
- The larva feeds voraciously on the corolla leaving only the corolla tube in mature buds.
- In the case of younger buds, the larva remains outside the buds and feeds on the inner floral whorl through a small hole in the corolla tube.
- The infested flower turns violet and eventually dries out.
- A single larva may damage upto 6 flower buds.
- During heavy infestation, the adjacent buds along the inflorescence are webbed together by silken thread.

Management:

- Spray 500 ml of dimethoate 30EC or 200 ml of cypermethrin 25EC in 500 litres of water per ha.

7. LILY MOTH

Scientific name: *Plytela gloriosae* Fabricius

Family: Noctuidae

Order: Lepidoptera

Marks of identification:

- The moth has mosaic patterns of red, yellow and black on fore wings, with a row of black and yellow dots on the apical margins.
- The hind wings are black.
- The full grown larva measures 3.9-4.2 cm and possesses black, white and red mosaic patterns on the body.

Life history:

- The female moth lays round, yellowish eggs on the apical portion of the undersurface of leaves in clusters of 13-42.

- The larvae emerge from eggs after 3-6 days and they feed on leaves for 16-20 days.
- When full fed, they pupate in the soil in an earthen cocoon and the adults emerge within 15-20 days.
- The insect has two generations in a year and the pupae of second generation hibernate.

Nature of damage:

- The larvae feed on green matter of leaves which may result in complete defoliation of the lily plants.

Management:

- Spray 500 ml of malathion 50EC in 500 litres of water per ha.

8. SUNFLOWER LACEWING BUG

Scientific name: *Cadmilos retarius* Distant

Family: Tingidae

Order: Hemiptera

Marks of identification:

- The sunflower lacewing bug is a small insect measuring about 4 mm, with transparent, shiny, reticulated wings and black body.

Life history:

- The adult female bugs lay eggs mainly on the upper surface of leaves of the host plants.
- The eggs are inserted slantingly into plant tissue leaving the opercula exposed, which appear like white or brown dots.
- The eggs hatch in 5-7 days and the young nymphs moult five times during nymphal period of 2-3 weeks. Then they become adults.

Nature of damage:

- Both nymphs and adults cause damage to many garden plants like sunflower, *Gaillardia*, daisy, *Chrysanthemum*, marigold, veronica, launea and the weed, *Argemone mexicana*.
- They suck plant sap and the infested leaves turn yellowish- brown and finally dry up.

Management:

- Spray 500 ml of malathion 50EC in 500 litres of water per ha.

9. HOLLYHOCK TINGID BUG

Scientific name: *Urentius euonymus* F

Family: Tingidae

Order: Hemiptera

Marks of identification:

- The bugs are easily recognized by their densely reticulate body and wings, and measure about 5-6 mm in length. The nymphs are spiny in appearance.

Life history:

- The adult female lays eggs on the upper surface of leaves.
- The incubation period of the eggs is 8-10 days.
- There are five nymphal instars and development is completed in 15-27 days.
- The full developmental cycle is completed on a single leaf. The pest overwinters in egg stage.

Nature of damage:

- The tingid bug infests the garden hollyhock, *Althaea rosea*, *Abutilon indicum*, *Sida cordifolia* and *Chrozophora rottleri*.
- Both nymphs and adults suck plant sap from the under-surface of leaves.
- The infested leaves become pale-yellow and turn brown. Ultimately they shrivel and dry up.

Management:

- Spray 500 ml of dimethoate 30EC or endosulfan 35EC in 500 litres of water per ha.

10. JASMINE THRIPS

Scientific name: *Thrips orientalis* Bagnall

Family: Thripidae

Order: Thysanoptera

Marks of identification:

- The insects are light brown in colour and are found in flowers

Nature of damage:

- The dark coloured jasmine thrips is mainly found on *Jasminum multiflorum* from February to April.
- Both nymphs and adults feed on flowers. The attacked flowers give a decayed look and fall off prematurely.
- Another thrips species, *Taeniothrips traegardhi* Tryban, also attacks the flowers of *Nerium indicum* and *Daedolacanthus nervosus* in the months of March-April.
- The insects are light brown in colour and are found in flowers, giving them a decayed look caused by feeding.

❖ PLANT PROTECTION IN PROTECTED CULTIVATION

Protected cultivation

Protected cultivation is the concept of growing potential crops in the modified natural environment for ensuring optimum growth of the crop plants without any or least stress. In other words, protected cultivation can also be defined as controlled environment agriculture (CEA) which is highly productive, conservative of water and land and also protective of the environment.

Types of protective structures

Greenhouse for vegetable production encompasses: glasshouse, polyhouse, insect-proof net house, low tunnel polyhouse, zero energy polyhouse. Protected structures are of different kinds, viz. open-ventilated, closed polyhouse with fan and cooling-pad system, shade net house, etc. Greenhouse structures are of different kinds based on shape (lean to type, even span type, ridge and furrow type etc.), utility (temperature and humidity controlled), construction (wooden, pipe or truss framed), covering material (glass, fiber glass, plastic-film). Plastic film covering materials are of different types such as acrylic, polycarbonate, fiber glass reinforced polyester, polyethylene film ^[17] and polyvinyl chloride film. Most greenhouse crops grow best in light whose wavelengths range from 400 to 700 nm and hence the glazing materials should be highly transparent

Insect-pests scenario under protected environment in India

Insect		Host
CommonName	ScientificName	
Aphids	<i>Aphisgossypii</i>	Capsicum
	<i>Macrosiphoniellasanborni</i>	Chrysanthemum
	<i>Myzusescalonicus</i>	Strawberry
	<i>Myzuspersicae</i>	CapsicumGerbera
	<i>Toxopteraaurantii</i>	Orchid
Caterpillars	<i>Helicoverpaarmigera</i>	Capsicum,tomato,carnation
	<i>Spodopteralitura</i>	Rose,tomato,capsicum,cucumber
Leaf-miners	<i>Liriomyzatrifolii</i>	Tomato,cucumber,chrysanthemum,gerbera
Mites	<i>Aceria lycopersici</i>	Tomato
	<i>Polyphagotarsonemuslatus</i>	Capsicum
	<i>Stenotarsonemusfragariae</i>	Strawberry
	<i>Tetranychuscinnabarinus</i>	Carnation
Thrips	<i>Scirtothripsdorsalis</i>	Rose
	<i>Thripspalmi</i>	Gerbera
Whiteflies	<i>Bemisiatabaci</i>	Gerbera,capsicum
	<i>Trialeurodesvaporariorum</i>	Tomato,cucumber,capsicum,beans,gerbera

Integrated Pest Management strategies for protected cultivation

- I. Preventive measures
- II. Scouting and early detection
- III. Curative measures
- I. Preventive Strategies**
- A) Exclusion**
- 1) Use of physical barriers**

Exclusion means keeping insects from entering the greenhouse by use of physical barriers such as insect proof screens. Insect exclusion is considered a first step in developing an integrated approach to greenhouse pest management. The pests not only damage the crop by direct feeding but may also transmit phytopathogenic organisms. Moreover, crop protection from insects is regarded from many growers in the Mediterranean basin as more important than protecting them from excessive heat. The exclusion is obtained by installing fine-mesh screens which act as mechanical barriers on the greenhouse openings . Some of exclusive mechanisms are discussed below:

a. Use of insect-proof nets

This includes common greenhouse pests such as thrips, aphids, leaf-miners and whiteflies, but also some less common pests such as fruit borers. Screen mesh of holes less than 200 micrometers is required for complete exclusion. Insect-proof screens 10 x 20 micron and 10 x 22 micron give adequate exclusion of whiteflies *Trialeurodes vaporariorum* and *Bemisia tabaci* without impeding natural enemies (*Diglyphus isea* and *Eretmocerus erimicus*) movement

b. Provision of double door

Limited access to screened areas is beneficial since insects may come in the protected structure on clothing or be swept in with the wind. Building a screened foyer to create a double-door entry partially solve the problem of wind-carried insects. Special efforts must be put in for repairing holes or tears immediately, and cleaning the screens to maintain airflow.

c. Use of reflective or metalized mulches

These are used primarily for the repelling effects on certain insects. Metalized mulch was effective in reducing silverleaf whitefly entrance by 90 per cent. The combination of screening and metalized mulch should be used together and will provide the greatest total reduction of whitefly entry [8]. Complete mulching of the greenhouse floor preventing weeds and acting as a mechanical barrier to certain insect (leaf-miners, thrips and other lepidopteran pests) life stages preventing them from moving into the soil for pupation.

d. Ultra-violet radiation absorbing sheets

Altering the visual behaviour of insects has been used successfully as a tool in IPM programmes directed to protect crops from insects and insect-borne viral diseases. The manipulation of the UV

vision of insects by using UV-blocking greenhouse cladding materials has been shown to be effective in preventing the immigration of a wide range of insect-pests (whiteflies, aphids, thrips and leaf-miners) from the external environment into the protected crop. It was found that populations of aphid (*Aphis gossypii*), greenhouse whitefly (*T. vaporariorum*), thrips (*Frankliniella occidentales* and *Scirtothrips dorsalis*) and leaf-miner (*Liriomyza* sp.) were lower on tomatoes grown in a plastic-house made of polyethylene treated to exclude UV wavelengths than on crops grown in an ordinary plastic house. The number of whiteflies, aphids and thrips trapped on sticky yellow cards under a UV-absorbing film were 10 - 100 times lower than the number trapped under regular films. The use of UV-A films also helped in reducing the number of insecticide applications by 50-80 per cent for the management of *Spodoptera lituralis*. UV-absorbing plastic roofs showed the most pronounced deterrent effect for thrips [20]. UV blocking PE films found very effective in reducing the no. of injured fruit in tomato and produces higher yield in comparison to other covering material

B) Sanitation and cultural practices

1) Sanitation

Sanitation involves the removal of both infested materials and potential sources of infestation, followed by disinfection of surfaces and includes various approaches like, clean planting material, ventilation, clean or sterile soils tools, flats and other equipments. Maintain a clean, closely mowed area around the greenhouse to reduce invasion by pests that develop in weeds outdoors, dispose of trash, boards and old plant debris in the area, removal of weeds and any plant debris and clean the greenhouse thoroughly after each production cycle.

2) Cultural Practices

a) Pre-season cleanup

Before introducing a new crop into the greenhouse, it is extremely important to pests from the previous crop. Remove all plant debris and weeds from the greenhouse. Many pests also occur on other crops or broadleaf weeds. For this reason, it is important to avoid growing other crops next to the greenhouse and to prevent heavy growths of broadleaf weeds around the outside edges of the greenhouse. Under protected environment monoculture is suggested, however, if one has to go for polyculture then avoid staggered planting. A fallow period of two to four weeks reduces the pest load considerably. To determine the presence of thrips, whiteflies, leaf-miners, or other insects, set up yellow sticky cards and indicator plants after watering. Observe for any insects that are trapped on the cards after two days and continue till the activity is ceased and only thereafter the decision regarding plantation of new crop be made.

b) Inspection upon arrival

One of the most important points in protected cultivation is to begin with insect-free planting material. When new plants arrive at the greenhouse, examine them closely for signs of pest infestation. If necessary, remove lower or damaged leaves to avoid spread of pests. Make the decision whether

treatment is needed from the first sign of symptoms of insects or mites. It is much easier to manage a pest infestation by treating a group of small plants (in seedling stage) rather than larger plants where the dense canopy prevents thorough coverage

c) Balanced use of fertilizer

Fertilization schedules based on balanced use of nutrients should be followed. Nitrogen should be applied only as needed for optimal growth. Periodic heavy applications set up nitrogen surpluses that cause excessive growth, which favour the population growth of aphids, and other pests. Application of potassium at desired levels has been found to reduce the incidence of insect-pests.

d) Pinching and Pruning

Pinching-off damaged plant parts, flowers, and spotted leaves (and those with insect larvae or egg deposits) can be a very effective way of reducing the spread of pests in the greenhouse. The plant debris should be placed immediately in a covered container before being disposed-off. This practice can be helpful in reducing the pest population of all the targeted pests. Pruning lower leaves after harvesting lower fruit clusters is helpful measure in removing large numbers of developing leaf-miners and whiteflies.

e) Trap crop/Indicator plants

For early detection and trapping of the target pests, some of the preferred hosts of the target pests can be used. Planting border rows of *Portulaca oleracea* in rose can be used as a trap crop for tobacco caterpillar under protected environment.

f) Plant Quarantine

Professionals or labours working in the greenhouse are one of the mechanisms for dispersal of insects and mite pests. One should try to avoid moving plants with mites or thrips and they should not be touched or moved immediately before handling clean and healthy plants.

II. Scouting and early detection

Scouting and early detection are critical to manage the insect infestation successfully. Monitoring or scouting is the regular, systematic inspection of the plants and exteriors to identify and assess pest problems. It includes visual inspection of foliage and flowers; and the use of sticky or light traps. Many insect infestations begin in isolated spots within the greenhouse. Timely crop monitoring identifies situations where pests are absent or are at levels well below economic injury, thus preventing unnecessary control applications and expenditures thereby.

Scouting

Scouting procedures for most greenhouse-grown crops are based on visual observations and are used to provide estimates of the pest population in protected environment. The common pests that attack greenhouse crops do not distribute themselves evenly throughout the crop. Therefore, it is imperative

to scout the entire greenhouse in a consistent, uniform pattern. Inspect the entire plant, including the soil surface, for the presence of arthropod pests. Look at the plant systematically each time. Begin at the bottom and work up. Look at the older leaves, the young, tender leaves, and the flush growth. When the crop is young, it is important to check all the leaves on the plant. Because a majority of arthropod pests associated prefers the underside of a leaf, it is important to turn the leaves over to check for pests. The detailed account of observations to be recorded is presented below.

Scout the crop on a regular basis and at least 1-2 per cent of the total plants should be inspected at weekly interval. A thorough greenhouse inspection reveals the location and severity of any current pest problems. One should use a field data sheet to record the identification, location, and severity of all pests present, and record the effectiveness of any treatments

Monitoring

It is a relative method of insect population estimation where no direct observations on the plants for the presence of insect-pests are needed. However, the pest population is estimated with the help of attractant traps. For whiteflies, aphids, thrips and leaf-miner adults, yellow sticky cards (4"x12" or 8"x12") are an excellent supplement to pest observation in the protected environment. Additionally, for thrips blue coloured sticky traps can also be used. The traps are placed in a grid pattern and 1-2 yellow sticky cards per 100 square meter of floor area are used. If the target is mass trapping, then number of traps can be increased to five or more. Hang the yellow sticky cards/ traps in the crop with the help of strings about 4" to 6" above the plant canopy. As the crop grows, cards can be moved up. Designate the location of each sticky card on a map of the greenhouse. Check the sticky cards every scouting visit (twice a week if possible) and record the total number of whiteflies, thrips, winged aphids and leaf-miners from each card on the field data sheet. Change the cards when more than 60-70 per cent of the area is covered by trapped insect.

III. Curative measures

A) Biological Control

Biological control is the action of parasites, predators or pathogens in maintaining another organism population density at a lower average that would occur in their absence. In entomology, it has been used to describe the use of live insect predator and parasitoids, entomopathogenic nematodes or microbial pathogens to suppress populations of different pest insects. The organism that suppresses the insect pest is referred to as the biological control agent (BCA). BCAs are of utmost importance in case of protected cultivation and widely used against a number of pests. Biological control in the greenhouse environment is a viable alternative to pesticide use from both environmental and economic perspectives. The important BCAs used against greenhouse pests are listed below in Table

Major BCAs of key pests of green houses

Pest	Predator	Parasitoid	Entomopathogens
Mites	<i>Phytoseiulus persimilis</i> , <i>Neoseiulus cucumeris</i> , <i>Orius laevigatus</i>	-	-
Whitefly	<i>Orius laevigatus</i> , <i>Chrysoperla</i> spp	<i>Eretmocerus mundus</i> , <i>Encarsia formosa</i>	<i>Verticillium lecanii</i> , <i>Beauveria bassiana</i>
Thrips	<i>Orius laevigatus</i> , <i>Neoseiulus cucumeris</i>	-	-
Leafminer	-	<i>Diglyphus isaea</i> , <i>Dacnusa siberica</i>	<i>Bacillus thuringiensis</i>
Aphids	<i>Orius laevigatus</i> , <i>Chrysoperla</i> spp., <i>Apidoletes aphidomyza</i>	<i>Aphidius colemani</i> , <i>Aphidius matricariae</i>	-
Caterpillars (<i>Spodoptera</i> p.)	<i>Chrysoperla carnea</i>	<i>Trichogramma</i> spp.	<i>Bacillus thuringiensis</i> , SINPV, HaNPV

B) Chemical control

Control of insects with chemicals is known as chemical control. The term pesticide is used to those chemicals which kill pests and these pests may include insects, animals, mites, diseases or even weeds. Chemicals which kill insects are called as insecticides. Insecticide may be defined as a substance or mixture of substances intended to kill, repel or otherwise prevent the insects. Some of the important chemical insecticides used against greenhouse insect pests are listed below in Table

Some of the important chemical formulations used against greenhouse insect pests

Targetpests	Chemicals
Mites	Diafenthiuron, Fenpyroximate, Abamectin @ 0.5ml/L
Thrips, Whiteflies, Aphids	Imidacloprid @ 0.4g/L, Acephate @ 1g/L or Acetamiprid @ 0.2g/L, , Abamectin @ 0.5ml/L,
Leafminer	Spinosad @ 0.3ml/L, Abamectin @ 0.5ml/L
Caterpillars	Spinosad, Chlorantraniliprole @ 0.3ml/L, Flubendiamide @ 0.1ml/L