ACHARYA N G RANGA AGRICULTURAL UNIVERSITY

PRINCIPLES OF ENTOMOLOGY AND PRODUCTIVE ENTOMOLOGY

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ANGRAU

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Lecture –I

INTRODUCTION TO ENTOMOLOGY

The term entomology is derived from two Greek words. Entomon means an insect and logos means to study. The term 'insect' is derived from the Latin word insectum which means 'cut into'. Insects are harmful to man as pests of cultivated crops, animals, stored products, carries of human diseases and pests of household and industrial articles. They are also helpful as producers of honey, lac, silk, dyes, etc., pollinators of crops and as natural enemies of crop pests. They also serve as important link in the food-web of biological cycle in ecosystem. Study of economically important insects in agriculture is called Agricultural Entomology. Insects belong to Phylum Arthropoda (Arthro=Joint, Poda=Legs), which is the biggest phylum of Animal Kingdom. The organisms with jointed appendages are kept under this phylum Arthropoda and they live in diverse environmental habitats like fresh water ponds, sea and terrestrial.

Important characters of Phylum Arthropoda :

a) Arthropods are the animals with bilateral symmetry
b) Haemocoelic body cavity
c) The segmented body
d) Paired jointed appendages usually terminates in a claws
e) Chitinous exoskeleton
f) Ventral nervous system
g) Muscles are composed of striated fibres, ciliated epithelium absent
h) Open type of circulatory system and heart .is on dorsal side
i) Grow by moulting
j) Alimentary canal is tubular with mouth at anterior and anus at posterior ends.

Phylum Arthropoda is classified into seven classes :

1.Onychophora	eg:Peripatus
2.Crustacea	eg: Prawns, Crabs
3.Arachnida	eg:Scorpion, Spider, Ticks, Mites
4.Chilopoda	eg:Centipedes
5.Diplopoda	eg:Millipedes
6.Symphyla	eg.Garden centipedes
7.Insecta (Hexopoda)	eg.Insects

Characters of class Insecta (Hexapoda ; Hexa-Six, Poda-Legs)

Insects occupy 2/3rd of total population of Phylum Arthropoda and belongs to sub-phylum Mandibulata. Insects are tracheate arthropods whose body is divided in to three regions namely head, thorax and abdomen possessing two pairs of wings and three pairs of legs in thoracic region, genital organs towards posterior end of the body and with decentralized nervous system.

Characters of Class Insecta:

1. Body divided in to head, thorax and abdomen
2. Possess three pairs of legs, hence the name Hexapoda
3. A pair of antennae
4. Presence of one or two pairs of wings
5. Possess exoskeleton made up of hard cuticle which plays important role for survival
6. Respiration by means of internal air tubes known as trachea
7. Possess open circulatory system and body cavity is called as haemocoel
8. Genital opening situated at the posterior end of the body
9. Presence of metamorphosis(incomplete/complete) during development
10. Excretion is mainly by malpighian tubules
11. Sensory organs are distributed in different parts of the body

Classification of Class Insecta:

Class Insecta is divided into two sub classes Apterygota and Pterygota based on presence and absence of wings. Apterygota are the primitive insects with no wings, no metamorphosis, mouthparts hidden inside the mouth and adults have pregenital abdominal appendages. Pterygota are the developed insects with wings, mouthparts are exposed, metamorphosis is present and adults does not possess any pre genital abdominal appendages.

Differences between two sub classes, Apterygota and Pterygota

S.No.	Apterygota	Pterygota
1	Wingless insects	Winged insects
2	Metamorphosis is absent	Metamorphosis is present
3	Mandibles are monocondylic	Mandibles are dicondylic
4	Pregenital abdominal appendages are present	Pre genital abdominal appendages are absent
	Ex : Silver fish	Ex : Grasshopper, Butterfly

Sub class Apterygota has four orders (Protura, Diplura, Collembola and Thysanura). Based on the development of wings Pterygota is further divided in to two divisions Exopterygota and Endopterygota. Exopterygota where wings develop externally. There are three developmental stages *viz*. Egg, Nymph and adult and pupal stage is absent. Exopterygota has 16 orders. Endopterygota (Development of the wings inside the body) has four developmental stages *viz.*egg, larva, pupa and adult and it has 9 orders.

Differences between two divisions, Exopterygota and Endopterygota

S.No.	Exopterygota	Endopterygota
1	Wings are developed outside to the body	Wings are developed inside to the body
2	Immature stages(Nymph) resembles adult	Immature stages (Larva) do not resemble adult
3	Metamorphosis is incomplete	Metamorphosis is complete
4	Pupal stage is absent	Pupal stage is present
	Ex : Praying Mantid	Ex : House fly

Class Insecta

(Imm's Classification)

Sub class **Apterygota** (Ametabola) (Wingless insects)

1. Protura – Telsontails
2. Diplura – Diplurans
3. Collembola – Springtails, snow fleas etc
4. Thysanura –Bristletails, Silverfish etc

Sub class **Pterygota** (Metabola) (Winged insects)

Division: **Exopterygota** (Hemimetabloa) (Wings develop externally)

5. Ephemeroptera - Mayflies
6. Odonata - Dragonflies & Damsel flies
7. Plecoptera - Stoneflies
8. Dictyoptera - Cockroaches and Mantids
8. Grylloblattodea - Grylloblattids
9. Orthoptera - Grasshoppers, Locusts, Crickets, Mole crickets etc
10. Phasmida - Stick insects
11. Dermaptera - Earwigs
12. Embioptera - Webspinners
14. Isoptera - Termites
15. Zoraptera - Zorapterans
16. Psocoptera - Book lice
17. Mallophaga - Bird lice
18. Siphunculata (Anoplura) - Sucking lice
19. Hemiptera - Plant bugs
20. Thysanoptera - Thrips

Division-**Endopterygota** (Holometabola) (Wings develop internally)

21. Neuroptera - Antlions & Lacewings
22. Mecoptera - Scorpionflies
23. Trichoptera - Caddisflies
24. Lepidoptera - Moths and Butteflies
25. Diptera - Flies and Mosquitoes
26. Siphonaptera - Fleas
27. Hymenoptera –Ants, Bees & Wasps
28. Coleoptera- Beetle and Weevils
29. Strepsiptera-Stylopids

The immature stages of insects consists of egg, nymph or larva and pupa. Young stage of exopterygote insects is known as Nymph and endopterygote insects is known as Larva. Larva of Lepidoptera is called as caterpillar, in Coleoptera and Hymenoptera it is called as grub and in Diptera the larva is called as maggot. Pupa is a non feeding and inactive stage of endopterygote insects between the larval and adult stages. The common types of pupa are exarate, obtect. chrysalis and coarctate.

LECTURE – 2

EXTERNAL FEATURES OF GRASSHOPPER

Insects are tracheate arthropods whose body is divided in to three regions namely head, thorax and abdomen.

Head consists of mouthparts, compound eyes, simple eyes (Ocelli) and a pair of antennae.

Thorax consists of 3 segments i.e. prothorax, mesothorax and metathorax, Meso and metathorax are together known as pterothorax. All the three thoracic segments possess a pair of legs each and meso and metathorax possess one pair of wings each.

Abdomen has 7-11 segments with genital appendages on 8^{th} and 9^{th} segments.

Insect head

Insect head is a hard and highly sclerotized compact structure. It is consisting of six segments that are fused to form a head capsule. The head segments can be divided in to two regions i.e. procephalon and gnathocephalon. The segments can be clearly distinguished by the presence of cuticular lines known as sutures and areas of head enclosed by these sutures are known as sclerites.

Head : It is the most anterior and compact body division. The head bears a pair of antennae, a pair of compound eyes, three dorsal ocelli and the mouthparts. Head capsule is covered with hardened plates or sclerites.

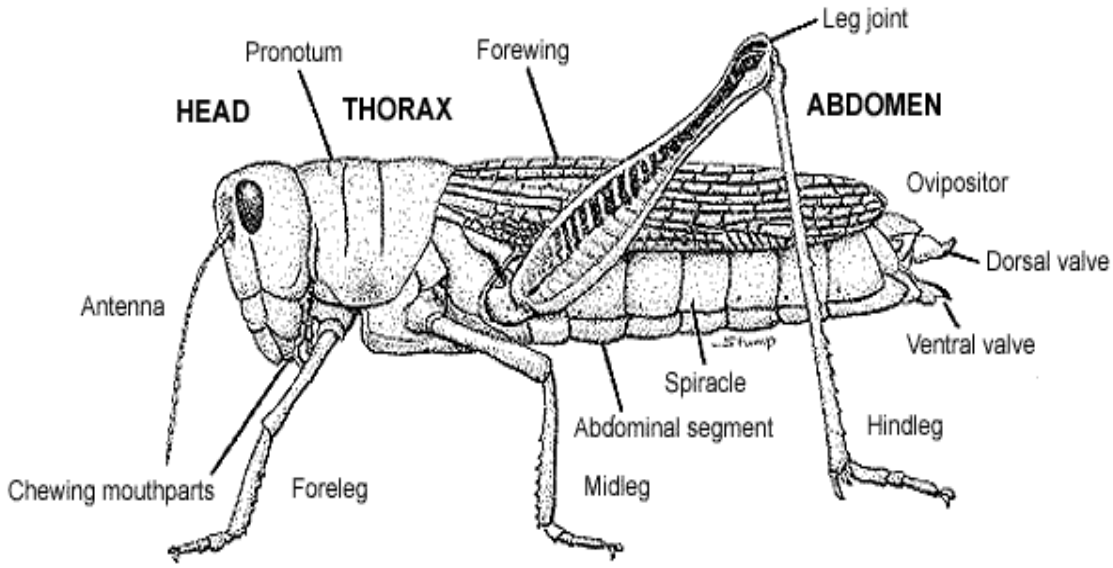
Compound eyes: These are two in number and located on either side of the head. Each eye consists of number of individual sensory units called ommatidia.

- Compound eyes are the major photoreceptors useful in image perception.
- In between the compound eyes there are three simple eyes called as dorsal ocelli.
- Out of the three one is median in position and other two are placed above on each side. They are sensitive to light.

Antennae: They are paired segmental appendages that articulate with the cranium between the compound eyes. Antennae are flexible and are sensory in function.

Mouthparts are mandibulate type

- They are used for biting and chewing of the food.
- Mouth parts consists of two lips (Labrum and Labium), two pairs of jaws (Mandibles and Maxillae) and a tongue like organ called hypopharynx.
- Head is connected to thorax by a membranous region the neck or cervix. The cervical membrane is quiet flexible and allows movement of head. Head is concerned with feeding and sensory perception



Grasshopper external features

Thorax : It is the middle tagma and locomotary part of the body. It is three segmented.

- The thorax, comprises three large segments: prothorax (Anterior most segment), mesothorax (Middle), and metathorax (Posterior) Each segment contains chitinous plates, or sclerites, which provide support and some protection.
- Each thoracic segment consists of a dorsal sclerite called notum and ventral sclerite called the sternum and on either side is the pleuron which is membranous.
- The notum of prothorax is called pronotum which is saddle shaped.
- Each thoracic segment bears a pair of segmented legs. Hind legs are more stronger than remaining two pairs and useful for jumping

- The wing bearing thoracic segments viz., mesothorax and metathorac collectively called as pterothorax. These segments bear one pair of spiracles each.
- Mesothoracic wing is called forewing. Forewings are leathery and known as tegmina.
- Metathoracic wings are called as hind wings. They are membranous and kept folded beneath the forewings at rest.

Abdomen:

- It is the posterior region and largest of the three body regions. Usually soft compared to the rest of the body.
- It consists of eleven segments. Body segmentation is more clear in abdomen
- Each segment is made up of an arched dorsal sclerite, the tergum and a small ventral plate sternum. There are no pleurons. The tergum is connected to the sternum by arthrodial membrane.
- An oval shaped transparent auditory membrane, tympanum is found laterally on either side of first abdominal segment.
- There are eight pairs of abdominal spiracles present from 2^{nd} to 9th segment.
- . Eighth and ninth segments in female and 9^{th} segment in male are called genital segments
- Posterior abdominal segments are modified for the purpose of mating and oviposition.
- The external male sexual organs (Genitalia) are present on ninth abdominal sternite. It consists of a median organ or aedeagus and lateral clasping organs called parameres.
- The female egg laying apparatus is called ovipositor. It arises from eighth and ninth abdominal sternites.
- The triangular dorsal plate of eleventh segments is called epiproct and paired lateral plates are called paraprocts.
- A pair of short unsegmented cerci is present on 11^{th} segment and is sensory in function.
- Anal opening is found immediately below the epiproct.

Lecture - 3

INSECT HEAD

TYPES OF HEAD, SCLERITES, ANTENNA, COMPOUND EYES

Insect body is divided in to a series of segments. 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 head

Insect head is a hard and highly sclerotized compact structure. It is the foremost part in insect body consisting of six segments that are fused to form a head capsule**.**

The different segments of head are represented as.

	Segment	**Appendage**
I	Pre antennary segment	No appendages
II	Antennary segment	Antennae
III	Intercalary segment	No appendages
IV	Mandibular segment	Mandibles
V	First maxillary segment	Maxillae
VI	Second maxillary / Labial segment	Labium

Types of Head: According to the position or projection of mouthparts, the head of the insect can be classified as

(a) Hypognathous (Hypo – Below: Gnathous – Jaw)

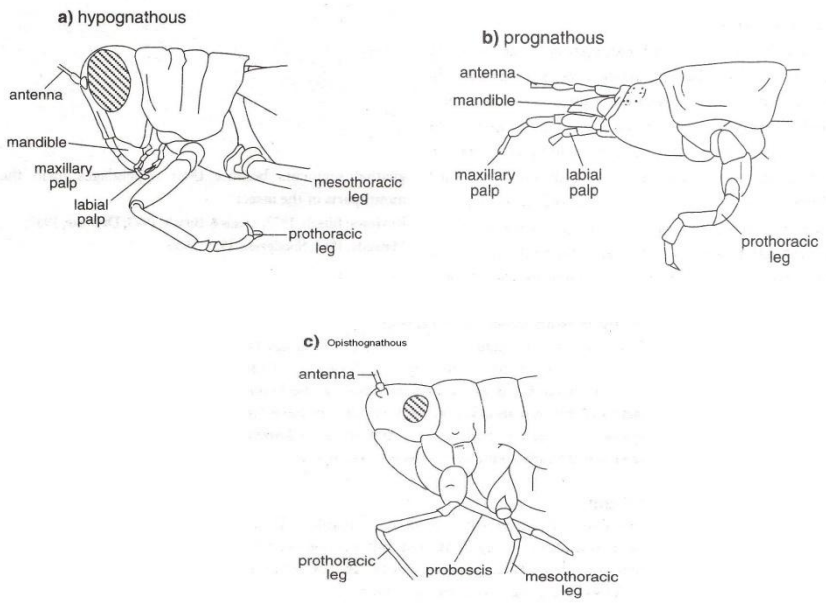
The head remain vertical and is at right angle to the long axis of the body and mouth parts are ventrally placed and projected downwards. Eg**:** Grasshopper, Cockroach

(b) **Prognathous** : **(Pro – infront: Gnathous – Jaw)**

The head remains in the same axis to body and mouthparts are projected forward. Eg: Beetles

(c) Opisthognathous : (Opistho – behind: Gnathous – Jaw)

It is same as prognathous but mouthparts are directed back ward and held in between the fore legs. This is also known as Opisthorhynchous type. Eg: Green stink bug



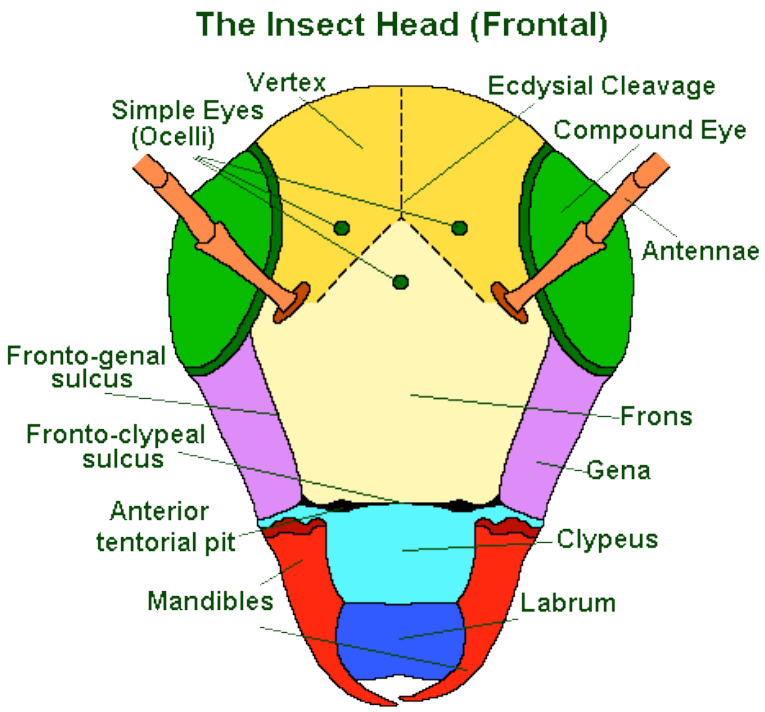
Types of insect head

(Source: Taken from The Insects- Structure and Function (4th Edition, 1998) – R.F. Chapman. Cambridge University Press.**)**

Sclerites:

1) **Labrum :** It is a small sclerite that forms the upper lip of the mouth cavity.
2) **Clypeus:** It is situated above the labrum
3) **Frons :** It is the facial part of the insect.
4) **Vertex :** It is the dorsal portion of the head behind the frons
5) **Epicranium :** It is the upper part of the head extending from vertex to occipital suture.
6) **Occiput :** It is an inverted “U” shaped structure between the epicranium and post occiput.
7) **Post occiput :** It is the posterior part of the insect head before the neck
8) **Gena :** It is the area extending from below the compound eyes to just above the mandibles

All the above sclerites get attached through cuticular ridges or sutures to provide the attachment for the muscles inside.

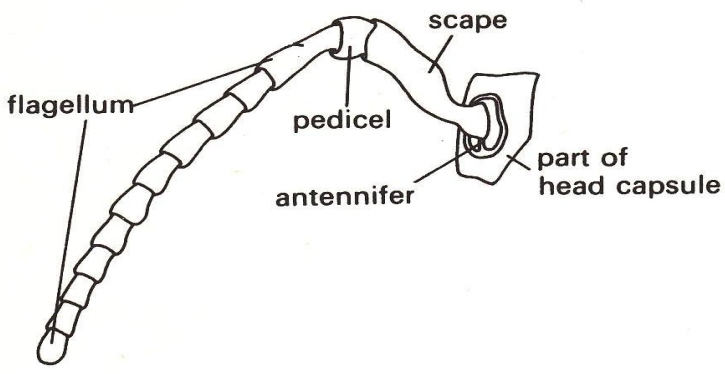


Front view of head of cockroach

Antennae

Antennae are first pair of head appendages arising from the 2nd or antennal segment of the head. They are well developed in adults and nymphs and reduced in larvae of endopterygota. These are said to be unbranched, segmented and mobile structures.

Structure of antenna:



A typical antenna of pterygote insect

(Source: Taken from The Insects- Structure and Function, 4th Edition, 1998) – R.F. Chapman. Cambridge University Press.)

Antenna consists of three parts

1. **Scape**: It is the first segment of antenna. It articulates with the head capsule.
2. **Pedicel:** It is the 2nd or middle segment of antenna that forms a joint between scape and flagellum. It consists a special auditory organ known as “Johnston’s organ”.
3. **Flagellum**: It is the last antennal segment which consists of many segments that varies in shape and size.

Functions of antenna:

1. Mainly serves as the sense organ responding to touch, smell, odour, humidity, temperature as well as wind speed.
2. Johnston’s organ on pedicel functions as an auditory organ responding to sound
3. Help the mandibles for holding prey and for mastication of food material
4. Aid in respiration by forming an air funnel in aquatic insects.

Compound eyes :

Compound eyes are two in number and located on either side of the head. Each eye consists of number of individual sensory units called ommatidia.

- Compound eyes are the major photoreceptors useful in image perception.
- In between the compound eyes there are three simple eyes or dorsal ocelli.
- Out of three one is median in position and other two are placed above on each side. They are sensitive to light.

Lecture – 4

THORAX

It is the middle part of the body consisting of three segments each possessing a pair of legs and a pair of wings is present on meso and metathoracic segments. Hence, meso and metathoracic segments together known as pterothorax.

Sclerite of dorsal region of thorax is called as tergum or notum, ventral region is called sternum and lateral region is called pleuron.

Insect legs:

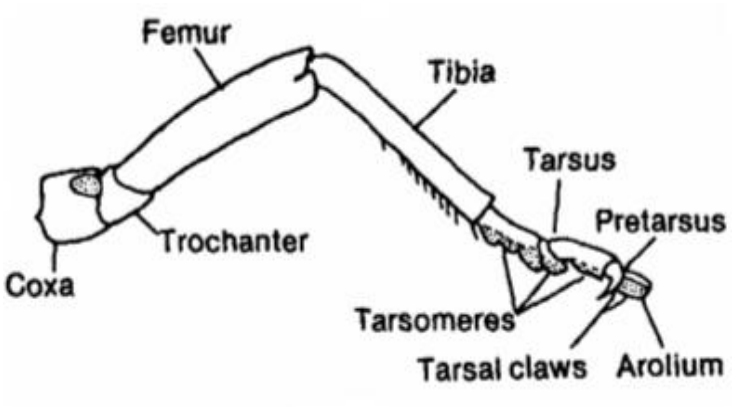
All the three thoracic segments of an insect possess a pair of legs as locomotory organs and hence the class insecta is called as hexapoda. Insect legs are modified for other than locomotion like digging, Grasping, clinging, cleaning etc. in different insects.

The typical iInsect leg mainly consists of 5 parts viz. coxa, trochanter, femur, tibia and tarsus.

Structure of insect leg:

1. **Coxa**: It is the functional basal / first segment and it is rigidly fixed to thorax or weakly articulated.
2. **Trochanter**: It is smallest part of leg and the second segment. It is articulated with coxa and more or less fixed to femur.
3. **Femur**: It is the largest, strongest segment and is articulated with tibia.
4. **Tibia**: It is equal or more than the length of the femur, articulated with tarsus.
5. **Tarsus**: It is the largest segment of the leg and usually devided into sub segments tarsomeres. The number of tarsomeres vary from 1-5 and are movable. Among the 5 segments, 1^{st} segment is large 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 a lobe like structure, it is known as "aroleum" as in Orthoptera (grasshopper) and if it is bristle like structure, it is called "empodium" as in Diptera.



Structure of typical insect leg

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 endopterygotes i.e. larva possess two types of legs.

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

ii. Abdominal legs or prolegs: Unjointed, not sclerotized, 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 variable upto 8 pairs. In caterpillars prolegs (5 Pairs) are distributed on 3^{rd}, 4^{th}, 5^{th}, 6^{th} and 10^{th} abdominal segments. Mustard sawfly larva has 6-8 pairs of abdominal legs.

In some insects legs are degenerated e.g.:Coccidae, endoparasitic hymenopterans etc.

Insect wings:

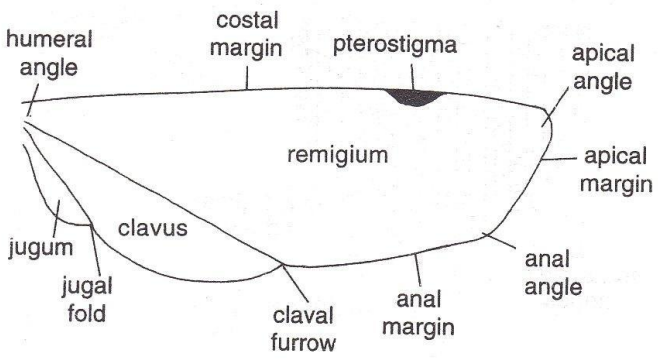
Insects are the only invertebrates possessing wings and capable of true flight. Based on the presence or absence of wings, class insecta is divided into two subclasses. 1. Apterygota 2. Pterygota.

The primitive apterygotes are wingless. Eg: Silverfish and Springtails

Among the pterygotes, wings arise from meso and metathoracic 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.

A typical insect wing is triangular with three margins and three angles. Three margins are costal or anterior, Apical or outer and Anal or inner. Three angles are humeral angle between body wall and costal margin, Apical or outer angle between costal and apical margin and anal angle or tornus between apical and anal margin.



Insect wing areas

(Source: Taken from The Insects- Structure and Function (4th Edition, 1998) – R.F. Chapman (Cambridge University Press))

Wings are very thin broad leaf like structures strengthened by a number of hollow narrow tubular structures called veins. Arrangement of veins on wing surface is known as Wing venation, which consists of two types of veins. Longitudinal veins are those that extend from base of the wing to the margin and cross veins that interlink the longitudinal veins. Shape and size of wing shows a great variation among insects.

Longitudinal Veins:

1. **Costa (C)**
2. **Sub costa (Sc)**
3. **Radial vein (R)**
4. **Media (M)**.
5. **Cubitus (Cu)**
6. **Anal veins (A)**

Cross veins:

Humeral cross vein (h) : Between costa and subcosta

Radial cross vein (r) : Between radius and radial sector

Sectorial cross veins (s): Between sub branches of radial sector

Radio medial cross vein (r-m): Between radius and media

Medical cross veins (m): Between branches of media

Medio-cubital veins (m-cu): Between media and cubitus

Wing coupling apparatus / Organs / Mechanisms:

For taking flight, insect need to keep both the fore and hind wings together as a single unit. The structures in the form of lobes, bristles, hairs or spines that help the wings to be together are known as wing coupling organs, they are

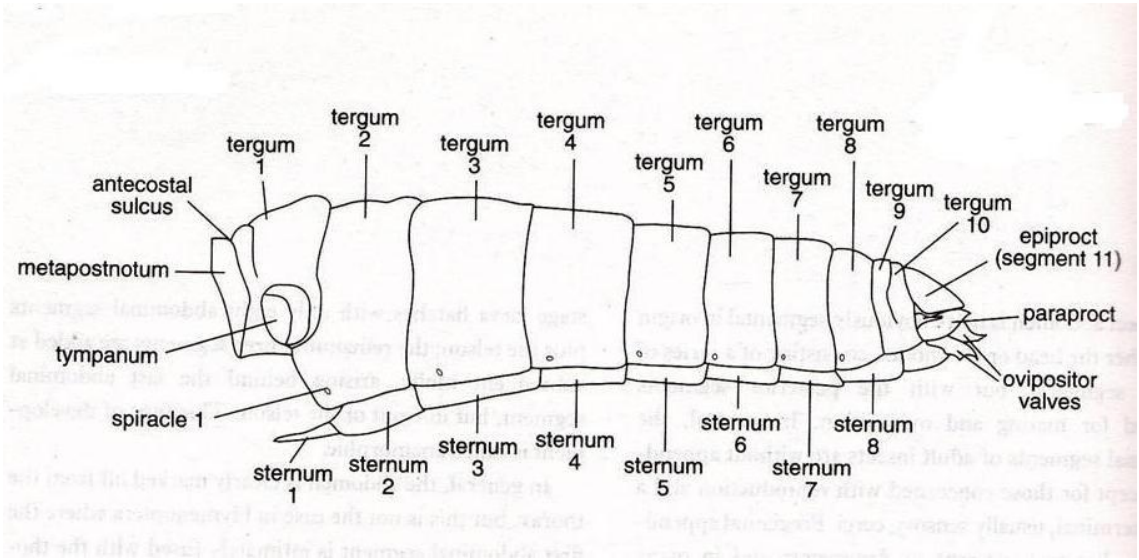
1. **Jugate type or jugum type** e.g.: Primitive Lepidopterans, family Hepialidae
2. **Frenulum and retinaculum type** e.g.: Moths
3. **Amplexiform** e.g.: Butterfly
4. **Hamuli** e.g.: Bees

Abdomen:

Abdomen forms the posterior part of the insect body. The abdomen in the embryo usually consists 12 segments; later the last segments degenerate and appear as 7-11 segments. In case of Protura the last segment is known as telson or tail.

Abdominal Segments from 1 to 7 are pregenital segments, eighth and ninth are known as genital segments as they form genital appendages i.e. ovipositor in females and aedeagus or penis in males. Tenth and eleventh segments are known as postgenital segments.

The 10^{th} segment in general forms the supra anal plate and 11^{th} segment is represented by a pair of anal cerci.



Abdominal segments

(Source: Taken from The Insects- Structure and Function(4th Edition, 1998) – R.F. Chapman (Cambridge University Press)

- Cornicles are tubular structures located on dorsal side of 5th or 6th abdominal segments in aphids
- The last abdominal segments are telescope in to each other to form a pseudo ovipositor in Diptera.
- The 1st abdominal segment get fused to metathorax forming propodeum whereas 2nd abdominal segment forms a narrow pedicel or petiole followed by enlarged gaster (Rest of the abdominal segments) in Hymenoptera**.**

Lecture – 5

MOUTHPARTS OF INSECTS

These are the organs primarily concerned with the uptake of food. Typical mouthparts of an insect consists of the following parts.

(i) Labrum (Upper lip) (ii) A pair of mandibles (iii) A pair of maxillae (iv) Labium (Lower lip) (v) Hypopharynx (Tongue)

The mouthparts of insects can be basically grouped in to following types based on the type of food and method of feeding.

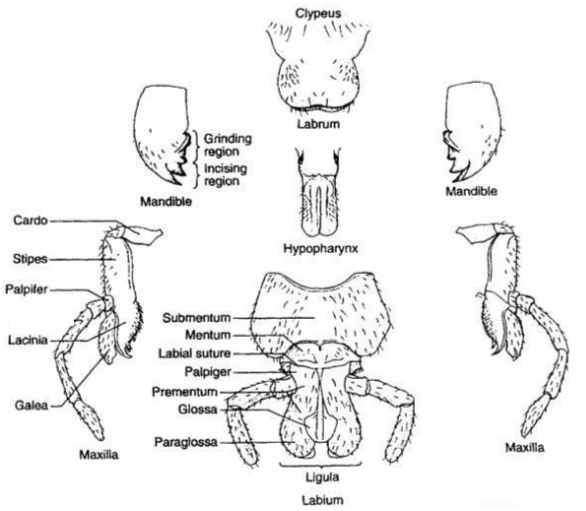
S.No	Type of Mouthparts	Example
I	**Biting and chewing type**	Grasshoppers, Cockroaches
II	**Sucking type / Haustellate type**	
	1.Piercing and sucking type	Plant Bugs and Mosquitoes
	2.Rasping and sucking type	Thrips
	3.Sponging type	Adult House flies
	4.Chewing and lapping type	Honey bees
	5.Siphoning type	Butterflies and Moths

I. Biting and chewing type of Mouthparts:

This type is considered as primitive and found in Orthoptera, Isoptera and Coleoptera, larvae of Lepidoptera and Neuroptera etc. The mouthparts include following parts.

a. Labrum : It is a small sclerite, the upper lip of the mouth cavity. It protects the mandibles and helps in closing of the mouth cavity and guide the food in to mouth.

b. Mandibles: These are the paired, unsegmented, strongest and sclerotized structures called jaws. They possess teeth like molars and incisors that help in the process of cutting the food material.



Biting and chewing type of mouthparts

c. Maxillae: These are paired homologous structures with basal triangular 'cardo', middle rectangular 'stipes' and the lateral 'palpifer' bearing maxillary palpi and lobe like inner 'lacinia' and outer 'galea'. Maxillae function as sensory organs. Galea and lacinia helps in holding the food material along with the mandibles.

d. Labium: It is known as lower lip and is also called as second maxillae. It closes the mouth cavity from below. It is divided in to proximal pre mentum, central mentum and distal sub mentum. Near the base of pre mentum, on either side a 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.

e. Hypopharynx: It is a tongue like structure situated between labrum and labium and ducts of salivary glands open on or near its base.

Lecture – 6

MOUTHPARTS OF INSECTS

II. Sucking type of Mouthparts:

This is considered as advanced type where the oral appendages get modified differently.

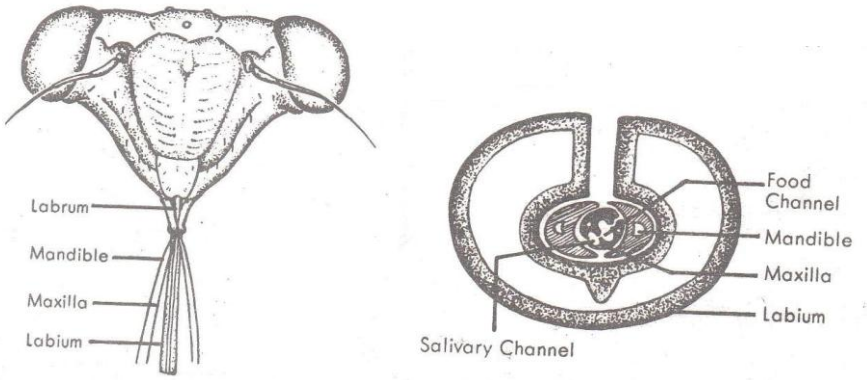
1. Piercing and sucking type e.g.: Plant bugs, Mosquitoes

They are mainly adopted for piercing the tissues and sucking either plant sap or the nectar or blood from the host.

Mouthparts 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 in to 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 in to 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 type 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.

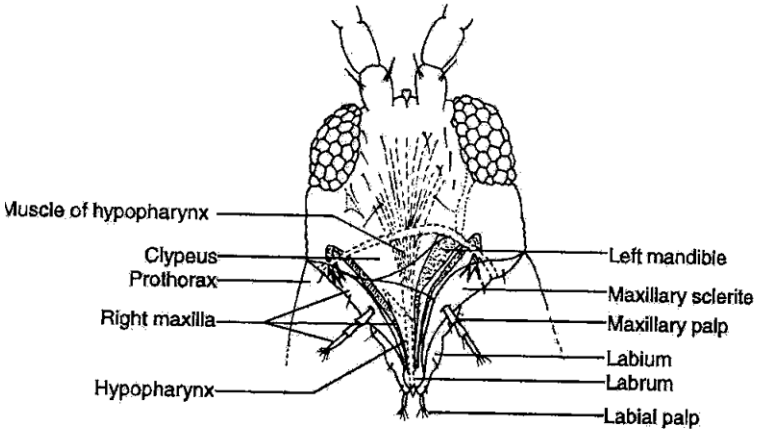


Piercing and sucking mouthparts

(Source: Taken from Entomology – Pramod Kumar (2001). Published by IVY Publishing house, New Delhi., India)

2. Rasping and sucking type of mouthparts : e.g. Thrips

These are called asymmetrical type, since right mandible is rudimentary. They are in between the biting and chewing type; and piercing and sucking type. Mouth parts are represented by mouth cone which is formed by the labrum and clypeus above and labium below. Within the beak/mouth cone hypopharynx and left mandible is present. Right mandible is absent where as the left mandible is modified in to a mandibular stylet.

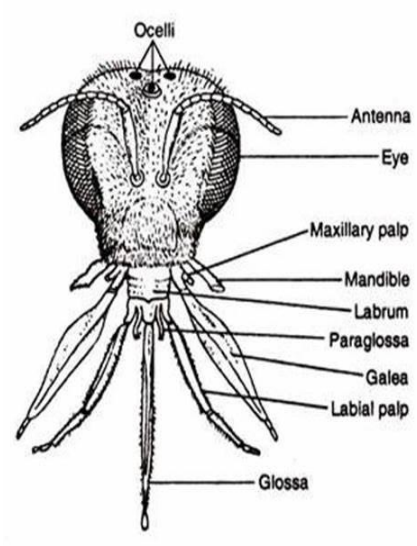


Rasping and sucking type

Maxillae are modified in to maxillary stylets which are mainly useful for sucking the sap that is released outside due to the rasping of tissues by the left mandible.

3.Chewing and lapping type of Mouthparts: e.g**.** : Honeybees

The labrum and mandibles are biting type whereas maxillae, labium and hypopharynx combine together to form a sucking proboscis. The mandibles are dumbbell shaped, non-trophic and industrial in function. A pair of maxillae and the labium combiney forms proboscis for sucking the nectar from flowers. Maxillae attaches to head capsule with cardo. Galea is wider, lacinia and maxillary palpi are very small. Glossa of labium is a key structure of proboscis in the centre. It is a long lapping tongue. At the base, glossa has pouch made with paraglossa. Labial palpi well developed. The nectar is taken with lapping action.



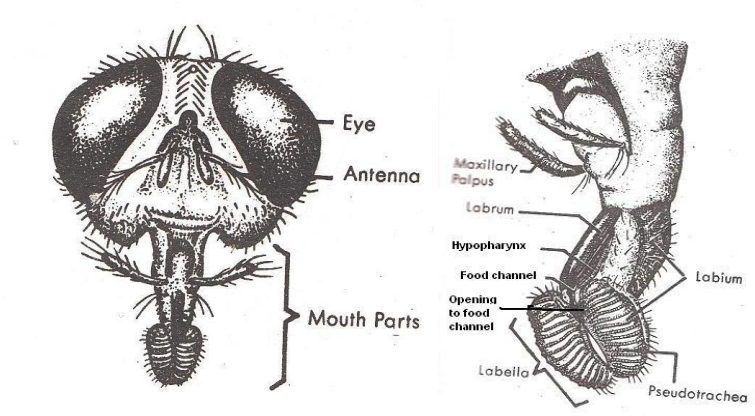
Chewing and lapping type of mouthparts

4. Sponging type of Mouthparts: eg: House fly

These mouthparts are represented by **proboscis** formed from the **labium**.

The proboscis is divided into a basal rostrum, middle haustellum and a distal labellum. The labellum is a sponge like structure. It is traversed by a number of narrow transverse channels called pseudotrachea which converge at one point in the centre of the labellum. From this point, the food enters in to food channel which is formed by the labrum- epipharynx and hypopharynx. Mandibles are absent (reduced) maxillary palpi are 1-3 segmented.

During feeding, the proboscis is pressed over the food material. The pseudo trachea gets filled with the food material by the capillary action and is sucked up from the central point in to the oesophagus.

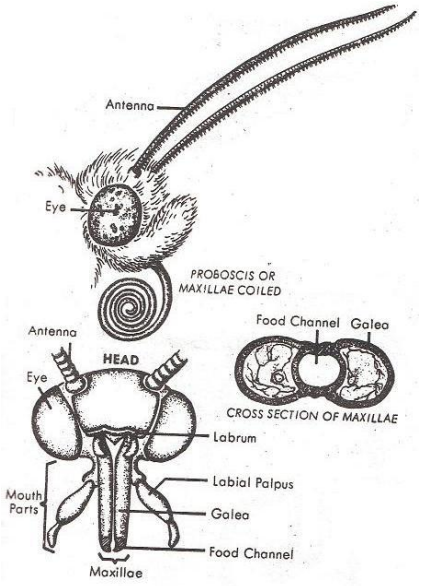


Sponging type of mouthparts

(Source: Taken from Entomology – Pramod Kumar (2001). Published by IVY Publishing house, New Delhi., India)

5. Siphoning type of Mouthparts : eg: Butterflies

These are specially modified for taking nectar from the flowers. The galea of maxillae form into a slender, hollow, tubular structure which remains as an elongated coiled proboscis underneath the head during non feeding. Mandibles are totally absent. The labrum and maxillary palpi are reduced. Labium is modified in to a small basal plate possessing a three segmented labial palpi. The food channel is formed by the fusion of both the galea. The nectar is sucked up from the flowers through muscular action.



Siphoning type of mouthparts

(Source: Taken from Entomology – Pramod Kumar (2001). Published by IVY Publishing house, New Delhi., India)

Lecture - 7

GENERAL CHARACTERS OF IMPORTANT ORDERS OF CLASS INSECTA

CHARACTERS OF ORDER ORTHOPTERA

(Orthos = Straight, Pteron = Wings)

Straight winged insects eg. Grasshoppers, Locusts , Crickets, etc

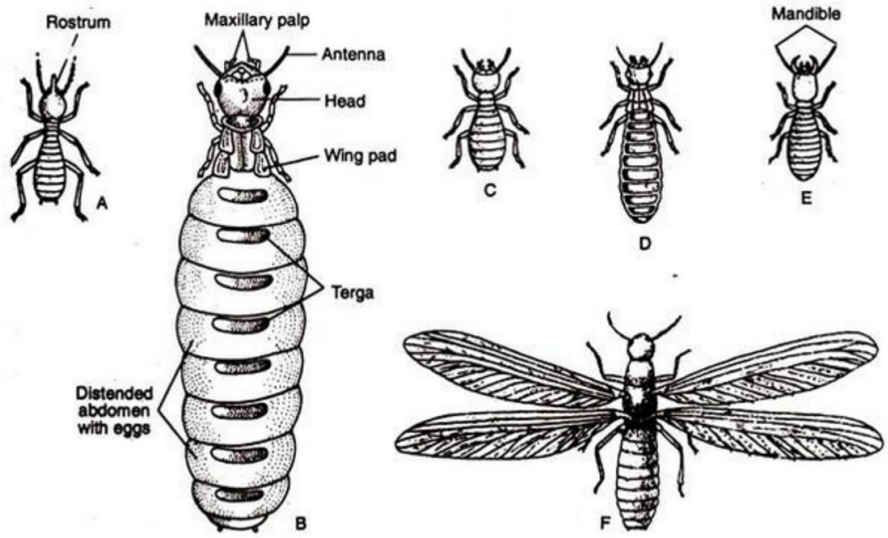
1. Usually medium or large sized insects with elongated body.
2. Head is hypognathous or prognathous with long or short usually filiform antennae.
3. Biting and chewing type mouthparts with well developed mandibles.
4. Prothorax is large, its notum extends laterally and conceal the propleurons.
5. Winged or wingless. The wings are straight, front wings are long and narrow, some what thickened and are known as tegmina. Hind wings are membranous, many veined folded fanwise beneath the forewings during rest.
6. Specialized stridulatory organs are present. Usually males alone can produce sound. Two types of stridulation is present. Alary type and femoro-alary type.
7. Auditory or tympanal organs are also well developed and are located on either side of the first abdominal segment or at the base of fore tibiae.
8. Legs normally developed, or fore legs modified for digging as in mole crickets or hind legs modified for jumping as in grasshopper.
9. Tarsus is 3 – 4 segmented
10. Females with well developed ovipositor with 3 pairs of valves which are useful for inserting the eggs in soil.
11. Anal cerci well developed, usually short and unsegmented.
12. Metamorphosis simple or incomplete

Eg: Rice grasshopper -*Hieroglyphus banian*

Rice small grasshopper - *Oxya nitidula*

CHARACTERS OF ORDER ISOPTERA
(Iso – Similar; Pteron – Wings)
Similar winged insects Eg:Termites or white ants

1. These are small to medium sized social living insects with well developed caste system
2. Antennae are moniliform (Bead like)
3. Compound eyes present in winged forms.
4. Mouthparts biting type with powerful mandibles.
5. Polymorphic insects (Apterous, brachypterous or winged.) In winged forms, the front and hind wings are similar in size, shape and venation. Wings are membranous and are capable of being shed after mating.
6. Frontal gland, Frontanella is a characteristic termite organ. Highly developed in soldiers. It appears to have defensive function.
7. Metamorphosis simple or incomplete



Castes of Termites

A. Nasuti soldier B. Queen in Physogastry condition

C. Worker termite D, F Males E. Mandibulate soldier

8. **Caste system –** Termites are social insects with a well-developed caste system.
   a) a**) Reproductives or Pirmary reproductives:** (King and Queen): These are highly developed and heavily pigmented. Queens live for several years. The abdomen of queen termite enormously enlarged due to the growth of ovaries, gut and fat body. This condition of the insect is called as physogastry.

   b) **Supplementary reproductives:** They have short wings and less pigmented. They sometimes carry on extensive reproduction in the colony and supplement the queen.

   c) **Workers:** These are sterile wingless adults. Pale in colour, lack compound eyes. They collect food and feed queens, soldiers and newly hatched young ones. They form the bulk of the colony.

   d) **Soldiers:** These are also sterile wingless adults with greatly enlarged head and mandibles. They protect the colony. Two types of soldiers are (1) Mandibulate type (2) Nasute type (Nasuti). In mandibulate type mandibles are developed. In nasute type, the individuals have the head prolonged anteriorly into a narrow snout.

9. The food of termites is the cast skins and faeces of other individuals, dead individuals and plant materials such as wood and wood products (Trophallaxis – Mutual exchange of food i.e secretions on the body)

   Eg: *Odontotermes obesus*,
   Microtermes obesi

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CHARACTERS OF ORDER THYSANOPTERA

(Thysano: Fringed and Pteron: Wing)

Fringed winged insects Eg: Thrips

1. Small to minute slender bodied terrestrial insects
2. Antennae 6-10 segments.
3. Compound eyes conspicuous.
4. Mouthparts asymmetrical, right mandible is rudimentary, lacerating and sucking or rasping and sucking type. Mouth cone is formed.
5. Winged or wingless. The wings are fringed with long hairs on the margins.
6. Legs short, tarsi 1 or 2 segmented with 1 or 2 claws.
7. Abdomen is elongate with 10-11 segments, usually tapering posteriorly
8. Anal cerci absent
9. Metamorphosis is accompanied by one or two inactive pupal instars i.e intermediary between simple and complete.
10. Parthenogenetic type of reproduction is common.

    Eg: Onion thrips -*Thrips tabaci*

    Chilli thrips - *Scirtothrips dorsalis*

Lecture - 8

IMPORTANT CHARACTERS OF ORDER HEMIPTERA

(Hemi: Half; Pteron: Wings)

A. Suborder: Heteroptera Eg: Plant bugs

1. Small to large mostly terrestrial and some are aquatic
2. Antennae fairly long, 4 or 5 segmented.
3. Compound eyes well developed.
4. Mouthparts piercing and sucking type and with slender segmented beak (modified labium).
5. Pronotum large, the mesonotum exhibits fivefold division. Scutellum is very prominent
6. Winged and wingless. When winged, the fore wings are basally thickened and membranous apically and are known as Hemelytra. Hind wings are membranous. At rest the wings are held flat on the body. Alary polymorphism is seen.
7. Odoriferous glands or repugnatorial glands or scent glands or stink glands are present which open near hind coxae giving out unplesant odour
8. Ovipositor small with two pairs of valves.
9. Anal cerci absent
10. Metamorphosis simple

Eg: Rice gundhi bug- *Leptocorisa varicornis*

Green stink bug – *Nezara viridula*,

Red cotton bug -*Dysdercus cingulatus*

B. Sub-order: Homoptera
(Homo: Alike; Pteron: Wings (Uniform wings)
Eg: Leafhoppers, Aphids, Mealybugs, Whiteflies etc

This suborder contains a large and diversified group of insects.

1. These are widely distributed minute to small insects.
2. Head is deflexed and not generally constricted behind to form a neck.
3. Compound eyes well developed.
4. Antennae well developed and usually 3 to 10 segmented
5. Mouthparts are piercing and sucking type, stylets often exceedingly long, and rostrum arising from the back of the head, in some cases appearing to arise between anterior coxae.
6. Thoracic segments generally fused together. Pronotum small and collar like.
7. The four wings are uniform in consistency and the wings are held roof like over the body at rest. Alary polymorphism is prevalent.
8. Wax glands usually well developed in most of the members.
9. Usually undergo simple metamorphosis. In some species, the last nymphal instar is quiescent and pupa-like.

Eg: Cotton leafhopper - *Amrasca biguttula biguttula*

Paddy leafhopper - *Nephotettix virescens*

Brown planhopper of paddy (BPH) - *Nilaparvata lugens*

Cotton aphid - *Aphis gossypii*

Cotton whitefly - *Bemisia tabaci*

CHARACTERS OF ORDER LEPIDOPTERA

(Lepido: Scales; Pteron: Wing) Eg: Butterflies and Moths

Small to large insects with flat overlapping scales and hairs on the body, wings and other appendages giving various beautiful colours to the insects

1) Head relatively small free with small neck.
2) Mouthparts siphoning type represented by a long coiled proboscis formed by the galeae of maxillae. Mandibles nearly always lacking.
3) Forewings usually large. In males of various insects, groups of more specialized scales known as androconia occur on the upper surface of wings serving as outlets of odoriferous glands.
4) Larvae are called caterpillars. Most of the larvae are phytophagous and are very serious pests of crops. Mouth parts are biting and chewing type. Abdominal segment 3 to 6 and 10^{th} usually bear a pair of prolegs which are fleshy and broad.
5) Pupae are usually obtect and generally enclosed in a cocoon. Butterflies do not form a cocoon and their pupae are called chrysalis.
6) Adults are harmless except fruit sucking moths.
7) Natural silk is a product of this order
8) Complete metamorphosis.

Differences between moths and butterflies

Character	**Moths**	**Butterflies**
Behaviour	Nocturnal (Active during night time)	Diurnal (Active during day time)
Antennae	Variable(Bipectinate, Filiform)	Clavate
Wings at rest	Held roof like over body	Folded vertically upward
Abdomen	Large and stout	Comparatively small and slender

Eg: Redgram pod borer - *Helicoverpa armigera*

Tobacco cutworm- *Spodoptera litura*

Citrus butterflies- *Papilio demoleus, Papilio polytes*

Mulberry silkworm – *Bombyx mori*

Lecture - 9

CHARACTERS OF ORDER COLEOPTERA

(Coleo : Sheath; Pteron: Wing) Eg: Beetles and Weevils

1. This is the largest order in class Insecta comprising about 40% of the known insect species.
2. Minute to large sized with horny integument.
3. Head highly sclerotized, free, normal or prolonged in to a snout as in weevils..
4. Antennae variable usually 11 segmented
5. Mouthparts are chewing type with well developed mandibles.
6. Prothorax large and freely movable, mesothorax much reduced and fused with metathorax.
7. Two pairs of wings present. Forewings are horny or leathery known as elytra**.** Hind wings membranous.
8. Legs well developed for walking, running and tarsal segments are variable Tarsal formula refers to the number of tarsal segments or tarsomeres on the front, mid and hind legs (4:4:4 or 5:5:5).
9. Abdomen usually 10 segmented.
10. The larvae are known as grubs and generally thoracic legs (oligopod) are present. Pupa is adecticous and exarate
11. Metamorphosis is complete and complex.

Eg. Lady bird beetle (Predator on soft bodied insects) - *Coccinella septempunctata*
Mango stem borer - *Batocera rufomaculata*

CHARACTERS OF ORDER HYMENOPTERA

(Hymen - Membranous; Pteron: Wing) Eg: Wasps, Bees, Ants, Sawflies *etc*

1. This is the most beneficial order. It includes parasites, predators and honey bees. Most of them are social living.
2. Varied in size and shape.
3. Antenna mainly geniculate or variable.
4. Mouthparts primarily adopted for biting and often for lapping and sucking also.
5. Usually two pairs of membranous wings are present. Hind wings are smaller.
6. Legs slender, trochanter 1 or 2 segmented
7. Abdomen usually basally constricted to form pedicel or petiole. The 1st abdominal segment fused with metathorax and known as propodaeum. Second segment forms pedicel. The remaining region of the abdomen is known as gaster.
8. Ovipositor very well developed and modified for sawing, boring, piercing, stinging etc.
9. Larvae are known as grubs and are usually apodous
10. Pupa exarate and a cocoon is generally present
11. Metamorphosis complete and complex

Eg: Indian honeybee- *Apis cerana indica*

Italian honeybee - *Apis mellifera*

Red ants - *Oecophylla smaragdina*

Black ant – *Camponotus compressus*

Characters of Order Diptera

(Di- Two; Pteron: Wing) Eg: Flies and Mosquitoes (Two winged insects or True flies)

1. These are small and soft bodied insects.
2. Eyes large : usually larger in males
3. Ptilinum or frontal sac is characteristic feature of certain members
4. Antennae mostly 3 segmented and aristate type
5. Mouth parts sucking type usually forming a proboscis. In many they are piercing and sucking and in others they are sponging type
6. Mesothorax large supporting the functional wings, pro and metathoracic segments small and fused with mesothorax
7. Only front pair of wings present. Hind pair is reduced as halteres which act as balancers.
8. Legs well developed, tarsus usually 5 segmented pulvilli and an empodium present
9. Larvae apodous known as maggots.
10. Pupa either free or enclosed in the hardened larval cuticle known as puparium (Coarctate pupa)
11. Metamorphosis is complete

Eg. Rice gall midge - *Orseolia oryzae*

Sorghum shoot fly- *Atherigona soccata* .

Lecture – 10

DAMAGE CAUSED BY INSECT PESTS HAVING DIFFERENT TYPES OF MOUTHPARTS

Insects utilize the plants mainly to derive their nutrition and also for the habitat. The plants sustain injury to satisfy the requirements of insects. Such injury to the plants by the insects is reflected as symptoms. The nature of injury/damage to the plant is related to the feeding habits of the insect. The peculiarity of mouthparts and mechanism/type of feeding determine to a larger extent the pest management strategies including the type of pesticide to be used. The nature and symptoms of damage caused by insects based on their feeding habits according to the modification of their mouthparts is furnished here under.

I. Biting and chewing type:

They are adapted for biting and chewing of the plant material. They bite leaves, buds, bracts, slender twigs etc, chew the bitten portions and swallow them. Leaves may be eaten up completely leaving only a network of veins.

Eg: Grasshoppers, caterpillars, beetles.

Based on the nature of damage, chewing insects can be classified into different groups as mentioned below.

1. Stem borers:

Larvae enter in to the stem and feed on internal contents. As a result, damaged part is cut off from the main plant and affected part wilts, dries up and exhibits symptoms like dead heart during vegetative stage and white ear during reproductive stage as in case of paddy due to larval feeding inside the stem and they can be easily pulled out and bunchy top in case of sugarcane (destruction of growing point results in the activation of side buds, just below the growing point and produces a bunch of side shoots called bunchy top).

Eg: Stem borers of paddy, millets, sugarcane and brinjal

2. **Shoot borers:**

Larvae attack tender shoots and bore inside during vegetative stage of crop growth and cause wilting, drooping of terminal plant parts which later dry up.

Eg: Shoot borers of brinjal, bhendi, cotton and castor

3. **Defoliators/Skeletonizers**:

Larvae feed on the leaves completely leaving only midrib/veins or scrape the chlorophyll content of leaves or cause numerous holes.

Eg: Castor semilooper, ash weevils, tobacco caterpillar, epilachna beetle on brinjal.

4. **Leaf miners:**

Larvae mine leaves/leaflets between the epidermal layers and feed on greenish matter, resulting in the appearance of translucent mines/white patches/zig-zag galleries

Eg: Leaf miner of citrus and Rice hispa.

5. **Leaf Webbers:**

Larvae webs leaves/leaflets by means of silken threads and feed on the chlorophyll content by remaining within the web. Often faecal pellets/frass are found within the web.

Eg: Leaf Webbers on gingelly, groundnut, sapota, mango and shoot and blossom webber on cashew.

6. **Leaf folders:**

Larvae fold leaves from tip to base / longitudinally / margin to margin there by giving appearance of a fold / roll and scrape the chlorophyll content remaining within the fold.

Eg: Rice leaf folder, Cotton leaf roller (Bell shaped rolling of leaf).

7. **Gall forming insects:**

Larvae feed inside the stem/tiller/leaf/flower bud stimulate excessive growth of cells at the affected portion and distort normal growth. It results in malformation of plant parts, exhibiting gall formation and gives shelter for the pest.

Eg: Paddy gall midge, tobacco stem borer, cotton stem weevil, mango inflorescence midge, chilli midge *etc*.

8. **Pod/capsule borers/boll worms:**

During the reproductive stage of the crop larvae enter in to the pods, capsules and feed on the seeds/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 / damaged tissues (chilli/lint on Cotton).

Eg: Spotted pod borer, Capsule borers of castor and gingelly, Tobacco caterpillar, Gram caterpillar, Pink bollworm

9. **Fruit borers:**

Larvae enter into the tender fruits and feed on fresh matter/pulp and plug the larval burrow with excreta.

Eg: Fruit borer of brinjal / bhendi / tomato, mango stone weevil, Cashew apple and nut borer.

10. **Bark borers:**

Larvae remain in a small tunnel at the axils of branches, under the bark constructing galleries of frassy web on the stem and near bark/angles of branches and move about, conceal inside the silken gallery and feed on the bark by scraping.

Eg: Bark eating caterpillars of citrus, mango, guava, casuarina, jack etc.

11. **Tree borers:**

Larvae bore deep into the tree trunk, make the tunnels in zig-zag manner and feed on inner tissues, arresting translocation of sap to top portions of tree, there by the tree exhibits symptoms like yellowing, withering of leaves, drying of twigs or complete drying of tree. Sometimes, gummy material oozes from the affected portion on the tree trunk.

Eg: Tree borers of mango, cashew, coconut red palm weevil etc

12. **Root feeders:**

Larvae feed on roots/root nodules resulting in stunted growth/poor tillering /drying of plants in isolated patches.

Eg:Rice root weevil, White Grubs, Banana Rhizome weevil, Termites in: Paddy – feed Sorghum, Groundnut, Sugarcane, Potato, Mango, Coconut.

13. **Seed feeders (Stored grain pests):**

Grubs/larvae and adults feed on stored seeds either internally /externally by webbing the food particles.

Eg: Groundnut bruchid, Rice weevil, Red flour beetle, Rice moth etc.,

Lecture – 11

THE SYMPTOMS OF DAMAGE CAUSED BY INSECT PESTS WITH BITING AND CHEWING TYPE OF MOUTHPARTS

a) **Defoliation / Skeletonization / Scraping of leaves:**

Early larval instars of large number of Lepidopteron pests with gregarious behaviour feed on leaves by scraping the chlorophyll content and gives papery/scorched appearance leaving membranous cuticular layer and stout veins. Such feeding leads to skeletonization .

Eg: Tobacco caterpillar, Bihar hairy caterpillar, Red hairy caterpillar

b) **Uneven cuts on leaf margins:**

Eg: Grasshoppers on various crops, larvae of mustard saw fly on cruciferous crops

c) **Uneven scraping of leaf surface (Lace like):**

Eg: Grubs and adults of *Henosepilachna vigintioctopunctata* on solanaceous, cucurbitaceous and leguminous crops

d) **Small white streaks parallel to midrib on rice leaves:**

Eg: Adults of Rice Hispa

e) **Tubular cases attached to leaf/ floating in water in rice fields:**

Eg: Larvae of case worm

f) **Shot holes on leaves:**

Eg: Larvae of sorghum and sugarcane stem borers, Adults of flea beetle on blackgram /greengram, crucifers.

II. The symptoms of damage caused by insect pests with Piercing and Sucking type of mouthparts

In sucking insects nymphs and adults suck sap from base of the plant /leaves /tender terminal plant parts and thereby affect the vigour and growth of plants. In case of severe infestation of soft bodied insects, sooty mould develops on plant parts covered with honey dew excreted by insects while feeding.

Different insects exhibit different symptoms. These insects cause hopperburn, discolouration, curling of leaves, necrosis on leaf margins and their eventual weakening and death of plant parts. They may also attack young twigs and other parts of the plant and cause them to dry up.

a) **Hopper burn:**

Planthoppers viz *Nilaparvata lugens* and *Sogatella furcifera* of Delphacidae are known to cause hopper burn on Rice, a monocotyledon crop .

Leafhoppers belonging to the genus *Empoasca* of Cicadellidae are known to cause hopper burn on dicotyledon crops like cotton, okra, castor, brinjal, potato, beans etc. The general symptoms of hopper burn caused by planthoppers and leafhoppers are furnished hereunder.

Eg:

a) Groundnut leafhoppers necrotic in a typical “V” shape, giving the crop a scorched appearance known as hopper burn

b) Curling of leaf margins/with necrotic patches Starting from leaf margin –Cotton leafhopper

c) Reduced vigour/sooty mold, squaer/bolldrop -White flies on cotton

e) Yellowing /reduced/stunted growth/sooty mould -Aphids

f) Shrivelled/chaffy and discolored grains/sooty mould on grain -Sorghum ear head bug/rice gundhy bug

g) Gradual wilting and drying of ragi plants in patches -Ragi root aphids

III. The symptoms of damage caused by insect pests with Rasping and Sucking / Lacerating and Sucking type of mouthparts:

Thrips are characterized by this type of mouth parts. Due to the peculiarity of mouth parts and their mechanism of action in rasping the tissues, exudation of juice from inside the plant takes place and it is sucked by thrips. The damaged part of the plant exhibit a whitish mottled/silvery appearance.

Eg: Thrips on Groundnut, Onion, Chillies, Blackgram, Rice

IV. Siphoning/simple sucking Type:

Adults of certain pests suck juice from fruits with the help of proboscis resulting in minute holes consequently resulting in rotting due to secondary infection

Eg: Adults of Citrus fruit sucking moths and Castor semilooper

V.Degenerate type of mouthparts:

In apodous maggots mouthparts are highly reduced and represented by a mouth hooks/ spines. With the help of these mouth parts maggots feed and cause damage on different plant parts.

Eg. Paddy Gall Midge: Maggot feeds on growing point which stimulates the leaf sheath to form a hollow pale green cylindrical tube similar to onion leaf/ silver shoot /gall. Affected tiller do not bear panicles.

Mango leaf galls, Chilli Midge, Shoot fly, Redgram Pod fly, cucurbit fruit fly, Mango fruit fly, Ber fruit fly.

SYMPTOMS	**EXAMPLE**
1. Hopper burn, complete drying of leaves and plants in patches, giving scorched appearance.	Paddy brown planthopper, white backed plant hopper, paddy leafhopper
2. Curling of leaf margins / mottling / necrotic patches	Leafhoppers
3. Upward curling of leaves.	Chilli thrips
4. Downward curling of leaves / elongation of Petioles / reduction in leaf size and clustering at tip of branch / brittleness.	Chilli white mites
5. Leaf drying from top to bottom.	Onion thrips
6. White/ yellow blotches on upper surface of leaves.	Mites on castor/ coconut/ bhendi.
7. Reduced vigour / sooty mould / square / Flower drop.	Whiteflies on cotton
8. Yellowing / crinkling of leaves.	Thrips on ground nut and pulses
9. Reduced vigour / stunted growth / Yellowing / sooty mould.	Aphids

Dipteran adults (House flies) possess sponging and sucking type of mouthparts and Hymenopterans (Honeybees) possess Chewing and Lapping type of mouthparts. These are not pests of agricultural importance

Lecture – 12

INTEGRATED PEST MANAGEMENT

The insect pest problems in agriculture are probably as old as agriculture itself. The insects under favourable conditions multiply enormously and different species multiply at different rates.When the number of an insect increase, it reaches the pest status. Rapidly increasing human population during last century has necessitated intensification of agriculture through expansion of irrigation facilities, growing of new crops, introduction of improved and exotic varieties and application of increased amounts of agrochemicals. Definitely modern agriculture technology package has resulted in increased higher yields and it has also led to severe outbreaks of insect pests in agricultural crops.

Evolution of IPM

Green revolution has attained self sufficiency in food through introduction of hybrids and high yielding varieties. Intensive cultivation of high yielding varieties demanded more of inputs in the form of fertilizers especially inorganic which in turn attracted more of pest and diseases. This necessitated intensive control measures to curtail the damage caused to the crops and the control was achieved mainly through chemical pesticides. Continuous use of chemical pesticides led to pest resurgence, resistance, residues and ecological imbalance by killing predators and parasitoids thus affecting natural balance and resulting in environmental pollution. The importance of integrated approaches to pest control was then felt and the concept of IPM evolved.

Modern concept of pest management is based on ecological principles and integration of different control tactics into a pest management system

IPM includes

I – Integration - that is harmonious use of multiple methods to control the impact of single pest as well as multiple pests.

P - Pest- any organism that is detrimental to humans including vertebrates and invertebrate or weed or pathogens.

M - Management refers to a set of decisions or rules based on ecological principles, economic and social consideration.

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".

Crop losses due to insect pests

Insect pests cause huge losses ranging from 5 to 80% or even up to cent per cent.. Acute food shortage following world war –II and Bengal famine (1943) due to failure of rice crop due to a paddy disease indicate the severity of the loss, caused by the pests and diseases. The insects in storage on an average consume and spoil an additional 4 million tonnes of grains every year. All this indicates the importance of plant protection by which we can save millions of tonnes of food grains which are otherwise eaten away by different pests. Losses due to insect pests in Indian agriculture are 23.3 per cent. One of the practical means of increasing crop production is to minimize the pest associated losses.

Methods of pest control

Any factor that is capable of making life hard for the insect that will repel or interfere with its feeding, mating, reproduction or dispersal can be taken as a method of insect control in its broadest application.

They can be divided into two major categories

1. Natural control
2. Applied control

Under natural control the population is kept under check by the environmental resistance without the interference of man. The control measures adopted by human agency are called applied or artificial control measures. Depending on the time of taking action the applied control measures may be

i. Preventive or prophylactic i.e. action taken to prevent the occurrence or spread of infestation and

ii. Curative or remedial measures i.e. measures which are taken to kill the already existing pest population.

Different components or tools of IPM :

1) Cultural methods
2) Mechanical methods

3) Physical methods

4) Legislative methods

5) Biological methods and

6) Chemical methods

Lecture -13
CULTURAL CONTROL

The manipulation of cultural practices at an appropriate time for reducing or avoiding pest damage to crops is known as cultural control. The cultural practices make the environment less favourable for the pests and or more favourable for its natural enemies. It is the cheapest of all methods.

The different methods are

i) Proper preparatory cultivation / summer ploughing: Several insects which live or hide in the soil get exposed to sun as well as predators like birds etc. due to proper preparatory cultivation or summer ploughing. Deep ploughing in summer exposes most of the soil inhabiting insects to sun and hot winds and get them killed

Eg. Pupae of moths like *Helicoverpa, Spodoptera* etc , roots grubs etc.

ii) Clean cultivation and removal of stubbles : Removal of weeds which act as alternate or collateral hosts

Eg. Paddy gall fly *Orseolia oryzae* breeds on grasses such as *Panicum* sp. *Cynodon dactylon* etc. Fruit sucking moth larvae, *Eudocima spp.* on weeds of Menispermaceae.

iii) Crop rotation: Crop rotation is most effective practice against pests that have a narrow host range and dispersal capacity. Lady's finger followed by cotton will suffer from increased infestation of pests. Hence if a non-host crop is grown after a host crop, it reduces the pest population.

Eg. Cereals followed by pulses.

Cotton should be rotated with non hosts like ragi, maize, rice to minimize the incidence of insect pests.

Groundnut with non leguminous crops is recommended for minimizing the leaf miner incidence.

iv)Trap cropping: Growing of susceptible or preferred plants by important pests near a major crop to act as a trap and later it is destroyed or treated with insecticides. Trap crop may also attract natural enemies thus enhancing natural control.

Eg:	**Trap crop**	**Main crop**	**Insect pest**
	Castor	Chillies	Tobacco caterpillar, *Spodoptera litura*
	Tomato	Citrus	Fruit sucking moths, *Eudocima spp*
	Marigold	Cotton	American bollworm, *Helicoverpa armigera*
	Bhendi	Cotton	Leafhopper, *Amrasca biguttula biguttula*

v) Use of healthy seed and planting material: Select sound healthy seed, nursery or planting material for cultivation. Some insects and nematodes will move from infected field to other field. So one must use healthy planting material, nursery or seed.

Eg: Nematode infected brinjal or tomato nursery, sugarcane setts affected with scales should not be used for planting.

vi) Adjusting planting or sowing or harvesting times to avoid certain pests : The manipulation of planting time helps to minimize pest damage by producing asynchrony between host plants and the pest or synchronizing insect pests with their natural enemies.

Eg. Early planting of paddy in *kharif* and late planting in *rabi* minimize the infestation of rice stem borer.

Delaying the sowing of sunhemp till the onset of South West Monsoon avoids sunhemp hairy caterpillar (*Utethesia lotrix)* attack.

Early sown sorghum in *kharif* reduces the infestation of shoot fly

Timely and synchronous planting has been found to reduce bollworm damage in cotton and stem borer damage in sugarcane.

vii) Use of recommended dose of fertiliser: The incidence of pests in a crop is influenced by the nitrogen, phosphorous and potassic fertiliser use. Excessive nitrogen increases susceptibility of crop to sucking and leaf eating pests. Higher rates of nitrogen application than the recommended rate to crops is the main factor for heavy pest and disease incidence. Balanced application of NPK helps the crop to tolerate pests and diseases considerably.

Eg: BPH, leaf folder, green leafhopper incidence in rice and sucking pest in cotton, thrips and aphids in chilli increases because of high N fertilizer application.

viii) Growing resistant varieties: Certain varieties resist pest attack so select those varieties.

Eg: Vajram, Chaitanya, Nagarjuna and Pratibha are resisitant to paddy BPH, Phalguna, Surekha, Vikram, Shakthi, Kakatiya, Dhanyalakshmi to gall midge, LPS 141, LK 861, N A 1280 are resistant to whitefly in cotton.

Other cultural methods:

1. Raking up and hoeing of the soil around gourds, mango and other fruit trees serves to destroy pupae of fruit flies.
2. Adoption of high seed rate in sorghum and later removal and destruction of shoot fly (*Atherigona soccata)* affected ones.
3. Trash mulching @ 3 t/ha 3 days after planting or earthing up after planting minimize early shoot borer (*Chilo infuscatellus)* attack in sugarcane
4. Destruction of crop residue: Stubbles of sugarcane and paddy that harbor borers should be ploughed up and burnt.
5. Periodical drying of stored produce against stored grain pests.
6. Pruning of dried twigs/ branches to eliminate pests like scales and orange borer

MECHANICAL METHODS

Reduction or suppression of insect pest population by means of manual devices or labour is called mechanical methods.

1. **Hand picking and collection with hand nets and killing insects:**

Handpicking is the most ancient method which can prove fairly effective under certain conditions. Egg masses, larvae or nymphs and sluggish adults can be handpicked and destroyed.

Eg.

a. Egg masses of paddy stem borer and groundnut hairy caterpillar can be collected and destroyed.
b. Early stages of *Spodoptera litura* and hairy caterpillars are easily located by their typical damage symptoms
c. The moringa hairy caterpillars which collect at tree trunks in the mornings can be burnt with flame throwers.
d. Most of the insects can be collected with hand nets and destroyed.

e. Collection and destruction of fallen fruits is effective against fruit flies and fruit borers.

f. Manual collection and destruction of pink bollworm attacked 'rosette' flowers, withered and drooped terminals infested by spotted bollworm can reduce the incidence of these pests in cotton.

2. Provision of preventive barriers:

1. **Trenches:** Digging of 30 - 60 cm wide and 60 cm deep trenches or erecting 30 cm height tin sheet barriers around the fields is useful against pests like hairy caterpillars.
2. **Bagging of fruits**: Bagging / wrapping of pomegranate and mango fruits in paper bags avoids the infestation of pomegranate butterfly *Deudorix* (*Virachola) isocrates* and mango fruit fly *Bactrocera dorsalis*
3. **Erection of tin bands:** Tin bands are fixed over coconut palms to prevent damage by rats.
4. **Sticky bands**: Creating sticky bands around the tree trunks against red tree ant.
5. **Use of Polythene bands:** Use of an alkathene band around the tree trunks of mango to check the migration of first instar nymphs of mealy bugs and red ants.

Other mechanical methods:

1. Extraction of adult Rhinoceros beetle (*Oryctes rhinoceros)* from the crown of coconut trees using an arrow headed rod/hook.
2. Shaking of plants / trees**:** Shaking of redgram plants to collect and destroy *Helicoverpa armigera*. Systematic shaking of root grub adults harbored trees during evening hours to dislodge and destroy.
3. Construction of rat proof godowns
4. Sieving and winnowing against stored grain pests
5. Using mosquito nets fly proof cages etc.

Lecture -14

PHYSICAL METHODS OF PEST CONTROL

Physical Methods of Pest Control:

Use of certain physical forces to minimize the pests

- A material called drie-die, consist of highly porous, finely divided silica gel which when applied abrades the insect cuticle thus encouraging loss of moisture resulting in death. It is mainly used against stored product pests.

- Kaolinic clay after successive activation with acid and heat can be mixed with stored grain. The clay minerals absorb the lipoid layer of the insect cuticle by which the insects lose their body moisture and die due to desiccation.

- Artificial heating and cooling of stored products will prevent insect damage.

- Steam sterilization of soil kills soil insects

- Vapour Heat Treatment (VHT): Used in case of mango against fruit flies.

- Oxygen stress and carbon dioxide concentration: In air tight containers small volume of air is enclosed, the available oxygen is quickly utilized by insects and raise concentration of carbon dioxide. High concentration of carbon dioxide leads to death of stored product insects.

- Light traps are arranged for attracting the insects, which are trapped by keeping water or oil in a container or a killing bottle below the light trap. Light traps are useful for monitoring the population of important insect pests in an area. Eg: Most of the moths and beetles.

- Flame thrower is a compressed air sprayer with kerosene oil for producing flames. There is a lance, which is fitted with a burner. When the burner is heated, the kerosene oil is released and it turns into flames. Used for burning locust populations, congregation of caterpillars, patches of weeds etc.

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 form 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.

Quarantine: The word quarantine is derived from Latin word Quarantum which means 'forty (40)'. Plant quarantine is defined as the legal enforcement of the measures aimed to prevent pests from spreading or to prevent them to multiply further in case they have already gained entry and have established in new restricted areas.

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 18^{th} 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" 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

1) Legislation to prevent the introduction of foreign pests:

To prevent the entry of foreign pests all countries have restrictions. 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 Faridababd in 1946. DPPQS deals with the commercial import of consignments of grains, plants and plant products for consumption through its network of 35 Plant Quarantine Stations spread across the country at seaports, airports and land frontiers.

These operate under the provisions made under the "Destructive Insect and Pests Act of 1914". The consignment should also be accompanied with the certificate issued by the Officers of agriculture department of the exporting country so as confirm that the consignments are pest free. This certificate is called as 'Phytosanitory certificate'.

2) Legislation to prevent the spread of already established pests:

The Destructive Insect and Pests Act, 1914, have empowered the states to enact such laws as are necessary to prevent the spread of dangerous insects within their jurisdiction.

The Madras Government enacted the Madras Agricultural Pests and Diseases Act in 1919 and was the first state to enact such laws in our country. This act was passed to prevent the spread of pests or diseases or weeds form one part of the state to another.

3) Legislation to enforce the application of effective control measures to prevent the damage by established pests:

Under the state pests act, the farmers were asked to remove and destroy coconut leaf lets infested with black headed caterpillar *Opisina arenosella* around Mangalore in 923 and in 1927 in Krishna and Guntur districts. Later it was withdrawn as the pest was successfully controlled by biological control agents.

4) Legislation to prevent the adulteration and misbranding of the insecticides:

To avoid malpractices and supply of substandard chemicals, the pesticide products are to be standardized through the Indian Standards Institute. Such products carry **ISI mark** and are expected to confirm the level of *a.i* (active ingredient). The Insecticide Act, 1968

has been enforced on 2nd September, 1968 by the Government of India to regulate the import, manufacture, sale, transport and distribution and use of insecticides. The government of India also constituted the Central Insecticide Board (CIB) to advise the state and central governments as per this act.

5) Legislation to regulate the activities of men engaged in pest control operations: They have to take certain precautionary measures to avoid pesticide poisoning and undergo regular medical checkups.

Lecture -15

BIOLOGICAL CONTROL

Management of an insect with other living organism is called as Bio-control. The successful management of a pest by means of another living organism (parasitoids, predators and pathogens) that is encouraged and disseminated by man is called artificial biological control. In such programme the natural enemies are introduced, encouraged, multiplied by artificial means and disseminated by man with his own efforts instead of leaving it to nature.

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.

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 parasite is called host.

Parasitoid: is an insect parasite of an arthropod, parasitic only in immature stages, destroys its host in the process of development and free living as an adult.

Qualities of a successful parasitoid :

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1. Should be adaptable to environmental conditions in the new locally
2. Should be able to survive in all habitats of the host
3. Should be specific to a particular species of host or at least a limited range of hosts.
4. Should be able to multiply faster than the host
5. Should be having more fecundity
6. Life cycle must be shorter than that of the host
7. Should have high sex ratio
8. Should have good searching capacity for host
9. Should be amendable for mass multiplication in the labs
10. Should bring down host population within 3 years
11. There should be quick dispersal of the parasitoid in the locality
12. It Should be free from hyperparasitoids

Eg: Egg parasitoid : *Trichogramma australicum*

Larval parasitoid: *Bracon hebetor*

Pupal parasitoid: *Trichospilus pupivora*

Predators

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:

1. A predator generally feeds on many different species of prey , thus being a generalist or polyphagous nature
2. A predator is relatively large compared to its prey , which it seizes and devours quickly
3. Typically individual predator consumes large number of prey in its life time

Eg: A single coccinellid predator larva may consume hundreds of aphids

4. Predators kill and consume their prey quickly , usually via extra oral digestion
5. Predators are very efficient in search of their prey and capacity for swift movements
6. Predators develop separately from their prey and may live in the same habitat or adjacent habitats
7. Structural adaptation with well developed sense organs to locate the prey
8. Predator is carnivorous in both its immature and adult stages and feeds on the same kind of prey in both the stages
9. May have cryptic colourations and deceptive markings

Eg. Praying mantids and Robber flies

Conservation of natural enemies: The actions to preserve the natural enemies by environmental manipulations or alter production practices to protect natural enemies that are already present in an area are called as conservation.

Important conservation measures are

- Use selective insecticides which are safe to natural enemies.
- Avoidance of cultural practices which are harmful to natural enemies and use favourable cultural practices
- Cultivation of varieties that favour colonization of natural enemies
- Providing alternate hosts for natural enemies.
- Preservation of inactive stages of natural enemies.

Successful examples of biological control

- A red ant, *Oecophylla smaragdina* was used by the Chinese citrus growers, on mandarin trees to control leaf chewing insects. This was the first use of predators.
- In 1762, the Indian myna bird, *Acridotheres tristis* was introduced to Mauritius where it successfully controlled Red locust, *Nomadacris septemfasciata*.
- Vedalia beetle, *Rodalia cardinalis,* a coccinellid beetle introduced from Australia into other countries to control the cottony cushion scale, *Icerya purchasi* on citrus.
- Biological control of water hyacinth**,** *Eichhornia crassipes ,* three exotic natural enemies were introduced in India– *Neochetina bruchi* and *N. eichhorniae* (Argentina) and galumnid mite *Orthogalumna terebrantis* (South America) in 1982 for the biological suppression of water hyacinth.
- Apple woolly aphis, *Eriosoma lanigerum* in Coonor area by *Aphelinus mali* (Parasitoid)

MICROBIAL CONTROL

Microbial control refers to the exploitation of disease causing organism to reduce the population of insect pests below the damaging levels. Microbial organisms or their products (toxins) are employed by man for the control of pests. Steinhaus (1949) coined the term ‘Microbial Control’.

Properties of entomopathogens are,

1. Host specific
2. Non-toxic to man
3. Non-phytotoxic
4. Safer to beneficial insects
5. Compatible with number of insecticides
6. No or less resistance is developed in insects

1. **Bacteria:** The entry of the bacteria is by ingestion, which infect the mid gut epithelia cells and enter the haemolymph to sporulate and cause septicemia.More than 100 pathogenic bacteria were recorded of which *Bacillus thuringiensis* (*B.t.*) is important.

B.t. is now being used by farmers mostly on lepidopterous larvae. It can infect more than 150 species of insects.

Properties of *B.t.:* Highly pathogenic to lepidopterous larvae, non-toxic to man safer to beneficial insects and non-phytotoxic. Compatible with number of insecticides available in different formulations.

Eg. *Bacillus thuringiensis*, *B. cereus*

Viruses: Among the different viruses attacking insects and causing diseases NPV (Nuclear Polyhedrosis Virus) is very important. About 300 isolates of NPV have been isolated from the order Lepidoptera. Among these viruses Baculoviruses (Baculoviridae) are successful in IPM. The NPV is observed to affect 200 species of insects. The virus infected dead larvae hang upside down from plant parts (Tree top disease).

The cuticle becomes fragile, rupturing easily when touched, discharges liquefied body fluids. NPV multiplies in insect body wall, trachea, fat bodies and blood cells. The polyhedra are seen in nuclei. The polyhedral bodies enlarge in size destroying the host nuclei to get released into the insect body cavity. Nuclear polyhedrosis Virus(NPV), Cytoplasmic polyhedrosis viruses(CPV), Granulosis viruses (GV) are important entomopathogenic viruses of agricultural importance.

H. a NPV, *S. l* NPV can be used in the field to control *Helicoverpa armigera* and *Spodoptera litura*, respectively which are available in liquid form. One acre requires 100 Larval Equivalents (LE) and it should be mixed in water and sprayed in the evenings. NPV liquid should be stored in cool place or refrigerator to maintain its shelf life for longer period.

3. Fungi: The fungal disease occurrence in insects is commonly called as mycosis. Most of the entomopathogenic fungi infect their hosts by penetration of the cuticle. The typical symptoms of fungal infection are, mummified body of insects and it does not disintegrate in water and body covered with filamentous mycelium. More than 5000 species of entomopathogenic fungi are recorded. Eg: *Beauveria bassiana*

Lecture -16
CHEMICAL CONTROL

Control of insects with chemicals is known is chemical control. The term pesticide is used to those chemicals which kill pests. 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 insect pests.

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 increase. There are many pest problems for which the use of chemicals provides the only acceptable solution. When their use made on sound ecological principles, chemical pesticides provide dependable and valuable tools for the biologist. Their use is indispensable to modern society.

Pesticides are generally available in a concentrated form which is to be diluted and used except in ready to use dust and granules. They are highly toxic and available in different formulations.

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.

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 grouped as

a. **Contact poisons**: These insecticides are capable of gaining entry into the insect body either through spiracles and trachea or through the cuticle itself. Hence, these poisons can kill the insects by mere coming in contact with the body of the insects. Eg.DDT and HCH.

b. **Stomach poisons:** The insecticides applied on the leaves and other parts of plants when ingested act on the digestive system of the insect and bring about the kill of the insect. Eg: Calcium arsenate, lead arsenate.

c. **Fumigants:** A fumigant is a chemical substance which is volatile at ordinary temperatures and sufficiently toxic to the insects. Fumigation is the process of subjecting the infested material to the toxic fumes or vapours of chemicals or gases which have insecticidal properties. Fumigants mostly gain entry into the body of the insect through spiracles in the trachea.

d. **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 demeton, Phosphamidon , Acephate

'Non systemic insecticides' are not possessing systemic action are called non systemic insecticides. Some non systemic 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.

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 protein especially destruction of cellular protoplasm of mid gut epithelium. Eg. Arsenical compounds.

3. **Respiratory poisons:** Chemicals which block cellular respiration as in hydrogen cyanide (HCN), carbon monoxide etc.

4. **Nerve poisons:** Chemicals which block Acetyl cholinesterase (AChE) and affect the nervous system. Eg. Organophosphorous and carbamate insecticides.

5. **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.

6. **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 of insecticides is expressed in terms of LD 50 (Median lethal dose) or LC 50 (Median lethal concentration)

LD 50 : It is the amount of toxicant required to kill 50% of the test population.

LC 50 : It is expressed in terms of percentage of the toxicant required (concentration) to cause 50% kill of the population of a test population.

It is expressed in terms of mg/kg body weight of animal, in insects its expressed in terms of micrograms/gm body weight of insects.

Sl. No.	Classification	Symbol	Oral LD50 mg/kg	Dermal LD50 mg/kg	Colour
1	Extremely toxic	Skull & Poison	1-50 Red	1-200	
2	Highly toxic	Poison	51-500	201-2000	
3	Moderately toxic	Danger	501-5000	2001-20000	
4	Less toxic	Caution	>5000	>20000	

Depending on severity of toxicity of poisons, they broadly classified into

Acute toxicity: toxicity that causes injury or death from a single exposure of toxicant over a short period of time.

Chronic toxicity: toxicity due to multiple dose exposure over a prolonged period of time.

Lecture - 17

FORMULATIONS OF INSECTICIDES

It is essential that the toxicant must be amenable to application in an effective manner so as to come into direct contact with the pest or leaf and uniform and persistent deposit upon the plant surface. 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. Following are the different formulations of insecticides.

1. **Dusts (D):** These are ready to use insecticides available in powder form. In a dust formulation the toxicant is diluted by mixing with 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%. 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. Chlorpyriphos 1.5 D, Malathion 5%

2. **Granules (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 is released from the formulation in its intact form or as it disintegrates giving controlled release. Toxicant in a granular formulation ranges from 1 to 10%. The granules are applied in whorls of plants or in soil or in water. Granular formulations are less harmful to natural enemies.
   Eg: Carbofuran3G, Phorate10G, 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 diluents 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. **Emulsifiable Concentrates (EC):** The formulation contains the toxicant, a solvent for the toxicant and an emulsifying agent. 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, Carbohydrates, gums, lipids, proteins etc. Eg: Malathion 50 EC, Profenophos 50EC.

5. **Concentrated Solutions:** 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. Active ingredient ranges from 80-100%. Eg: Malathion, Bifenthrin, Fenitrothion.

7. **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

8. **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

9. **Fumigants:** A chemical compound which is volatile at ordinary temperature and sufficiently toxic is known as fumigant. 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.

10. **Insecticide Mixtures:** Insecticide mixtures involve combinations of two or more insecticides in the right concentration into a single spray solution. The use of pesticide mixtures may result in synergism or potentiation (enhanced efficacy).
    Ex: Chlorpyriphos16% + Alphacypermethrin 1% EC
    Quinalphos 20% + Cypermethrin 3% EC.

Lecture - 18

IMPORTANT GROUPS OF INSECTICIDES

I) Organochlorines (Chlorinated Hydrocarbons)

They are contact and stomach poisons and exhibits long residual toxicity. Most of these insecticides are banned for agricultural use. Eg. DDT (Dichloro Diphenyl Trichloroethane), Hexa Chloro Cyclohexane (HCH) etc. When an HCH containing 99% gamma isomer, then it is termed as lindane.

Cyclodienes

The outstanding characteristic of the cyclodienes is their longer stability in the soil. None of the chemicals belonging to this group are now available for agricultural or industrial use. Eg. chlordane, aldrin, dieldrin, heptachlor, endrin, and endosulfan.

II. Organophosphates:

Organophosphate insecticides have two most important properties such as higher potency and low residual life. The insecticides under this group act as contact, stomach and systemic insecticides. The organophosphates (OPs) inhibit the cholinesterase (Ch E) enzyme leading to blockage of synaptic transmission of nerve impulses and finally death. Eg. Malathion, Dichlorvos, Dimethyl Dichloro Vinyl Phosphate – DDVP, Fenitrothion, Quinolphos, Phosolone, Chlorpyriphos, Phosphomidon, Monocrotophos, Methyl demeton, Dimethoate, Triazophos, Profenophos, Acephate, Phorate

III) Carbamates:

All carbamates are derivatives of carbamic acid. Like organophosphates, the carbamate insecticides interfere in cholinergic transmission. The carbamate insecticides enters the synapse and inhibits the acetylcholine esterase enzyme. The AChE recovers more readily from carbamates than from organophosphates, hence they are reversible inhibitors. Eg. Carbaryl, Propoxur, Carbofuran, Aldicarb, Methomyl, Thiodicarb

IV) Synthetic Pyrethroids :

Synthetic pyrethroids have got the properties of plant derivative pyrethrum as insecticides but are considerably more stable in light and air. Allethrin was the first synthetic analogue of pyrethroids. They act as nerve poisons. These insecticides act as contact and stomach poisons. Rapid development of resistance to synthetic pyrethroids in many insect species is observed. Eg. Allethrin, Resmethrin, Bioallethrin,

Fenvalerate, Permethrin, lambda-cyhalothrin, Cypermethrin, Decamethrin (Deltamethrin), Fluvalinate, Fenfluthrin.

Novel Insecticides: The extensive use of conventional insecticides (Oraganochlorines, Organophosphates, Carbamates and Synthetic pyretrhroids) has resulted in the development of severe pest resistance to insecticides, out-break of secondary pests, objectionable pesticide residues, direct hazard to the users and adverse effect on environment and non-target organisms. This has led to the search for and development of new compounds or newer bio-rationals or “low risk” insecticides viz., neonicotinoids, oxadiazines, phenylpyrazoles, pyridine, avermectins, spinosyns, pyrroles, insect growth regulators (IGRs), diamides, etc. which has now-a-days, because of their good controlling properties of insect pests at low rates or doses, high level of selectivity, greater specificity to target pests along with low toxicity to non-target organisms and the environment, replaced many old/conventional compounds.

a). Neonicotinoids: Neonicotinoids interact with acetyl choline binding site of nicotinic Ach receptor which cause excitation and eventually paralysis leading to death of insects. These are selective and safe to non target organisms. Eg. Imidacloprid, Acetamiprid, Thiomethoxam, Thiacloprid etc.

b) Juvenile Hormone (JH) Mimics:

These are having antimorphic effect which does not allow metamorphosis to take place there by forcing larva to continue as a larva. The larvae undergoes an extra larval moult (change in to super larva) or moult in to defective intermediate forms
Ex. Juvabione , Methoprene (Altosid), Hydroprene, Kinoprene

c) Benzoyl Phenyl Ureas: They are acting as chitin synthesis inhibitors which inhibits chitin synthase enzyme and prevents the chitin biosynthesis. It acts mainly by ingestion. Eg. Diflubenzuron, Flufenoxuron, , Novaluron, Buprofezin,

d) Spinosyns – The extract of the fermentation broth that contains spinosad is produced by the microorganism, *Saccharopolyspora spinosa.* Spinosad is a contact and stomach poison with some translaminar movement in leaf tissue. Ex. Spinosad

e) **Avermectins:** Avermectins form a new class of compounds having nematicidal, miticidal and insecticidal activity. These are produced by the soil microorganism *Streptomyces avermitilis*. Avermectins activate the GABA (Gamma-amino butyric acid) gated chloride channel of nervous system, causing insect's death. Eg. Emamectin benzoate and Abamectin.

f) Oxadiazines

Indoxacarb: Indoxacarb is a stomach poison with slight contact action. It acts as nerve poison by blocking the sodium channel. The result is impaired nerve function, feeding cessation, paralysis and death.

g) **Phenyl pyrazoles**

Fipronil: Broad spectrum systemic insecticide with contact and stomach poison activity. GABA receptor of nervous system is the target site for fipronil. This leads to exitation of the central nervous system and death of the insect.

h) Pyridine Azomethines

Pymetrozine: A new insecticide highly active and specific against sucking insect pests. Stylets are almost immediately blocked upon insertion of the stylets into the pymetrozine treated plant tissues. The sucking insects die due to starvation.(feeding depressant).

I) **Thio-Urea Derivatives:**

Diafenthiuron is a new type of thiourea derivative which acts specially on sucking pests such as mites, whiteflies and aphids. It inhibits ATP synthase at cellular level.

j) Ketoenols: They act as insecticides and acaricides against all developmental stages. They inhibit lipogenesis in treated insects and affects the reproductive abilities of adult insects.

Ex. **Spiromesifen**: it is effective against whitefly, spider mites and psyllids. Reduces egg laying capacity in mites.

k) Diamides:

Chlorantraniliprole is a novel insecticide. Effective against lepidopteron insects. It is active on chewing insect pests. Chlorantraniliprole activates ryanodine receptors of cell.

Flubendiamide is a new insecticide active against lepidoperan pests. Acts by ingestion and disrupts nervous system resulting in rapid cessation of feeding.

Lecture - 19

Nematicides, Rodenticides, Acaricides, Antifeedants, Attractants and Sex pheromones.

1. **Nematicides**: The chemicals which kill nematodes are called Nematicides. Most of the carbamate group of insecticides are having nematicidal action. Eg. Carbofuran
2. **Rodenticides**: The chemicals which kill rodents are called as Rodenticides. They are classified into 3 groups.
   i. Acute Poison : Zinc phosphide 2 %.
   ii. Anti Coagulants: Bromadiolone 0.25 CB
   iii. Fumigants: Aluminium Phosphide

Zinc phosphide 2%: It is a black powder having a distinct smell. Rats show bait shyness with this chemical. Hence, Pre baiting should be done 2 – 3 days before.

Bromadiolone 0.25% CB: This is available in powder and cake forms. In paddy, Bromadiolone is to be placed in the form of poison bait. Rats do not show bait shyness with bromadiolone and hence, no pre baiting is needed. This is also available in cake form.

Zinc phosphide and Bromadiolone can be applied as bait. Bait poison is to be prepared by mixing Broken rice (local food) – 96 parts + Edible oil- 2 parts + Zinc phosphide or Bromadiolone– 2 parts. The mixture is to be placed near rat burrows in the form of 10 g packets or loose bait can be placed at 10 bait stations / acre.

Aluminium Phosphide: Fumigation with Aluminium phosphide after enumeration of burrows @ 2 pellets / burrow. This process releases phosphene gas which in turn kills rats.

3. Acaricides: The chemicals which kill mites and ticks are called as Acaricides. Most of the organophosphouros insectides and dicofol in organochlorines act as acaricides.
Eg. Sulphur, Dicofol, Tetradifon, Aryl alkyl sulphide, Barium polysulphide, Spiromecyferon.

Insecticides with acaricidal properties: Phosphamidon, Dimethoate, Methyl demeton, Formothion, Phosalone, Monocrotophos, Ethion,Phorate granules,Disulfoton granules.

Note : Do not use wettable sulphur on cucurbits and Tea.

4.Insect Antifeedants / Feeding deterrents :

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 called as “Feeding deterrents”.

Groups of antifeedants:

a) Triazines : Ex.Acetanilide

b) Organotins : Ex.Triphenyl tin acetate (Brestan)

c) Carbamates: Ex. Arprocarb (Propoxur)

Advantages of Antifeedants:

i. Antifeedants affect only the phytophagous insects and so do not harm the beneficial parasitoids, predators and pollinators.

ii. As the pest is not immediately killed by antifeedant, its parasites and predators continue to feed on it, thrive, and keep it under control.

iii. Antifeedants produce no phytotoxicity (or) pollution.

Disadvantages of Antifeedants:

1. Only the chewing type of insects are affected by antifeedants, the sucking pests remain unaffected.
2. New growth of plant are not protected.

5. Insect Attractants

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. Geraniol + Eugenol mixture at 1:1 ratio attracts Japanese beetle. Methyl eugenol attracts fruit flies in orchards. These can be used in poison baits.

6. 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. Ex : Cotton boll weevil, cabbage looper, Mediterranean fruit fly etc.

Eg: Bombycol : Silkworm, *Bombyx mori*
Gyplure : Gypsy moth, *Porthetria dispar;*
Gossyplure : Pink bollworm, *Pectionophora gossypiella*
Litlure : Tobacco caterpillar, *Spodoptera litura*
Helilure : Red gram pod borer, *Helicoverpa armigera*

Sex pheromones in insect pest management

1) Monitoring of insect pests: Traps baited with synthetic sex pheromones are useful in estimating population and detecting early stages of pests. Four pheromone traps are used per acre.

2) Mass-trapping: (Male annihilation technique): Large number of pheromone baited traps (20-25 traps per acre) can be used in the fields to capture male moths and reduce the number of males available for mating.

3) Mating disruption: By permeating the atmosphere with higher concentration of the pheromone the opposite sex is rendered confused and unable to locate their mates.

Lecture – 20

INSECTICIDES OF PLANT ORIGIN

The insecticides of plant origin are extracted from seeds, flowers, leaves, stem and roots and are termed as botanical insecticides. Insecticides of plant origin unlike synthetic organic insecticides are safer to use.

1) Neem (*Azadirachta indica)*

It possesses medicinal, insecticidal, insect repellent, antifeedant, growth regulatory, nematicidal and antifungal properties. Neem seed extract and oil contains a number of components such as Azadirachtin, solannin, nimbin, epinimbin, nimbidin. Azadirachtin disrupts moulting by antagonizing the insect hormone ecdysone.

Ex. Neem Seed Kernel Extract (NSKE 5%) and Neem Cake Suspension.

NSKE 5 % preparation: soak 10 kg neem seed powder in 200 litres of water for 24 h and filter through muslin cloth.

2) Nicotine: Nicotine is found in the leaves of *Nicotiana tabacum* and *N.rustica* from 2% to 14%. Nicotine sulphate has been mainly used as a contact insecticide with marked fumigant action in the control of sucking insect's *viz*., aphids, thrips, psyllids, leafminers and leafhoppers. It is a nerve poison.

Tobacco decoction, It can be prepared by boiling 1kg of tobacco waste in 10lts of water for 30 minutes or steep it in cold water for a day. Then make it up to 30 litres and add about 90 g of soap. Addition of soap improves wetting, spreading and killing properties. Nicotine does not leave any harmful residue on treated surface.

3) Pyrethrum: It is extracted from dried flower heads of *Chrysanthemum cinerariaefolium*. The actual chemical ingredients having insecticidal action are identified as six esters. They are: pyrethrin I, pyrethrin II, cinerins-I and cinerin-II and jasmolin I and jasmolin II. The esters are derived from two acids – Chrysanthemic acid and Pyrethric acid and Three alcohols – Pyretholone, Cinerolone and Jasmolone.

Pyrethrins are powerful contact insecticides. A characteristic action of Pyrethroid is the rapid paralysis or **'**knock down' effect.

4) Rotenone: It is extracted from the roots of *Derris elliptica* plant. Insects poisoned with rotenone show a steady decline in oxygen consumption followed by paralysis and deaths.

5) Plumbagin: Plumbagin is naturally occurring napthoquinone of plant origin from the roots of *Plumbago europea.* Plumbagin is known for its medicinal, antimicrobial, molluscicidal, nematicidal and other pharmacological properties. It is having IGR properties *like* inhibition of chitin synthetase

6)**Sabadilla**: The extracts from seeds of Sabadilla, *Schoenocaulon officinale* are considered to be toxic to insects. The active principle are cevadine, veratridine etc.

7) **Ryania**: The roots and stem extacts of *Ryania speciosa* contain an alkaloid Ryanoddine which acts as insecticide.

8) ***Tephrosia*** sps: Certain species of *Tephrosia vogelli* (Leaves and grains), *Tephrosia macropoda* (stem) and *Tephrosia toxicaria* (roots) contain active which are toxic principles against insect species.

Acorus calamus, Pongamia glaabra, Allium sativum etc are also useful against insect pests.

Lecture - 21

COMPATIBILITY OF INSECTICIDES AND INSECTICIDE COMBINATIONS

Compatibility of insecticides and phytotoxicity: The ability of two or more chemicals to stand without any change in their physical form, action or effect on the plants, when brought together in a single spray mixture is called compatibility and they are said to be compatible and vice versa is incompatibility.

Incompatibility of spray chemicals is 3 types.

1. Chemical incompatibility: Here different compounds are formed when two or more chemicals are brought together in a single spray mixture due to chemical reaction among the mixed chemicals. Ex : Synthetic organic compounds with alkaline materials.

2. Physical incompatibility: When two or more chemicals are brought together in a single spray mixture they change their physical form to one that is unsuitable or hazardous for application.

3. Phytotoxic incompatibility:

The component chemicals though non phytotoxic individually, show phytotoxicity when brought together and applied as a mixture.

Hence, a knowledge of compatibility/incompatibility of pesticides is essential for applying combinations of insecticides or insecticides and fungicides.

Compatibility chart:

A type of tabular statement which readily indicate the effects resulting from mixing a specific chemical with other chemicals. These tables require be constantly revising and making up to date since newer chemicals are being produced continuously.

Phytotoxicity of Insecticides

The application of pesticides/insecticides on plants is intended to control the pests without causing adverse or harmful effects to plants. However, it is very common to see some adverse effects on plants after application of insecticides in fields which is called phytotoxicity. It is of two kinds

(1) Permanent phytotoxicity leading to the death of the affected part/plant and

(2) Temporary phytotoxicity which allows the plant to recover after showing phytotoxicity.

Combination of insecticides / Insecticide Mixtures:

Insecticide mixtures involve combinations of two or more insecticides in the right concentration into a single spray solution. The use of pesticide mixtures may result in synergism or potentiation (enhanced efficacy). 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 can suppress arthropod pest populations irrespective of the arthropod pests' resistance traits or mechanisms. Eg. Chlorpyriphos 50% + Cypermethrin 5% EC, Profenofos 40% + Cypermethrin 5%, Tiazophos 35% + Deltamethrin 1%.

Lecture – 22
SERICULTURE

Sericulture is the rearing of silkworms for the production of raw silk. The major activities of sericulture comprises of food-plant cultivation to feed the silkworms which spin silk cocoons and reeling the cocoons for unwinding the silk filament for value added benefits such as processing and weaving.

Preparation of planting material, planting of mulberry under irrigated and rain fed conditions

The important species of mulberry cultivated in India is *Morus alba* belongs to family Moraceae. The cultivation of mulberry is called as Moriculture.

Mulberry cultivation: Mulberry is a deep rooted, perennial, hardy crop. The quality of soil of mulberry garden influence not only the leaf yield, but also leaf quality, which in turn influences the growth and development of silkworm, subsequently the quantity and quality of cocoon production.

Soil: The soil should be deep, fertile, well drained, clayey loam to loamy in nature, friable, porous with good moisture holding capacity. The pH of the soil should be around 6.2 to 6.8.

Climate: Mulberry comes up well above 600-700 MSL. It can be grown in areas with rainfall of 600 mm to 2500 mm. Mean temperature of 24-28^{0}C, relative humidity of 65-80% are ideal for growth of mulberry.

Planting season: Planting after the onset of monsoon is ideal under both rainfed and irrigated conditions. Planting in winter and summer is to be avoided. Cuttings are to be planted either in north-south or east-west direction depending on sun shine hours and wind direction.

Land preparation: The land should be tilled properly before planting to bring the soil to fine tilth. Land should be free from weeds and stubbles and levelled properly. FYM is to be incorporated @ 10 and 20 t / ha for rainfed and irrigated crops, respectively as basal dose.

Preparation of planting material: Mulberry can be propagated in two ways. a) Sexual propagation by means of seedlings. b) Asexual propagation by means of cuttings.

Cuttings: Propagation through cuttings is most common and widespread practice. Shoots of proper maturity and thickness with active, well developed buds are chosen for cutting. The tips of tender branches and the bases of over matured branches are rejected. Branches with pencil thickness (10-12 mm dia.) from 8-10 months old plants of desired variety are used for cuttings. The branches are cut into 18-20 cm (7-8”) long cuttings with a minimum of 3 internodes with well developed buds. The ends are cut clearly with sharp knife with no splits or peelings in the bark. The cuttings are placed in the nursery bed with about 2.5 cm of cutting with one node projecting above the soil. The cuttings are watered regularly. In ten days, the roots develop from buds in the internodes below the soil and the leaves from bud in the internode above the soil. The cuttings may be planted directly in fields or may be grown in nursery for 2-3 months and then transplanted.

Planting systems :

a) Row system: It is followed under irrigated conditions. Ridges and furrows are made at 60 cm distance. Two cuttings are planted at each spot along the edges of ridges. The crop is grown as bush type.

b) Pit system: It is followed under rainfed condition with wider spacing. Pits of 40 x 40 x 40 cm are dug and filled with 1 kg each of FYM, red soil and sand. Three cuttings are planted in a triangle in each pit. Spacing is 90 x 90 cm for bush type of cultivation. Wider spacing of 180 x 90 cm and 270 x 270 cm is adopted for high bush and tree plantation, respectively.

Lecture - 23

MAINTENANCE OF MULBERRY GARDEN – IRRIGATION, FERTILIZATION AND LEAF HARVEST

Irrigation methods :

Judicious use of water for maximum production is important. During dry period, irrigation should be given at 7 to 15 days interval depending upon soil condition and water holding capacity.

Loamy soils – Once in 10 days
Clayey soils – Once in 15 days

a) Furrow method :

- Field is laid into ridges and furrows.
- Only one irrigation channel for every two rows of mulberry.
- Evaporation from soil surface is less.
- More efficient from the point of economy in water use.
- Furrow serves as drainage channel during heavy rains and avoids water stagnation.

b) Basin method :

- Suitable for tree plantation.

c) Flat bed method :

- Field is divided into rectangular bed with bunds all around and channels on sides.
- Bed size varies from 3.5 x 2.0 m to 4.0 x 6.0 m.
- Irrigation quicker but more labour required to make beds.

d) Overhead/Sprinkler method :

- Practiced in undulating lands where lower and high bushes are cultivated.
- Most efficient in economizing water use.

e) Micro irrigation by drip :

- More efficient in economizing water use.

Manure and fertilizers:

Manure/fertilizer	Row system	Pit system
FYM (t/ha): Irrigated	20	20
Rainfed	10	10
NPK (kg/ha): Irrigated	300:120:120	300:120:120
Rainfed	---	100:50:50*
Fertilizer schedule	5 splits	6 splits

* In two equal splits, i.e. first dose in August at 6 to 8 weeks after application of FYM and second dose in late November during NE monsoon rains.

Fertilizer Schedule (NPK (kg/ha) :

Phase	**Time**	**Row system**	**Pit system**
I	1st harvest of leaf	60-60-60	60-60-60
II	2nd harvest of leaf	60-00-00	40-00-00
III	3rd harvest of leaf	60-60-60	40-00-00
IV	4th harvest of leaf	60-00-00	60-60-60
V	5th harvest of leaf	60-00-00	40-00-00
VI	6th harvest of leaf	--	40-00-00
Total		300:120:120	280-120-120

Pruning : Certain branches of mulberry are periodically cut to give a proper shape and size to the plant, in order to increase the leaf yield and its feeding value. This is known as pruning.

Pruning objectives:

- To maintain a convenient height, shape and size of the plant.
- To induce more vegetative growth
- To synchronize leaf production with leaf requirement
- To remove dead and defunct wood.
- To expose plant for better sunlight and aeration

Types of pruning :

Based on the height of the plant from ground level where it is cut, there are 3 types of pruning.

a. Low cut pruning: It is widely practiced in Japan. Plant is cut at a level less than 0.5 m above ground level.

b. Medium cut pruning: Plant is cut at a height of 0.5 to 1.5 m above ground level. Large number of branches grows, but only 3-4 on the upper part are retained.

c. High cut pruning: Plant is cut at a height of more than 1.5 m above ground level. Leaf quality is poor with low moisture. Harvesting is difficult due to more height. Less damage due to floods, but more susceptible to pests, diseases and winds.

Precautions to be taken while pruning :

- The cut should be clean without any cracks.
- The bark around the cut should be intact without any peels.
- Cut ends should be washed with lime to prevent entry of pathogens.
- Application of fungicides, wax coating to cut ends should be done.

Leaf harvesting :

Leaf harvested during afternoon contain less water and more of carbohydrates due to active photosynthesis and transpiration taking place in day time and such leaves wither very quickly. Hence, leaf harvesting in early morning hours is recommended.

a) Leaf picking :

Leaves are picked individually from main stem with petioles. At the same time, terminal buds are nipped off so that lateral shoots develop rapidly. It requires more labour and leaves wither quickly.

b) Branch cutting (Batchi system in Kashmir) :

The entire branch is harvested and used to feed worms after third moult directly. It requires less labour and leaves retain succulence for longer period.

c) Whole shoot harvest:

The branches are cut to ground level by bottom pruning. The entire shoot is fed to larvae. Shoots are harvested at 10-12 weeks interval and 5-6 harvests are made per year.

Lecture - 24

INSECT PESTS AND DISEASES OF MULBERRY AND THEIR MANAGEMENT

Bihar hairy caterpillar :*Spilosoma obliqua* (Arctiidae ; Lepidoptera)

Marks of identification: Adults are light brown in colour with brick red abdomen, having dark rows of spots laterally and dorsally. The young larvae are gregarious in nature. The grown up larvae possess prominent hairs dorsally and laterally. It is a voracious feeder causing extensive damage to mulberry.

Nature and Symptoms of damage :

The young caterpillars feed on the chlorophyll layer of the leaf exposing the veins which impart dried/dead appearance to the leaves (skeletonization). The grown up larva feed on the entire leaf rendering the branches without leaves.

Management :

- Collection and destruction of egg masses and gregarious young caterpillars.
- Deep ploughing to a depth of about 15 cm to expose pupae to sun
- Flood irrigation will help to kill the pupae.
- Digging of trenches (30 cm width and 30 cm depth) around the garden and dusting with methyl parathion 1.5 % dust.
- Spray DDVP @ 1.0 ml/lt. or dimethoate 2.0 ml/lt. prepared in 0.5% soap solution. Safe period is 12 and 13 days respectively.

Tukra disease:

It is caused both in irrigated and rain fed gardens by the pink mealybug, *Maconellicoccus hirsutus*.

Marks of identification:

The later instar nymphs and adult females are protected by white filamentous waxy coating over their bodies.

Nature and Symptoms of damage :

The emerging young ones are called crawlers. The orange coloured crawlers feed by sucking the sap from leaves or tender stem portions.

- Damage leads to curling and crinkling of leaves.
- Swelling and twisting of internodes.
- Flattening and thickening of the affected part of the shoot.
- Shoots become brittle.
- Leaves become dark green in colour and deformed.

Management :

- Clipping of affected apical shoots and their destruction. Do not burry the infested plant parts in soil as nymphs/crawlers may crawl back on to the plants.
- Mass release of *Cryptolaemus montrouzeri*, a predatory Coccinellid beetle @ 250 adults/acre.
- Spray Dichlorvos 2.0 ml/lt. twice at an interval of 10-12 days, mixed with 0.5% soap solution (50 g of soap dissolved in 10 litres of water).
- Safe period for leaf harvesting is 3 days after second application of dichlorvos. and 20 days after application of oxydemeton methyl

Thrips: *Frankliniella* sp; *Scirtothrips dorsalis*

Marks of identification:

The females are dark brown and reproduce both sexually and parthenogenitically. The nymphs are pale yellow. Thrips incidence is low with protected irrigation where whole shoot harvest is practiced.

Nature and extent of damage:

Both adults and nymphs lacerate the leaf tissue and suck the oozing cell sap from young buds and leaves. The infested parts get hardened; leaves become brittle, malformed with reduced leaf area. In addition, sap extraction by the thrips results in necrosis and drying up of leaves.

Management :

Spraying with DDVP 1.0 ml/lt. or Dimethoate 2.0 ml/lt with a safe period of 3 and 15 days, respectively.

Mites : *Tetranychus equitorius*

Mites are found on the leaves, bud scales, nodes and apical shoots. Both nymphs and adults insert their stylets in to leaf tissue and suck the sap. The affected portion of the plant turns greyish white and ultimately withers. Infested plants remain stunted for a longer period without any sign of growth.

Management:

Spraying of dicofol @ 5 ml/lt

Root-knot nematode:

It is an endoparasitic nematode i.e., *Meloidogyne incognita*. They are highly infective and enter the roots to induce galls. The roots damaged by the disease lose their efficiency to absorb the available moisture and nutrients from the soil resulting in reduced metabolic function leading to the deterioration in leaf quality and yield.

Management :

- Saplings free of nematode infection should be used for planting.
- Heavily infected soils should be deep ploughed to expose nematodes and eggs to solar radiation.
- Inter cultivation with plants like marigold , sesame etc. is known to reduce the population of nematodes.
- Application of oil cakes @ 4 t /ha, green manure etc.
- Application of carbofuran @ 40 kg/acre to the soil around plants or in burrows.

Leaf spot disease : *Cercospora moricola*

Dark brown spots appear on infected leaves. Under severe conditions all the spots coalesce to form big patches and gradually leaves turn yellow and dry.

Management :

- Spray carbendazim 1 g/l for 2- 3 times at an interval of 15 days.

Powdery mildew: *Phylloctenia corilea*

White ash colour spots appear on infected leaves. White spores also appear on the spots. Gradually leaves dry and fall down.

Management :

- Spray karathane 1 ml/lt or wettable sulphur @3 g/lt.

Leaf Rust disease, *Acedium mori*

Reddish pustules appear on underside of the leaf during winter season. The infection slowly spreads to the upper side also. The disease spreads through air.

Management: Removal and burning of infected leaves. Spray copper oxy chloride 3 g/lt for 2- 3 times at an interval of 15 days.

The mulberry plants also suffer from root rot and trunk rot diseases.

Lecture- 25

SILKWORM REARING HOUSE, REARING EQUIPMENT, DISINFECTION AND HYGIENE

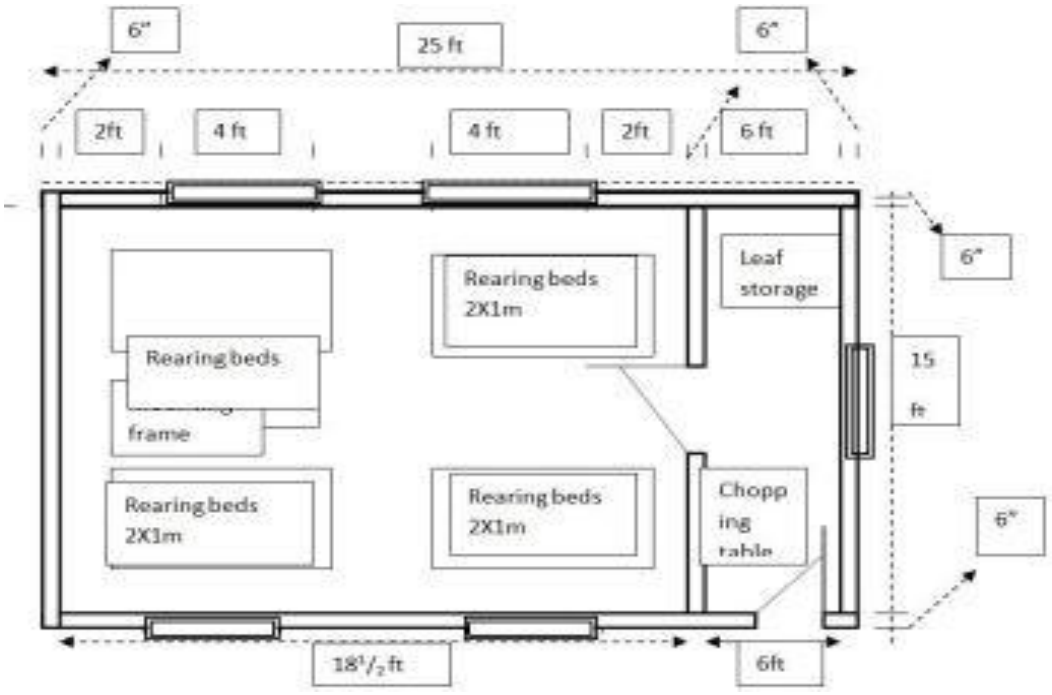
Rearing house and equipment

It is desirable to have a separate rearing house. Space requirement is minimum in shelf or stand rearing and maximum in floor rearing during old age larval rearing. Stand rearing is common in tropical countries.

Important guidelines to be followed while constructing rearing house:

1. The rearing house should be constructed in an elevated place to avoid water logging.
2. Shed direction: Walls should be east to west and windows direction should be north to south to facilitate ventilation.
3. Raise shade plants around the rearing house.
4. Room should have good ventilation. The floor should be plastered with cement.
5. Walls should be constructed with bricks to ensure cool ambience at a height of 10 feet.
6. The roof should be made of cement or tiles. The windows and doors should be wire meshed to prevent the entry of uzifly.
7. The room should be surrounded with a drainage trench to prevent rats. Room should be equipped with coolers and heaters.

Model of a silkworm rearing house:



For a capacity of 200 to 250 dfls (Disease free layings) the features required can be provided in a 30' x 20' house with the following facilities.

1. Ante – room
2. Open Verandah
3. Leaf room
4. Rearing hall & working space
5. Leaf inlet
6. Litter outlet
7. Two-step roofing
8. Exhaust
9. Air inlet
10. Wire mesh protected windows
11. False roof

Equipment for silkworm rearing

1. Rearing stands: These are made of wood or bamboo, portable and are 2.5 m high, 1.5 m long and 1 m wide with 10 shelves with a space of 20 cm between each shelf. The rearing trays are arranged in the shelves.

In whole shoot feeding method, rearing stand width should be 5 -5.5 ft. with One ft above the ground level and with –2 ft distance between rearing stand & wall

2. Ant wells: These are provided around the legs of stands to stop ants crawling on to the trays and attacking the worms. These are made up of concrete stone base 20 cm^2 and 7.5 cm high with groove of 2.5 cm depth to hold water. The legs of the stands rest in the center of the block.

3. Rearing trays: These are used to rear silkworms and are made of bamboo. They are round (1.2 to 1.4 m dia) or rectangular (0.9 to 1.2 m x 0.7 to 0.9 m) with a depth of 7.5 cm.

4. Rectangular wooden trays or boxes: These are used for rearing early age larvae, made of light wood, size being 0.9 m x 0.7 m with a depth of 7.5 to 15 cm. About 8 boxes are required for 100 dfls (DFL- disease free layings)

5. Paraffin paper: It is a thick craft paper coated with paraffin. It is used for rearing early age worms, on the bottom and as a cover of the rearing bed to prevent withering of chopped leaves and to maintain humidity in the rearing bed.

6. Foam rubber strips: Long foam rubber strips of 2.5 cm wide and 2.5 cm thick dipped in water are used to keep all around silkworm rearing bed during first two instars to maintain humidity.

7. Chop sticks: These are made of bamboo, 17.5 - 20.0 cm long and thin and tapering to one end. A pair of chop sticks are used to pick early age larvae and also for preparing the bed.

8. Feathers: Bird feathers, preferably white ones are used for brushing the delicate newly hatched worms onto the rearing bed.

9. Chopping board: It is made of soft wood and used for cutting the mulberry leaf to suitable sizes and the size is 0.9 m x 0.9 m and 5 cm thick.

10. Chopping knives: These are used for cutting the mulberry leaves and are 0.3 to 0.5 m long with a broad knife blade and wooden handle.

11. Mats: Mats of 1.8 x 1.2 m are used for collecting the leaves when chopping is done on floor to prevent the dust and dirt on the floor getting mixed with the leaves.

12. Leaf chambers: These are maintained in rearing house for storing the harvested mulberry leaf ready for feeding the worms at set intervals.

13. Cleaning nets: These are made of cotton or nylon of different mesh sizes to suit the stage of the larvae. These are used for cleaning the rearing beds and at least two nets are required for each rearing tray.

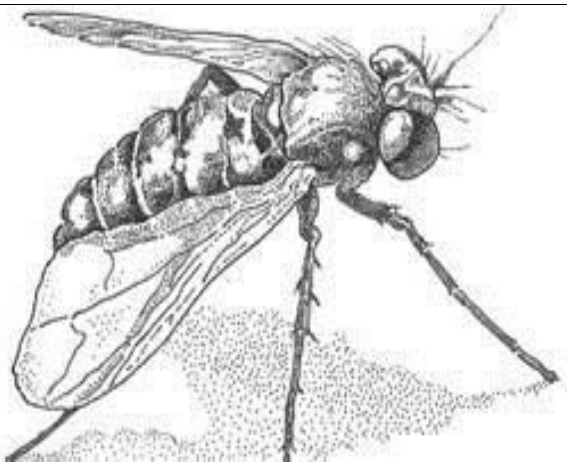
14. Mountages: These are used as supports for the silkworms to spin cocoons and are made of bamboo, usually 1.8 x 1.2 m. Over a mat base tapes of 5-6 cm wide woven out of bamboo are fixed in the form of spirals with a gap of 5-6 cm in between (Chandrika).

Other equipment includes thermometers, hygrometers, feeding stands, feeding basins, sprayers, leaf baskets etc.

Disinfection and hygiene:

The rearing house as well as the appliances used in rearing should be disinfected with 2 per cent formalin prior to commencement of every silkworm rearing.

For effective disinfection, the rearing house should be made air tight as far as possible and with the rearing appliances kept inside, the walls, windows, doors and the appliances should be sprayed with 2% formalin @ 7-8 litres for 100 m^2 and the doors closed immediately. After 24 hours of disinfection the doors and windows should be opened and the rearing house should be completely aerated at least 24 hours before the commencement of brushing.

	
Rearing stand	Brushing of hatched larvae
	
Chandrika	Uzifly

Lecture - 26

CHAWKI / YOUNG AGE AND LATE AGE SILKWORM REARING

Incubation: To ensure uniform hatching of the eggs, they are incubated at optimum temperature of 24-26^{0}C and relative humidity of 70-80%.

Black Boxing: Eggs incubated under optimum conditions reach pin head or head pigmentation stage by 7/8th day i.e. 48 hrs before hatching. A day later i.e 24 hr before hatching eggs turn bluish / brownish called as blue egg or body pigmentation stage. All eggs are kept in darkness at pin head stage which is called black boxing of eggs. Darkness arrests the hatching of the fully developed eggs but facilitates the lagging embryos to develop faster. Eggs after black boxing can be stimulated to hatch by exposing them to sunlight stimulus.

Brushing: Brushing is the process of separating newly hatched larvae gently and carefully from empty egg shells or egg sheets and transferring them to the rearing sheets. After black boxing and exposure to light, good hatching is obtained between 9 a.m. to 10 a.m. which is ideal time for brushing also. Bird feather or fine camel hair brush is used for brushing.

Chawki / young age silkworm rearing: Rearing of I, II and III instars is called chawki rearing or young age rearing.

Young age worms are more resistant to high temperature and humidity and grow healthier in such conditions. Young age worms require tender and succulent mulberry leaves. The larvae grow 400 times in body weight, 300 times in body size and 500 times in silk gland weight during chawki rearing.

Environmental conditions: Young age worms require tender and succulent mulberry leaves and a set of environmental conditions. The ecological factors, chiefly temperature, humidity, light and air have significant influence on growth of larvae and cocoon quality. The standard temperature and humidity recommended are as follows.

Instar	Temperature (^{O}C)	(%)Relative Humidity
I	26 – 28	85 – 90
II	26 – 28	85 – 90
III	24 – 26	80 – 85

Temperature influences body physiology, enzymatic reactions and biochemical exchange of nutrients. If temperature is more than $30^{O}C$, it has an impact on health of larva and it is less than $20^{O}C$, the larval growth retards and larvae become susceptible to diseases. In order to alter temperature aberrations, electric heaters or coolers may be used in rearing house. The house should be well ventilated.

High humidity makes the larvae susceptible to diseases, where as low humidity results in quick drying of leaves. Humidity is maintained by using paraffin papers as cover for the rearing bed and wet foam pads.

Silkworms are fond of dim light. It influences distribution of larvae in rearing bed. The worms are more crowded in dark and distributed in several layers. Photoperiod during early instars influences the type of eggs produced (hibernating / non-hibernating). A photoperiod of 16 hours light and 8 hours dark is ideal for young age rearing.

The composition of air and its circulation in rearing room are important for silkworm rearing. In rearing room, the air is polluted by CO_2, formaldehyde gas, ammonia (from silkworm excreta) and sulphur dioxide. The safe limit for silkworm rearing is 1 to 2% CO_2, 1% formaldehyde, 0.1% ammonia and 0.02% sulphur dioxide.

Mulberry leaf

Mulberry leaves for chawki rearing must be soft and rich in water content, protein, carbohydrates etc. For chawki rearing, the largest glossy leaf method is adopted to pluck the correct leaves. The largest glossy leaf is the one, light green and glossy, being the largest among the first few leaves. From glossy leaf to 5 or 6 leaves below for I instar, another 4 or 5 leaves for II instar and further down upto all tender leaves for III instar are used in young age rearing.

Feeding:

About 600, 800 and 1000 kgs of leaf are required to rear 100 dfls (40,000 larvae) of old cross, improved cross and bivoltine hybrids from brushing to spinning, respectively. Out of this 0.33%, 1% and 5% are utilized in I, II & III instars, respectively. Cut leaf method is found good during young age. The standard method is to give 4 feeds (6.00 AM, 11.00 AM, 4.00 PM and 10 PM) per day at equal intervals as far as possible. Amount and size of leaf required in chawki rearing are:

Instar	Leaf quantity (Kg/100 dfls)		Leaf size in Cm^2		
	Univoltine	**Bivoltine**	**To start**	**Peak eating**	**Preparation for wit age moult**
I	1-2	1-2	0.5	2.0	1.0
II	5-6	2-3	2.0	4.0	1.5
II	20-55	15-20	4.0	Full leaf cut into 4 pieces	2.0
Total	**26-63**	**18-25**			

Bed area:

To attain full larval growth, maximum survival and successful cocoon formation, maintenance of optimum bed area is important. Rearing bed area has to be increased daily to match the growth of silkworms.

The space requirement for larvae during chawki rearing is given below.

Instar	Uni/Bivoltine (mm^2 per larva)		Multivoltine(mm^2 per larva)	
	Beginning	End	Beginning	End
I	0.2	0.8	0.2	0.5
II	1.0	2.0	0.5	1.5
III	2.0	4.5	1.5	3.0

Bed cleaning:

Leftover leaf and litter accumulate in rearing bed leads to increase in humidity and temperature and multiplication of various pathogens. Hence, regular cleaning of bed is necessary. Since the young age worms are delicate, cotton / nylon nets are used for bed cleaning. The cleaning net is applied on the bed one feed before cleaning and the feed is given above the net. The worms crawl through the meshes and come up to feed on the leaves on the net. At the next feed the net along with the worms above is transferred to another tray and fresh feed is given. The faeces and left over feed are collected and put in manure pit. Cleaning is done once in I instar prior to I moult (on 3rd

day), twice during II instar and thrice during III instar. The mesh size of nets used for I & II instars is 2 mm^2 and for III instar it is 10 mm^2.

Handling of silk worm during moult:

During moulting the rearing bed should be thin and dry. Silkworms stop eating just prior to moult. The rearing bed is then thinned out for drying and a layer of lime powder is sprinkled. Comparatively low humidity (70% RH) is desirable during moulting. Worms in moult should not be disturbed and there should be good ventilation.

Late age / old age larval rearing : The IV and V instar silkworms are called late age worms. Late age worms require slightly lower temperature and humidity. During this period the silkworm body increases in size by 29 times, in weight by 25 times, and silk gland weight by 200 times.

Environmental conditions: The ideal standard rearing temperature and humidity during late age rearing are as follows:

Instar	Temperature (^{O}C)	Relative Humidity(%)
IV	24 – 25	75
V	23 – 24	70

Above $30^{0}C$, the temperature affects survival and pupation rate. Comparatively low humidity is preferable during moulting. Rearing rooms should have good ventilation to reduce the CO and CO_2 developed in the room. It is essential to ventilate the rearing rooms from III instar by removing paraffin paper cover at least for one hour before each fresh feed.CO_2 exceeding 1% in a rearing room is bad for silkworms. Silkworms are fond of dim light hence, avoid strong light or darkness. A photoperiod of 16 hours light and 8 hours dark are desirable during late age rearing also.

Feeding: Too tender and too mature leaves are not fit for feeding in late age. Care must be taken during leaf harvest to avoid over mature and yellowing leaves. Clipping off the terminal buds in row system, a week prior to the shoot harvest is desirable for IV and V instars. Quantitative requirement in late age forms the bulk (93.67%) of the total larval feed.

The feed requirement for 100 dfls is as follows:

Instar	Uni/Bivoltine (Leaf quantity in Kg)	Multivoltine (Leaf quantity in Kg)
IV	80-90	35-50
V	450 - 475	335 - 325
Total	530 - 565	335 - 375
Grand total from I to V instars	550 – 600	350 – 400

Leaf harvest is done by individual leaf plucking or shoots harvest. In leaf plucking, whole leaf is fed without cutting. In case of shoot harvest it is cut into convenient length to accommodate in rearing trays. Four feeds/day is the practice in late age rearing which can be reduced in rainy season or increased in summer, without changing the total quantum of feed. The feeding time usually is around 5.00 am, 11.00 am 4 pm and 10.00 pm.

Bed spacing

The successes of silkworm crop and cocoon quality also depend on spacing. Over crowded rearing leads to insufficient consumption of feed, poor growth, susceptibility to diseases and low cocoon yield of inferior quality. The spacing should be increased daily in proportion to the growth of silkworms. The rearing bed spacing recommended for IV and V instars is as follows.

Instar	Uni/Bivoltine (mm^2 per larva)		Multivoltine (mm^2 per larva)	
	Beginning	End	Beginning	End
IV	5	10	3	9
V	10	20	9	18

Bed cleaning

During IV and V instars bed cleaning is done every day with nylon or cotton nets of appropriate mesh size (20 mm or 2 cm X 2 cm). The net is fixed over the rearing tray one feed prior to cleaning and feed is given above the net. Before next feed the net along with worms and leaves is transferred to another tray. The faeces and left over leaf

are collected and put into manure pit. Paddy husk or charred husk is also used for bed cleaning in late age rearing. They are spread in a thin layer over the bed prior to feeding. The worms crawl through this layer and start feeding on fresh leaves. The worms and the leaves are removed to a fresh tray and the litter and old leaves are put in a manure pit.

Methods of rearing late age worms

1. Shelf rearing: Rearing of silkworms in rearing trays arranged one over the other in tiers on rearing stands is called shelf rearing.

2. Floor rearing: Rearing silkworms on fixed rearing seats arranged in two or three tiers is called floor rearing.

3.Shoot rearing: It is similar to floor rearing. Silkworms are reared on big branches in one or two tiers.

Care during moulting: The fourth moult takes nearly 30 hours under optimum conditions of temperature (24^0C) and humidity (60-70%). Feed should not be given and the worms should not be disturbed during moulting.

Lecture - 27

PESTS OF SILKWORM AND THEIR MANAGEMENT

Insect pests of mulberry silkworm are parasitoids and predators.

Indian Uzi fly, *Exorista bombycis*:

It has been causing 15-30% loss of cocoon crop. The uzi fly completes 2 generations within the host larval period. It prefers III, IV and early V instar larvae for oviposition.

Life cycle: The female fly appears like housefly but bigger in size. It lays 300-1000 creamy white eggs singly mostly on inter segmental regions. The young one (maggot) bore into the body of the silkworm. The maggots have 3 instars. The mature maggot pierces the integument and pupates outside on the floor. Total life cycle completes within 30-35 days.

Symptoms : Black spots can be observed on the inter segmental surface of larvae from where the maggots enter into the body of the silk worm. White creamy oval shaped eggs can also be observed on the skin of infested larva. Maggots can be seen on chandrikas, rearing house, cocoon storage places etc.

Management:

a) Use of nylon net (40-70 mesh) to prevent entry of uzi fly into rearing house.
b) Dusting with levigated china clay with a muslin cloth @ 3g/100 larvae before mounting and 4 grams /sq. ft on bamboo mountages to prevent uzi fly attack during spinning.
c) Collection and destruction of uzi fly affected silkworm larvae and cocoons.
d) Destruction of uzi fly maggots and pupae collected from rearing trays, mountages, cracks and crevices in the floor of rearing house.
e) Application of diflubenzuron (Dimilin 25 WP) mixed with levigated China clay as diluent (1:9) on third instar maggots.

PREDATORS:

1) **Dermestid beetles** : *Dermestes cadaverinus*

The stored cocoons after stifling (killing of pupa within the cocoon is called stifling) are mostly infested by the grubs of dermestid beetles. They make hole and feed on the pupae inside. The infested cocoons are not suitable for spinning.

Management: Cleaning of rearing house and cocoon store room. Do not store rejected cocoons and perished eggs for long time. Fumigate the dried cocoon storage rooms with Methyl bromide @ 0.5 kg/283 m^2 for a day or with chloropicrin @ 0.5 kg/283 m^2 for 3 days.

2. **Mites**, *Pediculoides ventricosus* :

The female mites attack silkworm larvae, pupae and adults causing death. The body surface of silkworms develops black specks. The infested ones become inactive and have difficulty in excreting and the excreta are attached bead like to the anus. If severely infested, the worms vomit yellowish green fluid.

Management: Avoid the storage of wheat/rice straw near rearing house. Treat the building and thatched materials with acaricide or fumigant before use.

3.) **Ants**: They attack silkworms in rearing trays. They can be prevented by placing ant wells with water below the rearing shelves.

Lecture -28
SILK WORM DISEASES

Diseases of mulberry silkworm: The silkworm *Bombyx mori* is prone to the attack of a number of diseases. Among the diseases pebrine, grasserie, flacherie and muscardine are important.

The predisposing factors for diseases in silkworms:

1. Continuous rearing of silkworms throughout the year makes the microbes active
2. Most of the sericultural operations and rearing are done in domestic areas and hence proper disinfestation is not taken up
3. Rearing of silkworms under unhygienic conditions

1. Pebrine : It is caused by a protozoan, *Nosema bombycis*.

Pebrine disease is also known as pepper disease or corpuscle disease.

De Quatrifuges (1860) gave the popular name pebrine to this disease because of the characteristic infection and appearance of dark pepper like spots on the body of the infected silkworm larvae. Pasteur (1885) observed that the disease is transmitted through the egg in three ways i.e.

a) By contact with the diseased silkworms.
b) By ingestion of contaminated food.
c) By transovarial transmission

The life cycle of *N. bombycis* is completed in 7 days after infection in a cold climate and in about 4 days in hot weather.

Symptoms of infection:

Egg stage:

a) Few number of eggs on egg cards
b) Overlapping of eggs one over the other, instead of closely side by side
c) Easy to detach eggs from egg card due to lack of adhesiveness.
d) Poor/less egg hatching.

Larval Stage:

a) No external symptoms in early stages of disease

b) With advance in disease, larvae become sluggish and dull.

c) Poor appetite, retarded growth resulting in irregular moulting.

d) Unequal sized larvae in the rearing bed.

e) Appearance of irregular dark brown spots or black spots on the body of larvae.

f) Hanging down of the head.

g) Infected larvae may die before spinning or it may spin only a poor and flimsy cocoon.

h) Affected larvae lack lustre and in later instars turn rusty brown.

Pupal stage:

a) The abdominal area is soft, swollen and dark in colour.

b) Black spots present on sides of the abdomen.

c) Pupa loses its lustre and become dull in its movements.

Adult Stage:

a) Discolouration of scales on abdominal area

b) Black spots may be seen on abdomen

c) Deformed wings

d) Distorted antennae and low fecundity

Prevention and control:

a) Production and supply of disease free layings (dfls) through mother moth examination.

b) Surface sterilization of disease free layings by dipping the egg cards in 2% formalin for few minutes and then washing in running water.

c) Destruction of diseased material.

d) Disinfection of rearing rooms and appliances.

Mother moth examination for identifying and destroying the pathogen is an essential programme in a grainage (Grainage is the place where silk worm eggs are produced). There are 3 methods of moth examination viz., Individual moth examination, Sample testing and Mass examination of moths.

Individual moth examination: The individual moth is crushed in a moth crushing set and tested for the pebrine spores. Spores are visible as shining oval bodies. A moth examiner can examine about 200 smears in a day of 8 hours.

Sample testing: In this method, about 20% of emerged moths picked at random are examined. This is generally followed in India.

Mass examination of moths:. Each sample consisting of 30 moths are kept in perforated paper covers after marking the date, lot number, sample number etc. They are stored in hot air oven and dried at 70^0C $\pm5^0$ c for 6 hrs. After 6 hrs of drying, the temperature in the oven is maintained at 30^0C to avoid accumulation of humidity and putrification. These batches are examined next day. This method of examination can be practiced for both live and dry moth examination. Dry moth examination is more effective in pebrine detection than live moth examination.

2. **Grasserie** (Jaundice, Hanging disease): It is caused by **borrelina** virus**.** The viral bodies engulfed along with food will get dissolved in midgut and virions infect the midgut cells. Later, the virus particles enter haemocoel and invade other parts and virus multiplication occurs inside the nucleus of the target cells. Fourth and fifth instar larvae are more susceptible.

Symptoms: Larvae become sluggish and lose appetite, Swelling of inter segmental region, Skin becomes fragile without elasticity, larvae become restless. The diseased larvae lose the holding power of legs except the last pair with which they hang head downwards (Tree top disease)

Predisposing factors:

a) High temperature, high humidity and their fluctuation in rearing room.
b) Excess moisture in leaf and rearing bed
c) Insufficient ventilation
d) Overcrowding during rearing.

Prevention and control:

1. Strictly avoid the predisposing factors.
2. Surface sterilization of eggs with 2% formalin.
3. Dusting of FBL mixture (Formaldehyde + Benzoic acid + Lime) in 2:1:97 ratio on larvae in the rearing rooms
4.Use of bed disinfectants like dusting resham keet oushad (RKO) @ 2-2.5 g/sq.ft during chawki rearing and @ 3.5-4.5 g/sq.ft during late age rearing once after each moult.

3. Cytoplasmic polyhedrosis virus (CPV) : It is caused by **smithia virus.** Virus invades the posterior part of midgut epithelium. Polyhedra are formed in the cytoplasm showing characteristic chalky white appearance of the whole midgut. Due to increased pressure, the cell walls break and numerous polyhedra are released in to the lumen of midgut which pass through excreta and further contaminate the mulberry leaves in bed.

Symptoms: Early instar larvae more susceptible. Loss of appetite. Retarded growth and development followed by vomiting gastric juice and diarrhea.

Prevention and control :

1. Thorough disinfection of rearing room and equipment
2. Rearing under hygienic conditions and feeding good quality mulberry leaves

4) Infectious Flacherie:· Caused by mortar virus. It invades the goblet cells of anterior midgut epithelium and multiplies in cytoplasm.

Symptoms : Stunted larval growth. Translucent cephalothorax and shrinkage of body. Flaccidity of the body. Frequent evacuation of semisolid and whitish faecal matter. Soiling of anal region. Excreta in the form of chain with beads. Rectal protrusion of whitish mid gut.

Prevention and control:

1. Disinfection of beds with RKO
2. Disinfection of rearing room and appliances with 2-4 per cent formalin
3. Destruction of infected larvae, faecal matter and bed refuse by burning

5) Bacterial diseases : These are referred to as **Flacherie**

a) Bacterial toxicosis: Also called as **sotto** disease caused by *Bacillus thuringiensis* whose spores produce toxic substances and affect nervous system leading to paralysis.

b) **Septicemia** – Caused by Sreptococci and Staphylocci

Symptoms:

a) Larvae become sluggish, b) Poor appetite, c) Retarded growth, d) Body shrinkage, e) Vomiting of gut juices, f) Excretion in the form of beads/chains, g) Body of dead larva turns black and emit a foul smell

Prevention and control:

a) Maintenance of hygienic condition in rearing room

c) Avoid fluctuation of temperature and humidity

6) Fungal diseases: White muscardine – *Beauveria bassiana*

Infection occurs through skin

Symptoms:

a) Presence of oily specks on body b) Infected larvae lose appetite and become sluggish

c) After death, larvae become mummified and gets hardened d) Body covered with white powdery conidia

Prevention and control:

1) Disinfection of room/equipment with 2% formalin / 5% bleaching powder

2) Reduce humidity in bed with lime powder

3) Application of formalin chaff @ 0.4, against I and II instars and 0.5, 0.6 and 0.8%, against III, IV and V instars, respectively.

Lecture- 29

SPECIES OF HONEYBEE

Apiculture : The science and art of rearing honey bees.

Apiary : A bee yard where colonies, hives and other equipment are assembled in one location for bee keeping.

The honey bees belongs to Order : Hymenoptera; Family : Apidae. ;

Important honey bee Species : a) *Apis.dorsata b)Apis . florae c) Apis .cerana .indica*

d) Apis .mellifera. First two are wild while remaining two are domesticated.and suitable for rearing in bee hives. In addition to the above, Dammar bee, *Trigona iridiepennis,* also produces honey and it is stingless.

Important Honey bee species with characters:

Little bee (*Apis florea*):

- They build single vertical combs
- They also construct comb in open of the size of palm in branches of bushes, hedges, buildings, caves, empty cases etc
- They produce about half a kilo of honey per year per hive
- They are not rearable as they frequently change their place
- The size of the bees is smallest among four *Apis* species described and smaller than Indian bee
- They distribute only in plains and not in hills above 450 MSL

Rock bee *(Apis dorsata)*

- They are giant bees found all over India in sub mountainous regions up to an altitude of 2700 m.
- They construct single comb in open about 6 feet long and 3 feet deep
- They shift the place of the colony often
- Rock bees are ferocious and difficult to rear.
- They produce about 36 Kg honey per comb per year. These bees are the largest among the bees described

Indian honeybee *Apis cerana indica*

- Indian bees are larger than little bee, smaller than European bee species found in plains and hills
- Indigenous and commercially exploited bee species
- In the wild, honeybees construct a series of parallel comb nests in dark enclosures like caves, rock cavities and hollow tree trunks. The normal nesting site is, close to the ground, not more than 4-5 meters high.
- Species is prone to heavy swarming , absconding, robbing and developing large number of laying workers
- Poor propolizers and more prone to wax moth
- Gentle in temperament and responds to smoking
- Stings when irritated
- Species is prone to heavy swarming and absconding
- Honey yield is usually 6- 8 kg per colony per year

European bee / Italian bee (*Apis mellifera*)

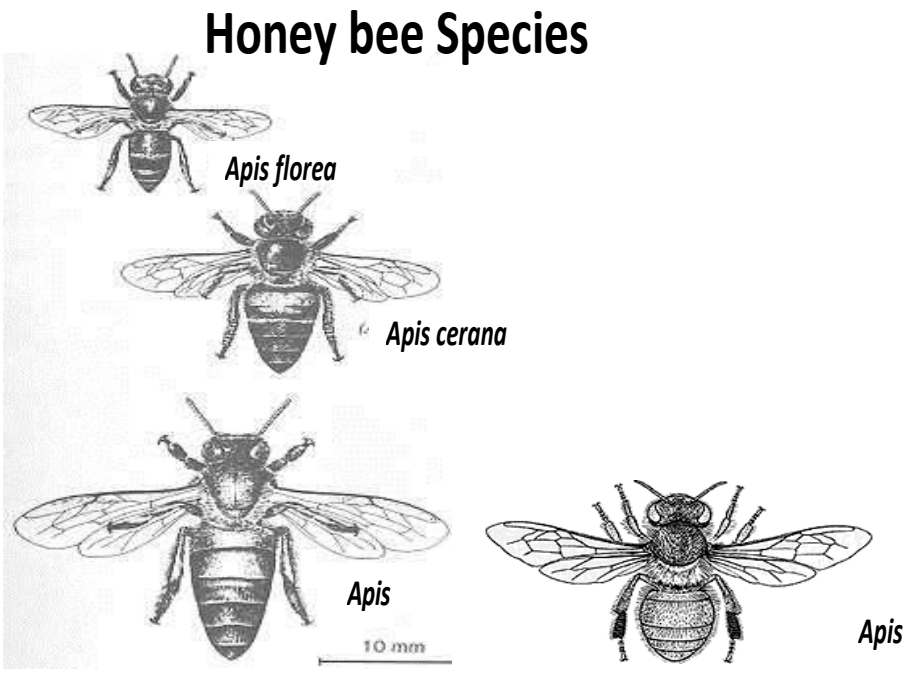
- They are also similar in habits to Indian bees, which build parallel combs
- They are bigger than all other honeybees except *Apis dorsata*
- The average production per colony is 25-40 kg. They have been imported from European countries (Italy)
- They are less prone to swarming and absconding
- More propolizers and less prone to wax moth

Dammer bees *Trigona iridiepennis*

Melipona iridipennis

- Small non *Apis* species of honey bee with a length 3mm found in plain areas
- Bees makes nests by construction of sac like comb in the ground , in hollows of trees bamboos , rocks or cracks of walls

- Comb cells are made of cerumen (wax , clay and propolis) with a maximum size of a grape
- Sting less bees as sting is poorly developed and defends colony by biting
- Poor gatherer of honey, gives 60 to 180 ml of honey in a year and difficult to extract



Castes of Honeybees

Differences between Honey bee castes :

S.No	Character	Queen	Worker	Drone
1	Number of bees per colony	One only	30,000 – 70,000	300 - 400
2	Sex	Perfect female	Sterile female	Perfect male
3	Size	Largest	Medium	Larger than worker
4.	Compound eyes	Dichoptic eyes	Dichoptic eyes	Holoptic eyes
5.	Thorax	Broad	Short	Broad
6	Wings	Do not cover full abdomen	Cover full abdomen	Cover full abdomen
7	Distal end of Abdomen	Elongated and pointed	Pointed	Blunt
8	Sting	Curved sting	Toothed	Absent
9	Pollen baskets	Absent	Present	Absent
10	Wax glands	Absent	Present on ventral side of 4,5,6 and 7 abdominal segments	Absent
11	Antennal cleaning structures	Present	Present	Present
12	Wax picks	Absent	Present	Absent
13	Supply of Food	Dependent upon workers	Not dependent on other castes	Dependent upon workers
14	Food of grubs	Royaljelly	Mainly bee bread	Mainly bee bread
15	Cell	Largest, oval in shape and usually on lower part of comb	Hexagonal, small with flat caps	Hexagonal , Larger than worker cell with convex cell caps
16	Number of cells per square inch of comb	One or two but not always	39	36
17	Mandibular glands	Very large	Large	Small
18.	Pharyngeal glands	Vestigial	Present	Absent
19.	Development period (Egg to adult emergence)	16 Days (3+5+8)	21 Days (3+5+13)	24 Days (3+7+14)
20	Adult life span	3- 5 years	6 weeks	Normally 8 weeks but mated drone dies
21	Egg laying	500 -800 eggs / day (*Apis cerana indica)* or 2000 eggs/day (*Apis mellifera).*	Queenless colony workers lays unfertilized eggs	-
22	Function	Egg laying and inhibits the development of ovaries of workers	First 3 weeks home work and next 3 weeks field work	Mating with queen (a few get chance to mate) and helps in maintenance of hive temperature.

Bee hives, Equipment for handling Honey bees

The successful use of movable frames and the discovery of bee space revolutionized the way of keeping bees. In 1851, Rev. L. L. Langstroth improved the earlier type of hive based on his discovery of “Bee Space”. Bee space (Passage way) is the space required between any two frames for the bees to move about between the combs. Bee space is different for different species. Langstroth hive and Newton’s hive are generally used for beekeeping with *A. mellifera* and *A. cerana indica,* respectively.

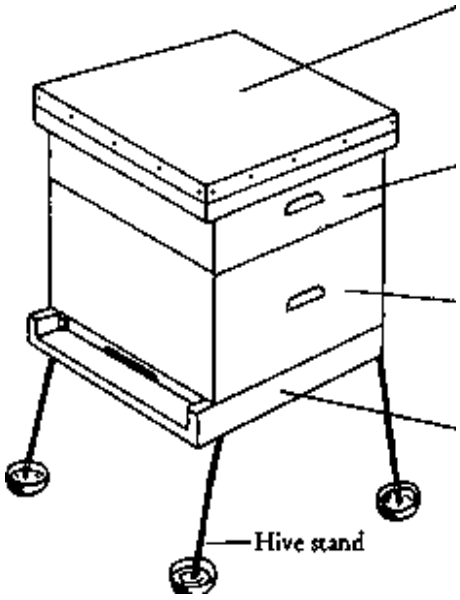
Beehive: It is a tool/equipment used in bee keeping. It consists of a bottom board, brood chamber, brood frame, super chamber, super frame, inner cover and top cover.

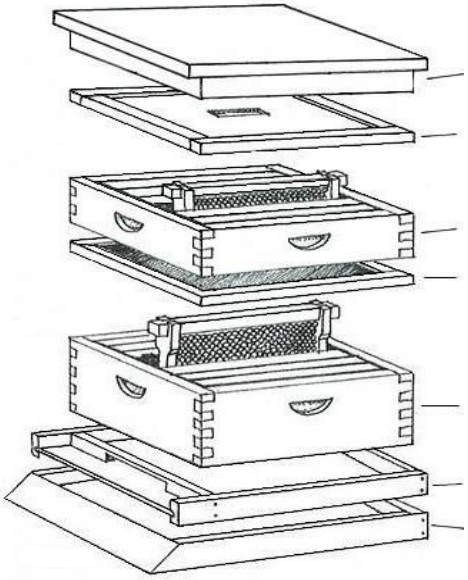
Bee Keeping Equipment for handling honey bees:

Beehive stand	This is made of RCC or wood or iron with provision for water cups to prevent ants from entering beehive. Bee hive is kept on the beehive stand.
Smoker	This is made of a tin or copper container attached with a leather bellow. This is used to smoke bees to subdue them while handling.
Hive tool	It is made of a thick iron plate to clean the hive, to handle the frames and to remove propolis etc.
Bee veil	This is made up of mosquito net type material for being worn to protect the face from being stung by bees while handling.
Gloves	These are used to protect hands from bee sting while handling.
Honey extractor	This is made out of tinned copper, brass or zinc drum with basket cages to hold frames and wheel to rotate them in order to extract honey by centrifugal force generated in it.
Queen gate	This is made out of zinc sheet with perforations to prevent queen from going out or from deserting hive
Queen excluder	This is made out of zinc sheet with perforations and is placed between brood chamber and super chamber to prevent the movement of queen bee from brood chamber to super chamber.
Drone excluder	This is used to prevent the reentry of drones into the hive after the bees have come out of the hive in evening.
Drone trap	It is useful for fixing in front of the hive entrance when workers and drones come out for play flight. Workers can easily go out through the groove at the bottom, but drones are trapped. Drones, thus trapped

	can be removed and killed, when they are no longer required in the hive.
Comb foundation Sheet	This is made of pure wax. It is used to aid the bees to construct straight parallel combs.
Dummy division board	This is useful to reduce the inner area of the broad chamber so that the bees can be confined to a limited space when bee population in the hive is low.
Swarm trap	During swarming season, when bees construct queen cells, the box is kept on the alighting board with open side close to the hive and tightly secured. One or two frames with comb foundation sheets are kept inside the box. When the swarm is issued in a few days, the queen is trapped in the box and settles in the comb foundation sheet with a few workers. Thus the swarm is induced to settle in the frame and it can then be transferred to any hive at a desired place.
Bee brush	It is used to brush off bees from honey comb before it is taken away for extraction.
Feeders	These are used to feed sugar syrup to bees. The division board feeder is commonly used. It is a wooden trough of regular frame dimensions of the hive to hang in the hive just like any other frame with a wooden strip to serve as a float
Queen cages	Several types of queen cages are available for caging the queens
Queen cell protector	A queen cell which may have to be introduced from a queen-right to a queen less colony is protected with a queen cell protector until its acceptance by the bees

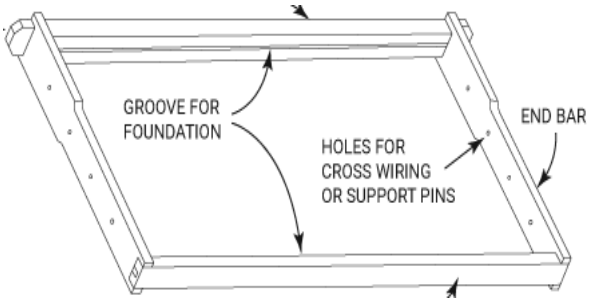
Bee Hive box



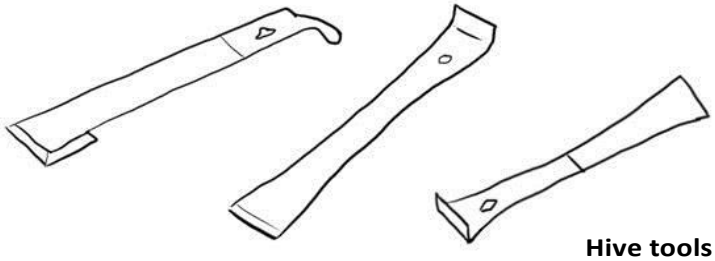


Parts of beehive box

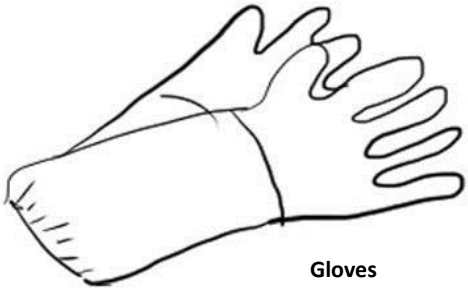
Queen excluder



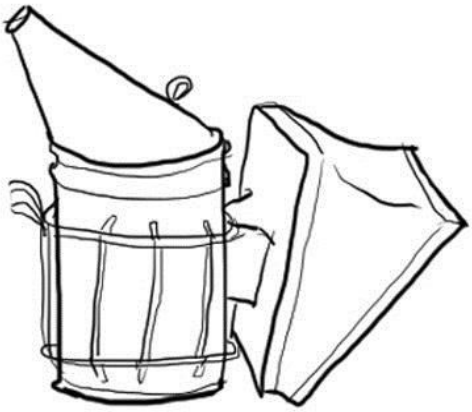
Brood frame



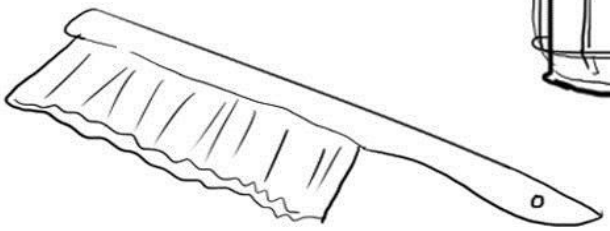
Hive tools



Gloves



Smoker



Bee brush

Honey Extractor

Bee pasturage:

Honey bees have close link with flora because they live solely on nectar and pollen. To maximize the honey production, bee keeper should have a thorough knowledge of floral calender, on set of major honey flow and dearth periods. Plants that yield pollen and nectar are collectively called bee pasturage

1.The plants which are visited by bees only for nectar are:

Tamarind, (rich source), Neem, Soap nut, *Eucalyptus* spp., Pongamia, *Morinda tinctoria*, *Prosopis spicigera, Quisqualis indica, Legasca mollis, Tribulus terrestris, Glyricidia maculata.*

2.Plants which supply pollen to the bees are:

Sorghum (rich source), maize, roses, bajra, finger millet, pomegranate, sweet potato, tobacco, castor, tea etc.

3.Plants which supply both nectar and pollen are:

Banana, citrus, apple, pear, plum, peach, guava, mango, coconut, sesamum, safflower, mustard, cruciferous and cucurbitaceous vegetables, bhendi, onion, Lucern, clover, hollyhock, aster, Cassia fistula, cotton (very rich source).

Honey extraction and processing:

When the honey flow begins to slow down, the frames with honey should be removed for extraction. To take out honey comb from hive , the colony is smoked, the desired combs taken out and bees brushed off with a soft brush or leaves. These combs are placed in tight hive bodies, carried to the extraction room. A room with wire gauged bee tight doors is necessary for honey extraction. Frames should be uncapped with a hot knife. The uncapped frames should be placed in extractor and rotated slowly and then at a faster speed. Then the frames are reversed and extraction is again worked. Finally, honey collected in the container is strained and packed in tins or bottles. After the extraction, the place should be swabbed with water and the appliances cleaned. The empty wet combs should be reused in the hive.

Lecture - 30

PESTS AND DISEASES OF HONEYBEES

Pests:

A) Greater wax moth, *Galleria mellonella;*

The greater wax moth, *Galleria mellonella* is a serious pest of honeybee colonies in India. It infests combs of all honeybee species throughout the world.

The wax moth larvae burrow into the comb by producing silken tunnels along with their excreta. They feed on the propolis, pollen and beeswax in the combs. During severe infestation, the combs are seen covered with silken web with numerous black faecal particles by destroying the combs. The grownup larva spins a dense silken cocoon, which are usually attached firmly to the hive parts.

Management:

a) Maintain the colonies strong to resist wax moth; b) Keep the hives without cracks and crevices; c) Reduce hive entrance size for effective guarding by bees; d) Keep the bottom board neat and clean without debris, e) Hold the comb against sun rays to observe the larvae f. The braconid wasp, *Apanteles galleriae* and the parasitic wasps, *Trichogramma* spp parasitize on the larval and egg stages of wax moth g) Extra combs stored should be fumigated with Ethylene dibromide or carbon di sulphide

B) Lesser wax moth, *Achroia grisella.* The caterpillars feed mainly on the debris of the combs.These wax moths at times decap the sealed cells exposing the pupae inside and this diseased condition is referred to as bald brood.

C) Mite pests

a) ***Acarapsis woodi***: **(**Acarine or Isle of Wight disease.**):** Endoparasitic mite of adult bees. It infests the trachea of first thoracic spiracle where they suck haemolymph.

Symptoms: I. Presence of bee crawlers at hive entrance; II. Bees are unable to fly and wings are disjointed in K winged condition; III. Infested bees are short lived

b) ***Varroa jacobsoni*****:** Varroa infested bee colonies become weak and show a spotty brood pattern with punctured cappina. The mites pierce the soft intersegmental

tissues of the abdomen and feed on the haemolymph. The bees become stunted with deformed legs and wings

Management: Mites can be controlled by dusting with sulphur @ 1 gr/ frame of the comb.

C) **Black ant**, *Componotus compressus* Fab. They carry adult bees as well as brood.

D) **Bee hunter wasps**, *Palaras orientalis* Kohl. *Philanthus ramakrishnae*

E) Birds: Black bee eater, *Dicrurus macrocercus; Dicrurus ater*

Green Bee eater, *Merops orientalis, Merops superciliosus*

They feed on honey bees at the entry point of bee hive or when they are at flight.

Diseases:

I) BROOD DISEASES:

Honey bee brood suffers from a variety of diseases. Adult bees are not affected by brood diseases, but they can spread the causal organism. Brood diseases are more serious than adult diseases.

A) Bacterial diseases:

i) American foul brood (*Bacillus* larvae); ii) European foul broad (*Melissococcus* plutonious)

B) Viral diseases:

a) Thaic sac brood b) Sac brood

C)Fungal diseases:

a) Chalk brood (*Ascophera apis*) b) Stone brood (*Asperigillus flavous*)

Symptoms of brood diseases:

Symptoms	**American foul brood**	**European foul brood**
General appearance of brood comb	Brood irregular. Much dead brood in capped cells, cells with punctured cappings and cells uncapped by bees.	Brood irregular Dead brood mostly in open cells
Time of death	Late larval/early pupal stage	Young larvae and rarely late larval
Cell capping	Cappings sunken and usually have holes	Some cappings perforated

Colour of dead brood	Dull white to dark brown or almost black	Dull white to yellowish white, often dark brown
Odour of dead brood	Putrid faint	Strong and sour
Brood affected	Worker, rarely drone or queen	Worker, drone and queen
Control	Tetramycin 0.25-0.40 g in 5 lit sugar syrup fed to infected colonies. Repeat after 7-10 days	Tetramycin 0.25-0.40 g in 5 lit sugar syrup fed to infected colonies. Repeat after 7-10 days

Thai sac brood disease :

The virus multiples in adults which transmits to larvae. Infected brood die in prepupal, but in unsealed stage. Dead larvae lie on their backs, with tip of head capsule turned upwards. Affected larvae are yellow/greyish, later turn to blackish. No definite preventive/curative measures available.

Management : Keep the colonies strong, avoid exchange of hive parts and restrict the bee movement

Sac brood virus :

Infected larvae fail to pupate and lie stretched on their back with head turned upwards. Larvae become sac like due to filling of fluid between new integument and unshed skin. Colour of larvae turns pale yellow and finally become dark brown, the darkening starts from head.

II ADULT BEE DISEASES

a. Protozoan disease – *Nosema apis*

Infected bees become dysenteric with distended and swollen abdomen. They have disjointed wings and found crawling in front of the hive. Disease is severe during spring and winter.

Lecture - 31

LAC CULTURE

Lac insect – Biology, Inoculation, harvesting and processing

Importance of Lac culture: The word *lac* is derived from the sanskrit word *laksha*, which represents the number 100,000. The great Indian epic 'Mahabharata' also mentions a 'Laksha Griha', an inflammable house of lac, cunningly constructed by 'Kauravas' through their architect 'Purocha' for the purpose of burning their great enemy 'Pandavas' alive. Lac insect *Kerria lacca* (Order: Hemiptera, and Family Tachardiidae) is a minute scale insect which inserts its suctorial proboscis into plant tissue, sucks juice, grows and secretes resinous lac from the body. Lac is secreted by insects for protection.

With increasing universal environment awareness, the importance of lac has assumed special relevance in the present age, being an eco-friendly, biodegradable, self-sustaining natural material .The lac insects are cultured on host trees which are growing primarily in wasteland areas, promotion of lac and its culture can help in eco-system development as well as reasonably high economic returns. It is a source of livelihood for tribal and poor inhabiting forest and sub-forest areas.

Lac insects are exploited for their products of commerce i.e., a) Resin b) Dye and c) Wax.. Lac resin is natural, biodegradable, non toxic, Used in food, textile, pharmaceutical industries, in addition to surface coating, electrical and other fields

Lac is cultivated predominantly in India, Thailand, Indonesia. China, Myanmar , Cambodia etc.,. . India is the largest producer of lac and produces about 65% of the world's total output. Production of raw lac in India is 18,000 MT per year. Major lac producing states are Jharkhand (57%), Chattisgarh (23%) and West Bengal (12%) while minor producers are Orissa, Gujarat, Maharashtra, U.P. and Telangana The lac produced in India is being utilised indigenously to an extent of 20%, whereas 80% lac is being exported. Lac cultivation provides livelihood to millions of lac growers and conserves vast stretches of forests and biodiversity. It is commercially available in the market as shellac , seedlac and button lac

There are 99 species of lac insects under 9 genera in the world. In India, 26 species belonging to two genera i.e., *Kerria* and *Paratachardina* are found .Species belonging to *Paratachardina* produce a hard, horny substance which is insoluble in alcohol. These are univoltine and are generally treated as pests of economically important plants like tea and sandal.. Species belonging to *Kerria* are bivoltine. It is distinguished into two strains or sub species forms i.e., Rangeeni and Kusmi on the basis of differences in life cycle, host preference and quality of lac produced. Rangeeni strain is characterized by unequal duration of bivoltine life cycle and non preference of kusum as a host. Kusmi strain is characterized by more or less equidurational life cycle and preferring kusum (*Schleichera oleosa*) as a host. Quality of resin produced by kusmi is superior to the resin produced by rangeeni on host tree(*Butea monosperma)*.

Biology and behaviour :

The female lays eggs inside the encrustation. They hatch almost immediately and the nymphs crawl out of the cell. A single female may produce 300-1000 nymphs.

Nymphs are minute, about 0.6 mm long, soft bodied, pointed posteriorly, deep red in colour with black eyes. They wander on the shoots, move mostly upward towards tender branches and settle on them. They start feeding by piercing the shoot. The nymphs settle on the shoot and do not move about. They secrete resin over their body after one/two days of settling. The resin glands are situated all over the cuticle except near mouth parts, anus and breathing pores (spiracles). The resinous covering increases with the growth of insect. The nymphs moult thrice and become the adults.

After first moult, both male and female nymphs lose their eyes, antennae and legs. The males regain their lost appendages at the last moult and females never regain them. After second moult, the female nymphs become swollen with no trace of segmentation.

The males may be winged or apterous and they live for 3 or 4 days after emergence. The male copulates with the female when female remains inside the cell.

A copulated female grows up very fast and secretes lac abundantly. Thus, the female insects are the chief producers of the lac.

Host plants :

About more than 400 species of plants are recorded as lac host plants. Out of which the followings are very common in India.

1) Palas – *Butea monosperma*

2) Kusum – *Schleichera oleosa*

3) Ber – *Zizyphus mauritiana*

4) *Flemingia semialata*

5) *Flemingia macrophylla*

6) Jalari – *Shorea talura*

7) Raintree – *Albizia saman*

8) Fig – *Ficus* species

9) Ghont – *Zizyphus xylopyra*

10) Arhar – *Cajanus cajan*

The time of inoculation and harvesting of different lac crops are

Strain	**Crop**	**Time of inoculation**	**With brood lac from**	**Time of harvesting**
Rangeeni	Baisakhi	Oct – Nov	Katki	June - July
	Katki	June - July	Baisakhi	Oct – Nov
Kusmi	Jethwi	Jan – Feb	Aghani	June - July
	Aghani	June – July	Jethwi	Jan- Feb

Lac cultivation: It is done by putting brood lac on suitably prepared specific host plants. The brood lac contains gravid females which are to lay eggs to give birth to young larvae. After emergence from mother cells, the young larvae settle on fresh twigs of host plants, suck the plant sap and grow to form encrustations.

Inoculation methods: Propagation of lac insects is done by inoculation of newly hatched (brood) nymphs on the same or different host plants.

a) **Natural/self/auto inoculation**: This is a simple and common process, when the swarmed nymphs infest the same plant again. Natural inoculation, repeated on the same host, makes the host plant weak and thereby nymphs do not get proper nutrition

b) **Artificial inoculation**: The old weak and diseased twigs of host plants are pruned in January or June. It induces host plants to new succulent twigs. The cut pieces of brood twig (i.e., 20 x 30 cm in length) are tied to fresh twigs in such a way that each stick touches the tender branches at several places. The nymphs swarm from brood and migrate to tender and succulent twigs and infest them. Following swarming, brood twigs should be removed from the host plant to prevent pest infestation.

Precautions for artificial inoculation:

a) Use fully matured and healthy brood

b) Don’t keep the brood meant for inoculation for long and use immediately after cutting.

c) Tie the brood sticks on upper surface of branches securely.

d) Inoculate only on non rainy day.

Lecture -32

HARVESTING OF LAC

It is done by cutting the lac encrusted twigs when the crop is mature. It is of 2 types.

a) **Immature harvesting**: In this method, lac is collected before swarming. The lac, thus, obtained is known as “ari lac”. In this method, lac insect may be damaged during harvest. Ari lac harvesting is recommended on Palas trees only.

c) **Mature harvesting:** In this method, lac is collected after swarming. The lac obtained is known as mature lac.

Cutting of twigs for harvest can be done at any time between stages while yellow spot occupies one third to one half of the cell area. It is sometimes desirable to wait till the emergence of first few nymphs. The Katki crop is harvested in Oct/Nov, baishaki in May/June; aghani in Jan/Feb and Jethwi in June/July. The brood lac left after emergence of nymphs is known as phunki lac.

Composition of lac:

Lac resin –68%; Lac wax –6%; Lac dye- 1-2%; Others-25%

Lac processing:

1. Stick lac: After harvest, lac encrustations are removed from the twigs of host plant by scraping. The raw lac thus obtained is known as crude/scraped/stick lac.

2. Seed lac/grain lac: The stick lac is crushed and sieved to remove sand and dust. It is then washed in large vats repeatedly to break open the encrusted insect bodies, to wash out the lac dye and twig debris.The remaining resin is dried, winnowed and sieved to get the semi refined commercial product called seed lac.

3. Shellac: The seed lac is processed into shellac by any of the 3 methods i.e., handmade country process/heat process/solvent process. The residue left inside cloth bag is another variety of refuse lac known as **Kirilac**. The molten filtered mass is stretched into sheets approximately 0.5 cm thick called as shellac. Alternatively the molten mass is allowed to solidify in the form of discs and then it is called **button lac**.

Yield: About 2.5 to 3 times the weight of brood lac can be expected as yield..

Pests and diseases of Lac insect

Lac insect , like any other insect has its own natural enemies namely predators and parasites and non insect pests like monkeys, squirrels, rats, birds and lizards.

Predators: Lac insect predators white moth *Eublemma amabilis* and black moth *Pseudohypatopa pulverea* are most important known to inflict severe damage upto 35-40% loss to lac crop. Larvae of *Eublemma amabilis* and *Pseudohypatopa pulverea* are predators on lac both in field and stores. Adult moths lay eggs on or near lac encrustation. The caterpillars bites its way into the encrustation and makes the tunnel lined with silk, excrete or pieces of lac in which it spends whole of its larval and pupal life. A single caterpillar *E. amabilis* can devour 40-45 lac cells. *P.pulverea* is more severe in stores than in fields. Katky and Aghani crops are greatly affected than Baishaki and Jethwi crops.

Minor predators:

Green lacewing*,Chrysopa* sps

Larvae of *Chrysopa* feed on nymphs and adults of the lac insect and does not tunnel its way through the lac encrustation but move freely in lac colonies.. The predators affect not only the quantity of lac produced, but also the quality by the presence of their larvae, pupae and their frass.

Parasitoids: The important parasitoids of lac insect are *Aprostocetus purpureus, Tachardiaephagus tachardiae , Parecthrodryinus clavicornis etc* which lay eggs in to the lac cell in or on the body of lac insect. The grub that hatches feeds on only lac insects and not on lac resin.

Methods of control:

a) Select brood lac from healthy trees.

b) Cut the brood lac from the trees as near the time of swarming, never more than a week before.

c) Remove the brood lac sticks immediately after two weeks of inoculation

d) Remove the lac sticks from field after harvest

e) Do not leave the crop in field for natural inoculation

f) Heavier inoculation is not desirable as it may result in death of host tree.

g)Use recommended insecticides for lac pest management