Course No. - ENTO 365

Course Title-

Management of beneficial insect

Credit - 2 (1+1)

Name. .....

Registration no. .....

Course No. : ENTO 365)	**Credit:** 2(1+1	**Semester-VI**
Course title: Management of Beneficial Insects		

Syllabus

Theory

Importance of beneficial insects.

Bee keeping, pollinating plants and their cycle, bee biology, commercial methods of rearing. Equipment used. Seasonal management. Bee enemies and diseases. Bee pasturage, bee foraging and communication. Insect pests and diseases of honey bee.

Types of silkworm. Voltinism and biology of silkworm. Mulberry cultivation, mulberry varieties and methods of harvesting and preservation of leaves. Rearing, mounting and harvesting of cocoons. Pests and diseases of silkworm, their management, rearing appliances of mulberry silkworm and methods of disinfection.

Species of Lac insect, morphology, biology, host plant, lac production – seed lac, button lac, shellac, lac- products.

Identification of major parasitoids and predators commonly being used in biological control. Insect orders bearing predators and parasitoids used in pest control and their mass multiplication techniques, important species of pollinators, weed killer and scavengers with their importance.

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4	Bee hives and their description, Bee pasturage, bee foraging, 2uxiliar and communication		22
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6	**Sericulture**: Related terminologies, History and development of silkworms in India, types of silkworm, voltinism and biology of silkworm	25	29
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12	Lac production and its uses, Types of lac- seed lac, button lac, shellac, and lac-products		**51**
13	**Biocontrol agents** (Natural Enemies): Introduction of bioagents, Ideal characteristics of bioagents, Successful examples of biological control	**25**	**56**
14	General classification: Important insect orders bearing predators and parasitoids used in pest control Identification of major parasitoids and predators commonly used in biological control of crop pests.		**58**
15	Major parasitoids: *Trichogramma sp., Chelonus blackburni, Cotesia (Apanteles) sp., Bracon sp., Epiricania melanoleuca, Goniozus nephantidis, Campoletis chloridae,* Major predators: *Chrysoperla* sp., Australian lady bird beetle- *Cryptolaemus*montrouzieri Weed killers: *Zygogramma bicolorata, Neochetina* spp.	**15**	**61**
16	Mass multiplication and field release techniques of some important parasitoids: *T. chilonis, Chelonus blackburni, Cotesia / Bracon, Goniozus nephantidis, Epiricania melanoleuca*		**68**
17	Mass multiplication and field release techniques of important predators: *Chrysoperla* sp., Australian lady bird beetle, Weed predators/killers: *Zygogramma bicolorata, Neochetina* sp.		**73**
18	Important species of pollinator and scavengers with their importance	**05**	**76**
	Total	**100**	

Lecture No. 1

Importance of beneficial insects in Agriculture, Honeybee, Silkworm, Lac insects, Bio-agents as natural enemies, Various Institutes related to beneficial insects

Importance of Benificial Insects:

- **Beneficial insects** (sometimes called **beneficial bugs**) are any of a number of species of insects that perform valued services like pollination and pest control.
- The concept of *beneficial* is subjective and only arises in light of desired outcomes from a human perspective.
- In farming and agriculture, where the goal is to raise selected crops, insects that hinder the production process are classified as pests, while insects that assist production are considered beneficial.
- In horticulture and gardening; pest control, habitat integration, and „natural vitality" aesthetics are the desired outcome with beneficial insects.
- Encouraging beneficial insects, by providing suitable living conditions, is a pest control strategy, often used in organic farming, organic gardening or integrated pest management. Companies specializing in biological pest control sell many types of beneficial insects, particularly for use in enclosed areas, like greenhouses.
- There are many insects found on agriculture land those are not threat to the crop production but beneficial to the farmers in different aspects, as Natural enemies, Pollinators, productive insects, Scavengers, weed killer and Soil builders.
- In present scenario the motive of the farmers is single sided, to gain only maximum profit, ignoring the impact on the beneficial insects, environment and human health.
- Insecticide can be a important crop production tool to maximize yield but Heavy and indiscriminate use of chemicals also exposes farmers to serious health risks, resulted in negative consequences for the insect those are beneficial to the farmers.
- Fields shared by many beneficial insects, positively affect the crop yield so careful decision should be taken to manage the insect pest and awareness among the farmers towards the beneficial insects.

Role of Beneficial Insects As

1. Pollinators:

- Insect pollinators are flower visiting Insects that forage on flowering plants to obtain plant-provided food (nectar, pollen).
- Flower-visiting insects have the potential to transfer male gametes (contained in pollen) to the female gametes while foraging, resulting in pollination.
- Insect-mediated pollination is an essential step in reproduction for the majority of the world's flowering plants, including numerous cultivated plant species i.e. Sunflower, Cucurbitaceous vegetables,
- Alfalfa, Coriander, Cardmom, Gingelly, Apple etc. Many crops depend on pollination for seed production and fruit set to achieve good yield. Globally, an estimated 35% of crop production is a result of insect pollination.
- The Apis meliffera L. (European honey bee) is responsible for the pollination servicesin majority of crops. Non-Apis bees also are important pollinators of crops, especially for crops in which honey bees are inefficient pollinators (e.g. alfalfa, squash).

- A few non-Apis species are managed for crop pollination. Examples of managed non-Apis species include bumble bees, Bombus impatiens Cresson (Hymenoptera: Apidae) managed for cranberry (Vaccinium spp.) and greenhouse tomato (Solanum lycopersicum L.) pollination.
- Although bees are considered the most effective insect-pollinator of most plant species, other insects have been recognized for their contributions to pollination.
- Flower visiting flies (Diptera) have been documented as proficient pollinators of several crops including carrot (Dacus carota L.), mustard (Brassica spp.), leek, (Allium ampeloprasum L.), and almond (Prunis dulcis). Weevil Elaeidobius kamerunicus (Coleoptera: Curculionidae) plays great role in pollination of Oil palm.

Example – honey bees, solitary species, bumblebees, pollen wasps (Masarinae); ants; flies including bee flies, hoverflies and mosquitoes; lepidopterans, both butterflies and moths; and flower beetles.

2. Natural Enemies:

Insect predators and parasitoids that attack and feed on other insects, particularly on insect pests of plants are considered natural enemies. Through this type of feeding, natural enemies contribute to a type of pest regulation referred to as natural biological control.

Example – Lady Beetles (aka Ladybugs)

3. Weed Killers:

- So many insects feed upon unwanted weeds just the same manner they do with the cultivated crops.
- In many cases the occurrence of these insects has contributed much towards eradication of the weeds.

Sr. No.	Bio – agents	Weeds
1.	Leaf beetle (*Octotoma scabripennis*) Leaf-mining chrysomelids (*Uroplata gualdi*)	*Lantana camara*
2.	*Common crap (Cyprimus carpio) Chinese crap Neochetina sp.*	Aquatic weed
3.	Manetee or sea-cow	Water hyacinth
4.	*Zygogramma bicolorata*	Parthenium (Congress)

4. Soil Builders:

- Insects which live in soil make tunnels, creating channels for smaller organisms, water, air, and roots to travel through.
- Insects improves soil aeration, and earthworm activity can enhance soil nutrient cycle, the soil physical properties, such as soil structure and tilth and activity of other beneficial soil organisms.
- Small Dung beetles makes tunnel walls with dung and also make dung balls that helps in maintaining the quality of the soil.
- Excreta of insets also enrich the soil. Examples- Beetles, Ants, Cut-worms, Larvae of flies, Crickets, Termites, Wasps etc.

➢ **<u>Institutes related to beneficial insects</u>**

1. Commonwealth Institute of Biological Control (CIBC)

· Indian Station was established in 1957 at Hebbal, Bangalore.

- The advent of CIBC marked the beginning of organized and systematic biological control research in India.
- During this period, our knowledge of natural enemies of crop pests and weeds increased manifold.
- CIBC Indian station was closed during 1987.

2. **All India Coordinated Research Project on Biological Control of Crop Pests and Weeds (AICRP-BC&W)**,

- which was launched in 1977 under the aegis of the Indian Council of Agricultural Research was shifted to the same campus in 1988.
- The centre was named as Biological Control Centre and the entire programme functioned under the administrative/financial control of the National Centre for Integrated Pest Management (NCIPM).

3. **National Centre for Integrated Pest Management (NCIPM)**,

- New Delhi established in 1988 is associated with achieving the goals of IPM by promoting environmentally sound IPM technologies.
- Centre strives for effective cooperation with All organisations in India for implementation of its programmes.
- In the eighth five-year plan, the project was elevated to an independent.

4. **Project Directorate of Biological Control (PDBC)**,
   with its headquarters in Bangalore during 1993.
   PDBC was the nodal agency in the country that organizes biological control research at the national level with 16 centres spread across the country.
   The Directorate at Bangalore carried out basic research on the biosystematics of important groups of insect bioagents.
5. The reference collection maintained at PDBC During XIth plan, PDBC was upgraded as **National Bureau of Agriculturally Important Insects (NBAII)** located in Hebbal, Bangalore to act as a nodal agency for collection, characterization, documentation, conservation, exchange and utilization of agriculturally important insect resources (including mites and spiders) for sustainable agriculture.
6. In the twelfth five year plan the Bureau is now re-named as **National Bureau of Agricultural Insect Resources (NBAIR)** located in Hebbal, Bangalore and the bureau's Mandate is To act as a nodal agency for collection, characterization, documentation, conservation, exchange, research and utilization of agriculturally important insect resources (including mites, spiders and related arthropods) for sustainable agriculture. Capacity building, dissemination of technologies and forging linkages with stakeholders. On-farm validation of biocontrol strategies, forging linkages with commoditybased crop research institutes, AICRP/AINP and capacity building.

7. **Khadi & Village Industries Commission, Mumbai (KVIC)**

- With the inspiration of Rastrapita Mahatma Gandhi took the task of development of the beekeeping Industry with a view to uplift the financial status of people living in extremely interior rural areas by introducing and popularizing modern beekeeping.
- KVIC in 1957 established **Central Bee Research & Training Institute** at Pune on 1 st Nov" 1962.

- KVIC established a separate department namely **Directorate of Beekeeping** in Mumbai and **Central Bee Research & training Institute** at Pune and started beekeeping in modern and scientific way throughout the country
- In view of the tremendous scope for increasing productivity due to cross pollination and increase in income through Apiculture, it was proposed to revive Beekeeping activity in the country, exponentially by pooling the resources of the Department of Agriculture and Cooperation with other organization, including private sector.

8. Accordingly, the **National Bee Board,** New Delhi **(NBB)** was reconstituted in June, 2006. The main objective of the National Bee Board (NBB) is overall development of Beekeeping by promoting Scientific Beekeeping in India to increase the productivity of crops through pollination and increase the Honey production for increasing the income of the Beekeepers/ Farmers.

Lecture No. 2

Apiculture : Introduction and History of Apiculture, Bee Keeping, morphology and anatomy, bee biology, pollinating plants and their cycle, bee conservation

Introduction to Apiculture

- In the animal kingdom honey bees belong to: Phylum-Arthropoda, Class- Insecta, Order-Hymenoptera, Superfamily-Apoidea and Family-Apidae.
- Honey is highly valued food produced by honey bees and it is also used as medicine. In addition to honey, other products like bees wax, pollen, royal jelly and bee venom are also produced by honey bees.
- More than the producers of these hive products; bees play an important role in pollination of plants while collecting their food from flowers in the form of nectar and pollen.
- Pollination is involved in a chain of complex events significant to our economy. Pollination by insects including honey bees is important for ecological balance.
- Visitation by honey bees between distant varieties or cultivars promotes hybridization and help sparse populations to survive. Their mutual dependency has resulted into great degree of co-evolution.
- **The science of rearing honey bees or beekeeping is known as apiculture.**

History of beekeeping

- Primitive man used to rob bee colonies found in the cavities of hollow trees or on rocks and in traditional mud houses (Fig. 1.1) and this is still being followed by some tribes
- There was no development in beekeeping until 16^{th} century.
- Proper beekeeping started only when man started giving protection to colonies found in the nature
- Idea to keep bees in log hives has been reported to come from the fallen trees which were nested by the cavity nesting bees.

- Development of modern beekeeping has its origin between 1500 and 1851 when many attempts were made to domesticate bees in different types of hives but were not successful because bees attached their combs together as well as to the walls of hive and combs required had to be cut for honey.
- The discovery of the principle of bee space in 1851 by L. L. Langstroth in USA resulted in first truly movable frame hive. This bee space was 9.5 mm for *Apis mellifera*.
- This discovery was followed by subsequent innovations like comb foundation mill, honey extractor, smoker, etc., which helped in the development of modern beekeeping we see today.

Beekeeping in India

- In India first attempt to keep bees in movable frame hives was made in 1882 in Bengal and then in 1883-84 in Punjab.
- In south India, Rev. Newton during 1911-1917 trained several beekeepers and devised a hive for indigenous bee *Apis cerana* based on principle of bee space (which was named after his name as "Newton hive").
- Beekeeping was also started in the Travancore state (now Cochin) in 1917 and in Mysore in 1925.
- In Himachal Pradesh modern beekeeping with indigenous honey bee *A. cerana* started in 1934 at Kullu and in 1936 at Kangra.
- The exotic bee *A. mellifera* was successfully introduced for the first time in India in 1962 at Nagrota Bagwan (then in Punjab state and now in Himachal Pradesh), because this bee has potentials to produce more honey.
- At present both the hive bee species are being used in modern beekeeping and lot of honey is also being collected from the wild bees viz. *A. dorsata* and *A. 8uxili*.
- India is producing approximately 70000 metric tons of honey annually from all the four species of honey bees.

Morphology and Anatomy of Bee

In honey bees, body parts are modified as per their food habits and social life. Like any insect, body of honey bee can be distinguished in to three parts

a. Head

b. Thorax

c. Abdomen

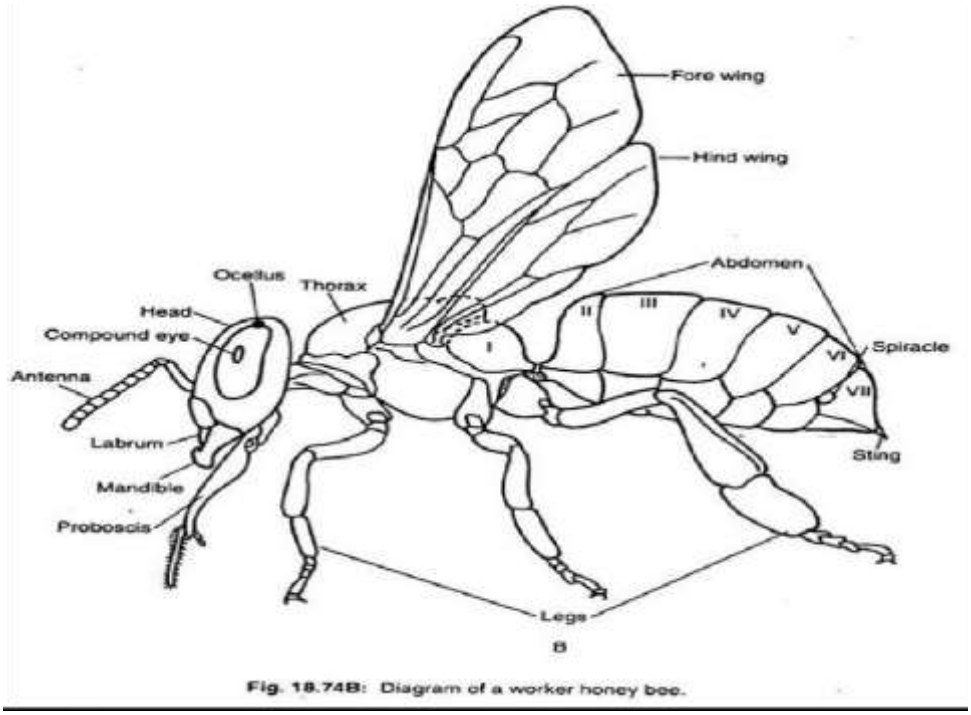


Fig. 18.74B: Diagram of a worker honey bee.

1. Head

- Bears a pair of geniculate antennae
- Two compound eyes on lateral side of head. Bees can distinguish different colours but are red blind and can perceive ultraviolet rays
- Head bears 3 ocelli (simple eyes) on top portion which perceive degree of light
- Two mandibles are attached to ventro-lateral part of head capsule. Mandibles differ in shape in three castes. Workers use mandibles for grasping and scrapping pollen from anthers, feeding of pollen and in manipulation of wax scales during comb building
- Mouth parts of worker bees are modified for sucking and lapping. Tongue or proboscis (formed by medium labium and two lateral maxillae) is used for ingesting liquids. Labium has long median glossa and spoon shaped lobe (flabellum) at the end
- Inside the head there are long coiled strings of small lobes known as hypopharyngeal glands which secrete glandular food known as royal jelly that is fed to queen and young larvae.

2. Thorax

- Consists of three segments: prothorax , mesothorax and metathorax, each bears a pair of legs. Meso and metathorax, each bears a pair of wings. Legs and wings are locomotory organs. In addition to locomotion legs in honey bees are also modified to perform following functions:
- Prothoracic legs serve as antenna cleaner. Basal part of basitarsus has a notch and a small lobe projects from distal end of tibia (tibial spur). It is found in all the three castes.
- On mesothoracic legs, bushy tarsi serve as brushes for cleaning of thorax. Long spine at end of middle tibia is used for loosening pellets of pollen from pollen basket of hind leg and also for cleaning wings and spiracles. Wax scales are also removed from wax pockets of abdomen by these legs.

- Hind or metathoracic legs differ from other legs in being larger in size and with broad flattened form of tibia and basitarsus. In worker bees, smooth somewhat concave outer surface of hind tibia is fringed with long curved hairs and forms pollen basket or corbicula.
- Two pairs of wings arise from sides of meso and metathorax. Fore wings are stronger than hind wings. Series of upturned hooks (hamuli) are present on front margin of each hind wing. Decurved fold on rear margin of fore wing works as coupling apparatus for holding hamuli and this result in unity of action of the wings in flight.

3. Abdomen

- First abdominal segment is united with the metathorax and forms anatomically a part of thorax known as propodeum
- Bee larva has 10 abdominal segments but in adult workers abdomen appears 6 segmented; segments 8-10 are reduced in size and first segment (propodeum) is transferred to thorax during pupal stage
- Abdomen bears sting, wax glands (on sternites 4 to 7) and scent glands (on last two terga) and genitalia in addition to other viscera
- In workers egg laying apparatus (ovipositor) is modified into sting
- Queen uses ovipositor for egg laying and for stinging rival queen.

Bee Biology:

Every **honey bee** colony comprises of a single **queen**, a few hundred drones and several thousand worker castes of **honey bees**.

Queen is a fertile, functional female, worker is a sterile female and the drone is a male insect.

1. Worker bees

- Are female bees, born from fertilized eggs, that engage in the majority of the work: tending larva, collecting and processing pollen, making honey, guarding the hive, and other general housekeeping.

2. Drones

- Are male bees produced from unfertilized eggs whose sole responsibility is to reproduce with queens at surrounding hives.
- They are only produced when the hive is growing, usually during peak pollination season, and before a swarm or when the queen is running low on sperm.
- Drones die once they reproduce.
- All drones from the same hive are clones of the queen since they are produced without genetic material from a male bee.

3. Queen bees'

- Are responsible for laying eggs.
- There is only one laying queen per hive and she can live several years under healthy conditions.
- She mates mostly with drones from other hives.

- When her health is weakening or the hive is preparing to swarm, she will emit pheromones to help create new, virgin queens which can start new colonies.

Thus the lifespan of workers can be divided into two phases as first three weeks for house hold duty and rest of the life for outdoor duty.

Household duties

- Build comb with wax secretion from wax glands.
- Feed the young larvae with royal jelly secreted from hypopharyngeal gland.
- Feed older larvae with bee-bread, a mixture of pollen and honey
- Feeding and attending queen.
- Feeding drones.
- Cleaning, ventilating and cooling the hive.
- Guarding the hive.
- Evaporating nectar and storing honey

Outdoor duties

- Collecting nectar, pollen, propolis and water.
- Ripening honey in honey stomach.

Five important species of honey bees are as follows.

1. The rock bee, *Apis dorsata* (Apidae).
2. The Indian hive bee, *Apis cerana indica* (Apidae).
3. The little bee, *Apis 11uxili* (Apidae).
4. The European or Italian bee, *Apis mellifera* (Apidae).
5. Dammer bee or stingless bee, *Melipona irridipennis* (Meliporidae).

➢ **The important features of these species are given below.**

1. **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.

2. Little bee (*Apis 11uxili*)

✓ 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.

3. **Indian hive bee / Asian bee (*Apis cerana indica*)**

✓ They are the domesticated species, which construct multiple parallel combs with an average honey yield of 6-8 kg per colony per year.
✓ These bees are larger than *Apis florae* but smaller than *Apis mellifera*.
✓ They are more prone to swarming and absconding. They are native of India/Asia.

4. **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.

5. **Dammer Bee**

✓ Besides true honey bees, two species of stingless or dammer bees, viz. *Melipona* and *Trigona* occur in our country in abundance.
✓ These bees are much smaller than the true honey bees and build irregular combs of wax and resinous substances in crevices and hollow tree trunks.
✓ The stingless bees have the importance in the pollination of various food crops.
✓ They bite their enemies or intruders. It can be domesticated. But the honey yield per hive per year is only 100 gms.

➢ Pollinating Plants

The importance of honey bee pollination varies per crop and can be classified as one of the following: essential, great, modest, and little.

Essential

- Honey bee pollination is considered essential for eight crops: kiwifruit, passion fruit, rowanberry, watermelon, squash (includes pumpkin, gourd, and zucchini), macadamia nut, and brazil nut.
- These plants grow across a wide variety of agricultural climates, from temperate to tropical.
- Kiwifruit is most successfully pollinated via saturation pollination.
- This method is when agricultural workers put about 8 hives for every 2.5 acres, thereby forcing bees to collect pollen from solely kiwifruit blossoms.
- Passion fruit is most successfully pollinated via bee pollination because its pollen is too heavy and sticky to be transported across the wind.
- In the US state of Florida, for example, honey bees are the only pollinator for the yellow passion fruit species.
- In Australia, agricultural workers encourage honey bee pollination by placing 2 to 3 hives for every 2.5 acres.

Great

- Bee pollination is characterized as having great importance in the following crops: cashew, starfruit, turnip, coriander, cucumber, durian, cardamom, loquat, buckwheat, feijoa, fennel, apple, mango, avocado, allspice, apricot, sweet and sour cherries, plum, almond, peach, pear, rose hips, raspberry, blackberry, naranjillo, and blueberry.
- Of these crops, blueberries require the greatest number of honey bee hives per acre, between 3 and 4 colonies on each acre.

- Blueberries are unable to self-pollinate and produce sticky, heavy pollen, which means this plant relies on insects to help it achieve fertilization.
- In Australia, honey bees make up 95% of the insects that pollinate this crop.
- Blueberry blossoms attract bees with sweet nectar, which is produced at the base of the stigma.
- Almonds are next, in terms of the number of colonies needed for pollination.
- This crop requires between 2 and 3 hives per acre for proper pollination.
- The almond plant attracts honey bees and other insects because it produces flowers earlier in the season than other crops, making it one of the only food sources available.

Modest

- Crops that fall under modest honey bee pollination include: eggplant, jujube, 13uxili, broad bean, service tree, sesame, elderberry, black currant, pomegranate, guava, prickly pear cactus, mammee apple, sunflower, cotton, strawberry, hyacinth bean, coffee plants, coconut, chestnut, caraway, sword bean, rapeseed, mustard, strawberry, and okra.

Life cycle:

Queen deposits egg at the base of cell and fastens with mucilaginous secretion. After 3 days egg hatches and workers provide pearly white food in which "C" shaped larva floats. Cell is sealed when larva is fully grown. In the sealed cell it turns into pupa from which adult emerges. Larva sheds skin five times during development. The sealed cells containing worker and drone brood and honey can be differentiated on the basis of appearance

Development: The developmental stages of honey bees are: egg, larva, pupa and the adult. Duration of life stages of different castes of honey bee varies which is given in the table and presented through

Castes	**Egg period (days)**		**Larval Stages (days)**		**Pupal Stages (days)**		**Total (days)**	
	A.cerana	*A. mellifera*	*A. cerana*	*A. mellifera*	*A. cerena*	*A. mellifere*	*A. cerana*	*A. mellifera*
Worker	3	3	5	5	7-8	8	15-16	16
Queen	3	3	4-5	5	11-12	12-13	18-20	21
Drone	3	3	7	7	14	14	24	24

Lecture No. 3

Commercial Methods of bee rearing, equipments used, seasonal management of bees

Commercial methods of Bee rearing

A. HIVE:

Two types of hives are used:

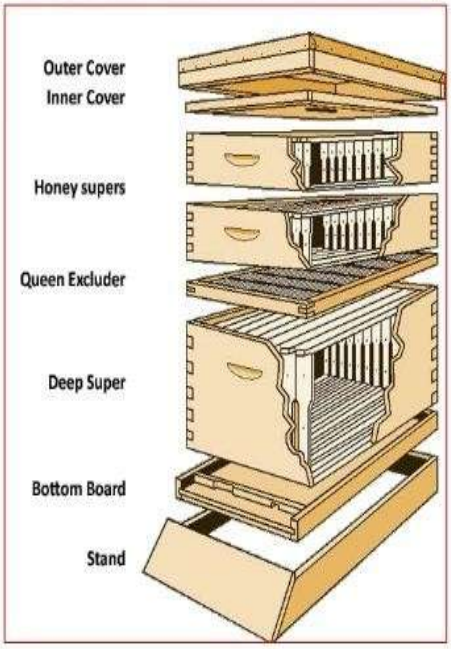
1. Indigenous methods of bee keeping
2. Movable hive.

B. Modern methods

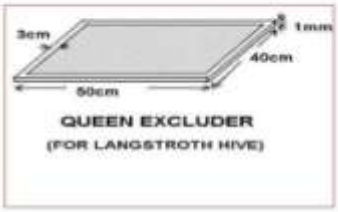
1. Typical movable hive
2. Queen Excluder
3. Honey Extractor
4. Uncapping Knif
5. Other Equipments

TYPICAL MOVABLE HIVE

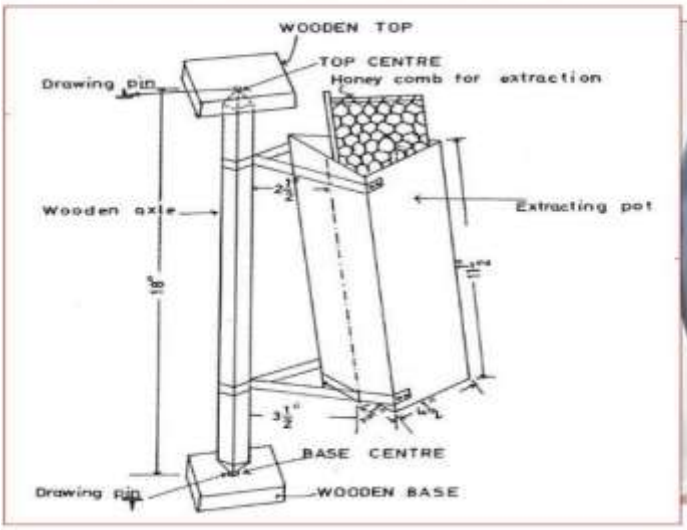
- It is a six type:
  - (a) Stand
  - (b)Bottom board
  - (c)Brood chamber
  - (d)Super
  - (e)Inner cover
  - (f) Top Cover

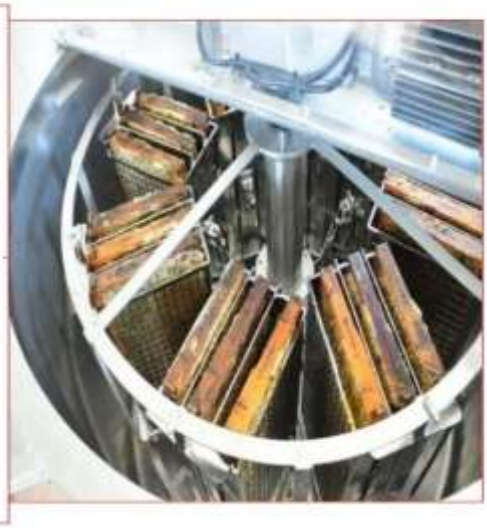


2. QUEEN EXCLUDER



3. HONEY EXTRACTOR:





4. UNCAPPING KNIFE:

Electric Uncapping Knife

For uncapping all sizes of frames.

L.L. Langstroth discovered the principle of bee space in 1851 in the U.S.A. This space permits free passage for worker bees and is too small to build a comb by bees or too large for depositing bee glue i.e. propolis. We can say that bee space is optimum distance between two surfaces in a bee hive essential for normal movement and functioning of bees. This principle was a big discovery for modern beekeeping. The modern hive has been designed on the bases of principle of bee space in which frames can be easily moved. The bee space measures 9.52 mm for *A. mellifera* and this was modified for *A. cerana* to be between 7 and 9 mm. Different parts of a movable frame bee hive are shown in Fig. 6.1.

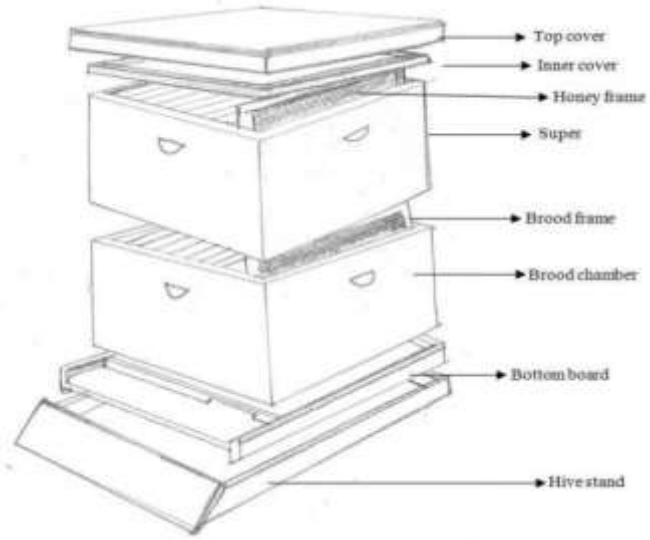


Figure 6.1 Parts of a movable frame hive

Stand: To support bottom board.
Bottom board: It is floor of the hive having an entrance for bees. On this board brood chamber rests.
Brood chamber: Chamber used for rearing of brood. Frames are placed in this chamber on which bees raise combs. The dimensions and number of frames vary with the type of hive. A wooden dummy board is used to limit the size of brood chamber and is placed at the end of brood frames.
Frame: Each frame consists of a top bar, two side and a bottom bar. Inner aspect of the top bar has a groove for fixing comb foundation sheet. Side bar has 4 holes for wiring the frame. The frame holds a comb.
Dimensions of hive: In general for *A. mellifera*we use Langstroth hive (named after L.L. Langstroth) and for *A. cerana*, BIS (Bureau of Indian Standard) hive A and B type. In 1995, BIS introduced C-type hive based on Langstroth hive, for *A. melifera*. Well seasoned wood of "Kail, "Toon", teak or rubber can be used for making good quality bee hives. Wood having strong smell is not used. Dimensions of different types of bee hives being used in India are given below:
Super: Dimensions may be same as that of brood chamber or half of it (depending on type of bee hive). This is the chamber where bees store surplus honey.
Inner cover: A board which acts as a partition between brood/super chamber and the roof .
Top cover: A type of lid acting as roof placed over inner cover.

OTHER EQUIPMENT

Nucleus hive: Small bee hive for keeping 4-6 frames. These are used for mating of queens and division of colonies.
Observation hive: Small hive with glass sides so as to observe movements and 17uxiliar of bees (Fig. 6.4).
Comb foundation mill: Used to print natural cell size of desired comb foundation sheet for *A. mellifera* and *A. cerana.*
Bee veil: Used for preventing bee stings on face and neck .

Smoker: Used to calm down the bees while opening the hive.
Uncapping knife: Large sized knife used to uncap the frames before honey extraction.
Hive tool: An iron strip used for opening of hive and its cleaning.
Queen cell protector: A spring like structure for protecting queen cells.
Queen cage: Used to introduce a queen to new colony and also to transport the queen.
Bee brush: To brush the bees from frames.
Feeders: Different types of feeders are used for feeding sugar syrup to the bee colonies. These can be (i) slow feeder (friction top pail feeders) in which holes are made in the lid and the feeder is placed inverted inside the hive (ii) fast feeder (division board feeder) which is of the size of a regular frame and the trough contains a wooden float inside the cavity.
Swarm basket: Basket to catch bee swarm.
Queen excluder: Perforated zinc sheets or round wires assembled in such a way that workers can pass through them and queen cannot (perforation size is 4.20mm for *A. mellifera* whereas worker thorax size varies from 3.33 to 3.50mm). It is used during honey flow season to restrict queen to brood chamber and thereby preventing egg laying in the super. It is also used in maintaining multiple queen system in a colony.
Honey extractor: It is a machine to centrifuge out the honey from uncapped frames Wax melter: Double walled chamber for melting of bees wax for making comb foundation sheets
Wax melter: Double walled chamber for melting of bees wax for making comb foundation sheets.
Pollen trap: For trapping corbicular pollen of returning bee foragers:. For *A. mellifera* pollen trapping screen has holes of 4.7 to 5mm. and for *A. cerana* 3.5 to 3.7mm.
Bee escape: To provide one way passage to bees

SEASONAL MANAGEMENT OF BEES:

All the management practices needed for increased honey production revolve around the following basic principles of bee management:

a) Ensuring built-up of foraging force of bees at right time for collection of surplus nectar.
ii) Providing space for storage and ripening of nectar into honey by the bees.
iii) Removing honey from hive at right time and extracting it.
iv) Preparing the colonies to withstand any period of dearth and menace of bee enemies.

Generally, beekeeping activities start with the onset of spring in cold areas. Therefore, it is appropriate to know the management practices, starting from spring. However, in some parts of the country there are different seasons and the management varies as per season.

1. SPRING MANAGEMENT

- The advent of spring, particularly in northern parts of the country, marks the beginning of warm weather and blooming of several tree species and cultivated crops. Following management practices are performed:
- Remove the protective covering of lightly packed hives in the early spring. But in the heavily packed colonies, the packing is removed only when daily maximum temperature has reached 16Oc.
- Examine the colonies on a sunny day. Check the food store and general condition of the colony. The examination should be for short duration to avoid brood chilling and robbing
- It is a good practice to equalize the strength of normal colonies in an apiary by giving brood frames to the needy colonies

- The colonies which do not have brood, are likely to be queen less or if queen has failed and has become drone layer, there will be predominance of drone brood. Such colonies if are weak (less than 5 frames), be united with other needy normal colonies. If these are strong, then provide a mated queen and if not available, give a frame of brood with eggs and young larvae for rearing new queen.
- Give stimulatory feeding of sugar syrup (dilute syrup; 30 per cent) to the bee colonies on the onset of spring which is indicated by the start of blooming of spring flowers. Take all the steps to guard against the robbing by bees. Bees will put their whole force during this period for brood rearing Provide raised combs or frames with comb foundation sheets if raised combs are not available so that there is no shortage of space for brood rearing. But be careful not to over expand the brood in the uncertain weather conditions of early spring, which may result in chilling of brood.
- Once the colony is strong enough to cover the brood, there is no risk of this problem
- Examine the colonies at least once a week on a sunny day and when conditions permit, clean the debris from the bottom boards. Provide empty frames as per needs of the colonies. Ensure that each colony always has at least 5 kg of food stores
- During spring old bees die which are normally replaced by young bees. If mortality of old bees exceeds the rate of emergence of young bees, the colonies show sign of dwindling which is known as spring dwindling.
- Such colonies should be provided with adequate stores of pollen and honey and be given 1-2 sealed brood frames from the strong colonies. If all above mentioned practices are followed, the colonies will be well built up by the time of honey flow when maximum strength is needed. However, increase in strength also induces swarming.
- In warmer areas of the country, all these practices can be carried out during early summer.

SWARMING AND CONTROL

What is swarming?

This is a natural instinct for increase in the number of colonies. Division of colony takes place in which worker bees (30 to 70 per cent), fill their honey stomachs with the food and leave the colony along with old queen and this divide, called as swarm, settles down temporarily generally in the nearby area of the colony on the bushes, hedges, tree branches etc.

Period of swarming: It occurs when queen has reached her peak of brood rearing activity under the stimulus of incoming pollen and nectar, mainly in late spring or early summer, but can also occur during summer or fall, depending upon floral conditions of the area. This generally occurs during the period before honey flow.

What causes swarming? Swarming occurs due to:

Overcrowding and lack of ventilation.

Presence of old queen

Sudden honey flow

Lack of space for egg laying and honey storage.

Problems due to swarming:

Loss of working force due to division of the colony

The morale of colony is not favourable for honey collection.

The bees direct their efforts towards building queen cells and searching for new home sites
Colonies show great variations in respect of swarming.
Some colonies do not swarm even after becoming quite populous yet many swarm without any apparent reason indicating genetic variations to the instinct of swarming.
b) *cerana* is more prone to swarming than *A. mellifera*.

Indication of swarming:

The colonies start raising large number of queen cells usually along the lower edges of combs . However, few emergency queen cells are also raised in the event of queen failure i.e. supersedure.
Many bees do not go to field creating additional crowding, resulting in clustering of bees outside the hive.

Time of swarming: Time to issue swarms by the colonies is from 10AM to 2PM on sunny days. If weather is not favourable, swarms may be issued even earlier in the morning or late in the evening.

Catching and hiving a swarm:

- A settled swarm can easily be caught using swarm catching basket . This basket is placed above the bee cluster and the cluster is gently pushed upwards so that the bees start ascending into the basket. Once the queen has entered, the whole swarm will follow the queen
- The swarm in this basket can be taken to the apiary for hiving To make the swarm settle properly, a hive is prepared by giving one frame each of capped brood, pollen and honey and provided with extra frames as per strength of the swarm.
- The swarm from the swarm catching basket is then shaken on the top bars of such a prepared hive and immediately covered with burlap cloth, inner cover and top cover
- Sugar syrup is also fed to such a newly settled swarm (1 part sugar dissolved in 1 part of water).

How to prevent and control swarming?

- Depending on the internal and external factors, one colony may issue one to several swarms resulting in loss of population of the parent colony.
- To prevent swarming do as given below:
- Avoid overcrowding by adding empty combs for egg laying. Sealed brood can be shifted to second hive body
- Remove the queen cells at regular interval as soon as these are made.
- Delay in queen cell removal is not much effective
- Provide shade and ventilation to the colonies
- Swarming can be prevented by removing old queen (which otherwise provides the supersedure impulse) followed by introduction of a young laying queen.
- Requeening the colonies annually is also a good practice.
- Another well known method of swarm control is " Demaree plan of swarm control" which is described below:
- Examine the brood of the colony and remove all the queen cells
- Remove the brood chamber from the bottom board. Place another hive body containing one comb of unsealed brood, eggs and the queen on this bottom board.
- Fill the remaining hive with empty combs.

- Place queen excluder on this hive body and keep the removed brood chamber along with remaining brood and bees over it
- Again inspect the top hive body after 10 days and remove all queen cells that may have been built in this interval. In 21 days, all of the brood will have emerged in the upper body and it will be used for honey storage. In this way swarming can be checked.
- Swarming instinct of the colonies can also be overcome by temporarily
- dividing the colony and then re-uniting them just before honey flow.

2. SUMMER MANAGEMENT

Under summer management, information on indication of honey flow, method of supering, honey extraction and management for dearth period has been provided.

What is honey flow? : It is the period when honey bees gather and store surplus honey in the hive after attaining peak population in the colony. **Honey flow is indicated by**:

Whitening of honey cells of the comb due to deposition of fresh wax

Appearance of large quantities of burr and brace combs (freshly prepared pieces of combs)

Increase in weight of the colonies due to incoming nectar (a colony kept on a stage balance in an apiary indicates the sudden increase in weight; such a colony is also known as balance colony).

During this period colonies should be quite populous but without swarming instinct and should gather maximum honey instead of only concentrating on brood rearing.

Colony morale should be high for honey collection.

Supering:

- With the first indication of honey flow, provide supers to the colonies. But before putting supers, examine the colonies for disease; check whether queen is present or not and whether laying satisfactorily because after the honey flow starts, the bee keeper becomes too busy in putting and taking off the supers
- Place queen excluder between brood chamber and super so as to prevent laying in the super by the queen
- Keep swarming under check by avoiding congestion in the brood chamber. Provide empty combs at all the times until end of honey flow.
- The space can be provided by removing sealed brood to super chamber
- Supers should contain drawn combs. If these are not available, provide frames with comb foundation sheets. In that case, also place at least one or two drawn combs with the comb foundation sheets to attract bees for raising the combs on foundations
- Supers can be of half or full depth. But full depth supers are more practical since frames can be exchanged among different chambers
- When first super is full and there is a need to put the second one, it should be added between brood chamber and first super
- If there is shortage of drawn combs and raising of new combs is likely to lower honey production (since bees consume about 7kg of honey to secrete one kg of beeswax), the fully sealed and two third sealed honey frames can be taken out for honey extraction and empty combs can be returned for re-use
- A strong colony can collect 4.5 to 10 kg of unripe honey in a single day during good honey flow. Therefore, keep the supers ready for meeting colony demand. It is better to supply at least one super ahead of needs of the colony.

HONEY EXTRACTION

For honey extraction only sealed honey frames are removed. Do not extract uncapped honey since it is unripe and due to higher moisture contents it is liable to ferment.

Time to remove supers: Early in the morning before bees start storing unripe honey in the combs. If combs are well sealed, these can be removed at any time of the day.

All the management practices of honey bee colonies are ultimately directed to get better quality hive products. It is, therefore, important that apiary honey is extracted properly so as to retain its quality. The process of extraction should be hygienic and prevent any extraneous material in honey.

Requirements:

Smoker, bee veil, hive tool, bee brush, empty super bodies, uncapping knife, boiling water, drip trays, honey extractor, honey storage container, muslin cloth

Procedure of honey extraction:

- To remove sealed honey combs, give few puffs of smoke to the colony and brush off bees from the honey combs using soft bee brush (Fig. 10.1) or bunch of soft green grass
- Place the honey combs in bee tight hive bodies and shift to honey extraction room
- Never rob the colonies of their entire honey stores. Depending on strength, keep with each colony at least 5-10 kg of honey in case of Apismellifera and 2-3kg with A. cerana for summer and monsoon dearth periods
- Honey extraction room should be bee tight. After bringing the honey frames for extraction, these can be uncapped (Fig. 10.2) either with a steam heated double walled uncapping knife or with ordinary uncapping knife by heating in boiling water.
- Keep these uncapped frames in hive bodies with drip trays below, till extraction
- Put the uncapped frames in honey extractor and work at about 150 revolutions per minute for 1 to 2 minutes. Then reverse the sides of the frames and repeat the extraction process Stock the emptied frames in hive bodies and return these to the colonies for cleaning.
- Shorten the hive entrance to avoid robbing
- Since freshly extracted honey is warm and easy to strain, arrangements for straining using muslin cloth and packing should be promptly made so as to prevent subsequent heating
- Clean the appliances and the place where honey is extracted Beeswax collected during uncapping of honey frames should be allowed to drain off its honey. Then purify this beeswax by putting in a muslin bag and boiling in a water bath. On, cooling pure beeswax will float over the surface of water and all impurities will remain in the muslin bag.

Precautions during honey extraction

- Remove only completely sealed or two third sealed combs of honey for extraction.
- Never extract unripe honey
- Keep sufficient food stores with the colonies as per strength and prevailing dearth
- period.
- Do not rob the colonies of their whole stores.

OTHER MANAGEMENT DURING SUMMER

- Honey flow in most of the areas is generally followed by summer dearth period.
- Summer is generally marked by hot winds and ambient temperature often exceeds 40Oc.

- During this period bees throw out drones and colony population also dwindles due to the death of old bees who have worked hard during honey flow season.
- Attack of bee enemies increases and robbing activity of bees is also more. If colonies are not managed properly, they may even abscond. This tendency is more in *A. cerana* and little in *A. mellifera*. Manage the colonies as described below:
- Provide the bee colonies with shade by shifting to shady areas or placing them under open straw huts Provide proper ventilation by slightly raising the brood chamber or the super such that bees do not pass through this ventilation.
- Otherwise robbing may be induced Close all cracks and crevices in the hive so as to prevent entry of the enemies and robbers.
- Ensure that colonies do not remain brood less for longer duration.
- Provide sufficient food stores if the colonies have been stripped heavily of their honey stores during honey extraction Do not examine the colonies very frequently Restrict the number of frames as per colony strength.
- Remove extra frames and store these safely for later use In areas where summer temperature rises above 40Oc, gunny bags or straw packs moistened twice a day with water should be spread over the top covers of the colonies Provide a source of fresh water as honeybees maintain their hive temperature during summer by collecting water from outside source, spilling it inside hive and evaporating it by fanning.
- This can easily be arranged in an apiary by hanging an earthen pitcher filled with water having a hole at its bottom, provided with a wick and allowing drops of water to fall on sloping stones or log of wood.

3. MONSOON AND AUTUMN MANAGEMENT

Monsoon management:

- In the tropical and sub- tropical regions of the country, June to September represents the monsoon or wet season. Bees face several problems of pests, predators, excessive humidity and starvation. Sometimes due to continuous rains, bees are confined to their hives for a long period. Honey bees become lethargic and may develop dysentery. The colonies need following management to keep them strong:
- Weak colonies which have become queenless, should be united with queen right colonies, since during this period due to absence of drones new virgin queen can not mate
- Avoid broodlessness in colonies; if pollen stores and fresh pollen is not available, feed
- the colonies either pollen substitute or pollen supplement
- If colonies have poor food stores (below 5kg) provide sugar in the form of candy or dry sugar instead of sugar syrup
- Keep in check the attack of enemies like wax moth, ants, mites and wasps.
- The hives are kept on stands sloping towards entrance in order to drain out water and prevent its accumulation inside the hive.

Autumn/fall management:

Management practices during this period depend on the climatic and floral conditions where bees are kept. In some parts of Himachal Pradesh, there is a second honey flow season in autumn. The colonies in such places are managed as described earlier for availing honey flow. Near the end of honey flow, reduce the hive space to the needs of colony for winter. Restrict the food storage space to the lower hive body so that bees are forced to store their winter stores there instead of super. During this period many colonies make preparation for

superseding old queens and raise few queen cells and this is natural replacement of failing queen in a colony. The new queen on emergence kills the old queen.

For successful overwintering, which is the non-productive season, following management should be done.

- Ensure that the colony has vigorous and productive queen.
- An ideal queen is one whose egg laying rate is high and continues to lay well till late fall and thus provides population of predominantly young bees in sufficient number for wintering Colonies below average population or having scattered or less brood than the average colonies indicate failure of queens.
- Replace queens of such colonies by early fall so that these colonies produce desirable number of young bees Colonies for wintering should be free from disease Reduce the comb space by removing extra frames to such a level which can be covered by the bees well Under moderate climatic conditions, colonies of bees on 3-5 frames can winter successfully, if the colonies have proper food stores.
- Unite the weak colonies with colonies of average bee strength If colonies have less honey stores, feed them with heavy sugar which is prepared by dissolving 2 parts of sugar in one part of boiling water and to avoid crystallization add 1 table spoon full of tartaric acid to each of 50kg of sugar.
- Fill this syrup in combs and exchange for empty combs in the hive.

Precaution:

- Sugar should be fed while outside temperature is sufficient for bees to take syrup and store in combs after reducing its moisture.
- To avoid robbing, feeding should be done only in the evening.

Lecture No. 4
Bee Hives and their description, Bee Pasturage, bee foraging, behavior and Communication

BEE HIVE:

Modern frame hives

Frame hives fitted with moveable frames on which the bees are persuaded to build their combs. They are usually composed of several boxes, one on top of the other, in which hives frame are suspended. The lower boxes (1-2) are used for holding the brood and the upper ones (1-2) are used for collection of honey, pollen and propolis.

The artificial comb was first introduced by Revd. L. L. Langstroth in 1851 in America. Langstroth hives use standardized sizes of hive bodied (rectangular boxes without tops or bottoms placed one on top of another) and internal frames to ensure that partes are interchangeable and that the frame s will remain relatively easy to remove ,inspect and replace without killing the bees. Langstroth hive bodies aer rectangular in shape and can be made from variety of materials that can be stacked to expand the usable space for the bees.Inside the boxes frames are hung in parallel .

Langstroth frames are thin rectangular structures made of wood or plastic and which have a wax or plastic foundation on which the bees draw out the comb. The frames hold the beeswax honeycomb formed by the bees. Yen frames side-to-side will fill the hive body and

leave the right amount of the bees space between each frame and between the end frames and the hive body.
Langstroth frames are often reinforced with wire making it possible to extract honey in centrifuges to spin the honey out of the comb. As a result the empty frames and comb can be returned to the beehive for use in the next season.

The modern Langstroth hive consist of the following parts

- **Hive Stand:** The upper hive components rests on this providing a landing board for the bees and helping to protect the bottom board
- **Bottom board:** This has an entrance for the bees to get into the hive.
- **Brood box:** it is the most bottom box of the hive and is where the queen bee lays her eggs.
- **Honey Supper:** Usually shorter than the brood box but is upper most-box (s) where honey is stored.
- **Frames and Foundation:** Wooden or plastic frames with wax or plastic sheets with honey comb impression where bees build wax honey combs.
- **Inner cover:** Provides separation from outer cover and can be used as a shelf for feeding or other purposes.
- **Outer Cover:** Provides weather protection for the hive.

Various Types of bee hives boxes are:

4. Lansgstoth box (American Hive) : 42.2 cm × 31.1 cm
5. Pant, Kanje and jeolokote no. 1 : 42.2 cm × 12.3 cm
6. Dadant box (Russian hive) : 47 cm × 28.6 cm
7. Thompson box : 30.5 cm × 15.2 cm

BEE PASTURAGE:

Honey bees collect nectar and pollen from flowering plants. Nectar is a sweet secretion from the floral and extra-floral nectarines of flowing and is the raw material for honey. Pollen is protein-rich food for the bees.

Bee Pasturage or bee forage

- The plants than yield nectar and pollen are collectively called bee flora, bee pasturage or bee forage.
- The period when a good number of plants providing nectar and pollen are available to bees is called honey flow period.
- If the nectar yield is copious from a good number of plants of a particular species, it is called major honey flow period.
- When the amount of nectar to be collected is small, it is called the dearth period.
- As nectar and pollen are basic raw material for beekeeping means managing honey bee colonies in such a way to obtain maximum colony population for honey production and pollination.

- Plants which are good source of nectar are tamarind, moringa, neem, Prosopis juliflora, soapnut tree, Glyricidia maculate, eucalyptus, Tribulus terrestris and pungam.
- Plants which are good source of pollen are sorghum, sweet potato, maize, tobacco, millets, coconut, roses, castor, pomegranate, and date palm.
- Plants which are good source of pollen and nectar are banana, peach, citrus, guava, apple, sunflower, pear, mango, and plum.
- **Foraging:** Collection of pollen and nectar by bees is called foraging**.**
- **Nectar foragers:** They collect nectar from flowers using lapping tougue and passes the nectar to hive bees. Hive bees repeatedly pass the nectar between pre oral cavity and tongue to ripen the honey later they drop the ripened honey into cells.
- **Pollen foragers:** They collect pollen by passing through different flowers pollen stiking to the body is removed by using pollen comb. Then it is packet using pollen press into corbicula or pollen basket. Then the pollen is dislodged by middle leg into cells. Pollen is mixed with honey and stored.
- **Floral fidelity:** A bee visits same species of plant for pollen and nectar collection until the source is exhausted. This is known as floral fidelity.

Qualities of honey bees which make them good pollinators

- Body is covered with hairs and has structural adaptation for carrying nectar and pollen
- Bees do case injury to the plants
- Adult and Larvae fed on nectar and pollen which is available in plenty.
- They are considered as super pollinators since they store pollen and nectar for future use
- No diapauses is observed and needs pollen through out the year.
- Body size and proboscis length is very much suitable for many crops
- Pollinate wide variety of crops
- Forage in extreme weather conditions also.

Effect of bee pollination on crops:

- It increases yield in terms of seed yield and fruit yield.
- It improves quality of fruits and seeds.
- Bee pollination increases oil content of seeds in sunflower.
- Bee pollination is must in some incompatible crops for seed set.
- Some plants such as figs, peas, seasonal flowers, chrysanthemum and many ornamental plants would produce no fruits unless pollinate by bees.

Crops benefited by bee pollination

Fruits crop: Almond, apple, apricot, peach, strawberry, citrus, litchi.

Vegetable crop: Cabbage, Cabbage, cauliflower, carrot, coriander, cucumber, melon, oninon, pumpkin, cardamom, radish, turnip

Oil seed crop: sunflower, safflower, niger, sesame, rapeseed, and mustard.

Forage crops: 27uxilia and clover.

Management of bees for pollination

- Place hives very near the fields
- Migrate colonies near field at 10% flowering
- Place colonies @3/ha for Italian bee and 5/ha for Indian bee
- The colonies should have 5 or 6 frames strength of bees, with sealed brood young mated queen
- Allow suffiecient space for pollen and honey storage

Behaviour and Communication of Honey Bee

A. Honey Bees Communicate Through Movement (Dance Language)

- Honey bee workers perform a series of movements, often referred to as the "waggle dance," to teach other workers the location of food sources more than 150 meters from the hive. Scout bees fly from the colony in search of pollen and nectar.
- If successful in finding good supplies of food, the scouts return to the hive and "dances" on the honeycomb.
- The honey bee first walks straight ahead, vigorously shaking its abdomen and producing a buzzing sound with the beat of its wings.
- The distance and speed of this movement communicates the distance of the foraging site to the others.
- Communicating direction becomes more complex, as the dancing bee aligns her body in the direction of the food, relative to the sun.
- The entire dance pattern is a figure-eight, with the bee repeating the straight portion of the movement each time it circles to the center again.
- Honey bees also use two variations of the waggle dance to direct others to food sources closer to home.
- The round dance, a series of narrow circular movements, alerts colony members to the presence of food within 50 meters of the hive.
- This dance only communicates the direction of the supply, not the distance.
- The sickle dance, a crescent-shaped pattern of moves, alerts workers to food supplies within 50-150 meters from the hive.
- The honey bee dance was observed and noted by Aristotle as early as 330 BC.
- Karl von Frisch, a professor of zoology in Munich, Germany, earned the Nobel Prize in 1973 for his groundbreaking research on this dance language.
- His book *The Dance Language and Orientation of Bees*, published in 1967, presents fifty years of research on honey bee communication.

B. Honey Bees Communicate Through Odor Cues (Pheromones)

- Odor cues also transmit important information to members of the honey bee colony. Pheromones produced by the queen control reproduction in the hive.
- She emits pheromones that keep female workers disinterested in mating and also uses pheromones to encourage male drones to mate with her.
- The queen bee produces a unique odor that tells the community she is alive and well.

- When a beekeeper introduces a new queen to a colony, she must keep the queen in a separate cage within the hive for several days, to familiarize the bees with her smell.
- Pheromones play a role in the defense of the hive as well.
- When a worker honey bee stings, it produces a pheromone that alerts her fellow workers to the threat.
- That's why a careless intruder may suffer numerous stings if a honey bee colony is disturbed.
- In addition to the waggle dance, honey bees use odor cues from food sources to transmit information to other bees.
- Some researchers believe the scout bees carry the unique smells of flowers they visit on their bodies, and that these odors must be present for the waggle dance to work.
- Using a robotic honey bee programmed to perform the waggle dance, scientists noticed the followers could fly the proper distance and direction, but were unable to identify the specific food source present there.
- When the floral odor was added to the robotic honey bee, other workers could locate the flowers.
- After performing the waggle dance, the scout bees may share some of the foraged food with the following workers, to communicate the quality of the food supply available at the location.

Lecture No. 5

Enemies- Insects pests and Diseases of honey bee and their Management

DISEASES OF HONEY BEE

1. **Acarine** disease is also known as ***Isle of wight***

First observed on the Isle of Wight in 1904

Causal organism: *Acarapis woodi*

Place of infection: Trachea and body fluid

Nature of damage: Mites live and reproduce in the trachea.

They pierce the tracheal tube walls and feed on the hemolymph of bees

Stage infected : Adult

Management:

- Use of grease patties placed on top bars of the hive Menthol allowed to vaporized from crystal form or mixed into the grease patties
- Use of resistant hybrid bee known as the Buckfast bee developed by Brother Adam at the Buckfast Abbey
- Cotton soaked in methyl salcilate and placed under the hive in flat perforated lid
- Destruction of effected colony.

2. Amoebic disease

Causal organism: *Malphigian gamoeba mellifera*

Place of infection: Malphigian tubules

Nature of damage: It causes dysentery. The cysted amoeba are passed out from intenstine with faeces and contaminate the healthy bees .

Stage infected: Adult
Management: Sterilization of brood box and frames with glacial acetic acid or 40% formalin

3. Nosema disease
Causal organism: *Nosema apis*
Place of infection: Stomach
Nature of damage: It invades the intenstinal tracts of adult bees and causes nosemosis and dysentery
Stage infected: Adult
Management:

- Increase the ventilation through the hives and treating a hive with antibiotics.
- Removing much of the honey from the beehive then feeding the bees on sugar water.
- Sterilization of brood box and frames with glacial acetic acid or 40% formalin.

4. American foul brood
Causal organism: *Paenibacillus larvae*
Place of infection: Gut
Nature of damage : Infected larvae normally die after their cell is sealed. Turn dark brown and later changes into sticky mass producing foul smell
Stage infected: Larvae
Management:

- Hive to be burned completely.
- Use of antibiotics such as oxytetracycline hydrochloride and tylosin tartrate.
- Dusting the combs with sulphathiazole powder.
- Dipping the hive parts in hot paraffin wax or a 3% sodium hypochlorite solution(bleach).

5. European foul brood
Causal organism: *Melissococcus plutonus Baccilus pluton*
Place of infection: Mid-gut
Nature of damage:
The diseased larvae turns yellow and then brown and the tracheal system becomes visible. Larvae dies in a coiled stage causing foul smell. Cells are poorly capped and mixed with normal cells.
Stage infected: Larvae
Management: use of oxytetracycline hydrochloride. The „Shook Swarm technique of bee husbandry can also be used to effectively control the disease

6. Chalk brood

Causal organism: *Ascosphaera apis*
Place of infection: Gut
Nature of damage: The fungus will consume the rest of the larva‟s body, causing it to appear white and „chalky‟
Stage infected:Larvae
Management: Prevelent during wet springs transfer of healthy bees into another bee hive Increasing the ventilation through the hive

7. Stone brood
Causal organism: *Aspergillus fumigatus A. flavus A. niger*
Place of infection: Alimentary canal
Nature of damage: Dead larvae turn black and become difficult to crush, hence the name stone brood. Fungus erupts from the integument of larva and forms a false skin and larvae are covered with powdery fungal spores
Stage infected: Larvae and adults
Management: Sterilization of the hive with formaldehyde fumes

IMPORTANT PESTS OF HONEY BEE
1. **Death's hawk moth**
Scientific name: *Acherontia styx*
Nature of damage: Enters the bee hive at night and drinks up honey
Management: The moths are thrown out by strong colony

2. Greater wax moth
Scientific name: *Galleria mellonella*
Nature of damage: The caterpillars make tunnels through near the midrib of comb during stress
Management:

- It will not attack the bees directly but feed on wax.
- Use of para dichlorobenzene.
- Simplest way is prevent wax moth getting into the hive through gaps and space.
- Use of traps to draw the moths away from the hive area.
- Wax moth larvae and eggs are killed by freezing for 24 hours.
- Wax moths can be controlled in stored comb by application of the aizawai variety of Bt spores by spraying.

3. Lesser wax moth
Scientific name: *Achroia grisella*
Nature of damage: The caterpillars make tunnels through near the midrib of a comb

Management:

- Lesser wax moths need warm climates to thrive hence, freezing beeswax combs reduces moth infection.
- Fumigation paradichlorobenzene when combs are not filled with honey.
- Fumigation with CO_2 for combs that are filled with honey.

4. Predatory wasps

Scientific name: *Vespa orientalis V. magnifera*

Nature of damage: Prey on bees. The wasps macerate the bees and feed their larvae.

Management: Destruction wasps nests by burning or with insecticides

5. Ants

Scientific name: *Dorylus labiatus*

Nature of damage: Take away honey and brood. Weaken and destroy the bee colony

Management: Destruction of ants nests by fumigation or with insecticides. Treating the legs of the apiaries with a repellent

6. **African small hive beetle**

Scientific name: *Aethina tumida*

Nature of damage: It lives in beehives. Comb slimed by hive beetle larvae and drive out bee colonies

Management:

- Use of para dichlorobenzene.
- Use of benzene inside the corrugations of a piece of cardboard.
- Use of cooking-oil-based bottom board traps.

Lecture No. 6

Sericulture: Related terminologies, History and development of Silkworms in India, Types of silkworms, Voltinism and biology of silkworms.

<u>Related Terminologies</u>

Sericulture:

"Sericulture is the rearing of silkworms for the production of raw silk".

Moriculture:

"Cultivation of Mulberry plants are called **moriculture"**.

Cocoon : A protective covering made by the larvae of insects belonging to the group of moths and butterflies.

Dupion : An irregular, rough silk reeled from double cocoons.

Green Cocoon : Freshly harvested cocoons with live pupa inside.

Inherited Genetic : Characters transmitted from the parents to offspring.

Character Integument : Hard outermost layer of the insect body.
Metamorphosis : Complete change of morphology during the life cycle of the insects.
Mountage : A device used for support of making cocoons by the silkworm larvae.
Raw silk : Fibre made with combination of filaments from several cocoons.
Reelers : People who convert cocoons into silk yarn.
Urination : Silkworm larvae excrete water before formation of cocoon is called urination.

History and development of Silkworms in India

- Sericulture, or silk production, from the moth, Bombyx mori (L.), has a long and colorful history unknown to most people.
- Although there are several commercial species of silkworms, B. mori is the most widely used and intensively studied, and techniques for its rearing are the most improved.
- This insect is the sole living species in its family, Bombycidae, and has been domesticated for so long that it probably no longer survives in the wild.
- World silk production has approximately doubled during the last 30 years in spite of man-made fibers replacing silk for some uses.
- China and Japan during this period have been the two main producers, together manufacturing more than 50% of the world production each year.
- China during the late 1970"s drastically increased its silk production and became the world"s leading producer of silk.
- The 1970"s were a period of tumultuous political and social upheaval in China, resulting in various economic reforms.
- Undoubtedly, these reforms are partially responsible for China"s increased silk production. Thus the country that first developed sericulture approximately 4,700 years ago has again become the world"s main producer of silk.
- China, India ans South Korea are the major silk exporting countries, while exports from Japan have declined over the years.

Types of Silkworms:

There are five major types of silk of commercial importance, obtained from different species of silkworms which in turn feed on a number of food plants: Except mulberry, other varieties of silks are generally termed as non-mulberry silks. India has the unique distinction of producing all these commercial varieties of silk.

1. Mulberry:

- The bulk of the commercial silk produced in the world comes from this variety and often silk generally refers to mulberry silk.
- Mulberry silk comes from the silkworm, *Bombyx mori* L. which solely feeds on the leaves of mulberry plant.
- These silkworms are completely domesticated and reared indoors.
- In India, the major mulberry silk producing states are Karnataka, Andhra Pradesh, West Bengal, Tamil Nadu and Jammu & Kashmir which together accounts for 92 % of country"s total mulberry raw silk production

2. Tasar:

- Tasar (Tussah) is copperish colour, coarse silk mainly used for furnishings and interiors.

- It is less lustrous than mulberry silk, but has its own feel and appeal.
- Tasar silk is generated by the silkworm, *Antheraea mylitta* which mainly thrive on the food plants Asan and Arjun.
- The rearings are conducted in nature on the trees in the open.
- In India, tasar silk is mainly produced in the states of Jharkhand, Chattisgarh and Orissa, besides Maharashtra, West Bengal and Andhra Pradesh.
- Tasar culture is the main stay for many a tribal community in India.

3. Oak Tasar

- It is a finer variety of tasar generated by the silkworm, *Antheraea proyeli* J.
- In India which feed on natural food plants of oak, found in abundance in the sub-Himalayan belt of India covering the states of Manipur, Himachal Pradesh, Uttar Pradesh, Assam, Meghalaya and Jammu & Kashmir.
- China is the major producer of oak tasar in the world and this comes from another silkworm which is known as *Antheraea pernyi*.

4. Eri:

- Also known as Endi or Errandi, Eri is a multivoltine silk spun from open-ended cocoons, unlike other varieties of silk.
- Eri silk is the product of the domesticated silkworm, *Philosamia ricini* that feeds mainly on castor leaves.
- Ericulture is a household activity practiced mainly for protein rich pupae, a delicacy for the tribal.
- Resultantly, the eri cocoons are open-mouthed and are spun.
- The silk is used indigenously for preparation of *chaddars* (wraps) for own use by these tribals.
- In India, this culture is practiced mainly in the north-eastern states and Assam.
- It is also found in Bihar, West Bengal and Orissa

5. Muga:

- This golden yellow colour silk is prerogative of India and the pride of Assam state.
- It is obtained from semi-domesticated multivoltine silkworm, *Antheraea assamensis*.
- These silkworms feed on the aromatic leaves of Som and Soalu plants and are reared on trees similar to that of tasar.
- Muga culture is specific to the state of Assam and an integral part of the tradition and culture of that state.
- The muga silk, an high value product is used in products like sarees, mekhalas, chaddars, etc.

➢ **Voltinism and Biology of Silkworm: Silkworm breeds are mainly two types:**

1. Biovoltanes

- Biovoltanes silkworm go through alternating lifecycle of hibernating and non hibernating eggs and complete ony two lifecycle in ayear.

- The silk obtained from biovoltines is superior with high silk content and possess longer filament length, higher neatness, cleanness, less size deviation low boil-off ratio, higher tensile strength and less variation in evenness.
- Culturing bivotine races is therefore more profitable and generally done by sericulturists.
- Bivotines races such as Kalimpong, KA, NB7, NB4D2, NB18 are commonly reared in India.
- Five bioltine breeds namely SK3, SK4, SK6, SK7, and YB have been registered in Tamilnadu.

2. Multivoltines

- Multivoltins races of silkworms are of great importance since they complete 5-6 lifecycles in year and develop non-hiberation eggs.
- Multivoltines cocoons are hard however , their yield is poor in comparison to biovoltines.
- Mysore multivoltines race is reared in Karnataka, Tamilnadu, Andhrapradesh, Nistari multivoltines race is reared in West Bengal.
- Nowadays, hybrids of multivoltines and biovoltines breeds are piopular in India and other silk producing country.
- Females of Mysore race and males of biovoltine KA, NB4D2 are hybridized.

Biology of Silkworm:

There are three main stages:

1. Egg

- Eggs are laid in the night in clusters on the under surface of mulberry leaves.
- A female lays about 300-400 eggs popularly called as silk seeds.
- The eggs are small, pale white and seed like in appearance.
- At the time of hatching they become black and hatch in 10-12 days during summer and 30 days during winter.
- In the univoltine race, the eggs do not hatch during winter but remain in hibernation, therefore, one generation is found in year in such case.
- Such type of race found in European countries and Kashmir and Punjab in India.
- Contrary to this, 2-7 generation are found in multivoltine races.

2. Larva

- The caterpillar on hatching is white to dark in colour and about 3 mm in length.
- There are three pairs of thoracic and 5 pairs of abdominal legs which are situated on the 3,4,5,6 and 10 the abdominal segments.
- Young caterpillar are reared in trays on tender mulberry leaves at 25-270C.
- Each day, the feed is provided 3-4 times with small quantity of leaves after 5 th day when they become big, a net of small mesh in placed over them and succulent leaves are put on the net.
- The larvae on getting the fod crawl above through the meshes of the net.
- The larva moults 4-5 times after every 6-7 days and become mature in 30-35 days.
- The full grown caterpillar is creamy white in colour and about 75 mm long.

3. Pupa (Cocoon)

- The cocoon is 38 mm in length and 19 mm in breath, oval in shaped and white or yellow in colour.
- The larva pupates inside the cocoon which is made up of a single thread.
- It spins about 15 mm thread in an hour.
- The pupa inside the cocoon is reddish-brown in colour and measures 25 mm * 7 mm.
- The pupal period lasts for 10-15 days.
- At the time of emergence of adult, it secrestes an alkaline fluid which piperces the cocoon and it comes out.
- It has been estimated that about 40-50 thousand caterpillar hatch out of 28 g of silk seed and they requires about 337 to 406 kg of leaves during their development.
- The weight in grams of 900 m ling silk filament is called a „denier" and the size of a normal cocoon is 1.8 to 3 deniers.
- A single cocoon weights is 1.8 to 2 gm and its shell, only 0.45 g. About 2500 cocoons yield 1 lb (0.45 kg) of silk.

Lecture No. 7
Mulberry Cultivation, crop varieties, method of harvesting and preservation of mulberry leaves

MULBERRY CULTIVATION:

Mulberry (*Morus* spp., Moraceae)

The important character of the members of the family Moraceae (especially *Morus* spp.) is the presence of idioblast, an enlarged epidermal cell in the leaf.

Ecological requirements

Climate

- Mulberry can be grown upto 800 m MSL.
- For the optimum growth of mulberry and good sprouting of the buds, the mean atmospheric temperature should be in the range of 13Oc to 37.7Oc.
- The ideal temperature should be between 24 and 28Oc with relative humidity of 65 to 80 percent and sun shine duration of 5 to 12 hours per day
- Mulberry can be grown in a rainfall range of 600mm to 2500mm. Under low rainfall conditions, the growth is limited and requires supplemental irrigation. On an average, 50mm once in 10 days is considered ideal for mulberry.

Soil

Slightly acidic soils (6.2 to 6.8 Ph) free from injurious salts are ideal for good growth of mulberry plant. Saline and alkaline soils are not preferred.

Mulberry varieties

Irrigated	:	Kanva 2, MR 2, S 30, S 36, S 54, DD (Viswa), V1
Semi irrigated	:	Kanva 2, MR 2
Rainfed	:	S 13, S 34, RFS 135, RFS 175, S 1635

Propagation of mulberry

- Mulberry is mostly propagated through cuttings.

- Cuttings may be planted straight away in the main field itself or nursery may be raised and the sprouted and rooted saplings may be planted in the main field.
- The latter method is advisable because of its easy establishment in the main field.

Selection of planting material

- Generally, the mulberry plants are raised from semi-hardwood cuttings.
- Cuttings are selected from well established garden of 8-12 months old.
- Only full grown thick main stems, free from insect and disease damages having a diameter of 10-12mm are chosen for preparation of cuttings.
- The cuttings should be of 15-20 cm with 3-4 active buds and should have 45o slanting cut at the bottom end.
- Care should be taken to make a sharp clean cut at both the ends of cuttings without splitting the bark.
- Manually/power operated mulberry cutter (stem cutting machine) is available for quick cutting of propagation material.

Nursery

Nursery bed preparation

- Select 800 sq.m. area of red loamy soil near water source for raising saplings for planting one hectare of main field.
- Apply 1600 kg of Farm Yard Manure (FYM) @ 20 t/ha and mix well with the soil.
- Raise nursery beds of 4m x 1.5m size.
- The length may be of convenient size depending upon the slope, irrigation source, etc.
- Provide a drainage channel and avoid shady area.

Pre-treatment of cuttings

- Mix one kilogram of *Azospirillum* culture in 40 liters of water.
- Keep the bottom end of the cuttings for 30 minutes in it before planting. *Azospirillum* is applied for inducement of early rooting.

Nursery planting

- Apply VAM @ 100 g/m2 of nursery area.
- Irrigate the nursery bed. Plant the cuttings in the nursery at 15 cm x 7 cm spacing at an angle of 45o.
- Ensure exposure of one active bud in each cutting.

Nursery management

- Irrigate the nursery once in three days.
- Dust one kg of any one of the following chemicals around the nursery bed to avoid termite attack.

1.malathion 5D
2.quinalphos 1.5D

To avoid root rot and collar rot, drench the soil with carbendazim 50 WP (2 g/l) or apply *Trichoderma viride* 0.5 g/m2 using rose can.

After weeding, apply 100 g of urea/m2 between 55 and 60 days after planting at the time of weeding.

Age of sapling

- The saplings are ready for transplanting in the main field after 90-120 days of planting.

Planting methods

Paired row system : Plant the cuttings/saplings at a spacing of 75 / 105 cm x 90 cm. Raise intercrops in the wider inter row space (amenable for mechanization also).

Planting method	**Spacing (cm)**	
	Irrigated	**Rainfed**
Ridges and furrows	60 x 60 / 90x90	90 x 90
Pit system	90 x 90	90 x 90

No. of cuttings / ha. - 27,780 (60 x 60 cm) ; 12,345 (90 x 90 cm)

Time of planting

- Plant during rainy season
- Avoid planting during winter and summer months

Planting of saplings

Plant the well rooted and sprouted saplings at a depth of 15-20 cm

- Earth up and level the area around the saplings
- Gap fill during monsoon months.

Nutrient management

c) **Irrigated / semi irrigated** (kg/ha)

	Row system			**Pit system**		
	N	**P**	**K**	**N**	**P**	**K**
Recommendation	300	120	120	280	120	120
Split doses						
First crop	60	60	60	60	60	60
Second crop	60	-	-	40	-	-
Third crop	60	60	60	40	-	-
Fourth crop	60	-	-	60	60	60
Fifth crop	60	-	-	40	-	-
Sixth crop	-	-	-	40	-	-

- For V1, fertilizer schedule is 375 : 140 : 140 kg NPK/ha.
- Apply fertilizers as per soil recommendation wherever possible
- Apply the first dose of fertilizers three months after planting
- Follow subsequent fertilizer application after each leaf harvest and pruning
- Apply straight fertilizers to minimize the cost

b) Rainfed (Kg/ha)

	N	**P**	**K**
Recommendation	100	50	50
First dose	50	50	50
Second dose	50	-	-

- Apply the first and second doses coinciding with South West and North East monsoons respectively.

Bio-fertilizers

- Apply *Azospirillum* @ 20 kg/ha in five split doses. Apply phosphobacterium @ 10 kg/h in two equal splits.
- Mix the bio-fertilizers with 50 kg of FYM for uniform distribution
- Ensure irrigation after application
- Do not mix bio-fertilizers with inorganic fertilizers
- Growing and insitu incorporation of sunnhemp.

Micro nutrients

- Apply recommended major/secondary nutrients based on the deficiency symptoms.
- For micro nutrients according to the deficiency symptom expressed, apply micronutrients as foliar spary @ Zinc sulphate 5 g, Ferrous sulphate 10 g, Borax 2.5 g, Copper sulphate 2.5 g, Manganese 2.5 g or Sodium molybdate 100 mg/lit of water using high volume sprayer (spray fluid 500 lit/ha).
- Add wetting agent, Teepol @ 0.5 ml/lit. for better adherence on the foliage.

Methods of Irrigation

Ridges and furrows method

- Most efficient method of irrigation
- Comparatively requires less amount of water
- The furrows serve as drainage channels during heavy rainfall.

Flat bed method

- Rectangular beds and channels are formed
- Water run off is relatively low
- More land is wasted and requires more labour for field preparation.

Drip Irrigation

- Most efficient in water use
- Substantial saving in irrigation water
- Better crop growth
- Suitable for undulating terrains
- Fertilizers can also be applied along with irrigation water
- Clogging of emitters by physical, chemical and biological impurities
- Initial cost is very high

Integrated Weed Management

Cultural method

- Remove the stubbles and roots of weeds while preparing the land
- Use well decomposed manure to avoid dissemination of weeds
- Clean the implements before use

Mechanical method

- Operate country plough after pruning in the interspace
- Remove the weeds by hand hoe

Chemical method

- As post-emergence application, use Paraquat (Grammoxone) @ 2-3 lit/ha.
- Spray Glycel 7.5 ml with 10 grams of ammonium sulphate per litre of water as post-emergence application. A total of 600 litres of spray fluid is required/ha.
- Use flooding / deflector / fan type nozzle for spraying weedicide. Apply the weedicide immediately after pruning or within 2-3 days after pruning.

Mulching

Mulching with pruned mulberry twigs and other materials like straw and dried leaves will have the following advantages

- Controls weed growth
- Conserves soil moisture by reducing run-off
- Increases the infiltration of water
- Reduces the soil temperature

Harvesting

The method of leaf harvest depends on the type of rearing practiced. It is preferable to harvest the leaves during morning hours. There are three methods of harvesting of mulberry leaves

Leaf picking

Individual leaves are harvested with or without petiole. Leaf picking starts 10 weeks after bottom pruning and subsequent pickings are done at an interval of 7 – 8 weeks.

Branch cutting

The entire branches are cut and fed to the worms. Before that, topping is done to ensure uniform maturity of the lower leaves.

Whole shoot harvest

The branches are cut at ground level by bottom pruning. Shoots are harvested at an interval of 10-12 weeks and thus 5 to 6 harvests are made in a year.

Time of harvest

It is preferable to harvest the leaves during morning hours.

Preservation of leaves

Use leaf preservation chamber or wet gunny bags to store the leaves or cover the bamboo basket with wet gunny bags to keep it cool and fresh.

Lecture No. 8
Rearing house and rearing appliances of mulberry silkworm, methods of disinfection and mulberry leaves

Rearing House

- A separate house is ideal for rearing of silkworm
- The rearing house should have sufficient number of windows to permit cross ventilation.
- Provision should be made to make it air tight for proper disinfection.
- Rearing house has to be built in such a way to provide optimum temperature of 26-28º c and RH of 60-70% for the growth of silkworm at minimum operational cost

Important principles

The most important principles to be remembered in silkworm rearing house are :

1. Avoid

Damp condition
Stagnation of air
Direct and strong drift of air

Exposure to bright sun light and radiation

2. Ensure

An equable temperature and humidity

Good ventilation.

Features:

- Rearing house should be built depending on the brusing capacity and the method of rearing.
- The rearing area of 2 sq.ft/ dfl for floor rearing and 3 sq. ft/ dfl for shoot rearing is the general criteria.
- Rearing house should have a main rearing hall, an ante room (8 x 8 ft) and leaf preservation room.
- Maintaining a separate chawki room (a must for two- plot rearing system; rearing room of size 10″ x 14″ with a height of 9-10 ft for an acre of garden) ideal.
- Rearing house should face east-west direction.
- Rearing houose should have facilities to maintain the required environmental conditions.
- Growing trees around rearing house helps to maintain favourable environment
- Rearing house should be constructed taking consideration he following points such as effective is disinfection, washable floor, etc.
- 480 sq.ft area is required for rearing 100 dfls.

Preparation of rearing house

- Rearing room is to be kept ready after disinfection atleast 3-4 days in advance of commencement of rearing.
- Preconditioning of the rearing house is essential *ie,* arrangement of rearing appliances and provision of essential environmental conditions one day in advance.

Preparation for brushing

- Before commencement of each rearing, the rearing equipments and rearing houses must be thoroughly washed and disinfected with chlorine dioxide.
- Chlorine dioxide is sprayed on equipments, walls, roof and floor uniformly to destroy the disease causing organisms.
- The rooms should be kept closed for about 24 hours after disinfection.
- The doors and windows should be kept open at least for 24 hours before commencement of rearing to avoid traces of disinfectants.
- To disinfect rearing room and rearing appliances, chlorine dioxide can be used. 500 ml of chloride dioxide is mixed with 50 g of activator and this is dissolved in 20 litres of water. To this, 100 g of lime powder has to be mixed.

Rearing appliances

Non recurring (General)

- Disinfection mask and protective gum shes
- Sprayer for disinfection
- Room heater
- Water air cooler
- Kerosene blow lap
- Wet and dry thermometer
- 6” forceps

Non-recurring (specific)

Egg transportation box	Leaf chopping board	Shoot rearing rack
Egg incubation chamber	Leaf chopping knife	Chandrike
Loose egg incubation frame	Leaf mat	Plastic basin
Black box	Bed cleaning nets	Buckets
Chawki rearing trays	Earthen pot	Mug
Rearing bottom stand	Litter basket	Plastic box
Feeding Stand	Late age rearing trays	Foam pads
Ant wells	Rearing stand	Foot rugs
Leaf chamber for late age	Leaf basket	Cleaning nets

Recurring

- Paraffin paper
- Formalin
- Bleaching powder
- Lime powder
- Bed disinfectants
- Slides and cover slips
- Gunny cloth
- Cora cloth

DISINFECTION

- Spray 2 % formalin with 0.3% slaked lime or 2.5 % chlorine dioxide with 0.5 % slaked lime @ 2 l/m2 area for disinfecting the rearing house immediately after completion of rearing and three days before brushing.
- Dip the rearing equipments in 2 % bleaching powder solution and sun dry before use.
- Dust 5% bleaching powder with slaked lime powder @ 200 g/m2 around the rearing house and passages and sprinkle water @ 1 lit / m2 floor area.

Incubation of egg and hatching

- The egg sheets should be spread out as a single layer in a chawki tray.
- Temperature of 25Oc and humidity of 80 per cent are maintained. For this, paraffin papers and wet foam pads may be used.
- When the eggs come to head pigmentation stage (about 48 hours before hatching), they should be kept in dark condition by wrapping them in black paper or by keeping them in a box (black boxing). On the expected day of hatching, eggs are exposed to light, early in the morning to ensure uniform hatching. This facilitates uniform development of embryo.
- Most of the eggs (90 to 95 per cent) will hatch in about 2 to 3 hours.

Low cost method of preservation of eggs

- The eggs can be kept in an earthen incubation chamber.
- Draw the diagram and observe how humidity is maintained in the chamber.

Brushing

- The hatched larvae should not be starved and they must be brushed on a paraffin paper in a rearing tray or blue polythene sheet (Rearing bed).
- This is done by sprinkling chopped tender mulberry leaves of size 0.5 to 1 cm2 over the hatched larvae. The larvae crawl on to the leaves.

- After 8 to 10 minutes, the egg sheet is inverted over rearing tray and gently tapped.
- Worms that are still attached to the egg sheets should be gently removed to the tray with a feather.
- A rearing bed is prepared and some more chopped leaves, if necessary, are sprinkled.
- To prevent drying of leaves and to maintain the required humidity in the rearing bed, wet foam pads and paraffin paper covering are provided.

Lecture No. 9
Silkworm Rearing, mounting, harvesting and marketing of cocoons.

YOUNG AGE SILKWORM (CHAWKI) REARING

Selection of leaves

- From brushing to the end of second age, the larvae are fed with tender leaves.
- The leaves are selected from the largest glossy leaf, 3rd or 4th from the top.
- The next 6 to 8 leaves are used to rear the young age worms upto II moult.
- The size of the chopped leaf is around 0.5 to 1.0 sq.cm. during 2nd age.
- Illustrate with the help of a figure, the selection of leaves from a fully grown branch.

Leaf preservation

- Silkworm grows best when fed with succulent leaves which are rich in nutrients and moisture.
- The leaves, if not preserved properly, dry up and become unsuitable for feeding.
- The harvested leaves must be preserved in fresh condition in a wet gunny cloth.
- If the climate is too hot and dry, the leaves are preserved in a leaf chamber which is lined with gunny cloth.
- The cloth is kept wet by spraying water at frequent intervals.

Cleaning

- It is the process of removing the silkworm excreta and left over leaves in the rearing bed
- In the first age, one cleaning is given just a day before the worms settle for moulting.
- In the second age, two cleanings are given, one after resuming feeding and the other before second moult.
- A net with mesh size of 0.5 x 0.5 cm is spread over the rearing bed and feeding is given.
- The worms crawl through the net and come to fresh leaves.
- The net along with the worms and leaves are transferred to another tray.
- The left over leaves and litter are discarded.

Moulting

- At the time of moulting, care should be taken not to disturb the worms.
- Correct detection of moult and stopping or resuming feeds are very important for uniform growth of silkworms.

During moult, the rearing bed should be kept thin and dry by applying lime @ 30 – 50 g/m2 and should have proper aeration.

LATE AGE SILKWORM REARING

- The third, fourth and fifth instar larvae are considered as late age worms. They are reared in bamboo trays. Newspapers are spread over the trays to absorb excess moisture in leaves and faecal pellets.

- The temperature and humidity requirement gradually comes down as the stage advances.
- Leaves of medium maturity (6^{th} leaf onwards) are fed in the third and fourth age and coarse leaves are fed in the fifth age.
- Over matured and yellow leaves should be rejected, since they may induce disease outbreak.
- **Bed disinfectants**
  Apply bed disinfectants like TNAU Seridust, Resham Jyothi, Vijetha or Sajeevini @ 4 kgs/100 dfls.

Stage (before feeding)	**Bed disinfectant (Qty/100 dfls) (g)**
After 1^{st} moult	50
After 2^{nd} moult	150
After 3^{rd} moult	800
After 4^{th} moult	1000
On fourth day of final instar	2000
Total	**4000**

Moulting

- Remove the paraffin papers
- Evenly spread the larvae in the rearing bed 6-8 h before settling for moult.
- Provide air circulation to avoid excess humidity inside the room.
- Provide charcoal stove/heaters to raise the room temperature during winter.
- Apply lime powder at 60 minutes before resumption of feeding daily during rainy/winter seasons to reduce the dampness in bamboo trays.

Mounting

- Apply Sampoorna @ 20 ml (dissolved in 4 l of water) per 100 dfls over the leaves for early and uniform spinning of cocoons.
- After attaining full growth in the final instar, the worms cease to feed and are ready to spin.
- Such worms are slightly translucent and raise their heads to find a place for spinning.
- These worms have to be picked up and transferred to a mountage for spinning cocoons.
- Mounting of worms should not be delayed as the ripened worms will waste silk.
- About 800-900 worms per m2 are to be kept on a mountage. For 100 dfls, about 30 to 40 chandrakis are required.
- Mountages should be kept under shade in well ventilated place.

Care during spinning

- Quality of silk depends on the care taken at the time of spinning.
- Mature worms are sensitive to temperature, humidity, light, etc., at the time of spinning.
- The ripe worm requires space equal in area to square of the length of its body for spinning.
- Proper spacing avoids wastage of silk for forming preliminary web and avoids double cocoons.
- To prevent staining of cocoons, keep mountage in an inclined position so that the urine may drop to the ground.

Maintenance of humidity

- Fluctuation of humidity causes abrupt thinning and thickening of silk filament.
- A relative humidity of 60-70% is ideal for spinning.
- Provide proper ventilation and straw mats below the mountage to quid excreta.
- Provide even and moderate lighting. Improper lighting (bright light or dark shadow) causes crowding of larvae to shaded area leading to double cocoons.
- Remove dead worms and non-spinners on the 2nd day of spinning.
- To protect the silkworm from predatory ants, apply malathion 5% dust/lakshman rekha at the base of mountage stand.

Harvesting

- The silk worms complete spinning in 2 to 3 days but the cocoons should not be harvested at this time as the worms inside are still in the prepupal stage.
- Harvesting should be done on the fifth day (7th day for bivoltine hybrids) when pupae are fully formed and hard.
- Do not harvest when the pupa is in amber colour.
- Dead and diseased worms on the mountages should be removed before harvest.
- Marketing of cocoons should be done on the sixth day (8th day for bivoltine hybrids).

Shoot rearing for late age worms

Silkworm larvae consume 85% of their food requirement during fifth instar. Fifty per cent of the labour input is utilized during the last seven days of rearing.

Rearing house

- Provide separate rearing house for shoot rearing in shady areas. Separate room should be provided for young age worm rearing, leaf storing and hall for late age worm rearing.

Shoot rearing rack

- A rearing rack of 1.2m x 11m size is sufficient to rear 50 dfls.
- Provide 15 cm border on all sides of the shelf to prevent the migration of the larvae.
- Arrange the shelves in three tier system with 50 cm space between the tiers.
- Fabricate the rack stand with wood, or steel and the rearing seat with wire mesh/bamboo mat.

Shoot harvesting

- Harvest the shoots at 1 m height from ground level at 60 to 70 days after pruning.
- Store the shoots vertically upwards in dark cooler room.
- Provide thin layer of water (3 cm) in one corner of storage room and place the cut of shoots in the water for moisture retention.

Feeding

- Provide a layer of newspaper in rearing shelf.
- Disinfect the bed, spread the shoot in perpendicular to width of the bed.
- Place top and bottom ends of the shoots alternatively to ensure equal mixing of different qualities of leaves.
- Transfer the third instar larvae to shoots immediately after moulting.
- Watch for feeding rate from 4th day of fourth instar. If 90% of larvae have not settled for moulting, provide one or two extra feedings.
- Provide 3 feedings during rainy/winter months and 4 feedings during summer rearing.

Spacing

- 18-36 m2/100 dfls.

Bed cleaning

- Bed cleaning is done once during second day of fifth instar following rope (or) net method.
- In rope method, spread 2 m length of rope (two numbers) at parallel row leaving 0.5m on other side.
- After 2 to 3 feedings, ends of the ropes are pulled to the centre to make it into a bundle.
- In net cleaning method, spread 1.5 cm2 size net across the bed.
- After 2 or 3 feedings, the nets are lifted and the old bed is cleaned and disinfected.
- Transfer the net to newer shelf, spread the net over the shoots; larvae will migrate to lower layer.

Advantages

1. Labour saving upto 70% when compared on hour to hour basis with leaf feeding method.
2. Leaf saving upto 15-20%. Hence, leaf cocoon ratio is less by 2-3 kg and extra cocoon production.
3. Better cocoon characters and effective rate of rearing (ERR).
4. Better preservation of leaf quality both during storing and on the bed.
5. More organic matter production (upto 18 tonnes per ha per year).
6. Better hygienic conditions can be maintained.
7. Handling of silkworms 45uxiliary. Hence, contamination and spreading of disease reduced.
8. Bed cleaning only once after IV moult.
9. Worms and leaves are kept away from the litter.
10. Hence, chances of secondary contamination are 45uxiliary.
11. Labour dependent risk is reduced.

Disadvantages

1. Required rearing room floor area is more (by 30%)
2. Bed refusals will not be available as a cattle feed.
3. Planting materials (cuttings) will not be available.

MARKETING OF COCOONS:

- In sericulture we are usually having two types of cocoon market:-

1. Seed cocoon market
2. Commercial cocoon market
    a) Dry cocoon market
    b) Green cocoon market

1. SEED COCOON MARKET

- It takes usually in commercial grainages where hybrid seeds are produced.
- The department of sericulture has identified certain areas which are P1 or seed cocoon producing areas.
- The silkworm rearer present in such areas are also called as P1 rearers.
- These rearers are highly trained in rearing pure breeds of silkworms and they produce cocoon which are also called P1 cocoons.
- No hybrids rearing are allowed in such P1 areas.

- The seed for P1 rearing in these areas is sent/produced in different P2 stations are called basic seed stations.
- Usually in first week of june when this P1 rearing finishes and seed cocoon or P1 cocoons are ready for transportation to various grainages where hybrid seed is to be produced.
- A small calendar for those limited no.of seed areas is drawn by the department and on each date a known quantity of cocoon is transported from these areas to the nearest grainages.
- The government of J&K has fixed a price of Rs. 100/kg of seed cocoon as against Rs.70/kg for commercial cocoons.
- These cocoons are weighed and stored in different trays in grainages and payment due to these farmers for their produce is made on the spot.

2. COMMERCIAL COCOON MARKET :

a) Green Cocoon Market:

- In J&K, the green cocoon market for commercial cocoons takes place for a limited quantity.
- Just after finishing the commercial rearing this type of market takes place in certain rearing areas where green cocoons are purchased by certain reelers.
- The reelers or buyers who desire to buy green commercial cocoon inform the department of sericulture prior to the culmination of spring rearing.
- They also inform about the quantity and nature of hybrid for which they are interested ton purchase as green commercial cocoon, accordingly the department organizes a meet between the buyers and producers i.e. rerears for sale/purchase of these cocoons.
- Usually some of the farmers prefers to sell their produce or cocoons in green cocoon market rather than to wait 2-3 months for dry cocoon market.
- The buyers make on the basis of on spot negotiation of price.

b) Dry cocoon Market:

- Dry cocoon market usually takes place in the month august/September in the valley and in the month of june/Jylly in the Jammu province.
- After finishing the commercial rearing the rearers dry these cocoon under various methods like sun drying bleck cloth sun drying and in hot air dryers so that the pupa inside it gets killed and the moisture is also removed so that no fungal attack could take place in these cocoons.
- After drying these cocoons, the rearers store them in loose gunny bags for a period of more than 2-3 months, preferably keep hanging with a roof on the ceiling so that the rodents or rats may not drainage them.
- At a start dry cocoon market a calendar is issued by the department of sericulture which is called "**cocoon marketing calendar**".
- It contains various details like the name of the district/market where auction will be done and the approximate quality of cocoons to be auctioned in each cocoon market and officers Incharge of the cocoon market along with their phone numbers.
- These market are established at each district headquarter for few days.

- Usually the grading takes place on the basis of shell weight and shell ratio percentage but usually the main method of grading is no. of cocoons/kg.
- If a lot has 1800-2100 cocoons/kg. It is designed as A-grade lot and more the no. of cocoons i.e. up to 2400 it is graded as B and similarly more than 2400 it is designed as C-grade cocoon.
- The govt. has fixed as floor price of Rs. 210/kg of dry cocoon but recently it has been revised upto Rs. 500/kg
- The auction/bidding of these lots takes place on the spot and various buyers participate in the auction.

Lecture No. 10
Peat and Diseases of Silkworm and their management

PESTS OF SILKWORM

1. Uzifly (*Exorista soebillans*)

Type of damage

- Mature maggot causes reduction in yield of cocoons and cocoon quality.
- Causes death of silkworm larva.

Symptoms

- Presence of creamy white oval eggs on the skin of larvae in the initial stage.
- Presence of black scar on the larval skin
- Silkworm larvae die before they reach the spinning stage (if they are attacked in the early stage).
- In later stage, pierced cocoon is noticed.

Period of occurrence

- Throughout the year, severity is more in winter months
- Maintain sanitary and hygienic conditions in the rearing room.
- Provide physical barriers like wire mesh in the doors and windows of the rearing rooms.
- Spray 1 per cent benzoic acid over the larvae to kill the eggs of uzi fly.
- Dissolve the uzicide tablets in the water (2 tablets/l) to attract the adults.
- Release the gregarious, ectopupal hyperparasitoid, ***Nesolynx thymus*** (Eulophidae: Hymenoptera) @ 1 lakh adults/100 dfls during night hours. Release the hyperparasitoid in three split doses @ 8000, 16,000 and 76,000/100 DFLs during fourth and fifth instars and after cocoon harvest.

2. Beetles (*Dremestes cadeverinus*) Coleoptera

Types of damage

The adults and grub and other dermestid beetls are attracted to the smell of cocoons in storage.

Symptoms

They eat of cocoons, enclosed pupa and often the eggs of silkworms.

The females of these beetles lay their eggs in creviceps, organic and wooden boards.

Management

Occasionally, the rooms could be fumigated with CH_3 Br (Methyl bromide)

3. Ants

The attack on silkworms in earning trays.

Management

At the time of spinning ash or kerosene is put at the handles of mountages to keep the ants off.

DISEASES OF SILKWORM

- Viral Disese
- Bacterial Diseases
- Fungal Diseases
- Protozoan disease : Pebrine

d) Viral Disese – 1Grasserie 2Flacherie

Symptom:

- The larvae will be sluggish with swollen intersegmantal region
- The integument of diseases larvae will be fragile and brakes easily
- On infury milky fluid containing many polyhedral inclusion bodies oozes out from the larval body
- The diseases larvae do not settle for moult and showshining integument
- The larvae appear to be restless
- The dead larvae hand by hind legs head downward

Management

1. Sun drying of rearing appliances for one/two days
2. Disinfection of rearing room and appliances with 5% bleaching powder
3. Disinfection of worms, trays and discarding of diseased worms
4. Ensure proper ventilation and air circulation
5. Provide proper bed spacing
6. Feed the larvae with nutritious mulberry leaves
7. Collect and burn infected larvae, faecal matter and bed refuses
8. Early diagnosis and rejection of infected lots
9. Dust the bed disinfectant, Vijetha (or) Resham Keet Oushadh on the larvae, after each moult and ½ hr. before resumption of feeding (3 kg/100 dfl).
10. Spray 1% of extract of *Psoralea coryleifolia* on mulberry leaves, shade dry and feed worms once during third instars.

e) Bacterial Diseases

Bacteria and viruses cause the disease individually or in combination. Fluctuating temperature and humidity and poor quality mulberry predispose the disease development.

- The diseased larvae will be stunted in growth, dill lethargic soft and appear flaccid
- The cephalothoracic region may be translucent
- The larvae vomit gut juice, develop dysentery and excrete chain type fecus.
- The larvae on death putrefy, develop different and emit foul smell

Management

1. Maintenance of hygienic condition
2. Disinfection of rearing room and appliances
3. Disinfection of worms, trace and discarding of sick worms
4. Avoid injury to the worms, overcrowding of trays and accumulation of faeces in the rearing bed
5. Sound management, improving the rearing environment and feed stuff
6. Feeding the larvae with healthy nutritious leaves.

7. Early diagnosis and rejection of infected lots
8. Avoid spraying commercial ***B. t.*** insecticides in nearby mulberry field.
9. Apply antibiotics like Streptomycin/Tetracyclin/Ampicillin

f) Fungal Diseases - Muscardine

White muscadine is caused by a fungus Beauveria bassiana and the green muscadine is caused by a fungus Spicaria prasina. Aspergillosis is common in young age silkworms and the infected larvae will be lustrous and die. Dark green (Aspergillus flavus) or rusty brown (Aspergillus tamari)49uxilia cluster are seen on the dead body.

- The diseases larvae prior to death will be lethargic and on death are flaccid
- oil specks may be seen on the surface of larvae
- They gradually be fome hard, dry and mummify into a white or green coloured structure
- The diseases pupae will be hard, lighter and mummifies

Magagement

2. Sundry the rearing appliances.
3. Disinfect the rearing room and utensils with 5 per cent bleaching powder
4. Avoid low temperature and high humidity in the rearing room
5. Keep the rearing bed thin and dry
6. Early diagnosis and rejection of infected lots
7. Apply Dithane M45 (3 kg/100 dfls) / Vijetha supplement as disinfectant on the larvae
8. Disinfect rearing rooms and trays with 4 per cent pentachlorophenol to control Aspergillosis.

a) **Protozoan disease : Pebrine**

- Diseases larvae show slow growth, undersized body and poor appetite.
- Diseases larvae reveal pale and flaccid body. Tiny black spots appear on larval integument.
- Dead larvae remain rubbery and do not undergo putrefaction shortly after death.

Management of Pebrine

1. Produce healthy eggs
2. Disinfection of rearing room and utensils
3. Maintain strict hygienic conditions during rearing
4. Surface disinfect the layings in 2 per cent formalin for 10 minutes before incubation.
5. Collect and burn the diseased eggs, larvae, pupae and moths, bed refuses, faecal pellets, etc.

Lecture No. 11

Lac Culture: Species of lac insects, morphology, biology, behavior, host plant.

Lac Culture:

"Lac culture is the scientific management of lac insects to obtain a high amount of quality lac".

This involves selection and maintenance of host plants, inoculation of host plants with healthy lac insects, collection and processing of lac and protection against enemies.

Lac:

"Lac is the resinous secretion of lac insects".

Two species of lac insects *Tachardia lacca* and *T.chinensis* are common, of which the former one is predominant in India. **India is the highest lac-producing country**.

Species of Lac Insect:

Four species of lac insects are

1. *Kerria lacca.*
2. *Tachardia signoret*
3. *Tachardiella cockrell.*
4. *Tachardina cockrell.*

Kerria lacca is available in Bangladesh.

The first scientific account of the lac insect was given by J. Kerr in 1782 which was published in Philosophical Transaction of Royal Society of London (vol. 71, pp.374-382). The first scientific name given to it was *Tachardia lacca* following the name of French Missionary Father „Tachardia". It was later changed to *Laccifer lacca* Kerr. The other name given to it hasbeen *Kerria Lac* Kerr.

Phylum – Arthropoda
Class – Insecta
Order – Hemiptera
Suborder – Homoptera
Super family – Coccoidea
Family – Lacciferidae
Genus – *Laccifer*

Morphology:

- Lac insect is a minute crawling scale insect which inserts its suctorial proboscis into plant tissue, sucks juices, grows and secretes resinous lac from the body.
- Its own body ultimately gets covered with lac in the so called „CELL".
- Lac is secreted by insects for protection from predators.
- The head, thorax and abdomen are not clearly distinct.
- Eggs hatch within a few hours of laying, and a crimson-red first instar nymph called **crawlers** come out.
- The **crawler measures 0.6 x .25 mm** in size.
- At this stage, both male and female nymphs live on the sap of the trees.
- They insert their suctorial proboscis into plant tissue and suck the sap.
- The resin secreted is semi-solid which hardens on exposure to air into a protective covering.
- The nymphs molt thrice inside the cells before reaching maturity.
- The duration of each instar is dependent on several factors, viz. temperature, humidity and host plant.

Biology and behavior

Eggs:

The female lays eggs inside the encrustation 200-500 eggs are laid which may be either fertilized or unfertilized

Female lays 3 types of eggs

1. Equal no. of male and female
2. More males and less females
3. More females and less males

Female lays eggs which will hatch within few hours- Ovoviviparous type

Nymphs:

Nymphs are minute, about 0.6 mm long, soft bodied, pointed posteriorly, deep red in colour with black eyes

Wander on the shoots (swarmimg), move mostly upward towards tender branches and settle on them

They start feeding by piercing the shoot andsettleon 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

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

Sex dimorphism is more pronounced after 1stmoult

Male cell is elongate with a pair of holes at the anterior end from which white hairs comes out

Female cell is globular with an irregular margin with 6 holes, 3 at top, 1 at hind and 2 at anterior end

Male nymphs start developing the organs after 2ndmoult

Adult:

Male and female are different from each other i.e., female is 3 times larger then male

Male:

2 types, winged or wingless

Only 1 pair of wings and winged males appear during dry season (Baisakhiand Jetwi)

Survives for 3-4 days and die after copulation

Elongate and slipper shaped

The males regain their lost appendages at the last moult

Female:

Short and spherical

After second moult, the female nymphs become swollen with no trace of segmentation

The posterior end of abdomen is bent upward and insect becomes roundish

Females never regain lost appendages

Mesothoraxis provided with a appendage through which spiracles are open

The male copulates with the female even while the later remains inside the cell

A copulated female grows up very fast and secretes lac abundantly and the size of the insect

The female cell size reach several times that of male cells

Thus, the female insects are the chief producers of the lac

Before egg laying, female develop 2 yellow spots posteriorly

Spots enlarge and turns orange by the time the female oviposit the eggs into ovisac
At this stage, the twigs are cut and removed for inoculation (Brood lac) to new trees
Egg laying ceases when the temperature inside the cell falls below 170C and the nymph becomes inactive below 200C

HOST PLANTS:

- Lac insects thrive on twigs of certain plant species, suck the plant sap, and grow all the while secreting lac resin from their bodies, These plants are called host plants.
- Although lac insect is natural pest on host plant, these insects enjoy the privileged position not being treated as pest.
- This is because: i) they yield a useful product, ii) the host plants are economically not so important, and iii) the insects cause only temporary and recoverable damage to the host plants.
- About 113 varieties of host plants are mentioned as lac host plant.
- **Out of which the followings are very common in India:**

1. *Butea monosperma* (Vern. Palas)
2. *Zizyphus* spp (vern. Ber)
3. *Schleichera oleosa* (Vern. Kusum)
4. *Acacia catechu* (Vern. Khair)
5. *Acacia 52uxilia* (Vern. Babul)
6. *Acacia auriculiformis* (Vern. Akashmani)
7. *Zizyphus xylopyrus* (Vern. Khatber- grown in part of M.P. & U.P.)
8. *Shorea talura* (Vern. Sal grown in mysore)
9. *Cajanus cajan* (Vern. Pigeon-pea or Arhar)
10. *Grewia teliaefolia* (Vern. Dhaman preferred in Assam)
11. *Albizzia lebbek* (Vern. Siris/Gulwang)
12. *Flemingia macrophylla* (Vern. Bholia)
13. *Ficus benghalensis* (Vern. Bargad)
14. *Ficus religiosa* (Vern. Peepal)

- Of these host plants, palas, kusum, ber and khair are of major importance, while others are of regional and minor importance.
- It is also important to mention that the quality of Lac Culture lac is directly related to the host plant and to the strain of lac insects.
- Based on industrial parameters, **kusumi lac** is better and fetches higher price in market.
- In this respect, ber tree as a potential kusumi lac host is already getting momentum.
- This host species is available in plenty and can supplement and fulfill the kusmi brood lac requirement in many areas.
- Similarly, siris (*Albizzia* sp.) has also been identified as good host for kusumi brood lac.
- The trees can be raised and utilized within a period of 5-6 years of plantation in comparison to around 15 years for kusum.
- *Flemingia semialata* is a bushy host plant and has also been identified as well as established as a good kusumi lac host on plantation basis.
- Thus, these three hosts viz., ber, siris, semialata and lately *Prosopis juliflora* (in Gujarat areas) are expected to enhance kusumi lac cultivation.
- Adoption of this activity may enhance lac production to the tune of 3-4%.

Lecture No. 12

Lac Production and its uses, Types of lac- Seed lac, Button lac, shellac, and lac-Products

Lac Production/Cultivation:

- Done by **inoculating 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, the young larvae settle on fresh twigs of host plants, suck the plant sap and grow to form encrustation

a) Local practice:

- The host plants are continuously exploited without giving rest for recoupment
- Only **natural inoculation** occurs and **Partial harvesting** is done.
- Few branches are left untouched for **auto inoculation.**
- The host trees lose the vigourand become weak and die.

b) Improved practice:

- To provide much needed **rest to host plant s**after harvest.
- Trees are divided into **coupes**i.e., **groups that consist certain number of trees.**
- **Only few numbers of trees** in a coupe are inoculated.
- After harvest, these trees are **made to rest and recoup the last vigor.**
- Other trees are **ready with succulent twigs** for inoculation.
- **Alternate groups of trees** are put to lac cultivation.
- **Kusum**is slowly growing, hence **18 months** rest is given
- The trees are divided into **4** coupes and inoculating each coupe once in two years
- Plants of resting coupes are pruned
- In**Rangeeni**hosts like **Palasand ber**, trees are divided into 3 coupes i.e., two large and one small in ratio of 3:1:3
- **The baisakhicrop** is raised in **2**large coupes in alternate years
- So that each coupe has a rest of **16** months in between and the katkicrop is raised in small coupe every year allowing a rest period of **8**months between two successive crops.

Selection of Site

Pruning

a) Inoculation:

- Propagation of lac insects is done by inoculation of newly hatched (brood lac) nymphs on host plants
- Lac sticks bearing alive mother cells which are about to oviposit are called as Brood Lac
- **One to 20 kg** of brood stick is needed for inoculating a tree based on size of kusumistrain, **0.4 to 5 kg** in case of Rangeeni**Natural/self/auto inoculation:** swarmed nymphs infest the same plant again
- Natural inoculation, repeated on the same host, makes the host plant weak nymphs do not get proper nutrition
- Uniform sequence of inoculation does not take place

b) Artificial inoculation:

- The old weak and diseased twigs of host plants are pruned in January or June.
- Induces host plants to throw out new succulent twigs.

- The cut pieces of brood twig (i.e., 20 x 30 cm in length) are tied to fresh twigs.
- 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) Inoculation should be done immediately after cutting the brood lac
c) Tie the brood stick on upper surface of branches securely
d) Raise brood sticks at room temperature to 200C to induce swarming
e) Avoid cultivation of rangeeniin kusumiarea and vice versa
f) Inoculate only on non rainy day

Harvesting of lac (Cropping):

Cutting the lac encrusted twigs when the crop is mature**. It is of 2 types.**

b) Immature harvesting:

- In this method, **lac is collected before swarming** and lac obtained is known as **"ARI LAC"**
- In this method, lac insect may be damaged during harvest
- Ari lac harvesting is recommended on **Palas**only

c) Mature harvesting:

In this method, lac is collected after swarming and lac obtained is **mature lac**

Symptoms of swarming of nymph include the following

a) A yellow spot develops on the posterior side of lac cell towards crop maturity
b) Dried out appearance of encrustation two weeks before swarming
c) Appearance of cracks on the encrustation at a later date

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 brood lac left after emergence of nymphs is known as **stick lac or phunkilac**

Composition of lac:

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

<u>Types of lac</u>

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**

The optimum moisture content is **4%** for storage of stick lac to avoid lump formation

2. Button lac:

- **lac** formed into cakes shaped like **buttons** by melting and solidifying.
- **Button Lac** is the preferred choice for French Polishing, Floor Finishing, tough & moisture resistant finishes.
- **Button Lac** contains wax and may not be as compatible as dewaxed shellac when being used in combination with other finishing products like Polyurethane, Waterlox etc.

3. **Seed lac/grain lac:**

- The stick lac is crushed and sieved to remove sand and dust, washed in large vats
- Decaying bug bodies turn the water a deep red that is processed further to get the byproduct,**lac dye**
- The remaining resin is dried, winnowed and sieved to get the semi refined commercial variety product called **seed lac**
- The seed lac is in the form of grain of **10 mesh** or smaller and yellow/reddish brown in colour

4. **Shellac:** The seed lac is processed into shellac by any of the 3 methods i.e., handmade country process/heat process/solvent process/ Solvent process

LAC PRODUCTS AND THEIR USE:

1. Lac dye

Lac dye is a mixture of anthroquinoid derivatives.
It is traditionally used to color wool and silk.
Its colour varies between purple red, brown and orange often depending upon the mordant used.
It is used in food and beverages industry for coloring.
In recent past, lac dye has been replaced by synthetic dye.
But, now-a-days with increasing stress and awareness on use of eco-friendly and safe material particularly associated with human contact and consumption has made revival of great demand of lac dye as a coloring material.

2. Lac wax

Lac wax is a mixture of higher alcohols, acids and their esters. It is used in –

- Polishes applied on shoes, floor, automobiles etc.
- Food and confectionary, and drug tablet finishing
- lipsticks
- Crayons

3. Shellac

- Shellac is a natural gum resin, a nature‟s gift to the mankind and is used in over 100 industries.
- It is natural, non toxic, physiologically harmless and edible resin.
- Shellac is a hard, tough, amorphous, and brittle resin containing small amount of wax and a substance responsible for its characteristic pleasant odour.
- The lac resin is not a single chemical compound, but an intimate mixture of several components.
- Shellac is slightly heavier than water. Its natural colour varies from dark red to light yellow.
- When slowly heated, it softens at 65-70^{O}c and melts at 84-90^{O}c.
- Shellac is insoluble in water, glycerol, hydrocarbon solvents and esters, but dissolves readily in alcohols and organic acids.
- The solvent most commonly employed to dissolve shellac is methylated spirit.

- Usually the milder alkalis, ammonia, borax and sodium carbonate can also be employed to prepare aqueous solutions.
- Shellac is acidic in character. Acid value is 70. It is an ester.
- Saponification value 230. It has free five hydroxyl groups and has hydroxyl number 260. It has unsaturation indicated by iodine value of 18.
- Free aldehydic group also has been indicated by carboxyl value of 18. Its average molecular weight is 1000.
- Normal wax content of shellac is 5% which is insoluble in alcohol.
- It is soluble in n-hexane, pure 56uxiliary56, and other hydrocarbon oils. It is hard and having melting point 84^0 C.

It has the following extra ordinary properties:

ii) It is thermoplastic.

iii) It is approved for various applications in the food industry.

iv) It is uv-resistant.

v) It has excellent dielectric properties, dielectric strength, a low dielectric consent, good tracking resistance etc.

vi) It has excellent film forming properties. Its film shows excellent adhesion to wide variety of surfaces and possess high gloss, hardness and strength

vii) Shellac is a powerful bonding material with low thermal conductivity and a small coefficient of expansion. Its thermal plasticity and capacity of absorbing large amounts of fillers is noteworthy.

viii) Shellac under tropical conditions of storage, may soften and form a solid block, without adverse effects on its properties. Long storage under adverse conditions, however, may lead to deterioration in properties

Use:

- It is used in fruit coatings, e.g. for citrus fruits and apples, parting and glazing agents
- for sweets, marzipan, chocolate etc. Also used as binder for foodstuff stamp inks, e.g. for cheese and eggs.
- It is used as binder for mascara, nail varnish additive conditioning shampoo, film
- forming agent for hair spray, micro-encapsulation for perfumes.
- It is used for enteric (i.e. digestive juice-resistant) coatings for tablets and as odour
- barrier for dragées.
- It is used in manufacturing of photographic material, lithographic ink and for stiffening felt and hat material.
- It is utilized in preparation of gramophone records.
- Jewellers and goldsmiths use lac as a filling material in the hollows in ornaments.
- It is also used in preparation of toys, buttons, pottery and artificial leather.
- It is also used commonly as sealing wax.

With increasing environmental awareness of consumers, this natural and renewable raw material is being used increasingly in the development of new products apart from the conventional user industries. Few to name:

- Leather**:** Seasoning, Leather care products
- Printing inks**:** As binder for flexographic printing inks for non-toxic printing of food packaging
- Wood treatment: Primers, polishes, matt finishes
- Textiles: As stiffeners
- Electrical: Insulation, capping, lamination
- Abrasives**:** Binder for grinding wheels
- Others: Binder for inks and water colours, Micro-encapsulation for dyes

4. Bleached shellac

- Bleached shellac is non-toxic, physiologically harmless (edible), and is widely used in the food industries, food packaging and allied industries.
- Apart from the above, bleached shellac is also used for its qualities i.e. binding, adhesive, hardening, gloss, odourless, fast drying, and extending shelf life (in absence of refrigeration) etc.
- Clear and transparent or very light coloured alcoholic or water – alkali solutions can be obtained from bleached shellac.

Use:

Bleached shellac is widely used in the following industry:

- **Paints** (primer for plastic parts and plastic film)
- **Aluminium industry** (primer for Aluminium and Aluminium foils)
- Flexographic printing inks
- **Pharmaceuticals** (for coating of pills, tables and gel caps and coating for controlled release preparation)
- **Confectionery** (in coating of confections, chewing gums, marzipan chocolates, nutties, jelly- and coffee-beans etc)
- Binder for food marking and stamping inks and Binder for egg coating
- Barrier coating for processed food, vegetables, fruits and dry flowers
- **Textiles** (used as textile auxiliaries and felt hat stiffening agents)
- **Cosmetics** (used in hair spray, hair and lacquers, hair shampoos, and binder for mascara)
- **Wood finishing** (as binder for wood coatings and wood stains and as filler/sealer for porous surfaces and cracks)
- Antique frames for paintings and Wood polish (French polish)
- **Fire works and pyrotechnics** (as binder for fireworks, matches etc and used in coating of magnesia
- **Electric** (as binder for lamp cements)

- **Electronics** (it is binder for insulation materials, serves as additive to moulding compounds. Mass coating for print-plates and is adhesive for si-cells.)
- Grinding wheels (it is binder for additive of grinding wheels)
- **Plastic** (it is primer for plastic parts and films)
- **Rubber** (it is additive to natural rubber)
- **Leather** (in leather auxiliaries)

5. Dewaxed bleached shellac

Dewaxed white shellac is used in the same way as any other grade of shellac. The major difference between this shellac and the others is that it is a bit harder, shines a bit brighter, is completely free from wax.

Use:

- Coating of fruits and vegetables
- Coating in tablets & capsules
- Coating in confectionary
- Coating in aluminium foil, paper
- Coating in cosmetic industry
- In cosmetics, it is used in hair sprays (pump sprays or aerosol sprays, hair setting lotions, hair shampoos, mascara, eyeliners, nail polishes, lipsticks, micro encapsulation
- by coacervation of fragrances and perfume oils.
- In food, it is used for coating of confections, chewing gum, candles, cakes, eggs, citrus fruits and apples, and printing inks for eggs and cheese.

Lecture No. 13

Biocontrol agents (Natural Enemies): Introduction of bioagents, Ideal characteristics of bioagents, Successful examples of biological control

Definition:

"Biological control or **biocontrol** is a method of controlling pests such as insects, mites, weeds and plant diseases using other organisms".

OR

"Biological control has been defined simply as the utilization of natural enemies to reduce the damage caused by noxious organisms to tolerable levels".

Introduction of Bioagents:

- Biological control agents are living organisms, including parasites, predators and disease causing fungi, bacteria and viruses.

- These are the natural enemies of pests, which can intervene the life cycle of insect pests in such a way that the crop damage is minimized.
- They are both less toxic and more flexible than chemical pesticides.
- Biological control includes a wide range of approaches, from natural predators to biologically produced molecules.
- Microorganisms, including viruses, bacteria, fungi and protozoan, cause disease or poison their targets through toxin production.
- These bio agents can be conserved, preserved and multiplied under Laboratory condition for field release.
- Once these bio-agents are introduced in the field to build their population considerably, they are capable of bringing down the targeted pest" population below economic threshold level (ETL).
- However, the crux lies in their mass production and application at the appropriate time.
- Among all pest management techniques, the microbial agents are most effective in controlling the target insect-pest and require appropriate formulation and application.

Ideal Characteristics of Bioagents

a. **Narrow host range**.

Generalized predators may be good natural enemies but they don"t kill enough pests when other types of prey are also available.

b. **Climatic adaptability**.

Natural enemies must be able to survive the extremes of temperature and humidity that they will encounter in the new habitat.

c. **Synchrony with host (prey) life cycle**.

The predator or parasite should be present when the pest first emerges or appears.

High reproductive potential. Good biocontrol agents produce large numbers of offspring. Ideally, a parasite completes more than one generation during each generation of the pest.

d. Efficient search ability.

In order to survive, effective natural enemies must be able to locate their host or prey even when it is scarce. In general, better search ability results in lower pest population densities.

e. Short handling time.

Natural enemies that consume prey rapidly or lay eggs quickly have more time to locate and attack other members of the pest population. Small populations of efficient natural enemies may be more effective biocontrol agents than larger populations of less efficient species.

f. **Survival at low host (prey) densit**y.

If a natural enemy is too efficient, it may eliminate its own food supply and then starve to death. The most effective biocontrol agents reduce a pest population below its economic threshold and then maintain it at this lower equilibrium level.

Successful examples of biological control

i. Sugarcane Pyrilla (Pyrilla perpusilla):

There was a severe outbreak of Sugarcane Pyrilla during 1972-73 in the states of Punjab, Haryana, U.P. and Bihar which was successfully controlled by utilization of potential biocontrol agents like Egg parasitoid *Tetrastichuspyrillae* and Nymp halpredator *Epipyropsmelanoleuca*. This pest in Karnataka was successfully controlled by its potential biocontrol agents.

ii. Sugarcane white woolly aphid (Seratovacunalanigera):

This pest of sugarcane was also successfully managed by bio agents viz. Diphaaphidivora, Chrysoperla spp., Coccinellid beetles, Syrphid flies and some spiders in the states of Maharashtra and Karnataka, where its outbreak during 2003-04 had caused considerable economic damage to the farmers.

iii. Apple woolly aphid (Eriosomalanigerum) and Sanjose scale (Quadraspidiotusperniciosus)

These two dreaded pests of apple plants are under check by their bioagents like *Aphelinusmali, Syrphusconfrater, Chrysopascelestesetc*. In case of apple woolly aphid and Encarsiaperniciosi, Aphytisspp., Chilocorusbijugus, Pharoscymnus spp. Etc. in case of Sanjose scale in apple growing states of the country

iv. Water hyacinth (Eichhorniacrassipes):

This aquatic weed was successfully controlled in Southern states of India through its two exotic phytophagous weevils i.e.*Neochetinaeichhorniae* and *N. Bruchi.*

v. American bollworm / Gram Caterpillar (Helicoverpaarmigera):

A polyphagous insect pest was successfully managed with the use of Nuclear Polyhidrosis virus (NPV) on Cotton, Pulses, Vegetables, Oilseeds etc.in India.

vi. Aphids

An example of biological control is the release of parasitic wasps to control aphids. Aphids are a pest of plants and cause huge damage to plants as they remove nutrients from the plant. In this way the aphid population will decrease quickly.

vii. Entomopathogenic nematodes to control wine weevil

Heterorhabditis bacteriophora nematodes are used to control pests such as wine weevil; their control effect is helped by releasing bacteria into the soil which attack the wine weevil.

viii. *Sclerotinia sclerotiorum* controlled by fungal spores

Soil application of fungal spores of *Coniothyrium minitans* is used to destroy surviving structures of the common plant pathogen *Sclerotinia sclerotiorum*.

ix*. Control of powdery mildew by *Ampelomyces quisqualis

Another example of biological control is leaf application of fungal spores of *Ampelomyces quisqualis* to control mildew on greenhouse crops

x. Codling moth killed by viruses

A spray with entomopathogenic viruses such as *Cydia pomonella* granulovirus (CpGV) is used to kill codling moths.

Lecture No. 14

General classification: Important insect orders bearing predators and parasitoids used in pest control Identification of major parasitoids and predators commonly used in biological control of crop pests.

Important insect orders bearing predators and parasitoids used in pest control:

Used in biological control of insects and mites . Most parasites and pathogens, and many predators, are highly specialized and attack a limited number of closely related pest species. Learn how to recognize natural enemies by consulting resources such as the *Natural Enemies Handbook* and the.

1. **Parasites**

- A parasite is an organism that lives and feeds in or on a host.
- Insect parasites can develop on the inside or outside of the host's body.
- Often only the immature stage of the parasite feeds on the host.
- However, adult females of certain parasites (such as many wasps that attack scales and whiteflies) feed on and kill their hosts, providing an easily overlooked but important source of biological control in addition to the host mortality caused by parasitism.
- Although the term "parasite" is used here, true parasites (e.g., fleas and ticks) do not typically kill their hosts.
- Species useful in biological control, and discussed here, kill their hosts; they are more precisely called "parasitoids."
- Most parasitic insects are either flies (Order Diptera) or wasps (Order Hymenoptera). Parasitic wasps occur in over three dozen Hymenoptera families.
- For example, Aphidiinae (a subfamily of Braconidae) attack aphids. *Trichogrammatidae* parasitize insect eggs.
- Aphelinidae, Encyrtidae, Eulophidae, and Ichneumonidae are other groups that parasitize insect pests.
- It's important to note that these tiny to medium-sized wasps are incapable of stinging people. The most common parasitic flies are the typically hairy Tachinidae.
- Adult tachinids often resemble house flies. Their larvae are maggots that feed inside the host.

2. **Predators**

- Predators kill and feed on several to many individual prey during their lifetimes.
- Many species of amphibians, birds, mammals, and reptiles prey extensively on insects. Predatory beetles, flies, lacewings, true bugs (Order Hemiptera), and wasps feed on various pest insects or mites.
- Most spiders feed entirely on insects.
- Predatory mites that feed primarily on pest spider mites include *Amblyseius* spp., *Neoseiulus* spp., and the western predatory mite, *Galendromus occidentalis*.

3. **Pathogens**

- Natural enemy pathogens are microorganisms including certain bacteria, fungi, nematodes, protozoa, and viruses that can infect and kill the host.
- Populations of some aphids, caterpillars, mites, and other invertebrates are sometimes drastically reduced by naturally occurring pathogens, usually under conditions such as prolonged high humidity or dense pest populations.
- In addition to a naturally occurring disease outbreak (epizootic), some beneficial pathogens are commercially available as biological or microbial pesticides.
- These include *Bacillus thuringiensis* or Bt, entomopathogenic nematodes, and granulosis viruses.
- Additionally, some microorganism by-products, such as avermectins and spinosyns are used in certain insecticides; but applying these products is not considered to be biological control.

Identification of major parasitoids and predators commonly used in biological control of crop pests.

1. **Predators**
   - Predators are mainly free-living species that directly consume a large number of prey during their whole lifetime.
   - Given that many major crop pests are insects, many of the predators used in biological control are insectivorous species.
   - Lady beetles, and in particular their larvae which are active between May and July in the northern hemisphere, are voracious predators of aphids, and also consume mites, scale insects and small caterpillars.
   - The spotted lady beetle (*Coleomegilla maculata*) is also able to feed on the eggs and larvae of the Colorado potato beetle (*Leptinotarsa decemlineata*).
   - The larvae of many hoverfly species principally feed upon aphids, one larva devouring up to 400 in its lifetime.
   - Their effectiveness in commercial crops has not been studied. Predatory *Polistes* wasp searching for bollworms or other caterpillars on a cotton plant Several species of entomopathogenic nematode are important predators of insect and other invertebrate pests.
   - Entomopathogenic nematodes form a stress–resistant stage known as the infective juvenile. These spread in the soil and infect suitable insect hosts.
   - Upon entering the insect they move to the hemolymph where they recover from their stagnated state of development and release their bacterial symbionts.
   - The bacterial symbionts reproduce and release toxins, which then kill the host insect. *Phasmarhabditis hermaphrodita* is a microscopic nematode that kills slugs.
   - Its complex life cycle includes a free-living, infective stage in the soil where it becomes associated with a pathogenic bacteria such as *Moraxella osloensis*.
   - The nematode enters the slug through the posterior mantle region, thereafter feeding and reproducing inside, but it is the bacteria that kill the slug.
   - The nematode is available commercially in Europe and is applied by watering onto moist soil.
   - Entomopathogenic nematodes have a limited shelf life because of their limited resistance to high temperature and dry conditions.
   - The type of soil they are applied to may also limit their effectiveness.
   - Generalized life cycle of entomopathogenic nematodes and their bacterial symbionts.
   - Species used to control spider mites include the predatory mites *Phytoseiulus persimilis*, *Neoseilus californicus*,[43] and *Amblyseius cucumeris*, the predatory midge *Feltiella acarisuga*, and a ladybird *Stethorus punctillum*.
   - The bug *Orius insidiosus* has been successfully used against the two-spotted spider mite and the western flower thrips (*Frankliniella occidentalis*).
   - Predators including *Cactoblastis cactorum* (mentioned above) can also be used to destroy invasive plant species.
   - As another example, the poison hemlock moth (*Agonopterix alstroemeriana)* can be used to control poison hemlock (*Conium maculatum*).
2. **Parasitoids**

- Parasitoids lay their eggs on or in the body of an insect host, which is then used as a food for developing larvae.
- The host is ultimately killed.
- Most insect parasitoids are wasps or flies, and many have a very narrow host range.
- The most important groups are the ichneumonid wasps, which mainly use caterpillars as hosts; braconid wasps, which attack caterpillars and a wide range of other insects including aphids; chalcid wasps, which parasitize eggs and larvae of many insect species; and tachinid flies, which parasitize a wide range of insects including caterpillars, beetle adults and larvae, and true bugs.
- Parasitoids are most effective at reducing pest populations when their host organisms have limited refuges to hide from them.
- *Encarsia formosa*, widely used in greenhouse horticulture, was one of the first biological control agents developed.Life cycles of greenhouse whitefly and its parasitoid wasp *Encarsia formosa* Parasitoids are among the most widely used biological control agents.
- Commercially, there are two types of rearing systems: short-term daily output with high production of parasitoids per day, and long-term, low daily output systems.
- In most instances, production will need to be matched with the appropriate release dates when susceptible host species at a suitable phase of development will be available.
- Larger production facilities produce on a yearlong basis, whereas some facilities produce only seasonally.
- Rearing facilities are usually a significant distance from where the agents are to be used in the field, and transporting the parasitoids from the point of production to the point of use can pose problems.

Lecture No. 15

Major parasitoids: *Trichogramma sp., Chelonus blackburni, Cotesia (Apanteles) sp., Bracon sp., Epiricania melanoleuca, Goniozus nephantidis, Campoletis chloridae,*
Major predators: *Chrysoperla* sp., Australian lady bird beetle *Cryptolaemus*montrouzieri
Weed killers: *Zygogramma bicolorata*, *Neochetina* spp.

Major parasitoids:

1. **Trichogramma sp.**

- ***Trichogramma*** is a genus of minute polyphagous wasps that are endoparasitoids of insect eggs. *Trichogramma* is one of around 80 genera from the family Trichogrammatidae, with over 200 species worldwide.
- Although several groups of egg parasitoids are commonly employed for biological control throughout the world, *Trichogramma* spp. Have been the most extensively studied. More than a thousand papers have been published on *Trichogramma* species, and they are the most used biological control agents in the world.
- *Trichogramma* spp. Have less than 10,000 neurons, approaching the size limit of how small an insect can be, determined by how few neurons they can fit in their central nervous systems, yet exhibiting a complex behavior to sustain their lives.

Identification

- *Trichogramma* wasps are small and very uniform in structure, which causes difficulty in identifying the separate species.
- As females are all relatively similar, taxonomists rely upon examination of males to tell the different species apart, using features of their antennae and genitalia.
- The first description of a *Trichogramma* species was in North America in 1871, by Charles V. Riley.
- He described the tiny wasps that emerged from eggs of the viceroy butterfly as *Trichogramma* minutum.
- In taxonomy, original specimens are very important, as they are the basis of reference for subsequent descriptions of species.

Biological control:

- *Trichogramma* spp. Have been used for control of lepidopteran pests for many years.
- They can be considered the *Drosophila* of the parasitoid world, as they have been used for inundative releases and much understanding today comes from experiments with these wasps.
- Entomologists in the early 1900s began to rear *Trichogramma* spp. For biological control. *T. minutum* is one of the most commonly found species in Europe and was first mass reared in 1926 on eggs of *Sitotroga cerealella*. *T. minutum* has been investigated as a method of biological control of the *Choristoneura fumiferana*, a major pest of spruce and fir forests.
- Nine species of *Trichogramma* are produced commercially in insectaries around the world, with 30 countries releasing them.
- *Trichogramma* wasps are used for control on numerous crops and plants; these include cotton, sugarcane, vegetables, sugarbeets, orchards, and forests. Some of the pests controlled include cotton bollworm (*Helicoverpa armigera*), codling moth (*Cydia pomonella*), lightbrown apple moth (*Epiphyas postvittana*), and European corn borer (*Ostrinia nubilalis*).
- *Trichogramma* species vary in their host specificity.
- This can lead to nontarget hosts being parasitized.
- This, in turn, can cause problems by reducing the amount of parasitism of the target host, and depending on the rate of parasitism, nontarget effects could be significant on nontarget host populations.
- Research is being done on the use of *Trichogramma* wasps to control populations of spruce bud moth (*Zeiraphera canadensis*), which damages white spruce trees.

2. Chelonus blackburni

Taxonomic position

Hymenoptera: Braconidae: Cheloninae

Hosts

Egg-larval parasitoid of several lepidopterous pests like potato tuber moth, *Phthorimaea operculella*, cotton bollworms, *Hellula undalis*, *Plutella xylostella*, etc. It has been used for the biological suppression of *P. operculella* in Maharashtra, *Earias vittella* (Fabricius) in Karnataka, *E. insulana* Stoll. *(=E. fabia)* in Maharashtra, *Pecinophora gossypiella* (Saunders) in Maharashtra and *Helicoverpa armigera* (Huebner) on cotton and

other host plants in many states. It is becoming an important component of IPM systems on potato, cotton, etc.

Mass production

This parasitoid is commonly mass produced on the standard laboratory host, *Corcyra cephalonica* (Stainton) and the potato tuber moth, *Phthorimaea operculella* (Zeller). It could also be multiplied successfully on *Achroia grisella* (Fabricius) and *Spodoptera exigua* (Huebner). Detailed production and release procedures are outlined in Singh (1994a,b).

Field release

The following release dosages are often adopted, depending on the pest.

- Potato tuber moth: Two releases @50,000 adults/ release in the field and 5 adults/kg potatoes in godowns.
- Cotton bollworms: 50,000 adults/ week, first release coinciding with sighting of eggs in the field.
- *Helicoverpa armigera* at weekly intervals, first release coinciding with sighting of eggs in the field.

3. Cotesia (Apanteles) sp.

A parasitoid identified as *Omphale metallicus* Ashmead (Hymenoptera: Eulophidae) attacks sweetpotato leafminer. In Hawaii this parasitoid is thought to be a significant mortality factor; nevertheless, leafminer can be a serious problem in the absence of insecticides. *Apanteles bedelliae* was introduced to Hawaii to aid in suppression of sweetpotato leafminer, and is reported to be effective (Zimmerman

4. Bracon sp.

- ***Bracon*** is a genus of wasps in the Braconidae, a family of parasitoid wasps.
- There are several hundred described species but there are thousands still undescribed.
- The genus is cosmopolitan, distributed throughout the world, with most of the described species occurring in the Palearctic ecozone.
- These wasps are mostly ectoparasitoids, with the larvae developing on the outside of the body of the host.
- Recorded Hostsin clued the larvae of many species of lepidopterans, beetles, flies, hymonopterans, and true bugs.
- They are idiobionts, halting the development of the host when they lay eggs on its body. Some *Bracon* wasps are specific to one host species, and some are known to utilize many different hosts.
- The eggs of the wasp can be very hardy.
- In one report, *Bracon* wasps oviposited on tortrix moth larvae, which then entered privet seeds and were consumed by birds along with the fruit. The wasp eggs were later excreted and the larvae emerged.
- This large genus has been divided into several subgenera, some of which are further divided into species-groups.

- A DNA analysis showed that the genus is paraphyletic, that its subgenera and other defined groups are not all valid on a molecular basis, and that revising it into informal groups would be more practical.
- Other authors still divide the genus into subgenera using morphological characters to make identification easier.

Species Include

Bracon acrobasidis *Bracon agathymi* *Bracon americanus* *Bracon analcidis* *Bracon angelesius* *Bracon apicatus* *Bracon argutator* *Bracon bembeciae* *Bracon brachyurus* *Bracon brevicornis*

5. Gonious nephantidis

Hosts

Goniozus nephantidis is a gregarious larval ectoparasitoid of the coconut black-headed caterpillar, *Opisina arenosella* Walker (=*Nephantis serinopa* Meyrick) (Lepidoptera: Xylorictidae). It is apparently host-specific, but may have a broader host range. Remadevi *et al*. (1996) reported *Anigraea albomaculata* as an alternate host. Krombein (1996), after examining a paratype from Tamil Nadu, India, bearing the label „par. On cotton bolls", has also suggested this possibility.

Field Application

The adults are released either in the crown region of coconut palms or on the trunk, preferably early in the season before the build up of *O. arenosella*. Usually, releases of *G. nephantidis* are recommended as part of the following package: 20.5% of *G. nephantidis*, 49.4% of *Elasmus nephantidis* (pre-pupal parasitoid) and 31.9% of *Brachymeria nephantidis* (pupal parasitoid). Four releases of *G. nephantidis* @10/palm are recommended to get good control.

6. Campoleties chloridae

Hosts

Larval parasitoid of Noctuidae, particularly *Helicoverpa armigera* (Huebner) and *Spodoptera litura* (F.). It is a key parasitoid of the early-instar larvae of *H. armigera* throughout India. Its numbers in nature appear to have come down drastically in recent years, possibly due to indiscriminate use of insecticides and other factors.

Field Application

The recommended dosage is 15000 adults / hectare. One to three releases are necessary depending on the population density of young larvae in the field. Field utilization of this parasitoid is severely limited due to the lack of effective mass production techniques and the highly male-biased sex ratio.

Major Predators:

1. Chrysoperla sp.

Chrysoperla carnea, known as the **common green lacewing**, is an insect in the Chrysopidae family. Although the adults feed on nectar, pollen and aphid honeydew, the larvae are active predators and feed on aphids and other small insects. It has been used in the biological control of insect pests on crops.

Chrysoperla carnea was originally considered to be a single species with a holarctic distribution but it has now been shown to be a complex of many cryptic, sibling subspecies. These are indistinguishable from each other morphologically but can be 67uxiliary67 by variations in the vibrational songs the insects use to communicate with each other, which they especially do during courtship

These delicate predators consume aphids, mealybugs, spider mites, leafhopper nymphs, caterpillar eggs, scales, thrips, and whiteflies. Green lacewing are shipped as eggs packed in bran.

Release rates:

In gardens and greenhouses, release eggs at about 1,000 eggs/200 sq. ft., 10 to 50 thousand per acre. Once the larvae emerge, they will feed for 1-3 weeks before they become adults. The adults eat only honey, pollen, and nectar, which they need to reproduce. Repeated releases may be necessary if the infestation has not been arrested 5-7 days after the larvae have emerged. Availability: year-round.

2. Australian lady bird beetle- *Cryptolaemus montrouzieri*

Biological comtrol agent

This species has been used as a biological control agent against mealybugs and other scale insects. It was introduced to Western Australia. In California it has been introduced in 1891 by Albert Koebele to control the citrus mealybug. It has also been introduced to New Zealand for biocontrol. As biological control agent outside Australia, C. montrouzieri has the common name *Mealy bug destroyer*.

Host

The mealybug ladybird feeds on scale insects (superfamily Coccoidea) from three families, mealybugs (Pseudococcidae), soft scale (Coccidae) and felted scale (Eriococcidae). It is particularly associated with the Australian golden mealybug, *Nipaecoccus aurilanatus* (Maskell, 1890), found on Bunya pine and Norfolk Island pine (both *Araucari*a species). The ladybird is reported to feed on aphids and each other.

Economic importance:

Cryptolaemus montrouzieri is an important predator of mealybugs (especially those infesting citrus and grapes and occasionally also of soft scales and whiteflies. It controls large mealybug populations, but tends to leave the area as these prey become scarce. If later populations of the prey resurge, it becomes necessary to release the predator again. The predator is available from several companies.

Morphology:

The female is 3-5 mm long. The head, the prominent thorax and the legs red-brown, the elytra is shiny black covered by short hairs and slightly shorter than the abdomen. Larvae 7-10 mm in length, covered by white waxy strands, similar to mealybugs.

Life history:

Both larvae and adults of these beetles feed and may completely devour the eggs and other stages of mealybug and other coccids. Total development at 27°C required about 4 weeks and several hundred eggs (depending on the prey and its host plant) may be laid. The eggs are initially placed among the eggs of the prey, where on the predator feeds voraciously. The calculated threshold of development is around 0°C. The adults may live for several months,

feeding also on honeydew. This predator is sensitive to low temperatures and several efforts had to be made in order to establish it in North America and in the Middle East.

Weed Killer:

1. ***Zygogramma bicolorata***

- *Zygogramma bicolorat**a***, variously referred to as the **Parthenium beetle** or **Mexican beetle**, is a species of leaf beetle in the subfamily Chrysomelinae, native to Mexico.
- *Z. bicolorata* is a small lead beetle with a brown head, brown and yellow graduated pronotum and yellow elytra marked with characteristic elongated brown stripes. The pattern on the elytra is greatly variable – in a study of 478 beetles, 29 variations on this pattern were identified.

Economic benefits of biological control by Z. *bicoorata*

- In a conservative estimate, the beetle controlled 200-hectare land infested with *Parthenium* within three years of its release at Jabalpur.
- The cost of most effective herbicide metribuzin for one time application for 200 hectares accounted to be about Rs 5,40,000/-.
- It is also to be noted that during rainy season, about 70-80% *Parthenium* germinates at different time after commencement of rains.
- Hence, at least two applications are required to control *Parthenium* which might have costed Rs 10,80,000/- in a season.
- By fourth year of release, beetle was estimated to control 900 –hectare land that amounted to be worth of Rs 2.43 million of herbicide. If the same area has to be removed manually or mechanically, it will be about three times more of the herbicide cost.
- Therefore, it was concluded that biological control through Z. *bicolorata* has great potential at least in higher rainfall areas to manage *Parthenium.*
- The economic benefits will increase many-folds, if we take into consideration the indirect benefits derived in the form of environmental safety and increase in people health.

Number of beetles to be released :

- Sufficient numbers should be released to increase chances of breeding and thereby ensuring establishment.
- One adult was found to bring about defoliation of a single *Parthenium* plant in 6-8 weeks.
- Therefore, if releases are to be carried out at this rate, about 0.4. to 0.7 million insects will be required per hectare, as in general the weed density varied between 40 to 70 plants per square meter.
- In practical, it is neither possible nor necessary to release so many insects as they are capable of multiplying rapidly.
- Releases of about 500-1000 beetles can bring about establishment and eventual control.
- Once plants are eaten up in the release spot, the insects migrate in to adjacent areas.
- Taking this into consideration a number of release spots can be selected in a particular place or city, which can act as a focal point.
- More releases mean quicker establishment of the beetle and therefore, better control.
- So, do as many releases as affordable during first couple of years of introduction and make additional releases in isolated areas in future.

- This method reduces the time for the beetle to build up the population and help the beetles to disperse fast.
- The least affordable approach is to introduce one or two releases into infested area and do nothing more.
- This method will get a colony started, but will be slow in terms of time and area.

Time of release :

- The ideal time for carrying out releases is after the commencement of the rains during rainy season.
- During that time plenty of succulent *Parthenium* plants are available in nature.
- There is no benefit in undertaking releases between Novembers to May when they normally do not breed.
- However, beetles can be released in dry season also in those sites where sufficient moisture allows the continuous germination of new *Parthenium*.
- Such sites may provide suitable microclimate for the beetle to multiply.

2. Neochetina spp.

- *Neochetina* is a genus of weevils known as **water hyacinth weevil** which are native to South America.
- *Neochetina* feed almost exclusively on the highly vigorous water hyacinth (*Eichhornia* spp.). There are at least two species: *N. eichhorniae* or *mottled water hyacinth weevil* which gets its name from the plant it feeds on and *N. bruchi* or *chevroned water hyacinth weevil* which is characterized by a chevron–shaped marking on its back.
- Both weevils have been introduced extensively in countries around the world to help control water hyacinth growth which threatens to choke numerous waterways and lakes worldwide.

Use of biocontrol agents for weed control

Name of the weed	Bioagent
Cyperus rotundus	*Bactra verutana*
Ludwigia parviflora	*Haltica cynea* (Steel blue beetle)
Parthenism hysterophorus	*Zygrogramma bicolarata*
Lantana camara	*Crocidosema lantana, Teleonnemia scrupulosa*
Opuntia dilleni	*Dactylopius tomentosus, D. Indicus* (cochineal scale insect)
Eichhornea crassipes	*Neochetina eichhornea, N. Bruchi* (Hyachinth weevil) *Sameodes alliguttalis* (hyancinth moth)
Salvinia molesta	*Crytobagus singularis* (weevil) *Paulinia acuminate* (grass hopper), *Samea mutiplicalis*
Alternanthera philoxaroides	*Agasides hygrophilla* (flea beetle) *Amynothrips andersoni*
Tribulus terrestris	*Microlarinus lypriformis, M. lareynii*
Solanum elaegnifolium	*Frumenta nephalomicta*

Lecture No. 16

Mass multiplication and field release techniques of some important parasitoids: *T. chilonis, Chelonus blackburni, Cotesia / Bracon, Goniozus nephantidis, Epiricania melanoleuca*

1. T. chilonis:

Trichogranna chilonis (family – Trichogrammatidae, Order – Hymenoptera)

Being indigenous parasites, is proved to be one the most potent egg parasitoid for various Lepidoptera tissues borers.

Materials:

- Egg cards: Trichocards, 17.5 × 14 cm sized with 17 × 10cm spaced for glueing host eggs and 5 × 1.75 cm sized 20 pre punched segments.
- Corcyra eggs Gum Arabic
- Camel hair brush/ cotton swab, cotton wool. Test tube
- Refrigerator Honey
- Glass/ plastic jars, polythene bags, muslin cloth, rubber bans, scissors, clips.
- UV chamber, fluorescent tube light (40w) Working tables

Methods:

- Steps involved in mass rearing are as followes:
- Take the Corcyra eggs which were already separated from scales and dust particles and passed through 15, 30 and 40 mesh sieves. Measure its quality with measuring cylinder to assess the numbers.
- The eggs are exposed to UV rays (30 watt UV tube for 45 minutes at a distance of 2 feets) to prevent hatching during and/ or after parasilization of unparasitized.
- On backside of the Trichocards fill up the information like name of the parasites species, date of release of parasitoid for parasilization, name of the manufacturing institute, initials of technical person, etc.
- Smear the upper side (Punched) of the cards uniformly with gum Arabic solution using the soft camel hair brush/ cotton swab. The gum should be so thin that the segment can dry easily.
- Then the Corcyra eggs are glued/ layered on the card by sprinkling uniformly on the gum coated card. The cards are followed to dry and overlapped egg layers are removed gently.
- The processed egg card is then placed conveniently in plastic bowl or glass tube or in the polythene bags.
- Introduce the duly parasitized egg card in such container or expose these egg card to adult females of Trichogamma for 24 hrs. the parasitized and unparasitized eggs in each of the containers should be in the ratio of 1:6 to have optimum parasitization.
- Close the tube with cotton plug and close other containers conveniently. The adult female parasitoids emerge from the parasitized blackened eggs of Corcyra after mating.
- After 4 days of parasitization, brush out all the host larvae if any hatched from unparasitized eggs, as these larvae may destroy parasitized eggs. The parasitoids complete its life cycle mostly within 7-8 days.
- The parasitized eggs of Corcyra start changing their color from creamy white to blackish due to accumulation of urate granules after 4 days of parasitizaton.

- Such parasitized egg cards could be stored for about 30-35 days at 10^0c temperature in refrigerator.

Use of Trichocards:

- After parasitization, 6 days old parasitized cards become ready for shipment/ field releas.
- A coat of 10% gum 71uxili is applied on the grids (G1-30) and the eggs are sprinkled uniformly in a single layer with the aid of a tea strainer.
- The excess eggs pasted are removed by gently passing a shoe brush over the card after sufficient air drying under fan.
- The egg cards are placed into polythene bags of suitable size and the nucleus card of *Trichogramma* are introduced in it. The easiest way to accomplish this is to place a piece of „*Tricho* egg card" containing parasitized eggs (i.e. pharate adults) that are ready to yield the adults and to hold them in subdued light for 2 to 3 days.
- The emerging parasites readily parasitize the fresh eggs. The parasitoid – host ratio is adjusted accordingly to 1:6 get effective parasitism.
- The parasitized eggs in the *Tricho Card* turn back in 3 or 4 days and the adult parasitoids emerge in 8 to 10 days from the date of parasitization.
- The parasitized eggs in which the parasitoids in the larval or pupal stage (i.e. before or after turning black) can be stored in the refrigerator (at 50C) for about 3 weeks without any loss in emergence.

Field release

The parasitoids are released in the pharate stage or when few adults begin to emerge from the host egg during the evening hours. The cards are cut into bits neatly along the grids with least damage to the eggs and stapled beneath the foliage in the upper canopy level. To maximize the field parasitization it is recommended to release the parasitoids is as many locations as possible. Recently scientists are beginning to advocate the release of cards @ 1/5m row length.

Precautions

- Poor quality of mass reared *Trichogramma* can result in control failures.
- The artificial conditions of mass rearing can select for genetic changes that reduce the effectiveness of the *Trichogramma* in the field.
- Such rearing conditions include rearing multiple generations on unnatural host eggs, the absence of plants, crowding and interference, rapid generation time, and failure to rejuvenate genetic stock.
- Except for obvious problems such as lack of adult emergence or wing deformities, growers and pest consultants cannot detect poor quality *Trichogramma* prior to release.
- Commercial suppliers are responsible for maintaining desirable characteristics necessary for good performance in the field.
- Production colonies should be periodically replaced with individuals from a stock culture maintained on the natural or target host.
- Suppliers also should assess the per cent host egg parasitization, adult emergence, and the sex ratio of emerged adults to be sure they are within acceptable standards.
- Standards for established cultures on *Corcyra*are 95±5 per cent egg parasitization, 90±5 per cent adult emergence, and a sex ratio of 1 to 1.5 females per male.

2. *Chelonus blackburni:*

(Braconidae : Hymenoptera)

Cotton bollworm causes severe losses (40%) in yield of seed cotton. Chelonus blackburni is a highly potent eggs larval parasitoid of the bolloworms. Method of mass multiplication of parasitoid is given below.

Material:

- Rearing unit of Corcyra cephalonica which includes wooden boxes, crushed grains of sorghum, egg cards, gum Arabic, Corcyra eggs etc.
- Rearing unit of PTM, which include potato tubers, plastic basket, sterilized soil, puncturing brush, egg sheet of PTM.
- Breeding glass jars, muslin cloth, ribber bands, scissor, wide mouth plastic jar.
- Nucleus culture of chelonus blackburni adults.

Laboratory host:

Rice moth, Corcyra cephalonica, potato tuber, moth Phthorimaea, operculella.

Targeted pests

1. Pink bollworm,
2. Spotted bollworm
3. Potato tuber

Methods:

- A set of 100, 0-24 hr old eggs of *Corcyra* (not exposed to UV) are pasted to 5 x 5 cm card. This card containing eggs is exposed to 30 *C. blackburnii* adults in a 1.5 l container.
- The plastic container has windows with plastic mesh for aeration. Two cotton swabs, one soaked in 10% honey solution and the other in drinking water are also placed inside from the side opening which is closed tightly with a cloth covered cotton plug.
- The egg card after exposing to *C. blackburnii* for 24 hrs is removed and placed on 500 g sterilized cumbu medium. In 30 days time, adults start emerging from the cocoons formed in the cumbu medium after completing development on *Corcyra* larvae.
- The adults live for 25 days and their fecundity is about 400 eggs.
- The parasitoid could also be reared on potato tuber moth (PTM). A set of 1500 egg of laid on a cloth are stapled to a card.
- This card containing 0-24 hr old eggs is exposed to 30 *C. blackburnii* adults. The plastic container (14 cm x 11 cm) is converted into *C. blackburnii* rearing unit by cutting windows and fixing plastic mesh aeration.
- Two cotton swabs, one soaked in 50% honey solution and the other in drinking water are also placed inside from the side opening which is closed tightly with a cloth covered cotton plug.
- The PTM egg card after exposing to *C. blackburnii* for 24 hrs is removed and placed on punctured potatoes. This provides more entry points for PTM larvae and kept in a similar plastic container as described for exposure to *C. blackburnii*.
- The bottom of this container is lined with sterilized sand. In 25-27 days time, adults start emerging from the cocoons formed in sand at the bottom of the cage or sometimes inside potatoes after completing development on potatoes.
- The adults live for 23-31 days and their fecundity is about 288-390. Parasitoid host ratio of 1:50 should be maintained and the fresh lot of eggs provided every day.

Field Utilization of Chelonus blackburni potsto

The adult parasitoids could directly be released in the field crops or even in stored potatoes as described for earlier parasitoid

Dose: Release of 60,000 adults/he i.e. 15000 adults per week / release and such 4 releases in the field crop. In case of stored potatoes release, 2 adults / kg tubers.

Cotton: Release 2 lakhs adult parasitoids / ha / week. Total 6 release starting after 60days of planting.

4. Cotesia / Baracon:

- *B. brrvicornis* is an important gregarious larval ecto-parasitoid of many lepidopterans.
- It is widely distributed and recorded from *Antigastra catalaunalis*, *Adisura atkinsoni*, *Earias* sp., *Helicoverpa armigera*,*Noorda moringae*, *Opisina arenosella*, *Pectinophora gossypiella*, *Chilo partellus* etc.,
- Its natural parasitism is not very high.
- However, it paralyses many lepidopteran larvae and some of them never revive. This contributes to indirect control.

Production procedure

- *B. brevicornis* is amenable for mass rearing in the laboratory on the alternate host, *Corcyra cephalonica*. For small scale culture, glass chimney and the „Sandwich" technique are adequate.
- About 20 mated females are confined in a glass chimney, covering both sides of the chimney with muslin sheet held in place with rubber bands.
- A cotton swab soaked in 50% honey water solution is stuck to the side of the chimney to serve as food. With many hymenoptera, adult nutrition is of great importance as it influences sex-ratio.
- High protein diet at times improves the sex ratio so that more female progeny are produced. „Proteinex" can be used to produce the desired results.
- Replacing honey with laevulose or fructose also is beneficial in some cases. Exposure to sunlight frequently stimulates mating, oogenesis and fertilization of eggs.
- About 10 full grown larvae of *Corcyra* are placed between two sheets of facial tissue paper and placed over the muslin sheet covering the wider mouth of the chimney.
- The tissue is again covered with a sheet of muslin and fastened with a pair of rubber bands.
- The chimney is then placed with the host larvae facing a window or light source. Females of *B. brevicornis* are attracted to the host larvae, probe through the muslin and paralyze the larvae on each of which they lay about 25 eggs per day.
- At the end of 24 hours, the tissue sheets bearing parasitized larvae are removed and held in flat plastic containers until the parasitoid grubs hatch, complete development and spin cocoons.
- The egg, larval pupal and adult stages are completed in 28-36 hours, 4-7, 3-6 and 15-40 days respectively.
- The female parasitoid is capable of depositing 150-200 eggs in its life time. Emerging adults are again collected for mating and egg laying.
- Adults survive up to 15-40 days but egg laying usually tapers off after the first ten days. Two day old adults of *B. brevicornis*could be stored for 30 days at 50C and 50-60% RH.

5. Goniozus nephantidis:

- *Goniozus nephantidis* is the most widely used parasitoid of *Opisina arenosella*. It is a sturdy gregarious larval or prepupal ectoparasitoid.
- The female practices maternal care of eggs and larvae. The host larvae are parasitized and the parasitoid even feeds on host body fluid.
- The parasitoid is also capable of suppressing the population by merely stinging and paralyzing $1^{st} – 2^{nd}$ instar larvae.
- *G.nephantidis* is the most common and effective parasitoid of late instars caterpillars of *O. arenosella* in several parts of the country.
- The parasitoid is being mass multiplied and released in Karnataka, Kerala and several other states.

Method:

- The parasitoid is multiplied on *Corcyra cephalonica* larvae in diffused light.
- A pair of parasitoid is introduced in tube (7.5 x 2.5 cm).
- The adults are provided honey in the form of small droplets on wax coated paper.
- After a pre-oviposition period of six days one healthy last instar larva is provided in a vial.
- The larvae parasitized and containing eggs of *G. nephantidis* are removed regularly from the vials till the death of the female.
- Such larvae are kept in accordion type strips of paper in plastic boxes which are covered by muslin cloth.
- Considering the fecundity as 20-50, the female is capable of parasitizing 6-7 larvae in three oviposition spells each separated by 4-5 days.
- The life cycle of the parasitoid is completed in 10-14 days (incubation 24-36 hrs, larval feeding 36-48 hrs, prepupal stage 48-60 hrs and cocoon period 48 to 56 hrs + resting adult inside the cocoon 108-128 hrs).

6. ***Epiricania melanoleuca***:

Epiricania melanoleuca is an important ectoparasitod on nymphs and adults of sugarcane pyrilla *Pyrilla perpusilla* (Walker). The parasitoid does not multiply in sufficient numbers in dry period and as the temperature drops to 16C, the females lay eggs in trash for overwintering. The redistribution of *E. melanoleuca* for the management of sugarcane pyrilla has proved a notable success in many areas of the country

Method:

- The initial culture of *Epiricania melanoleuca* is started by collecting the cocoons of the parasitoid from the field.
- The cocoons are kept in 5 cm petridishes the bottom of which is lined by filter paper.
- The moths emerge in 5-7 days and mate immediately.
- The females readily lay eggs on the filter paper provided. The larvae from these eggs hatch within a week.
- 5 day old 100 nymphs / adults of pyrilla and 200-400 freshly emerged larvae of the parasitoid are kept in a glass tube (15 x 5 cm) for 15-30 minutes.

- For further rearing the parasitized individuals are transferred in battery jars where sugarcane leaves and diet containing 2.5 percent sugar and 2.5 protinules is made available.
- The optimum room temperature for rearing the parasitoid is 27-30Oc. Nylon net field cages 3x2x2 m. can also be used for mass multiplication of *E. melanoleuca*.
- Sugarcane or sweet sorghum plants grown inside the cages are infested with laboratory reared sugarcane pyrilla eggs.
- Once the pyrilla are 5 days old, the newly emerged *E. melanoleuca* are introduced into of such cages.
- The cocoons of *E. melanoleuca* are collected after about a week by cutting the leaflets which could then be released in the fields.
- Efforts are on to multiply *E. melanoleuca* on semisynthetic diet so that the labour on host rearing could be saved.

Lecture No. 17

Mass multiplication and field release techniques of important predators: *Chrysoperla* sp., Australian lady bird beetle, Weed predators/killers: *Zygogramma bicolorata, Neochetina* sp.

1. *Chrysoperla* sp:

- In India, 65 species of chrysopids belonging to 21 genera have been recorded from various crop ecosystems.
- Some species are distributed widely and are important natural enemies for aphids and other soft bodied insects.
- Amongst them,*Chrysoperla carnea* is the most common.
- It has been used in cotton ecosystem for protection from aphids and other soft bodied insects. *C. carnea* is now used extensively all over the country.

Morphology and Biology

- The eggs are stalked and green in colour.
- The length of the egg in various species ranges between 0.7 to 2.3 mm and that of the stalk between 2 to 26 mm.
- The eggs are laid singly or in clusters.
- Eggs turn pale whitish and then black before hatching.
- Egg period lasts 3-4 days. The larva is white in colour on hatching.
- The larva has 3 instars which are completed in 8-10 days.
- The larva spins a cocoon from which the adult emerges in 5-7 days.
- Adults on emergence mate repeatedly.
- Generally, pre-oviposition period lasts for 3-7 days.
- Adult females start laying eggs from 5^{th} day onwards and peak egg-laying period is between 9-23 days after emergence.
- The male longevity is 30-35 days and female can even live up to 60 days.
- Fecundity is 600-800 eggs/female.

- The sex ratio Male: Female is 1: 0.85.
- The adult males and females live 41 and 53 days, respectively.

Production procedure

- In mass production, the adults are fed on various types of diets.
- The larvae are either reared in plastic tubes or empty injection vials or in groups in large containers or in individual cells.
- The adults are collected daily and transferred to pneumatic glass troughs or G.I. round troughs (30 cm x 12 cm).
- Before allowing the adults, the rearing troughs are wrapped inside with brown sheet which act as egg receiving card.
- About 250 adults (60% females) are allowed into each trough and covered with white nylon or georgette cloth secured by rubber band.
- On the cloth outside three bits of foam sponge (2 sq.in) dripped in water is kept.
- Besides an artificial protein rich diet is provided in semisolid paste form in three spots on the cloth outside.
- This diet consists of one part of yeast, fructose, honey, Proteinex R and water in the ratio 1:1:1:1.
- The adults lay eggs on the brown sheet.
- The adults are collected daily and allowed into fresh rearing troughs with fresh food.
- From the old troughs, the brown paper sheets along with *Chrysopa*eggs are removed.

2. Australian lady bird beetle:

- *montrouzieri* has been introduced from Australia for the control of *Coccus viridis* on coffee.
- But the predator has established on many species of mealybugs and green shield scale.
- In the field its practical use for the suppression of mealybugs *viz*., pink mealy bug, *Maconellicoccus hirsutus,* citrus mealy bug *Planococcus citri,* tailed mealy bug *Ferrisia virgata* and mealy scale *Pulvinaria maxima* on citrus, coffee, grapes and several other fruit crops and ornamentals has been demonstrated.
- Use of *C. montrouzieri* is the break through in applied classical biological control.
- The coccinellid predator is native of Australia.
- In 1892, it was introduced into California by Albert Koebele for the control of citrus mealy bugs.
- Following the success, the beetle was introduced into India in 1898 by New Port.
- It has given effective control of mealy bugs in fruit crops like citrus, grapes, guava, etc.
- *C. montrouzieri* is one of the outstanding examples in the biological control history. Its importance is also evident by its growing commercialization in India.

Method:

- In the laboratory, the life cycle is completed in approximately 30 days.
- The premating and preoviposition periods are about 5 and 10 days respectively.
- The oviposition is about 10 days.
- Eggs are laid from late evening to early morning.
- They are pale yellowish white, the surface being smooth and shiny.
- It is oval to cylindrical, both the ends beings smoothly rounded.
- Incubation period ranges from 5 to 6 days but extended in winter months.

- Viability of eggs is 90 to 100 per cent.
- The newly hatched grub is sluggish but becomes active after 3 to 4 hours.
- The tiny grub is pale 77uxilia with white lines across the body along intra segmental regions.
- These white lines become prominent after few hours and white wax strands develop after a day. The grub has four larval instars, and the larval stage occupies about 20 days.
- They feed on all stages of mealy bugs.
- Duration of first, second, third and fourth instar grubs are 3-4, 4, 4-5-7-8 days respectively.
- Grownup grubs are entirely covered with white wax strands.
- When the grub is disturbed, it exudes a yellow fluid from the dorsal surface of the body for defensive purpose.
- The prepupal period is 2 to 4 days when it suspends feeding activities.
- The pupal period varies from 7 to 9 days.
- The adult spends about one day in the pupal case before it emerges.
- It is covered with a white powder like substance for a day.
- The male could be distinguished from the female by the colouration of first pair of legs.
- The first pair of legs in the case of male is brown and the latter two pairs being black, whereas in the female all the three pairs are black.
- Male to female ratio is 1 : 1. Adults are also known to attack and feed the mealy bugs.
- Longevity of adults ranges from 50 to 60 days and the fecundity is about 200-220 eggs.

Weed Predators:

1. Zygogramma bicolorata:

- Adults and larvae of Z.*bicolarata* feed on parthenium leaves.
- The eggs are laid single or in small groups of up to five mostly on the undersurface of the leaves and egg period lasts four five days the early stage larvae feed on the terminal and 77uxiliary buds and move on to the leaf blades as they grow.
- The full grown larvae enter the soil and pupate ,larval and pupal periods last 10-15 days and 8-10 days, respectively.
- Each female is capable of laying up to 1,786 eggs (mean 836.13).

Production procedure:

- 10 pairs of adults (male and female)is placed on bouquets of parthenium leaves in 14×12cm transparent plastic container.
- After observance of egg laying such leaves are replaced and fresh bouquets in egg laying jars can be repeated for one month.
- Small parthenium plants are removed from soil and transplanted in 45×60×90cm cages with zinc sheet trays at bottom.
- These trays are filled with soil and parthenium plants are transplanted and water daily. Once plants start growing, leaves with egg of Z.*bicolarata* are placed over theme.
- Around 100-150 eggs can be transferred in one such cage. On hatching leaves and pupate in soil. In such process they consume all plants inside cages.
- Generally ration is 10-15grubs to one plant. This way around 15-20 small plants are provided in each cage.
- Such cages yield around 100-125 adults.

- It can also be bred in open field cages by releasing 1 pair/2 plants .
- Such cages can accommodate around 100 plants. And yield about 300 adults.

Field releases;

For inoculative raleases 500 adults of *zygogramma bicolarata* are released per hectare coinciding with the start of monsoon showers. The beetles spread automatically to the adjoining fields.

Lecture No. 18

Importance species of pollinator and scavengers with their importance

Important Species Pollinators

Pollinators are Bees, Butterflies, Hummingbirds, and other animals which feed from flowers, transferring pollen in the process. Nearly 80% of all flowering plants need pollinators to transfer pollen in order to produce fruits, seeds and vegetables. One out of every three bites of food we eat depends on the work of pollinators.

1. **Native Bees** – There are 3,500 native bee species in North America and they are the most important group of animal pollinators. Native bees are more effective pollinators than non-native honeybees and their body structure plays a role. Some bees pack pollen into baskets on their legs. Most native bees are like tiny flying dust mops. Pollen clings to hairs on their bodies and easily brushes off. In this way, flowers get pollinated more completely. Native bee behavior can also play a roll in pollination. Unlike honeybees, native orchard bees are willing to fly when it"s cold and damp. And while honeybees will visit a single fruit tree, methodically going from flower to flower, orchard bees fly from tree to tree, resulting in the cross-pollination some trees need to set fruit.
2. **The Bumble Bee** Is the only true social native bee with worker bees to care for the hive. Bumble bee species are known to pollinate many important food crops. When other pollinators are inactive due to cold temperatures, bumble bees are able to shiver which warms their wings enabling them to fly. Bumble bees also do something called "buzz pollination." They vibrate their flight muscles at the exact frequency needed to shake pollen loose from the plants anthers. Tomatoes for example, don"t really need bees because they self-pollinate but when tomatoes get regular visits from "buzz pollinators", they produce larger fruit and more of it. Bumble bees are also more effective than honeybees at pollinating crops grown in greenhouses. A mated queen is the only bee in the colony to survive over winter. She emerges from hibernation each spring to start a new hive.
3. **Solitary native bees** are also important pollinators. They include **squash bees** whose pollination includes cucumbers, melons, and squashes; **mason bees** who pollinate many orchard crops such as apples; **green sweat bees** who pollinate many flowers including strawberry; and **mining bees** who are generalists, pollinating many plants. Solitary bees are not aggressive since they have no hive to defend. They do not sting. 70% of solitary bees nest in the ground. Some species nest in holes excavated by beetles in logs and snags or in hollow plant stems.
4. **European Honeybees** are managed by beekeepers in specialized hive boxes. They were imported from Europe in the early 1600"s to pollinate introduced crops and for honey and beeswax. Farmers depend on honeybees to pollinate many food crops from pumpkins to

oranges and are also relied upon for honey. Honeybees are the only bee to produce and store large quantities of honey.

5. **Other Important Pollinators** –

Wasps, **Butterflies**, **Moths**, **Flies**, **Beetles**, **Hummingbirds** and even **bats** contribute to the pollination of a variety of plants. Butterflies, while not as efficient as bees, flutter from flower to flower seeking nectar while carrying pollen. They like bright red, orange, yellow, and purple flowers. Moths take over pollination on the night shift, seeking fragrant night bloomers in white or pale colors to reflect moonlight. For every butterfly you see pollinating during the day, 19 moths are actively pollinating at night. Flies that sport stripes as bee mimics to fool predators are not like our common housefly pest. They prefer less showy flowers that other pollinators pass by. Among these "respectable" flies are the hoverfly, flower fly and midge. After bees, flies are the second most important pollinator of many flowers. Beetles pollinate 52 plant species in North America. They are very beneficial insects for both pollination and for controlling pest insects

Importance of Scavengers:

- Scavengers play a fundamental role in the environment through the removal of decaying organisms, serving as a natural sanitation service.
- While microscopic and invertebrate decomposers break down dead organisms into simple organic matter which are used by nearby autotrophs, scavengers help conserve energy and nutrients obtained from carrion within the upper trophic levels, and are able to disperse the energy and nutrients farther away from the site of the carrion than decomposers.
- Scavenging unites animals which normally would not come into contact, and results in the formation of highly structured and complex communities which engage in nonrandom interactions.
- Scavenging communities function in the redistribution of energy obtained from carcasses and reducing diseases associated with decomposition.
- Oftentimes, scavenger communities differ in consistency due to carcass size and carcass types, as well as by seasonal effects as consequence of differing invertebrate and microbial activity.
- Competition for carrion results in the inclusion or exclusion of certain scavengers from access to carrion, shaping the scavenger community.
- When carrion decomposes at a slower rate during cooler seasons, competitions between scavengers decrease, while the number of scavenger species present increases.
- Alterations in scavenging communities may result in drastic changes to the scavenging community in general, reduce ecosystem services and have detrimental effects on animal and humans.
- The reintroduction of gray wolves (*Canis lupus*) into Yellowstone National Park in the United States caused drastic changes to the prevalent scavenging community, resulting in the provision of carrion to many mammalian and avian species.
- Likewise, the reduction of vulture species in India lead to the increase of opportunistic species such as feral dogs and rats.
- The presence of both species at carcasses resulted in the increase of diseases such as rabies and bubonic plague in wildlife and livestock, as feral dogs and rats are transmitters of such diseases.

- Furthermore, the decline of vulture populations in India has been linked to the increased rates of anthrax in humans due to the handling and ingestion of infected livestock carcasses.
- An increase of disease transmission has been observed in mammalian scavengers in Kenya due to the decrease in vulture populations in the area, as the decrease in vulture populations resulted in an increase of the number of mammalian scavengers at a given carcass along with the time spent at a carcass.

Scavengers:

Terrestrial Vertebrates

• Vultures & Buzzards, like Bearded, White-Backed, & Turkey Vultures
• Ravens & Crows, like Jungle, Torresian, & American Crows; Australian Ravens
• Seagulls
• Marabou Storks
• Magpies
• California Condors
• Bald Eagles
• Spotted Tail Quolls
• Spotted Hyenas & Striped Hyenas
• Dingos
• Raccoons
• Opossums
• Mice & Rats
• Hedgehogs
• Coyotes & Jackals, such as Golden Jackals
• Red Foxes
• Lions
• Grey Wolves
• Wolverines
• Leopards
• Black Bears
• Polar Bears
• Alaskan Brown Bears
• Grizzly Bears
• Tasmanian Devils
• Monitors, such as Lace Monitors & Gould"s Goanna

Terrestrial Invertebrates

• Flies, such as House Flies, Horse Flies, Blow Flies
• Ants, such as Gravel Ants & Army Ants
• Several species of Beetles, including Burying Beetles & Water Beetles
• Roaches, such as Cockroaches
• Termites
• Yellowjackets
• Centipedes & Millipedes

Aquatic Vertebrates

• Great White Sharks

• Eels
• Remoras

Aquatic Invertebrates

• Crabs, including Alaskan King Crabs
• Lobsters
• Sea Slugs
• Snails
• Prawns

Many animals which are thought of as predators (e.g. Lions, Polar Bears, Great White Sharks) will take opportunity to scavenge on carrion.