Lecture Note

of

Fourth Semester UG course
(As per fifth Deans Committee Recommendations/syllabus)

Ag. Ento. 4.3: Management of Beneficial Insects
(1 + 1 = 2)

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N.M. COLLEGE OF AGRICULTURE
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Academic Year: 2019-20

COURSE CONTENT (SYLLABUS)

Ag. Ento. 4.3 **Management of Beneficial Insects** **Credit: 1 + 1 = 2**

THEORY SYLLABUS:

Part I: Importance of beneficial Insects, Beekeeping, pollinating plant and their cycle, bee biology, species of honey bees**,** commercial methods of rearing, equipment used, seasonal management, bee enemies and diseases. Bee pasturage, bee foraging and communication. Division and uniting of honey bee boxes. Toxicity of pesticides to honey bees.

Part II: Types of silkworm, voltinism and biology of silkworm. Mulberry/castor cultivation, mulberry varieties and methods of harvesting and preservation of leaves. Rearing and mounting larvae and harvesting of cocoons. Pest and diseases of silkworm and management. Rearing appliances of mulberry silkworm and methods of disinfection.

Part III: Species of lac insect, morphology, biology, host plant, lac production – seed lac, button lac, shellac, lac- products. Enemies of lac insects.

Part IV: Identification of major parasitoids and predators commonly being used in biological control. Insect orders bearing predators and parasitoids used in pest control and their mass multiplication techniques. Important species of pollinator, weed killers and scavengers with their importance.

PRACTICAL SYLLABUS:

Honey bee species, castes of bees. Beekeeping appliances and seasonal management, bee enemies and disease. Bee pasturage, bee foraging and communication. Division and uniting of honey bee boxes. Migration of honeybee boxes. Types of silkworm, voltinism and biology of silkworm. Mulberry/castor cultivation, mulberry varieties and methods of harvesting and preservation of leaves. Species of lac insect, host plant identification. Identification of other important pollinators, weed killers and scavengers. Insect orders bearing predators and parasitoids used in pest control and their mass multiplication techniques. Visit to research and training institutions devoted to beekeeping, sericulture, lac culture and natural enemies.

SUGGESTED READINGS:

- A text book of Applied Entomology, Vol. II by K. P. Srivastava and G. S. Dhaliwal, Kalyani Publisher
- Elements of Economic Entomology by B. V. David and V. V. Rammurthy. Namrutha Publications (7^{th} Edition)
- Principles of Applied Entomology by K. N. Ragumoorthy, M. R. Srinivasan, V. Balasubramani and N. Natarajan Published by A. E. Publication, Coimbatore
- Modern Entomology by D. B. Tembhare, Himalaya Publishing House (ISBN : 978-93-5051-828-1)
- Essentials of Agricultural Entomology by G.S. Dhaliwal, Ram Singh and B.S. Chillar, Kalyani Publisher
- Element of Agricultural Entomology by G.S. Dhaliwal (2015). Published by Kalyani Publishers, New Delhi (ISBN: 978-93-272-5134-0).

INDEX

Part- I: Honey bee

Importance of honey bees:

The field of entomology may be divided into two major aspects, as fundamental entomology or general entomology and applied entomology or economic entomology.

Fundamental Entomology deals with the basic or academic aspects of the Science of Entomology. It includes morphology, anatomy, physiology and taxonomy of the insects. In this case we study the subject for gaining knowledge on Entomology irrespective of whether it is useful or harmful.

Applied Entomology or Economic Entomology deals with the usefulness of the Science of Entomology for the benefit of mankind. Applied entomology covers the study of insects which are either beneficial or harmful to human beings. It deals with the ways in which beneficial insects like predators, parasitoids, pollinators or productive insects like honey bees, silkworm and lac insect can be best exploited for our welfare. Applied entomology also studies the methods in which harmful insects or pests can be managed without causing significant damage or loss to us.

There are two type of insects (i) Beneficial insects e.g. Honeybee, Silk worm, Lac insect etc.

(ii) Harmful insect e.g. *Helicoverpa*, *Spodoptera*, Aphids, etc.

Beneficial insects are important as they are:

(i) Productive insects:

A. Products from secretion of insects and forest trees (Industrial Entomology)

- Silk (silkworm) **(Sericulture)**
- Bees wax (honey bees) **(Apiculture)**
- Shellac (lac insect) **(Lac culture)**

B. Collect, elaborate and store plant product

- Honey (Honey bee) **(Apiculture)**

(ii) Helpful insects:

- Aid in pollination **(Pollinators)**
- Parasitoid and predators of injurious insects **(Biological control)**
- Destroy weeds **(Weed killers)**
- Improve soil fertility **(Agricultural entomology)**
- As scavengers
- Insects and their products useful in medicine **(Cantharidine)**
- Helpful in solving crimes **(Forensic entomology)**

(iii) Beekeeping is an ideal subsidiary or whole time occupation. It fits well in diversification of agriculture. Besides adding to the farm income through production of honey, beekeeping also leads to the generation of other sources of income and employment opportunities including the development of several allied industries.

BEEKEEPING

Beekeeping is an art and skill maintaining the bees in modern movable frame hives for hobby or fascination, production of hive products (honey, bee wax etc.) and for pollination services **OR** the practice of rearing bee is called **beekeeping or Apiculture.** Apiculture is synonym of the beekeeping and is derived from Latin word '*Apiscultura*'. *Apis* means 'bee' and *cultura* means 'cultivation through education'. The place where the hives are maintained is called an A**piary**. Beekeeping is a high profit enterprise it can be taken up both as subsidiary industry and as well as whole time profession.

Initially in 1953 as many as 230 beekeepers, who maintained around 800 bee colonies in modern bee boxes and were producing 1, 200 Kg of honey annually. Presently it is estimated that with 25.00 Lakhs of bee colonies, 2.50 Lakhs beekeepers and wild honey collectors' harvest around 56, 579 MT of honey in country, which valued Rs. 476.04 crores. The average annual per capita consumption in India is 8.4 g.

HISTORY OF BEEKEEPING –WORLD

It is not clear when man started beekeeping, but there are archaeological evidences that about 4,000 years ago, the Egyptians kept bees in clay pots and used not only for honey, but also for propolis and wax. In fact, the honeybee was the symbol of Lower Egypt. Still many rock and cave paintings are available across the world depicting the honey bee in different shapes.

In ancient Greece and Rome, apiculture was a common practice. The philosopher Aristotle in his book "*Historia Animalum*" talked about honeybees' floral fidelity, division of labour within the colony and winter feeding. He also described some brood disease. Hippocrates, the Father of Medicine, depicts the nutritional and pharmaceutical value of honey. Greek athletes used honey as an energy boost.

Commercial beekeeping started during the second half of the 19th century. In 1851, **Rev. L. L. Langstroth** discovered the concept of **'bee space'** (3/8 inch space is kept by the bees between two adjacent combs as their passage for free movement all around the combs). Bee space or passage way is the space required between any two frames for the bees to move about conveniently between two combs. Based on this concept, modern age **'Langstroth bee hive'** with movable parallel frames/combs was developed by **L. L. Langstroth** is known as **Father of Modern Beekeeping**.

HISTORY OF BEEKEEPING – INDIA

Bees and honey were known to human being in India since time immemorial as their references are mentioned in epics, on murals, sculptures, etc. Vaishali Stupas in Muzaffarpur (Bihar) were built in commemoration of offering of honey to Lord Buddha by king of monkeys and his people whenever Lord Buddha visited the place. Several references of bees have been made in the oldest scripture of India, the **Rig Veda**.

The earliest method of keeping bees was to use hollowed out tree trucks, empty pots or any other suitable receptacles smeared with wax and sweet scented leaves of *Cinnamomum iners* on the inner surface; these receptacles were kept in jungles to entice (invite) the bees during swarming seasons. When the bees had settled there, these receptacles were carried to and kept in desired places. This type of hive is called *pot hive* and it was in practice in Mysore, Coorg, Malabar, Godavari, Kasmir, etc.

In our country, first attempt to keep honey bees in movable frame hive was made in early 1880s in pre-partition Bengal and Punjab. Commercial beekeeping in India started in 1910 in South when **Rev. Newton** devised a movable frame hive suitable for Asiatic hive bee, *Apis cerana*. This hive was named after him as **'Newton Hive'**. This hive is still popular for keeping the indigenous hive bee, *A. cerana*. During 1911-17, Newton also trained a large number of beekeepers in Southern India.

The Royal Commission on Agriculture (1928) recommended development of beekeeping as a cottage industry in India. The **All India Beekeepers' Association (AlBA)** was established in 1938-39. This association started publishing the ***Indian Bee Journal*** **(lBJ)**. During 1880, high yielding **European bees, *A. mellifera***, were introduced in our country. A sizable quantity of this species was imported from 1920 to 1951 in the states of Maharashtra, Kerala, Karnataka, Tamil Nadu, West Bengal, Punjab and Kashmir but none succeeded to establish this exotic honey bee species in the country.

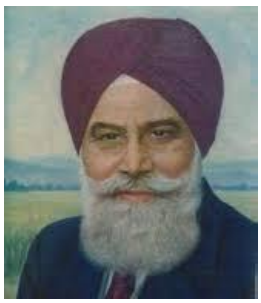
STRENGTHENING OF BEE KEEPING RESEARCH AND DEVLOLNMENT IN THE COUNTRY

After independence, **Khadi and Village Industries Commission (KVIC)**, Govt. of India took up beekeeping as one of its ventures. Some states like Jammu and Kashmir, Karnataka, Uttar Pradesh and Himachal Pradesh established Departments of Beekeeping under their Ministry of Agriculture/Industries. Further, considering the importance of applied and basic research in apiculture, KVIC established **Central Bee Research and Training Institute (CBRTI)** at Pune (Maharashtra) in 1962.

The research in beekeeping started when Indian Council of Agricultural Research (ICAR), New Delhi started funding to the different projects. Two Beekeeping Research Stations were also established at **Nagrota-Bagwan** (erstwhile Punjab, now in H.P.) in 1945 and at **Coimbatore** (Tamil Nadu) in 1951. Recently in Gujarat, Department on Entomology, N.M. College of Agriculture, Navsari Agricultural University, Navsari has initiated research on honey bees and other pollinators sponsored through ICAR, New Delhi with Project entitled **"All India Co-ordinated Research Project on Honey bees and Pollinators from the year 2015-16"**

SUCCESSFUL INTRODUCTION AND ESTABLISHMENT OF *Apis mellifera* IN INDIA

After a long gap of unsuccessful attempts of ***A. mellifera*** introduction in our country, Professor **A. S. Atwal,** an Entomologist of the Punjab Agricultural University (PAU), Ludhiana with his associates introduced ***A. mellifera*** in 1962 at Beekeeping Research Stations of Nagrota-Bagwan (H.P.) by adopting the **'Inter-specific Queen Introduction Technique'**. They imported disease free *A. mellifera* gravid queens along with worker bees. Later the worker bees were burnt and *A. mellifera* queens were introduced one each into the de-queened colonies of Asiatic hive bee (*A. cerana*). After the adaptation of *A. mellifera* queens, the workers of Asiatic hive



bee (*A. cerana*) reared the brood. It resulted in gradual replacement of workers of *A. cerana* who died with the age. Thus, *A. mellifera* stocks were further strengthened by importing disease free consignments of the gravid queen bees.

Convinced with the performance of *A. mellifera* in the Punjab, H.P. and Haryana and due to the outbreak of Thai Sac brood Viral Disease causing large scale mortality of *A. cerana* colonies during late 1970s to early 1980s in the states, practicing *A. cerana* beekeepers of many other states expressed desire to adopt *A. mellifera*. Due to this, ICAR in 1986 decided to extend this species from Punjab to other states. Now, this exotic honey bee (*A. mellifera*) has been spread to almost whole of the country. During 1993, **Department of Agriculture and Cooperation (DAC)**, Ministry of Agriculture, Govt. of India laid special emphasis on beekeeping and started a National Scheme on the **'Development of Beekeeping for Increasing Crop Productivity'**. Under this Scheme, beekeeping research, training and development projects were sanctioned to various State Agriculture Universities (SAUs), State Agriculture Departments, Government and Non-Government organizations (NGOs). Govt. of India established **National Bee Board in 2006**.

1. Honey bee:

Scientific classification		
Kingdom	:	Animalia
Phylum	:	Arthropoda
Class	:	Insecta
Order	:	Hymenoptera
Family	:	Apidae
Subfamily	:	Apinae
Tribe	:	Apini Latreille, 1802
Genus	:	***Apis*** Linnaeus, 1758

Biology/ Life history of Honey bee:

Eggs:

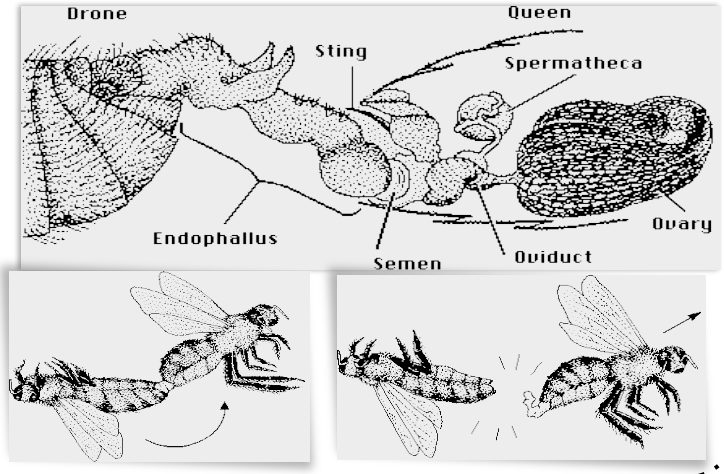
Eggs are laid by queen and when a colony wants to produces a new queen, the special cell is constructed at the lower border of the brood comb. On these cells, singles egg is laid by the queen in each cell which hatched after 3 days. The newly hatched grubs are provided with royal jelly. The grub is fully developed in 5 or 6 days and then queen cell is capped where grub changes into pupa and after a week adults come out by biting the cap of queen cell. The adult who comes out earlier become the daughter queen and it kills the remaining pupae before their emergence.

Nuptial flight:

After 2-3 days the daughter queen takes nuptial flight accompanied by hundreds of drones during day. She overtakes drone in flight. The drone which follows her takes the chance of copulation. The male soon dies after copulation and the mated queen return to the comb. She mate only once in her life time. The seminal fluid (male sperms) is collected in a special receptacle (spermatheca) and used as and when required.

Drone honeybee die after copulation…….WHY??

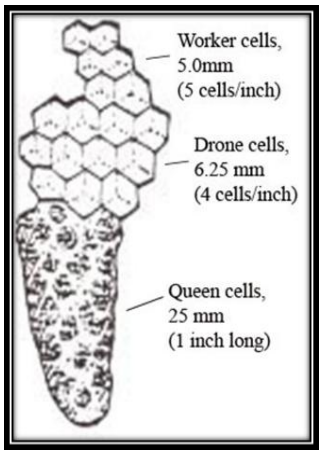
The drone mounts the queen, inserts his endophallus, and ejaculates his semen. During ejaculation, the male falls back and his endophallus is ripped out of his body and remains attached to the queen. Drones mounting later remove the previous drone's endophallus and lose their own through similar matings. The emasculated drones die very quickly with their abdomens burst in this fashion.

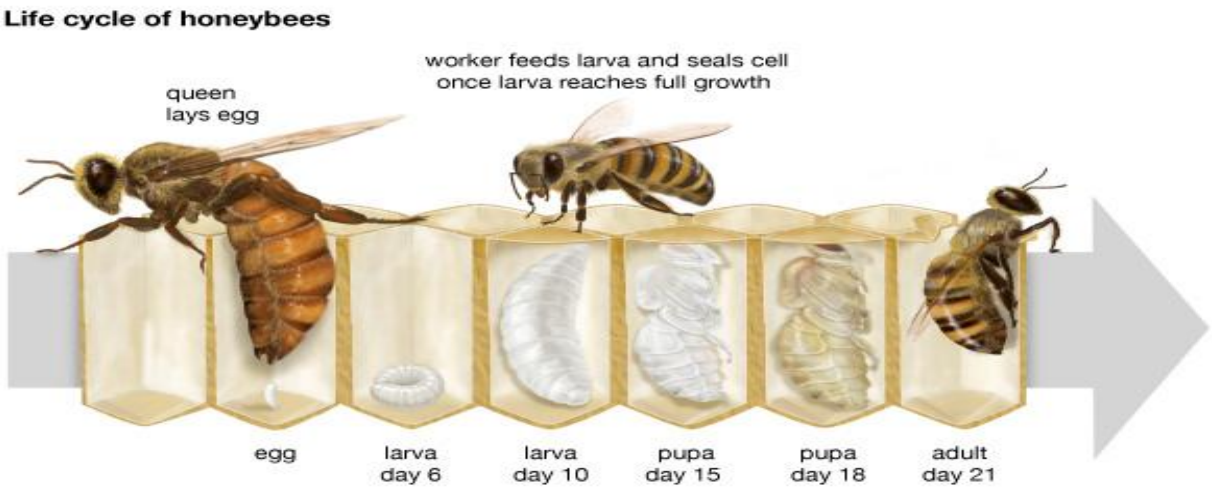


Oviposition

After some times the daughter queen starts eggs laying and is called as mother queen. She lays fertilized or unfertilized eggs at her will. Once egg is laid in a cell, it hatched in 3-4 days. The eggs are long, oval and light brown in colour.

The **queen measures the cell opening with her front legs** as she inspects each cell prior to laying her egg. Worker bees develop horizontally in hexagonal cells of approximately 0.2 inch (5 mm) diameter (5 cells/inch). Drones develop in slightly larger horizontal cells. The female queen develops in a vertically-oriented cell. The existing queen herself lays fertilized eggs in special cup-like structures, called **queen cups**, oriented vertically on the face of the horizontal worker and drone comb or more usually **at the bottom margin** of the comb.





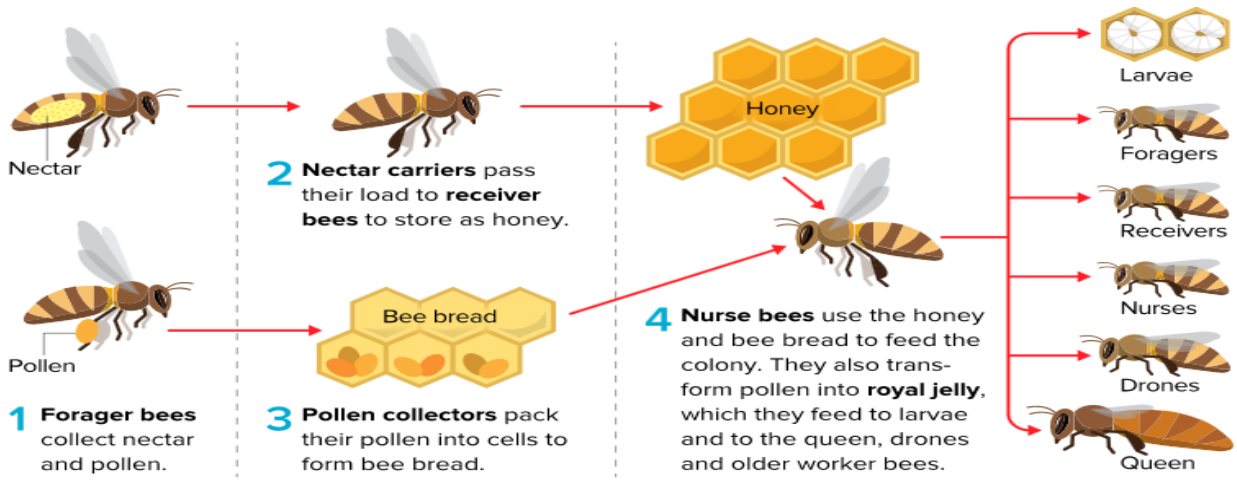
Grub:

From the fertilized eggs the **queen and worker** are developed, while from the unfertilized eggs **drones** are developed. The grubs are cylindrical in shape and light yellow in colour, they fed with the royal jelly for 2-3 days after that they are provided with honey and nectar, etc. The grub period lasts for about 5-6 days.

Worker bees are raised in the multipurpose, horizontally arranged cells of the comb. Future workers receive the royal jelly only during the first 3 days as compared to future queens, who are fed with royal jelly throughout their larval life.

The developing queen larva is always surrounded by royal jelly, a special highly nutritious food produced by head glands of the workers. This feeding scheme, called massive provisioning is unique to the queen and continues throughout her entire developmental period.

Worker bees mix the honey with pollen and feed to the drone larvae. Future drones receive royal jelly for the first 3 days. After that, they are shifted to progressive feeding as discussed in worker feeding.



Pupa:

Full grown grub forms a cocoon and pupates insides the cell. The pupal periods lasts for about 7-14 days depending upon the type of adult to be produced. The time required for development of different castes of *A. mellifera* is given below:

Adult	Eggs	Grub	Pupa	Total
Queen	3 days	6.5 days	6.5 days	16 days
Worker	3 days	8.0 days	10.0 days	21 days
Drone	3 days	9.5 days	11.5 days	24 days

Total lifespan/biology of honey bee:

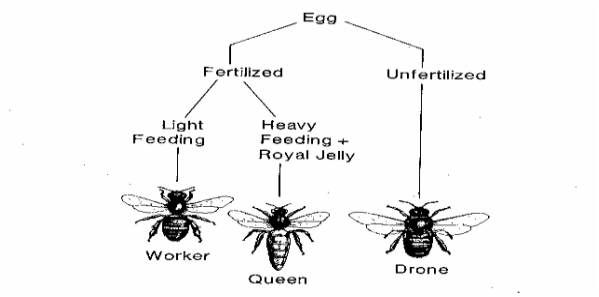
Development Stage	Castes		
	Queen	**Worker**	**Drone**
Egg	3 days	3 days	3 days
Unsealed stage	5 days	5 days	7 days
Cell sealed	8^{th} day	8^{th} day	10^{th} day
Cocoon information	10^{th} day	11^{th} day	14^{th} day
Adult formation	15^{th} day	20^{th} day	22^{nd} day
Adult emergence	16^{th} day	21^{st} day	24^{th} day
Sexual maturity	within 2-3 days	-	13 days
Adult longevity	3-4 years	6 weeks	2-3 months

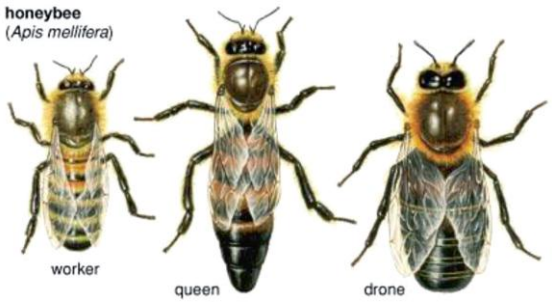
Honey bees are the only bees to die after stinging …….WHY??

Because when a honey bee stings a person, it cannot pull the barbed stinger back out. It leaves behind not only the stinger, but also part of its abdomen and digestive tract, plus muscles and nerves. This massive abdominal rupture kills the honey bee.

HONEY BEE CASTES

The honeybee is a social insect and lives in colonies with a highly organized system of division of labour. Many combs are found in a colony in which the members of the same family used to live. Each family consists of three castes: queen (fertile female), drones (males) and workers (sterile females). Each caste has its special function in the colony. The workers are undeveloped females, the drones are known as males and the queen is the fully developed female. Every honey bee colony comprises of 35000 to 70,000 members includes a queen, 200-300 drones and several thousand workers.





Sex differentiation in bees

A. Queen:

The queen is a **true mother bee**. Queen is the only female that is completely developed sexually from fertilized egg. This is a result of a total diet of **royal jelly** during the developmental period. She has a long abdomen extending well beyond the apical margins of the wings. In the colony, she is found in the area of the brood nest. A well developed queen is generally two to three times bigger than a worker and measures about 15-20 mm in length.

Duties of a queen:

1. The only individual which lays eggs in a colony (**Mother of all bees**).
2. Lays upto 2000 eggs/day in *Apis mellifera* and maintaining a populous colony.
3. Five to ten days after emergence, she mates with drones in one or more nuptial flights.
4. When her spermatheca is filled with sperms, she will start laying eggs and will not mate any more.
5. **She lives for 3 years** and when it is weak or unable to lay eggs it is replaced by one of the daughter queen.
6. The secretion from mandibular gland of the queen is called **queen's substance**.
7. The queen substance if present in sufficient quantity performs following functions.
    a) Prevent swarming and absconding of colonies.
    b) Prevent development of ovary in workers.
    c) Colony cohesion is maintained.
8. The queen can lay either fertilized or sterile eggs depending on the requirement.

B. Drone:

Drones, the functional males of the colony are produced from unfertilized eggs, and are larger and darker than the worker. It is smaller than queen and measures about 15-17 mm in length. Drones are not a permanent member of colony. The queen can control whether or not the egg is fertilized as she lays it. The compound eyes are holoptic i.e. very large and are united at the vertex. The end of the abdomen is blunt and is covered with a tuft of small hairs. **Drones cannot sting.** As the sting is a modified structure of the female genitalia, drones do not have stings. They also **do not have any of the structures necessary to collect nectar and pollen**. It dies after successful mating with the queen.

Duties of a drone

1. Their important duty is to fertilize the queen.
2. They also help in maintenance of hive temperature.
3. They cannot collect nectar / pollen and they do not possess a sting.

C. Workers

Workers are **sexually sterile female** caste and is the smallest in size as compared with the above two castes. On ventral side of the abdomen, **wax glands** are present. Hind legs are modified for **pollen collection**. The mandibles are flattened and spoon shaped which are used for molding the wax for comb building. They do the work of the colony and maintain it in good condition. Workers have special structures and organs which are associated with the duties they perform.

Duties of a worker

1. Their adult life span of around 6 weeks can be divided into:

(i) First three weeks- house hold duty.
(ii) Rest of the life- out door duty.

[i] House hold duty includes:

a. Build comb with wax secretion from wax glands.
b. Feed the young larvae with **royal jelly** secreted from **hypopharyngeal gland**.
c. Feed older larvae with bee-bread (pollen+ honey).
d. Feeding and attending queen.

e. Feeding drones.

f. Cleaning, ventilating and cooling the hive. g. Guarding the hive.

h. Evaporating nectar and storing honey.

[ii] Outdoor duty includes:

1. Collecting nectar, pollen, propolis and water.

2. Ripening honey in honey stomach.

Schedule of a worker bee in the hive

Days after emergence	Task
1–2	Clean cells and warm the brood nest
3–5	Feed older larvae with honey and pollen
6–10	Feed younger larvae with products of the head glands
11–18	Ripen nectar, produce wax and construct comb
19–21	Guard and ventilate the hive, take exercise and orientation flights to learn to fly and locate the hive
22 +	Forage for nectar, pollen, water or propolis

❖ **Morphological differentiation among different castes of *A. mellifera***

Character	Queen bee	Drone bee	Worker bee
Adult			
Body size	Longest	Medium	Smallest
Wings	Do not completely cover the abdomen	Completely cover the abdomen	Completely cover the abdomen
Head	Triangular and little roundish	Roundish	Triangular
Abdomen	Long, gradually tapering	Tip of abdomen blunt and hairy	Tip of abdomen conical and subtly pointed
Compound eyes	Small and well apart	Large kidney shaped, meeting at vertex	Small and well apart
Pollen collecting legs	Not developed	Not developed	Well developed
Sting	Present but without barbs	Absent	Present with barbs

DIFFERENT SPECIES OF BEES AND THEIR IMPORTANT CHARACTERS:

The honey bees belong to superfamily Apoidea and the family Apidae and the order Hymenoptera. There are six species of *Apis viz., Apis cerana, Apis florea, Apis dorsata, A. andreniformis, A. laboriosa and A. koschevnikovi* which are indigenous to India and *A. mellifera* which has been introduced from European countries. The commercialized honey bees in India are two domesticated/hive bees, *Apis mellifera* Linn. and *Apis cerana* F. and two well-known wild species, *Apis dorsata* F. and *Apis florea* F. They have well developed stings. The Dammer bee or little bee, *Trigona iridipennis* (Meliponinae) has only a vestigial sting. All five species are social insects living in colonies with remarkable degree of social instincts and division of labour among the different members of the colony.

There are five important species of honey bees as follows.

Scientific name	**Common name**
(1) *Apis dorsata*	: The rock bee
(2) *Apis cerana indica*	*:* The Indian hive bee
(3) *Apis florea*	: The little bee
(4) *Apis mellifera*	: The European or Italian bee
(5) *Trigona iridipennis (T. laeviceps)*	: Dammer bee, stingless bee

(1) The rock bee or giant bee, *Apis dorsata* Fabricious

1. It is largest of the honey bees and measuring about 20 mm in length.
2. It construct single comb of huge size in open (About a meter in diameter)
3. The comb is fully exposed and hung from inaccessible branches of trees, along sides of steep rocks in the forest and even from the walls, rafters and other parts of buildings.
4. It produces plenty of honey i.e. **37 Kg honey /comb/year**.
5. It represents a major portion of honey sold in our markets.
6. Rock bees are irritable and ferocious in nature and difficult to rear.
7. They shift the place of the colony often. In winter, they migrate to plains and come back to hills during summer season.

(2) Indian hive bee/Asian bee, *Apis cerana indica* Fabricious

1. It is common Indian bee found in both forest as well as in plains throughout country.
2. It is smaller than the rock bee but the larger than the little bee. Bee measures about 15 mm in length.
3. They make **multiple parallel combs** on trees, cavities, caves in darkness and such other hidden sites, the combs being parallel to the direction of the entrance in the plains and the right angle to the entrance in cold regions.
4. It is mild and capable of being domesticated and is commonly reared in south India.
5. They produce about **2 - 5 Kg of honey/year/colony**.
6. A queen can lay 350 – 1000 eggs per day.
7. They are more prone to swarming and absconding.
8. They are native of India/Asia.

(3) The little bee, *Apis florea* Fabricious

1. It is known as the little bee since it is smallest of the four species of Apis. Bee measures about 7 mm in length.
2. It is seen only in the plains and not in hills above 450 mt MSL.
3. It does not like darkness therefore forms its comb in the open place e.g. bushes, hedges, buildings, caves, empty cases etc.
4. It builds a single comb which is very small and produces about 0**.5 to 1 kg honey/year/hive** and so it is not domesticated and reared.
5. A queen can lay 323 – 365 eggs per day.
6. They are not rearable as they frequently change their place.

(4) European bee or Italian bee, *Apis mellifera* Linnaeus

1. It is extensively reared in Europe and America.
2. It was introduced in India in the year 1962 by **Prof. A. S. Atwal** in Nagrota (HP) from European countries (Italy). He is called as "**Father of Modern Beekeeping in India"**.
3. The behaviour and appearance of *A. mellifera* is similar to *A. cerana*.
4. It makes its nest in enclosed space (in darkness) in **multiple parallel combs** and is endowed with all the good qualities of a hive bee, i.e. has a prolific queen, swarms less, gentle tempered so, domesticable, good honey gatherers and can guard its nest against enemies.
5. They yield on an average **45-180Kg honey/hive/year**
6. They are larger than Indian bees but smaller than Rock bees.

(5) Dammer bee or stingless bee, *Trigona irridipennis* Dal. *(T. laeviceps)*

1. This is the smallest species and differs from other bees in its appearance and habitats.
2. They do not have sting *i.e.*, stingless.
3. They built their comb in hollow walls or tree trunks.
4. They construct their comb with a dark material called "**Cerumen**" which is a mixture of earth and wax or resin collected from plants as they do not secrete wax to build combs.
5. It is very poor honey gatherers and yields only **60-180 ml/colony/year**.
6. Its honey is used in ***Ayurvedic* medicine**.

Identification/differentiation among different bee species

Sr. No.	**Characteristics**	**The rock bee, *Apis dorsata* (Giant honey bee)**	**The little bee, *Apis florea***	**Indian hive bee/Asian bee, *Apis cerana indica* (Asiatic honey bee)**	**European bee or Italian bee, *Apis mellifera* Linnaeus**	**Dammer bee or stingless bee**
1.	Body size	Largest	Smallest	Medium	Medium	Smallest
2.	Body colour	Head blackish, abdomen reddish-yellow anteriorly	Abdomen orange anteriorly with black & white stripes posteriorly	Body colour blackish, abdomen with white & black stripes	Body golden yellow, profusely hairs with faint black and yellowish stripes	Body is reddish brown in colour

		& black at the tip			posteriorly	
3.	Wings	Smoky	Transparent	Transparent	Transparent	Transparent
4.	Proboscis size	Largest	Smallest	Medium	Medium	Smallest
5.	No. of worker cells/4 linear inches	18. 75	32.8 to 36.0	21.25 to 25.00	19.3	--
6.	Nature and Temperament	Wild bee, hostile	Wild bee, relatively less hostile	Can be hived, docile	Can be hived, docile	Can be hived, docile, do not have sting *i.e.*, stingless.
7.	Comb construction	Single, large (5-7' x 2-4') combs, constructed under the roof projections, water reservoirs and on trunks of tall trees	Single, small (Palm to quarter plate size) combs, constructed in bushes/hedges, cotton sticks	Many parallel combs inside the enclosure/cavities or in bee hives	Many parallel combs inside the enclosure/cavities or in bee hives	Built their comb in hollow walls or tree trunks.

MAJOR ACTIVITIES OF HONEY BEES:

The honey bees remain active generally throughout the year except during severe winter. Following are the main activities of honey bees:

1. Foraging:

The field bees get activated in the morning and go out on foraging and collect pollen, nectar, propolis and water, carry them to the hive and make a number of trips till sunset. The bees that go out first to find out new sources of these materials are called ***searcher bees* or *scout bees.*** They return to the hive and communicate the message to young foraging bees by means of definite patterns of **dancing**. At any time bees collect most of the materials from a single or a few plant species but bees in two different colonies located side by side may visit entirely different sources, mainly due to the differences in discoveries by the scout bees. The bees collect materials from a source till they are exhausted when they may go in search of new areas. The honey bees usually forage within about **100 meters distance** from the hive but they can **go up to 1.5 km**. They are capable of flying at a speed of **25-30 km per hour**. The bees are most active in foraging

within a temperature range of 25-27°C. The bees do not go out for foraging at wind speed of more than 24 km per hour.

Nectar is collected by the foragers from the flowers and is stored in the crop where it is mixed with saliva. The **invertase** contained in the saliva acts upon sucrose of the nectar and converts it to **dextrose or levulose**. The bee returns to the hive and regurgitates the contents of the stomach into comb cells which are covered by flat airtight cappings. The weight of nectar load varies from **25 to 40 mg**. On a given trip, a bee visits and exploits 1-500 flowers and makes, on an average, 10-15 trips in a day. During honey flow when there is abundance of food available, bees work to their full capacity and may make upto **150 trips a day**. The pollen is collected and carried to the hive by the bees in the pollen baskets located in their hind tibiae. The bee returns to the hive and the pollen pellets are pushed down to the appropriate cells by means of spine in the middle leg. The weight of pollen load varies from **10 to 30 mg**. The workers make about 6,000 trips to collect 0.5-1 g of pollen. The **propolis** is also carried in the pollen basket by the worker bees. As soon as the collecting bee returns to the hive, another worker unloads the propolis from the former, carries the same in its mandibles to the place requiring cementing and presses it into the crevices in the comb.

2. Combing:

The comb of honey bees comprises of several **hexagonal cells** on both side of mid-rib. The combs are built with **beeswax** which is secreted by 4 pairs of wax glands located on 3-6 abdominal sterna. The wax secreted in a liquid form, collects in the intersegmental regions, hardens into thin flakes that are picked up by the legs and passed on to the spatulate mandibles for being kneaded and stuck to the top of nesting cavity and extended downwards bit by bit. Several bees hang like a sting to do the job. Usually, the cells meant for honey storage are located uppermost near the point of attachment below which are pollen cells spread in 5 cm wide band, further down are worker brood cells which are followed by the drone and queen cells. The worker cells are the smallest, drone cells larger than the worker cells and queen cells the largest. Worker and drone cells are directed sideways and queen cells vertically with open ends downwards. Cells of the size of worker and drone cells are used for storing honey and pollen. **Cells containing unripe honey or developing brood are uncapped; those with fully ripe honey and fully fed grubs are capped, and pollen cells are generally not capped.** Freshly built comb is generally white, but becomes dark after some time.

3. Swarming:

Swarming is a **method of reproduction** in which a part of the colony migrates to a new site to make a new colony. During spring and summer when conditions are favourable and food is available in plenty, the bees multiply greatly with the result the comb becomes crowded and the bees begin to make preparations for swarming. At this stage, the daughter queen cells are built at the bottom and when new queen is ready to emerge out, the new queen and a large number of workers which have previously filled the cells with honey, leave the nest to start a new colony. Swarm settles in a suitable place already searched out by the workers for building new comb. In a parent colony the first daughter queen which emerges after swarming, kills the baby queen in the other cell and establishes herself as a mother queen. After that, they start their routine work of gathering nectar and pollen.

4. **Absconding and migration:**

Complete **desertion of a hive** is known as absconding. This may occur due to lack of water, exhaustion of food store (either due to short supply of nectar or robbery of honey), unfavourable environment, constant pest attack (ants, wax moth, etc.) and even by excessive interference by the beekeeper in which case he is regarded as an enemy. Prior to absconding, the bees 'drink' whatever honey their nest has and then migrate leaving behind empty combs, brood and sometimes even food. Absconding can be prevented by providing water or sugar solution near the hive particularly during summer.

5. Language of bees:

Honey bees have a unique and one of the best understood animal languages with which they inform each other the distance and direction of the source of food. The **forager bee** on return to the nest makes two kinds of dances on the surface of the comb, i.e. **round dance and tail-wagging or figure of eight dance** (Fig. 1), which the insiders perceive by contacting the forager's body with their antennae. In the round dance, which is used to indicate a short distance (less than 50 m in case of *A. mellifera)*, the bee runs in circles, first in one and then in opposite direction (clock and anticlockwise), while in the tail-wagging dance which is used to indicate a longer distance (beyond 50 m in case of *A. mellifera)*, the bee makes two half-circles in opposite directions with a straight run in between. During the straight run, the bee shakes its abdomen from side to side and the number of wags per unit time is related to the distance the food was located, i.e. **more the wags, nearer is the food**. The direction of the food is conveyed by the angle that the dancing bee makes its straight run and top of the hive which is the same as between the direction of the food and direction of the sun. **Prof. Karl von Frisch was awarded the Nobel Prize** in Physiology and Medicine in 1973 for discovering and interpreting the language of the honey bees in early 1920s. Later on, it was found that honey bees employ both dance and sound in their language.

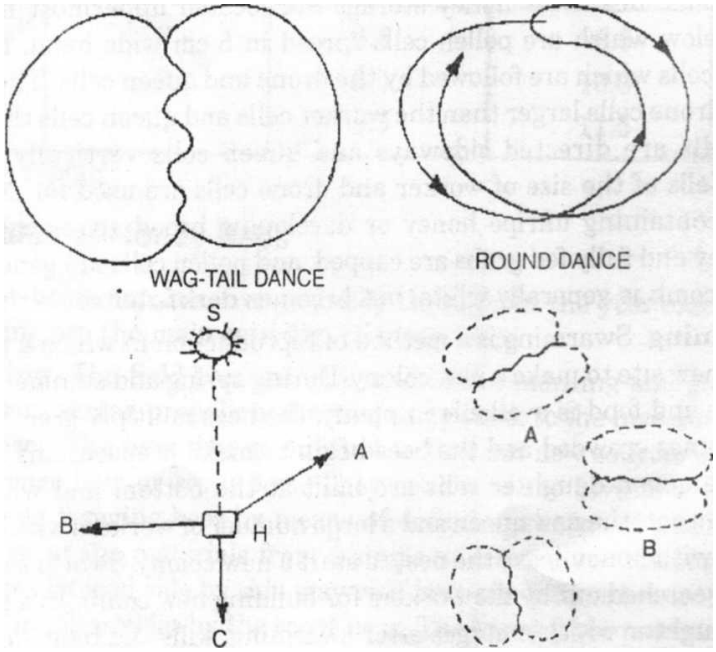


Fig-1: Communication dances in honey bees according to location of the food source and direction of the sun (A, B, C = Directions. S=Sun. H=Beehive)

6. Air conditioning:

Among the living creatures, honey bees are the only organisms which make their comb air-conditioned. They keep their comb warm in winter and cool during summer. The brood temperature is stabilized between 33 and 36°C averaging about 34.5°C. Clustering begins when the temperature inside the nest dips below 18°C and they generate heat by sitting on one another and rubbing their legs due to which the temperature of the comb rises. In summer, when the temperature rises above 33°C, the bees start fanning with their wings at the gate inside as well as outside with the result water evaporates from the honey and comb remains cool. The brood nest is usually kept at 40 per cent relative humidity.

A large number of foragers start collecting water from outside, that is received by house bees inside and carried by them to the site where most needed and evaporated They spread minute drops of water in cells and also form thin films from regurgitated water on their tongues for evaporation. In the event of extreme hot weather they even suspend collecting concentrated nectars but prefer dilute nectars in case water is in scarcity, as the dilute nectars may be used for making thin films.

COMMERCIAL METHODS OF REARING OF HONEY BEES

Rearing the bees in artificial hives is known as **beekeeping or apiculture**. In India, the beekeeping industry started with the designing of a small hive suitable for *A. cerana* by Rev. Father **Newton in 1910**. This hive named '**Newton Hive**' is still popular for keeping of ***A. cerana***. The father also trained a large number of beekeepers in Southern India and helped them to establish beekeeping as an economically viable proposition. Mahatma Gandhi realized the importance of beekeeping and included it in his rural development programmes. He inspired rural freedom fighters to take up beekeeping as a venture of livelihood. In earlier times, people after wrapping the blanket on the body or after smoking in night and collect honey from the comb. This was a **crude method**. After some times, people thought to keep the honey bees and many villagers took interest in keeping honey bees and provided various types of hives in their houses.

Thus, beekeeping can be divided into primitive and modern methods:

A. Primitive or Indigenous Methods

This is primitive and unplanned method of apiculture. In this method, two types of hives are used,

- **Fixed type:** Providing a receptacle in the wall of the house with an entrance and observation holes.
- **Movable type:** Providing a basket, empty boxes, hollowed logs, bamboo, mud pipes, earthen pots, etc. Anything that can protect bees from sun and rain.

In the indigenous method, the bees are first killed or made to escape from the hive with the help of smoke when the bees are at rest during night. This method has many drawbacks and it is not suitable for commercial large-scale production of honey. The following are the disadvantages of indigenous method:

1. The honey cannot be extracted in the pure form. The extracted honey also contains the larvae, pupae and pollen cells.
2. The future yield of the honey is affected as the colony has to be destroyed to extract the honey. Moreover, it takes lot of energy of the bees to build new hive.

3. The bees may not construct the new hive in the same place as the old one.
4. The natural hives also have the danger of attack by the enemies like rats, monkeys, ants etc. The natural hives can also be damaged by the climatic factors.
5. Also scientific intervention is difficult in the indigenous method and thus improving of the bee race is impossible.

B. Modern Method or Frame Hive Method

Frame hives are fitted with movable frames on which the bees are persuaded to build their combs. They are usually composed of several boxes, one on top of the other, in which hive frames are suspended. The lower boxes (1-2) are used for holding the brood and the upper ones (1-2) are used for collection of honey, pollen and propolis. The artificial comb was first introduced by Revd. L.L. Langstroth in 1851 in America. In India, during 1910 Rev. Father Newton designed a small hive suitable for *A. cerana*.

Beekeeping with Frame Hive Method:

Apiary is the place where the honey bees are reared for honey and wax either commercially or as a hobby. Often a beekeeper is left with no choice for location of his hives, when he intends to keep them in his backyard or a small home garden. But where a selection among many possible sites can be exercised, the following points.

Requirements for site selection for apiary:

- **Apiary** should be located where there is abundance of nectar and pollen yielding plants within the radius of one to one and half kilometer.
- The site should not be exposed to strong winds or at least the hives should not face the direction of the prevailing winds. Trees and bushes may be provided to make the site less windy.
- The site should be flat but with good drainage facilities.
- Clean and fresh running water should be available to the bees in or near the apiary.
- A young orchard is an ideal choice.
- If the site is shade less and exposed, an artificial shade may be provided.
- An apiary should not be located too near highways.
- A good barbed wire fence or live hedge may be provided to keep out intruder/thief.
- The site should be free from termite and black ant infestation.

I. Bee hives: Various types of bee hives are available for beekeeping. They are wooden boxes having two parts: upper ¼ comb is chamber and lower ¾ is brood chamber. Following types of bee boxes are used in beekeeping.

Sr. No.	Box type	Dimensions	Remark
1.	Ghos box	36 cm x 21.5 cm	These two types of bee hives are more popular in India. In India Newton's beehive are manufactured based on Bureau of Indian Standards (BIS) specifications and called as **BIS hives**.
2.	Newton box (BIS hive)	20.2 cm x 14.0 cm	
3.	Langstroth hive	42.2 cm x 31.1 cm	Some other familiar bee

	(American hive)		boxes. Nowadays these boxes are widely used in commercial beekeeping. **Langstroth hive is suited to *A. mellifera***.
4.	Pant, Kanje and Jeolikote No.l	42.2 cm x 12.3 cm	
5.	Dadant box (Russian hive)	47 cm x 28.6 cm	
6.	Thompson box	30.5 cm x 15.2 cm	

Hive parameters	**BIS hive C type for *A. mellifera* (Modified Langstroth type)**	**BIS hive A & B type for *A. cerana* (Modified Newton and Jeolikote types)**
Frames	Contains 10 frames	May contain 4, 8 or 10 frames
Super Chamber	Generally full super chamber is used.	Half (shallow) super chamber is generally used.
Brood/super frame size	Outside: 448 x 232 mm Inside : 428 x 192 mm	**Type A: Modified Newton Type** Outside: 230 x 165 mm Inside : 210 x 145 mm **Type B: Modified Jeolikote Type** Outside : 300 x 195 mm Inside : 280 x 175 mm
Bee space	10 mm	**Type A :** 7 to 9 mm **Type B :** 8 or 9 mm

II. Equipments used in commercial beekeeping:

A movable frame hive is composed of the following parts/appliances

1.	**Bee hive:** • It is movable wooden hive for bees with an entrance and parallel movable frames on which bees raise their combs. • It provides protection to the colony from adverse effects of external environment. The important parts of the hive are bottom/floor board with alighting board, entrance, lower/brood chamber, frames, dummy board, super/honey chamber, inner cover (crown board) and top cover.
2.	**Nucleus hive:** • Small bee hive for keeping 4-6 frames. These are used for mating of queens and division of colonies.
3.	**Observation hive:** • Small hive with glass sides to observe movements and behaviour of bees.
4.	**Synthetic combs:** • It is made up of high density polythene (plastic). It can be used in both super and brood chambers. • Since the comb is fully moulded, bees only put wax caps on the cells. • **Advantages of synthetic combs *viz*.,** More honey can be extracted, Combs can be easily sterilized, Resist to wax moth attack, Combs will not be damaged during honey extraction.
5.	**Hive stand:** • This is used to keep the bee hive above the ground so as to protect the colony from termites, ants and other crawling insects and also prevent soil moisture getting into the

	hive or facilitate ventilation from below the hive. • The stand is made of wood or iron tubing or angle iron. • Any four legged stand of 15-25 cm high is sufficient. • Ant wells of 15 cm in diameter kept under four legs to prevent ants and other crawling insects entering into the hive.
6.	**Bottom board:** • It forms the floor of the hive made up of a single piece of wood or two pieces of wood joined together. • Wooden beading are fixed on to the lateral sides and back side. • There is a removable entrance rod in the front side with two entrance slits to alter the size of the hive entrance based on need. • The board is extended by 10 cm in front of the hive body which provides a landing platform for bees. • Size of alighting board is 40 x 28 cm (BIS hive).
7.	**Brood chamber:** • It is a four sided rectangular wooden box without a top and bottom. • It is kept on the floor board. • A rabbet is cut in the front and back walls of the brood chamber. • The brood frames rest on the rabbet walls. • In brood frames, bees develop comb to rear brood. • Size of brood frame is (outer dimensions) 29 x 29 x 17 cm. • There will be 8 frames. Length and height of frame is 20.5 x 14.0 cm (BIS hive).
8.	**Super chamber:** • It is kept over the brood chamber and its construction is similar to that of brood chamber. • Super frames are hung inside. • The length and width of this chamber is similar to that of brood chamber. • The height may also be similar if it is full depth super as in Langstroth hive. But the height will be only half if it in a shallow super as in Newton's hive. • Surplus honey is stored in super chamber.
9.	**Hive cover/Top cover:** • It insulates the interior of the hive. • In Newton's hive, it has sloping planks on either side. • On the inner ceiling plank there is a square ventilation hole fitted with wire gauze. • Two holes present in the front and rear also help in air circulation. • In Langstroth hive and BIS hive, the hive cover consists of a crown board or inner cover and an outer cover.
10.	**Inner cover:** • The inner cover is provided with a central ventilation hole covered with wire gauze help in air circulation. • The outer cover is covered over with a metallic sheet to make it water proof to rain water.
11.	**Hive frames:** • The frames are so constructed that a series of them may be placed in a vertical position in the brood chamber or the super chamber so as to leave space in between them for bees to move. • Each frame consists of a top bar, two side bars and a bottom bar nailed together. • Both the ends of the top-bar protrude so that the frame can rest on the rabbet.
12.	**Dummy or Division board/ Movable wall:** • It is a wooden board slightly larger than the brood frame.

	• It is placed inside the brood chamber. • It prevents the bees from going beyond it. • It can be used as a movable wall there by limiting the volume of brood chamber which will help the bees to maintain the hive temperature and to protect them from enemies. • It is useful in managing small colonies.
13.	**Bee feeder:** • Used for providing sugar syrup as feed to the bees during dearth period. • A normal method of providing feeding is to keep a can with small holes punched on its lid. The can is filled with sugar syrup and kept over the frames in an inverted position.
14.	**Queen excluder:** • It is made up of perforated zinc sheet. • The slots are large enough to allow the workers to pass through but too narrow for the queen. • A wire grid/dividing grid with parallel wire mounts can also be used as a queen excluder. • It is inserted in between the brood frames and super chamber.
15.	**Queen gate:** • It is a piece of queen excluder sheet and fitted on the slot of entrance gate. • The holes in the sheet are large enough to allow free movement of worker bees in and out of the hive, but too small to allow queen's passage. • It confines the queen inside the hive. It is useful to prevent swarming and absconding. It also prevents the entry of bee enemies like wasps into the hive.
16.	**Queen cage:** • This is used for transport of queen either with a few attendant worker bees, in packages. • It is a cage made up of wood or wire gauge or plastic structure. This is useful for queen introduction.
17.	**Queen cell protector:** • It is a cone shaped structure made of a piece of wire wound spirally. It fits around a queen cell. • It is used to protect the queen cell, given from a queen right to queen fewer colonies until its acceptance by bees.
18.	**Swarm trap:** • It is a rectangular box used to trap and carry the swarm. • It is fixed near the hive entrance with one or two combs inside during the swarming season. • This box traps and retains the queen only. But the swarm coming out from the hive reenters the hive and settles on the comb, since the queen is trapped.
19.	**Drone excluder or drone trap:** • It is a rectangular box with one side open. The other side is fitted with queen excluder sheet. • At the bottom of the box there is a space for movement of worker bees. There are two hollow cones at the bottom wall of the box. • Drones entering through the cones into the box get trapped. • The narrow end of the cone is wide enough to let the bees pass out but not large enough to attract their attention or re-entry. This device is used at the entrance to reduce the drone population inside the hive.
20.	**Pollen trap:** • Pollen trapping screen inside this trap scrapes pellets from the legs of the returning foragers. • It is set at the hive entrance.

	• The collected pollen pellets fall into a drawer type of receiving tray.
21.	**Hive tool:** • It is a piece of flattened iron with flattened down edge at one end. • It is useful to separate hive parts and frames glued together with propolis. • It is also useful in scrapping excess propolis or wax and superfluous combs or wax from various parts of the hive.
22.	**Protective dress:** **(a) Bee veil:** • It is worn over the face for protection against stings. • It is particularly useful for a beginner, for protecting face from bee stings during the handling of bees. **(b) Gloves:** • These are used while inspecting and handling colonies to protect hands and arms. Soft leather gloves with canvas gauntlets to the elbow are the best for use. **(c) Boots:** • A pair of gum boots will protect the ankles and prevent bees from climbing up under trousers. **(d) Overalls:** • White overalls are occasionally worn. Light colored cotton materials are preferable since they are cooler and create less risk for antagonizing bees.
23.	**Bee brush:** • A soft-camel-hair brush is used to brush the bees off the honeycomb before it is taken for extraction.
24.	**Smoker:** • The smoker is used to calm bees and drive away bees from super. • It consists of a metal fire pot with a funnel shaped cover and a bellow. • A smoke releasing fuel (dried cow dung, hessian, waste jute bags or cardboard, old rag, wood shaving etc.) is burnt in the fire pot. • Air is injected into the pot by operating the bellow and the smoke is directed to the desired spot.
25.	**Decapping knife/ uncapping knife:** • Single or double edged steel knife is used for removing wax capping from the honey comb before putting it in the honey extractor.
26.	**Honey extractor:** • It is invented by Frang von Hruschkain 1885. • It consists of a cylindrical drum. • A rack is fixed inside the drum to hold the supper frames. • The rack is rotated by a set of gear wheels. • The decapped honey frames are kept in the slots of the rack. The rack is rotated by operating the handle. Honey flow out from the combs by centrifugal force. The excreted honey comes out through the spout present at the bottom of the container. • The honey comb is not damaged. So, it can be reused.
27.	**Travelling screen/net:** • It is a wooden frame with wire screen. It is highly useful for migration of honey bee colonies during hot summer season.
28.	**Comb foundation mill:** • This is a machine to prepare comb foundation sheet used in beekeeping to make-bees build regular combs in frames that are convenient to handle. • J. Mehring of Germany made the first comb foundation in 1857.

	• Comb foundation is made by passing plain sheets of beeswax between two rollers that have the regular 3-faced cell base pattern embossed on them. • The patterns on the two rollers interlock properly, so that the 3-faced cell base on one roller matches with the base of each of the three cells on the other roller. • The distance between the rollers is fixed in such a way that a thin foundation is made that is readily accepted by the bees. • The rollers rotate on opposite sides. • The rotation is done by a handle attached to the lower roller. The cell size in the cell base pattern varies according to the size of the brood cells.
29.	**Comb foundation sheet:** • It is a thin sheet of bee wax embossed with a pattern of hexagons of size equal to the base of the natural brood cells on both sides. • The size of the hexagon varies with bee species. For *A. mellifera* there are 19 cells and for *A. cerana* 22- 23 cells/100 mm linear length.
30.	**Embedder:** • It is a small tool with a spur or round wheel on the top. It is used to fix the comb foundation sheet on the wires of the frame. • Electric wire is also used for this purpose which is useful to reinforce the comb and give extra strength to the comb.
31.	**Miscellaneous:** • Apart from these equipments, there are several miscellaneous equipment which are required from time to time *viz*., propolis screen, venom extractor, drip tray, swarm basket, wax melter, queen bee rearing equipment, comb foundation making equipment, honey straining, storage and processing equipment, etc.

DIVISION AND UNITING OF HONEY BEE BOXES:

I. Division of honey bee boxes:

Colony division is a method of multiplying bee colonies, *i.e.* producing two or more colonies from a mother colony. Colony division is used to control swarming as well as in commercial beekeeping to increase the number of colonies.

Methods for colony division:

(i) Natural division using queen cells developed during swarming

The presence of multiple queen cells in a colony during the swarming season indicates a need for division. Dividing such colonies and using the queen cells in new daughter colonies can help control swarming. However, although it solves the immediate problem of swarming it does not help improve the genetic traits.

(ii) Colony division from queen production

Select the best colony based on the selection criteria given above. Produce queens from this colony before the onset of honey flow. These queens can be used to replace the old queen and to start new daughter colonies. The mother colony can be multiplied into several nucleus colonies but each should have at least 2 brood combs and 3–4 combs with food (nectar and pollen). The prepared colonies can then be sold or migrated according to need.

(B) Uniting of honey bee boxes:

Uniting two colonies into one is done when one of them is weak or queen less or for other reason like bad traits etc. Each colony has its own colony specific odours and it is very difficult to combine the two colonies unless their odour is mixed well. Any attempt to unite these colonies without mixing their odour result in infighting and deaths will occur on large scale. Therefore,

first step will involve bringing the two colonies into contact with each other. If uniting is done abruptly, the field workers of the colony shifted will not recognize the new place and returning to their original place will persist. This problem can be overcome by moving a hive gradually at the rate of two or three feet per day, so that the field bees get habituated to the changing position of their hive and will not drift back to the old site. When colonies are sufficiently close, one or two feet apart, they are ready for uniting. They can be united by three methods either (1) Direct uniting (2) Newspaper method (3) Smoking method.

(i) Direct uniting:

The two hives to be united are brought near gradually and kept side by side. The queen with undesirable traits in one of the hives is removed. Next morning, when the bees are busy, the frames of two hives are gently put in one. The success of this method depends upon the skill with which it is done.

(ii) Newspaper method:

Top cover is removed and the frames are covered with a piece of newspaper having a few holes made with a small nail the bottom, board of the upper colony is then removed and the brood chamber, is placed above the other colony, the newspaper forming a partition between the two. After a day or two, the odours of the colonies will mix and the bees will cut through the paper and will unite together, forming a single colony. After a few days all the frames can be placed in one hive and the upper chamber can be removed.

(iii) Smoking method:

Colonies can be united using smoke method. When the colonies to be united have been brought close to each other, both should be smoked heavily and thin sugary syrup scented with oil of peppermint or wheat flour sprinkled over them. The combs with the bees of the colony to be united should be altered with the combs of the other colony. More smoke and syrup or flour should be applied and the colony closed. The work of the queen may be checked up after three or four days. It is better to unite a laying worker colony to several strong colonies by giving from one to two frames to each of them. If all its frames are united to one colony there is danger of latter's queen being killed by the laying workers.

Note: See schematic representation of division/uniting of bee boxes at the end of notes.

SEASONAL MANAGEMENT OF HONEY BEE BOXES:

Pollens and nectar are available only during certain period. When surplus food source is available is known as "**honey flow season**". In contrast during **dearth period** there will be scarcity of food. Suitable season for starting beekeeping coincides with mild climatic conditions and availability of bee flora in plenty. Normally, spring (February-April) and post-monsoon (Sep.-Nov.) seasons are the best periods to start beekeeping. Indian seasons are Spring season (*Vasant ritu*: mid February – mid April), Summer season (*Grishma ritu*: mid April to mid June), Mansoon season (*Varsha ritu*: mid June to mid August), Autumn season (*Sharad ritu*: mid August- mid October), Pre-winter season (*Hemant ritu*: mid October- mid December) and Winter season (*Shishir ritu*: mid December- mid February). Various operations required to be undertaken for augmenting colonies productivity are given below:

I. SPRING MANAGEMENT

Management operations to be undertaken during spring are given below:

1. Examination of colonies

a) On some warm and sunny day, examine the colonies quickly and carefully with least exposure to the chilling weather and robber bees.
b) Unpack the colonies, clean the bottom board and replace the worn out hive parts.
c) Assess the colony condition, working of the queen bee, brood rearing and food reserves.
d) Provide early season stimulative **sugar feeding (sugar: water =1:2),** pollen or pollen substitute feeding to increase the foraging and brood rearing activity.
e) Inspect the brood rearing. If there is no brood, the colony may be queenless. If there is less brood, the queen may be old and exhausted. Unite the weak/queenless colonies with the other colonies. If fresh dead bees are found, try to find out the cause. Bee mortality may be due to the bee disease or infestation of mite.

2. Equalizing the colonies

The colonies can be equalized by:

a) Substituting the combs with food reserves/supplementary feeding.
b) Providing the emerging bee combs.
c) Uniting the bee combs/colonies.
d) Giving young bees to the weaker colonies.

3. Provision of space

During spring, the colonies enhance the brood rearing. Hence, there should be no dearth of space to cope up with increased egg laying by the queen bee.

a) Add good quality drawn combs (with worker cells) or frames with good quality comb foundations to the brood chamber as and when required.
b) Avoid adding raised combs with too many drone cells.
c) While providing super chamber, lure the bees to the super chamber with some bait in the form of a brood/honey comb.

4. Swarm prevention and control

a) Examine the colonies and remove congestion. Provide more drawn combs/comb foundations, supers, etc.
b) Improve ventilation and provide required shade.
c) Clip the wings of the laying queen.
d) Use wire entrance guard/queen excluder at the bottom board.
e) Reversing brood and honey chambers for mitigating congestion in brood chamber.
f) Destruction of the queen cells raised due to swarming instinct,
g) Dividing over-crowded colonies.

5. Control of mites and brood diseases

Examine the symptoms of various mites and brood diseases. On spotting any, take appropriate management measures to contain the menace.

6. Colony multiplication and commercial queen rearing

March-April is the best season for colony multiplication and commercial queen rearing. Improve the existing stock by selective breeding of best performing colonies. Mass reared queen bee can also be used for multiplication of existing stock and also for replacement of older queen bees (re-queening).

7. Extraction of spring season honey

Multiple extractions of honey during this period are possible. Only ripe honey from broodless combs from super chamber should be extracted.

II. SUMMER MANAGEMENT

Mid April to June months are extremely hot. However, this is the major honey flow period too. The following operations need to be considered during the season.

1. Shifting the colonies to thick shade

Colonies should be moved to shady places every day by less than three feet.

2. Regulating the microclimate of the colonies

By using wet gunny bags over the colonies and sprinkling water around the colonies in the apiary during noon hours, temperature in the apiary can be reduced and humidity increased in hot and dry months of May and June.

3. Provision of ventilation

Improve the ventilation of the colonies to cope up with the respiration of the bees and hastening the honey ripening by:

a) Widening the entrance of the colony.
b) Providing additional entrance in multi-chambered colonies.
c) Staggering the chambers.
d) Placing thin wooden splinters between two adjacent chambers for the circulation of fresh air.

4. Provision of fresh water

a) Running water channel in the field.
b) Cemented water reservoir tanks near the tube wells/pump sets with a sufficient number of sticks or wood pieces in the tank for the bees to sit on and lap the water.
c) Earthen water bowls underneath the legs of hive stand also fulfill the water requirement of the colonies.
d) An earthen pitcher with a small hole at its bottom is placed on a tripod and a slanting wooden plank is kept below the hole of the pitcher.

5. Honey extraction

Summer season honey can be extracted.

III. MONSOON MANAGEMENT

Manage the colonies during this season as below:

a) Ensure colonies placement on upland area and away from village water ponds.
b) Clean and bury deep the debris lying on the bottom board.
c) Keep the surrounding of the colonies clean by cutting the unwanted vegetation which may hamper circulation of air.
d) Provide **sugar feeding (sugar : water=l:l),** if required.
e) Check robbing within the apiary.
f) Unite weak/laying worker colonies. Control wax moth, ants, wasps and bee eating birds.

IV. AUTUMN MANAGEMENT

Important operations to be undertaken during this season, are:

a) Provision of space.

b) Strengthening the colonies to stimulate drone brood rearing, if queen bee rearing is to be undertaken.
c) Control of ectoparasitic mites, brood diseases, wax moths and wasps.
d) Autumn honey extraction before the winter sets in.

V. WINTER MANAGEMENT

Normally winter extends from December to mid February but this period may vary from region to region. During winter, very low temperature, westerly chilly winds, foggy/cloudy days and winter hamper the bee activity. *Brassica* comes in bloom during January. To perpetuate the colonies through winter, following operations are generally required:

1. Colony examination

Examine the colonies on a warm, sunny day for the presence of queen, brood and food reserves. Open the colony for minimum time to avoid chilling of brood. Weak colonies should be united with stronger ones so that the strong unit over-winters well.

2. Feeding

If there is food scarcity or expected in the ensuing winter, feed concentrated **(sugar: water = 1:1) sugar syrup** (supplementary feeding) by filling in the drawn combs at the onset of severe winter.

3. Shifting colonies to sunny places

The colonies should be shifted to sunny places with hive entrances facing south-eastwards.

4. Protection from the chilly winds

Plug cracks and crevices and narrow down the hive entrance.

5. Unite weak colonies with stronger ones

Follow newspaper method for uniting the colonies.

6. Removal of extra drawn combs and winter packing

Remove the extra empty combs and store them properly to save them from mice/rats. Depending upon the strength of the colonies and severity of winter, provide one or two-sided inner winter packing combined with need based outer packing.

MIGRATORY BEEKEEPING (HONEY BEE BOX MIGRATION)

While preparing the honey bee colonies for migration, a number of points needed to be considered are given below:

1. Season:

a) Fasten the various hive parts and move the colonies during late evening, night or early morning, when all the bees are inside the hive, after closing the hive entrances with wire screen, ensuring required ventilation.
b) In cold and rainy weather, the hives should be covered with a tarpaulin when being moved. Exposure to cold has the effect of causing bees to consume stores heavily to produce more heat and cluster together on the nest as they do in winter.
c) During summer or monsoon season, colonies should be migrated during night when it is cooler and in hives with enough ventilation by exchanging the inner cover with traveling-screen.

2. Distance of migration site:

a) Very long distance migrations of apiaries during winter at a stretch are possible provided the

bees have sufficient food reserves and required ventilation. During cold weather, bees consume excessive food stores to produce heat and cluster together over the brood.

b) The hive body and supers should be nailed or fixed properly to avoid their slipping *enroute.*

c) During summer, it is better to have one or two halts/ journey breaks for short temporary sitting of the apiary for a day or two at some suitable place having some bee flora for easing out the confined bees. Moving the colonies continually for more than 48 h often leads to their brood mortality.

3. Number of hives:

If the number of colonies is small, it will not be economical to migrate them as the carriage/ transport charges per colony will be much higher than when the beekeeper has full vehicle load. However, in such cases, make it a full truck load by joining with other fellow beekeepers who also intend to take up migration to the same or nearby areas.

4. Colony strength:

Bees are killed very often by overheating and lack of aeration but seldom by getting too cold. If weather is very hot and the colony is populous and hive is not spacious enough to allow expansion of the cluster, bees may very quickly smother/ get suffocated even when the top of the hive is covered with full wired travelling-screen. Thus, alternatively, the populous colonies may be divided and empty combs may be added for the expansion of the cluster in the hives before migration.

5. Preparation and packing of the colonies for migration:

a) Extract the surplus honey, if any, a few days prior to migration.

b) All cracks and crevices in the hive should be sealed to bee-tightness.

c) Excessively broken hive parts should be replaced with new ones.

d) The hive body, bottom board and inner cover should be fastened together by stapling/ nailing.

e) Always use two nails in slanting position on each side of every juncture. An alternative to the nails is to use metal or nylon travelling belts (migration belts) around the hive.

6. Type of the vehicle, and loading and unloading the colonies:

a) While migrating the colonies in vehicles such as trucks, the jerking movements will be forward and backward, hence, the length side of the hives should be kept parallel to the length of the vehicle.

b) While loading the colonies in a tractor-trailer where the jerking movements are sideways, the bee hives (colonies) should be loaded with their length side parallel to the breadth of the vehicle or the axle of the vehicle.

7. Time of the day:

If the whole of the apiary is to be shifted, it is better to move the bees in the evening or at night (when all the bees are inside the hive and temperature is low) or during rainy or cold weather when the bees are not foraging.

8. Timing in relation to flowering of crops:

Colonies should not be taken to crop needing pollination until it is flowering sufficiently to be the predominant species in the locality. The delay in shifting colonies to the crop until flowering has begun, always increases pollination, particularly when the crop has short flowering period and is less attractive to bees than the other crops in the area. The same is true for honey production.

9. Placement of the migrated stock

a) The migrated honey bee colonies should be sited away from the passages/ walkways where human or domestic animals' movements are expected.

b) If migration is for pollination purpose, the bee colonies be placed within the crop and should be evenly distributed in the area to harvest the maximum pollination benefits and should not be crowded at one place.

HONEY BEE PASTURAGE, FORAGING AND COMMUNICATION:

Honey bees gather nectar and pollen from plants as their food. Honey bees collect nectar and pollen from flowering plants. **Nectar** is a sweet secretion from the floral and extra-floral nectaries of flowers and is the raw material for honey. **Pollens** are protein-rich food for the bees. As nectar and pollen are basic raw materials for beekeeping, a thorough knowledge of the bee flora of a locality is essential. Efficient beekeeping means managing honey bee colonies in such a way to obtain maximum colony population to coincide with the major honey flow in an area and to utilize the honey production and pollination.

To judge the potential of a locality for beekeeping, followings points should be considered:

1. Are blooming plant species available in abundance within **two kilometer radius** of the locality?
2. During which period of the year, the bee flora is on bloom?
3. How long is their blooming duration?
4. Whether they are source of nectar, pollen or both?
5. Whether the flora is annual or perennial?
6. Which utility category do they belong to?
7. How long is the duration of nectar and pollen dearth period?

Important terminologies:

1. **Bee flora or bee pasturage or bee forage**: The plants that yield nectar and pollen are collectively called bee flora or bee pasturage or bee forage.
2. **Honey flow period:** The period when a good number of plants providing nectar and pollen are available to bees is called honey flow period.
3. **Major honey flow period:** If the nectar yield is copious from a good number of plants of a particular species, it is called major honey flow period.
4. **Minor honey flow period:** When the amount of nectar to be collected is small, it is called minor honey flow period.
5. **Dearth period:** The day when there is no honey flow is called the dearth period.
6. **Foraging:** This refers to collection of nectar and pollen by bees.
7. **Nectar foragers:** They collect the nectar from flowers by using lapping tongue and pass the nectar to hive bees. Hive bees repeatedly pass the nectar between pre-oral cavity and tongue to ripen the honey. Later they drop ripened honey into cells.
8. **Pollen foragers:** They collect pollen by passing through different flowers. Pollen sticking to the body is removed by using pollen comb. Then it is packed by using pollen press into corbicula or pollen backset. A single bee carries 10 to 30 mg of pollen which is 25% of bee's body weight. Then the pollen is dislodged by means of middle leg into cells. Pollen is mixed with honey and stored.

9. **Floral fidelity:** A bee visits same species of plant for pollen and nectar collection until the source is exhausted. This is known as floral fidelity. Bees travel 2 to 3 km distance to collect pollen and nectar.

Duties of forager bees

Collect i) pollen, ii) nectar, iii) water, iv) propolis v) juice of damaged fruits (when bloom is scarce)

Use of pollen: Major food for grubs in combination with honey: also required by adult bees secreting royal jelly.

Use of nectar: Raw material for honey; honey is reserve food for the colony; food for grubs as Well as adults

Use of propolis: Comb repair; protect the colony from large enemies like mouse which enter the hive; water proof the hive

Use of water: hive temperature maintenance (air – conditioning system); and to dilute the honey before catering it.

Utility of bee flora to honey bees:

In general, a honey bee depends on a wide variety of plants for nectar and pollen. These include several species of wild and cultivated plants. For commercial beekeeping, large crop acreage with good floral qualities is required. A beekeeper must have the details about the availability and suitability of bee flora.

Following are the qualities of good bee flora:

- Long flowering period
- High density of flowers per unit of the plants
- Good quality of nectar with high concentration of sugars
- Easy accessibility of the nectaries to the honey bees and ease in collection of nectar
- Availability of flora in the close vicinity of the apiary

LIST OF IMPORTANT BEE FLORA IN INDIA

S. No.	Botanical Name	Common Name	Family	Flowering period	Source type
Field crops					
1.	*Eleusine coracana*	Ragi	Poaceae	3-4	P_2
2.	*Oryza sativa*	Rice	Poaceae	9-10	P_1
3.	*Pennisetum tyhhoides*	Bajra	Poaceae	11-10	P_2
4.	*Sorghum bicolor*	Sorghum	Poaceae	9-10	P_2
5.	*Zea mays*	Maize	Poaceae	1-12	P_3
6.	*Fagopyrum esculentum*	Buck wheat	Polygonaceae	7-9	N_1
Legume Crops					
7.	*Cajanus cajan*	Red gram	Fabaceae	8-11	N_3P_2
8.	*Cicer arietinum*	Bengal gram	Fabaceae	12	N_2P_2
9.	*Dolichos biflorus*	Horse gram	Fabaceae	10	N_1P_1
10.	*Medicago sativa*	Lucerne	Fabaceae	3-4	N_2P_2
11.	*Phaseolus mungo*	Black gram	Fabaceae	8 - 10	N_1
12.	*Phaseolus radiatus*	Green gram	Fabaceae	8	N_1P_1
13.	*Pisum sativum*	Peas	Fabaceae	8-9	N_1
14.	*Sesbania aegyptica*	Sesbania	Fabaceae	10-11	P_1
15.	*Sesbania graniflora*	Dhiancha	Fabaceae	6- 7	P_1

16.	*Trifolium alexandrium*	Berseme	Fabaceae	3-4	N_3P_2
17.	*Vigna unguiculata*	Cowpea	Fabaceae	8	N_1P_1
Oilseed Crops					
18.	*Arachis hypogea*	Groundnut	Fabaceae	8-9	N_2P_2
19.	*Brassica campestris var. sarson*	Sarson	Brassicaceae	10-11/10-1	N_1P_1
20.	*Brassica campestris var. toria*	Toria, Indian rapeseed	Brassicaceae	10-11	N_1P_1
21.	*Brassica juncea*	Raya, Indian mustard	Brassicaceae	12-2	NP
22.	*Brassica napus*	Rapeseed	Brassicaceae	12-3	N_1P_1
23.	*Brassica nigra*	Black mustard	Brassicaceae	8-9	N_3P_3
24.	*Brassica rapa*	Turnip, Canola	Brassicaceae	2-4	N_2P_2
25.	*Carthamus tinctorius*	Safflower	Asteraceae	12-1	N_3P_2
26.	*Eruca sativa*	Taramira, Rocket	Brassicaceae	12-8	N_2P_2
27.	*Guizotia abyssinica*	Niger	Asteraceae	4-5	N_1 P_3
28.	*Helianthus annuus*	Sunflower, Surajmukhi	Asteraceae	1-12	N1P3
29.	*Linum ustitassium*	Linseed, Flax	Linaceae	2-3	N_2P_2
30.	*Ricinus communis*	Castor	Euphorbiaceae	8-9	N_1P_1
Fiber Crops					
31.	*Corchrus olitorius*	Jute	Malvaceae	3-4	N_2P_2
32.	*Gossypium arborium*	Cotton	Malvaceae	4-1	N_1P_1
33.	*Hibiscus cannabinus*	Kenaf	Malvaceae	4- 6	N_1P_1
34.	*Crotolaria juncea*	Sun hemp	Malvaceae	8-11	N_3
Vegetable crops					
35.	*Abelmoschus esculentus*	Lady‘s finger	Malvaceae	1-12	N_3P_2
36.	*Allium cepa*	Onion	Liliaceae	5-7	N_3P_3
37.	*Amaranthus viridis*	Amaranthus	Amaranthaceae	1-12	N_1
38.	*Brassica oleracea. capitata*	Cabbage	Brassicaceae	2-4	N_3P_2
39.	*Brassica oleracea botrytis*	Cauliflower	Brassicaceae	2-4	N_3P_2
40.	*Capsicum annum*	Chilli	Solanaceae	1-12	N_3P_1
41.	*Capsicum chinense*	Capsicum	Solanaceae	11-2	N_3P_1
42.	*Coccinia indica*	Little gourd	Cucurbitaceae	1-8	N_3P_2
43.	*Coriandrum sativum*	Coriander	Apiaceae	2-3	N_1P_1
44.	*Cucumis melo*	Muskmelon	Cucurbitaceae	3-4	N_3P_2
45.	*Cucumis sativus*	Cucumber	Cucurbitaceae	10-11	N_3P_2
46.	*Cucurbita maxima*	Squash gourd	Cucurbitaceae	2-3	N_3P_1
47.	*Daucus carota*	Carrot	Apiaceae	3-4	N_2P_2
48.	*Dolichos lablab*	Field bean	Fabaceae	9	N2P1
49.	*Glycine max*	Soybean	Fabaceae	8-9	N1P2
50.	*Ipomea batatus*	Sweet potato	Convolvulaceae	10-12	N_1P_1
51.	*Lagenaria vulgaris*	Pumpkin	Cucurbitaceae	3-9	P_1
52.	*Laginaria siceraria*	Bottle gourd	Cucurbitaceae	1-12	N_3P_2
53.	*Luffa acutangula*	Ridge gourd	Cucurbitaceae	11-2	N_3P_1
54.	*Lycopersicon esculentum*	Tomato	Solanaceae	1-12	P_1
55.	*Momordica charantia*	Bitter gourd	Cucurbitaceae	4-7	N_2P_2
56.	*Moringa oleifera*	Drumstick	Moringaceae	12-4	N_1P_1

57.	*Phaseolus vulgaris*	French bean	Fabaceae	1-12	N_1P_1
58.	*Raphanus sativus*	Radish	Brassicaceae	2-4	N_3P_1
59.	*Solanum melongena*	Brinjal	Solanaceae	1-12	P_1
60.	*Solanum tuberosum*	Potato	Solanaceae	12-2	P_1
61.	*Trigonella foenumgracum*	Methi	Fabaceae	1 -12	N_1
Plantation Crops					
62.	*Cocos nucifera*	Coconut	Arecaceae	1 -12	P_3
63.	*Coffea arabica*	Coffee	Rubiaceae	4-5	N_3P_1
64.	*Hevea brasiliensis*	Rubber	Euphorbiaceae	3	N_1
65.	*Nicotiana tabaccum*	Tobacco	Solanaceae	12-1	P_1
Fruit Crops					
66.	*Anacardium occidentale*	Cashewnut	Anacardiaceae	12-2 9-10	N_2P_1
67.	*Annona squamosa*	Custard apple	Annonoceae	4- 6	N_1P_2
68.	*Areca catechu*	Arecanut	Arecaceae	1 -12	P_3
69.	*Artocarpus integrifolia*	Jack fruit	Moraceae	12-3	P_1
70.	*Averrhoea carambola*	Carambola	Averrhoaceae	5-7	N_3P_1
71.	*Carica papaya*	Papaya	Caricaceae	7-9	N_3P_2
72.	*Cinnamomum verum*	Cinnamon	Lauraceae	12-2	N2
73.	*Citrus spp.*	Citrus	Rutaceae	2-3	N_1P_1
74.	*Citrus medica var acida*	Acid lime	Rutaceae	1 -12	N_1P_1
75.	*Fragaria spp..*	Strawberry	Rosaceae	5-9	N_2 P_2
76.	*Litchi chinensis*	Lychee	Sapindaceae	3-4	N_1
77.	*Malus domestica*	Apple	Rosaceae	3-4	NP
78.	*Mangifera indica*	Mango	Anacardiaceae	12-3	N_1P_1
79.	*Manilkera achras*	Sapota	Sapotaceae	10-3	N1
80.	*Muntingia calabura*	Singapore cherry	Eleocarpaceae	1-12	N_2P_1
81.	*Musa paradisiaca*	Banana	Musaceae	1 -12	N_1P_1
82.	*Phoenix dactylifera*	Date palm	Palmae	6-7	N_2P_3
83.	*Prunus armeniaca*	Apricot	Rosaceae	3-4	N_1P_1
84.	*Prunus domestica*	Plum	Rosaceae	2-3	N_1P_1
85.	*Prunus dulcis*	Almond	Rosaceae	5-8	N_1P_1
86.	*Prunu spersica*	Peach	Rosaceae	2-3	N_2P_2
87.	*Psidium guajava*	Guava	Myrtaceae	2-4	N_3P_3
88.	*Punica granatum*	Pomegranate	Punicaceae	4-7	N_1P2
89.	*Pyrus communis*	Pear	Rosaceae	2-8	N_2P_2
90.	*Rubus spp.*	Rasberry	Rosaceae	2-6	N_3P_2
91.	*Sechium edule*	Chow chow	Cucurbitaceae	8	N_1P_1
92.	*Sesamum indicum*	Sesamum	Pedaliaceae	4-9	N_3P_3
93.	*Syzigium cumini*	Nerala	Myrtaceae	2-5	N_2P
94.	*Syzigium jambos*	Rose apple	Myrtaceae	12- 4	N_3P_2
95.	*Vitis vinifera*	Grape	Vitaceae	9-12	N_2P_1
Ornamental Plants					
96.	*Ageratum conyzoides*	Ageratum	Fabaceae	12-3	N_1P_1
97.	*Antigonon leptopus*	Mexican creeper	Polygonaceae	4-5	N_3P_3
98.	*Aster thomsoni*	Aster	Asteraceae	8 - 10	N_1P_1
99.	*Barleria cristata*	Barleria	Acnthaceae	1-12	N_1P_2
100.	*Calendula officinalis*	Calendula	Asteraceae	6-10	N_3P_1
101.	*Callistemon lanceolus*	Bottle brush	Myrtaceae	5-7	N_3

102.	*Cassia spp.*	Cassia	Caesalpinaceae	4-7	N_2P_2
103.	*Celosia argentea L. var cristata*	Cockscomb	Amaranthaceae	1-8	N_1
104.	*Celosia argentea L. var plumosa*	Celosia	Amaranthaceae	1-8	N_1
105.	*Chrysanthemum coronarium*	Chrysanthemum	Asteraceae	7-10	N_1P_1
106.	*Cosmos bipinnatus*	Cosmos	Asteraceae	3-5	N_3P_2
107.	*Cosmos sulphureas*	Cosmos	Asteraceae	6-11	N_1P_1
108.	*Delonix regia*	Gulmohar	Fabaceae	3-5	N_1P_1
109.	*Euphorbia mili*	Euphorbia	Euphorbiaceae	11-2	N_1P_1
110.	*Euphorbia pulcherrima*	Poinsettia	Euphorbiaceae	11-2	N_1P_1
111.	*Evolvulus glomeratus*	Blue daze	Convoulaceae	1-12	N_1P_1
112.	*Gerbera launiosa*	Gerbera	Agavaceae	1-12	N_1P_2
113.	*Hamelia patents*	Hamelia	Asteraceae	5	N_2P_1
114.	*Helichrysum arenarium*	Everlasting flower	Asteraceae	1-3	N_3P_3
115.	*Hibiscus rosasinensis*	Shoeflower	Malvaceae	1-12	N_2P_2
116.	*Impatiens balsamina*	Garden Balsam	Balsaminaceae	6-10	N_1P_1
117.	*Ipomea carica*	Railway creeper	Convolvulaceae	1-12	N_2P_2
118.	*Jacquemontia violacea*	Jacquemontia	Convolvulaceae	1-12	N_2
119.	*Jasminium angustifolium*	Wild jasmine	Oleaceae	12-6	N_3P_2
120.	*Lagerstromia indica*	Pride of India	Lythraceae	2-4	P_1
121.	*Melampodium paludosum*	Melampodium	Asteraceae	6-10	N_2P_2
122.	*Petrea volubilis*	Purple wrath	Verbenaceae	2-4	N_2P_2
123.	*Poinsettia pulcherrima*	Poinsettia	Euphorbiaceae	11-2	N1P1
124.	*Polyanthus tuberose*	Polyanths	Agavaceae	1-12	N_2
125.	*Rosa indica*	Rose	Rosaceae	6-7	N_3P_3
126.	*Tagetes minuta*	marigold	Asteraceae	1-12	N_2P_2
127.	*Thevetia peruviana*	Kanagila	Apocynaceae	1-12	NP
128.	*Zinnia elegans*	Zinnia	Asteraceae	6-10	P_2
129.	*Zoysia sp.*	Mexican grass	Poaceae	4-7	N_1P_1
Medicinal and Aromatic plants					
130.	*Ammi mages*	Honey plant	Apiaceae	3-4	N_3P_3
131.	*Anethum graveolens*	Dill	Apiaceae	12-3	N_3P_3
132.	*Apium graveolens*	Celery	Apiaceae	6-8	N_2P_2
133.	*Bacopa monnieri*	Brahmi	Scrophulariaceae	5-7	N_1P_1
134.	*Bidens pilosa*	Bidens	Asteraceae	6-2	N2P2
135.	*Carvia callosa*	Karvi	Acanthaceae	8-10/7-9	N1P1
136.	*Centratherum sp.*	Wild cumin	Asteraceae	5-9	N_2P_1
137.	*Foeniculum vulgare*	Fennel	Apiaceae	4-5	N_3P_3
138.	*Lavandula stoechas*	Lavender	Lamiaceae	6-11	P_2
139.	*Lathyrus sativus*	Khesari	Euphorbiaceae	3-4	N_1P_2
140.	*Lawsonia inermis*	Mehandi	Lythraceae	2-5	N_1P_1
141.	*Matricaria chamomilla*	Chamomile	Asteraceae	5-9	N_3P_3
142.	*Mentha spicata*	Spear mint	Lamiaceae	1-12	N_3
143.	*Nepeta cataria*	Cat mint	Lamiaceae	1-12	N_3P_3
144.	*Ocimum basilicum*	Sweet basil	Lamiaceae	2-8	N_2P_3
145.	*Ocimum canum*	Hairy basil	Lamiaceae	1-12	N_1P_1

146.	*Ocimum gratissimum*	Clocimum	Lamiaceae	1-12	N_2P_1
147.	*Ocimum kilimandscharium*	Camphor Basil	Lamiaceae	1-12	N_2P_3
148.	*Ocimum sanctum*	Sacred basil	Lamiaceae	1-12	N_2P_2
149.	*Porana volubilis*	Snow creeper	Convolvulaceae	3-5	N_2P_2
150.	*Ruta graveolens*	Garden rue	Rutaceae	1-12	N_1P_1
151.	*Salvia spp.*	Sage	Lamiaceae	7-10	N_2P_2
152.	*Trachyspermum ammi*	Ajwain	Apiaceae	3-7	N_2P_2
		Weeds			
153.	*Abelmoschus ficulneus*	Van Bhindi	*Malvaceae*	8-9	N_3 P_2
154.	*Argemone mexicana*	Yellow mexican poppy	Papavaraceae	11-3	N_1P_1
155.	*Artimesia vulgaris*	Mugwort	Asteraceae	2-7	N_1P_2
156.	*Crotan sparciflora*	Mirchaiya	Euphorbiaceae	7-8	N_3 P_2
157.	*Dhatura fistula*	Dhatura	Salanaceae	1-12	N_3 P_2
158.	*Jatropha curcus*	Boghandi	*Euphorbiaceae*	9-10	N_2 P_2
159.	*Lantana camera*	Lantana	Verbenaceae	1-12	N_1
160.	*Leucas aspera*	Leucas	Lamiaceae	11-6	N_2P_1
161.	*Mimosa pudica*	Touch me not	Mimosaceae	1-12	N_2P_2
162.	*Nerium indicum*	Sormari	*Apocynaceae*	9-10	N_2 P_2
163.	*Plectranthus rugosus*	Shain/ chhihhri	Lamiaceae	8-10	N_1P_3
164.	*Prosopis juliflora*	Mesquite	Mimosaceae	7-11	N_3P_1
165.	*Stachytarpheta indica*	Stachytarpheta	Verbenaceae	1-12	N_1
166.	*Tridax procumbens*	Tridax	Asteraceae	1-12	N_1P_2
		Trees			
167.	*Acacia arabica*	Babul	Mimosaceae	7-11	N_1P_1
168.	*Acacia catechu*	Khair	Mimosaceae	7-9	P_1
169.	*Acacia modesta*	Acacia	Mimosaceae	5-7	N
170.	*Actinodaphn ancustifolia*	Pisa	Lauraceae	10-3	N_1
171.	*Actinodaphn hookeril*	Pida	Lauraceae	10-1	N_3P_1
172.	*Adhatoda vasica*	Maker	Acanthaceae	8-10	N_3P_4
173.	*Aegel marmelos*	Bad	Rutaceae	5-6	N_2P_2
174.	*Aeqiceras corniculatum*	Mangrove	Myrsinaceae	1-2, 7	N_3P_2
175.	*Albizia lebbeck*	Siris tree	Mimosaceae	2-4	N_1P_1
176.	*Albizia amara*	Chigere	Mimosaceae	1-3	P_1
177.	*Azadirachta indica*	Neem	Meliaceae	3-4	N_2
178.	*Bauhinia purpurea*	Khairwal	Fabaceae	2-8	N_1P_1
179.	*Bombax ceiba*	Simal	Malvaceae	1-3	N_1P_2
180.	*Boreria stricta*	Boreria	Rubiaceae	1-12	P_1
181.	*Butea monosperma*	Dhak	Fabaceae	2-3	N_1P_1
182.	*Callistemon lanceolatus*	Bottle brush	Myrtaceae	1-12	N_3P_1
183.	*Canthium parviflorum*	Canthium	Rubiaceae	3- 6	N_2P_2
184.	*Cassia javanica*	Cassia	Caesalpinaceae	3-5	N_1P_1
185.	*Ceiba pentandra*	White silk cotton tree	Bombaceae	2-4	N_1
186.	*Chenopodium album*	White goose foot	Chenopodiaceae	6- 9	N_1P_1
187.	*Crotolaria striata*	Crotolaria	Fabaceae	1-5	P_1
188.	*Dalbergia sissoo*	Sissoo	Fabaceae	3-4	N_1

189.	*Datura stramonium*	Thorn apple	Solanaceae	11-6	P_1
190.	*Ehretia acuminate*	Puna	Boraginaceae	4	N_1
191.	*Elaeagnus umbelata*	Wild olive	Elaeagnaceae	4-5	N_2P_3
192.	*Eucalyptus spp.*	Safeda	Myrtaceae	11-4	N_1P_1
193.	*Eugenia spp.*	Bhedas, Gudda	Myrtaceae	2-4	N_1
194.	*Gliricidia septium*	Gliricidia	Caesalpinaceae	2-4	N_1P_1
195.	*Grewia spp.*	Phalsa	Teliaceae	7-11	N_2P_1
196.	*Jacaranda acutifolia*	Jacaranda	Bignoniaceae	2- 4	N_1P_1
197.	*Kaya sinegensis*	Kaya	Meliaceae	1-3	N_2
198.	*Lagascea mollis*	Lagascea	Asteraceae	7-12	N_3P_1
199.	*Leucaena leucocephala*	Subabul	Mimosaceae	1-12	P_1
200.	*Madhuca longifolia*	Madhua	Sapotaceae	2-3	N_1
201.	*Mallotus philippensis*	Kumkum	Euphorbiaceae	11-2	P_1
202.	*Manihot glagiovii*	Rubber Tree	Euphorbiaceae	7-8	N_3
203.	*Michalia champaka*	Michalia	Magnoliaceae	4- 6	N_1
204.	*Morus alba*	Mulberry	Moraceae	2-6	P_1
205.	*Parthenium hysterophorus*	Congress weed	Asteraceae	1-12	P_1
206.	*Peltophorum ferrugineum*	Copper pod	Caesalpinaceae	5-7	N_2P_3
207.	*Phyllanthus emblica*	Amla	Euphorbiaceae	2-4	N_1P_1
208.	*Pithecollovium dulce*	Manila	Caesalpinaceae	2-4	N_1
209.	*Polygonum glabrum*	Polygonum	Polygonaceae	12-3	N_1 P_1
210.	*Pongamia pinnata*	Karanj, Sukhchain	Caesalpinaceae	3-4	N_1 P_2
211.	*Pterospermum personatum*	Pterospermum	Bignoniaceae	4i-5	N_1 P_1
212.	*Rubinia pseudoacacia*	Rubinia	Fabaceae	9-4	N_1 P
213.	*Samanea saman*	Rain tree	Mimosaceae	3-6	N_1 P_1
214.	*Santalum album*	Sandal wood	Santalaceae	12-7	N_1
215.	*Sapindus laurifolius*	Soap nut	Sapindaceae	3-5, 10-12	N_1 P_1
216.	*Saraca indica*	Saraca	Caesalpiniaceae	2- 4	N_1
217.	*Simaruba glauca*	Simaruba	Simaroubaceae	2-3	N_3 P_3
218.	*Spathodea campanulata*	Scarlet bell	Bignoniaceae	1-12	N_3
219.	*Sterculia foetida*	Foetid tree	Sterculiaceae	11-2	P_3
220.	*Tabubia argentia*	Tabubia	Bignoniaceae	2-3	N_1 P_1
221.	*Tamarindus indica*	Tamarind	Caesalpinaceae	5-6	N_1 P_1
222.	*Tecoma stans*	Tecoma	Bignoniaceae	1-12	N_1 P_1
223.	*Terminalia arjuna*	Arjune	Combretaceae	3-5	N_1
224.	*Thelepaepale spp.*	Whayati	Acanthaceae	4-1	N P
225.	*Toona ciliata*	Tun	Meliaceae	3-4	N_1 P_3
226.	*Wendlandia spp.*	Tiliya	Rubiaceae	2	N_1 P_1
227.	*Zizyphus jujuba*	Wild Ber	Rhamnaceae	5-6	N_3 P_2
228.	*Ziziphus mauritiana*	Ber	Rhamnaceae	3-5	N_1 P_1

N : Source of nectar; **Flowering Period (Month):-** January to December (1-12)
P: Source of pollen **Source:-1:** Major; **2:** Medium; **3:** Minor

II. Communication in honey bees

Bees communicate by using various pheromones including the **queen's substance**, **vasanov gland secretion**, **alarm pheromone** emitted from sting and secretion of tarsal gland. In addition to that the bees also communicate by performing certain dances. When scout bees return

to the box after foraging they communicate to the other forages present in the box about the direction and distance of the food source from the hive by performing dances.
The important types of dances are noticed.

1. **Round dance** is used to indicate a short distance (Less than 50m in case of *A. mellifera*). The bee runs in circles, first in one direction and then in opposite direction, (clockwise and anticlockwise).
2. **Tail wagging dance or Wag-tail dance:**
   This is used to indicate long distance (more than 50 m in case of *A. mellifera*). Here the bee makes two half circles in opposite directions with a straight run in between. During the straight run, the bee shakes (wags) its abdomen from side to side, the number of wags per unit time inversely proportional to the distance of the food (more the wags, less the distance.). The direction of food source is conveyed by the angle that the dancing bee makes between its straight run and top of the hive which is the same as between the direction of the food and direction of the sun. The bees, can know the position of the sun even if it is cloudy.

TOXICITY OF PESTICIDES TO HONEYBEES AND PRECAUTIONS TO REDUCE THE TOXICITY TO BEES:

The use of pesticides has become inevitable in modern agriculture. During the last four decades the consumption of pesticides in India has increased several folds. Pesticides used on field crops for the control of pests have the side effect, one of which is toxicity to honey bees. Honey bees are susceptible to many pesticides. Three Types of harmful effect evident in Agriculture are:

- Loss in production of honey
- contamination of bee products
- Reduction in the yield of cross pollinated crops

The harmful effects may be due to direct exposure of honey bees to pesticides or through indirect contact with their residues. Direct exposure occurs from treatment of bee hives with pesticides for disinfestation purpose or bees visiting the fields at the time of spray. While the indirect exposure occurs from spray drift from nearby fields or bee foraging in sprayed crops.

Symptoms of bee poisoning:

- Dead or dying bees near the entrance of hives /colonies.
- Dead bees on the top of frames or bottom board.
- Lack of recognition of guard bees.
- Aggressiveness.
- Fighting among bees.
- Paralysed bees crawling on nearby objects.
- Sudden decline in food storage and brood rearing.
- Dead and deserted brood in the hive.
- Poor recognition of pollen and nectar by bees.
- Finally results in contamination of bee products

Causes of poisoning:

- Pesticides application during crop bloom.
- Drift of toxic chemical on to flower, pollen and nectar.

- Bee feeding on contaminated food and water sources.
- Use of broad spectrum insecticides (chlorinated hydrocarbons, synthetic pyrethroids).
- Type of formulation used like dust, EC which are more harmful than WP and granules.
- Types of spray, fineness of spray, stage of crop, weather condition and age of the colony.
- Use of insect growth regulators may inhibit brood production.
- Herbicides indirectly affect through damage to the foliage.
- Use of diesel oil as a career in insecticide formulations.

Management of bee poisoning

The basic principle in the management of bee poisoning is to avoid the exposure of honey bees to toxic effects. This could be achieved with the help of both beekeepers and the farmers. The practice to be followed by bee keepers includes the following.

- Bee colonies should be maintained where use and drift of pesticide is minimum
- Close co-operation with farmers to avoid irrational use of pesticides
- Feeding of colonies with sugar syrup at the time of pesticide application to reduce bee foraging

Management practices

- Need based use of pesticides.
- Informing the beekeepers in advance about the spray programme.
- Use of less hazardous, selective and repellent insecticides.
- Spraying in the evening when the bee activities subside.
- Granules, EC are conferred compared to dusts.
- Avoid formulations with attractants like Sevimol during crop bloom period.
- Development of bee strain resistant to toxic effects of pesticides.
- Addition of adjuvant, Sylgard 309 silicon surfactant to reduce the bee mortality.

Less hazardous insecticides

- Granules: Fenthion and phorate
- EC: Phosalone and fluvalinate

Highly hazardous insecticides

- Dust: Carbaryl, diazinon and fenvalerate
- WP: Carbaryl
- EC: Chlorpyriphos, cypermethrin, deltamethrin, diazinin, dichlorvos, dimethoate, ethion, fenitrothion, fenthion and fenvalerate
- SL: Imidacloprid

PESTS AND DISEASES OF HONEY BEE:

Bee enemies cause great loss to honey bee colonies. These bee enemies destroy the raised combs, hives and hive parts, catch and kill bees and brood, adversely affect colony development, eat away the food reserves and cause nuisance to the bees and beekeeper thereby reducing the colony productivity and returns per colony. Major bee enemies are wax moths, wasps, birds, ants and mites, etc.

A. Wax moths

Colonies of all honey bee species are attacked by two species of wax moths *viz.* Greater wax moth, *Galleria mellonella* Linnaeus and Lesser wax moth, *Achroia grisella* Fabricius. Out of these two species, *G. mellonella* is more damaging to the bee hives.

1. Greater wax moth *(G. mellonella)*

Greater wax moth is present throughout the world with rare exception at high elevations. Its life cycle is completed in four stages *viz.* egg, larva, pupa and adult. Eggs are smooth, spherical, pinkish to creamish white with size ranging between 0.4-0.5 mm. Eggs are laid in clusters of 50 to 150 in cracks and crevices. Single female lays on an average of 300-600 eggs (the number may reach up to 1800) in its life time of two weeks. Larva is white to dirty grey in colour, 3-30 mm in size. After hatching, it feeds on **honey, nectar and pollen.** It lives in long **silken tunnels**. The larva makes burrows/ tunnels in combs and extends these to the midrib of comb. It spins silken galleries that give it protection from bees and trap the newly emerged bees in their cells. This condition is known as **Gallariasis**. The larva moults 4 to 6 times in its life. Pupa is brownish white to dark brown and 14-16 mm long in size. Pupation takes place in silken cocoons spun around them by the last instar larvae. The larva moves to hive body and make a small depression in the wood in which it pupates. These cocoons may be found on inner walls of chamber, inner cover and on frames. The white colour cocoons are present in clusters. Adult moths are brownish grey; the females are lighter in colour, larger and heavier than males. In the females, the outer margin of fore wing is smooth while semi-lunar notch is found in males. Life cycle is completed in four weeks to six months.

Seasonal activity:

Stored and deserted combs, improperly cleaned wax and weak or poorly managed colonies and deserted combs of wild bees are constant source of wax moth population. Depending upon the availability of food, temperature and habitat of the pest, several overlapping generations can be produced in a year. Wax moths are active from March to October, but peak activity is from August to October. It **over-winters in larval and pupal stages** in stored combs during November to February.

Nature of damage:

This pest is more serious during dearth and monsoon. The moth infests combs with all stages of **brood, cells and pollen**. Silken galleries spun by wax moth larvae around them near the mid-rid of the brood comb is the cause of **Gallariasis**, a condition in which adult bees are unable to come out of cells as their legs get entangled in the silken galleries underneath. Wax moth larvae can reduce the combs to a mass of web and debris which has black thin and elongated excreta entangled in it. Severe infestation leads to suspension in brood rearing, foraging activity and ultimately desertion of colony. *A. mellifera* species collect more propolis; hence, it is less prone to the attack of wax moth than other *Apis* species.

2. Lesser wax moth *(A. grisella)*

It is troublesome particularly in stored combs. Its egg stage varies between 2 to 4 days, larval 34-48 days, pupal 5-12 days and adult longevity is about 7 days. *A. grisella* larvae are 15-20 mm in size, white in colour with brown head and live segregated in silken tunnels covered with frass and webbings whereas greater wax moth larvae congregate. Moths are smaller than greater wax moth and silver grey without markings on wings. Female moth may lay 250-300 eggs. They complete 3-4 generations during active season and hibernate as larvae or pupae.

Management of wax moths:

- Maintain strong and healthy colonies.
- Close all cracks and crevices of the hive and reduce entrance size.
- Keep the bottom board clean. Collect and burn the debris periodically.
- Control diseases and other pests that make the colony weaker.
- Avoid pesticidal poisoning which otherwise weaken the colonies.

- Remove excessive combs from the hive, especially during dearth period.
- Destroy the silken tunnels of wax moth larvae to kill larvae in initial stages.
- Destroy severely attacked combs and melt them in water to render bees wax.
- Keep empty infested combs in sun for a few minutes or in hot water (60°C) for 4-5 h to kill the larvae.
- Artificial cold e.g. -6.7°C for 4-5 hrs, or -12.2°C for 3 hrs or -15°C for 2 hrs is effective in killing all the stages of wax moth.
- Fumigation with following chemicals is effective in killing the larvae in stored combs in air tight rooms/containers/ chambers:
  (i) Aluminium phosphide @ 0.75g/ m^3 space

B. Predatory wasps

Wasps/ hornets are known to cause serious damages to honey bees. These are especially serious during rainy season when their population is nearly at peak in their nests. Their attack causes colonies to diminish or abscond.

While adult wasp feed on liquid food, their brood feed on animal food which is provided by the adult wasps. The adult wasps catch honey bees and their brood for feeding to their own brood.

Wasp species	Identifying characteristics	Nesting behaviour
Vespa mandarinia (Giant brown wasp)	Largest, dark brown, hairy and has a robust look. Head bright orange, rear part of thorax has two eye spot like markings; has strong mandibles.	Lives in the hollows of tree trunks. **Seasonal activity:** Sept-Nov
Vespa tropica (Yellow banded wasp)	Has a yellow broad band in the middle of the dorsum of abdomen.	Nests in the ground. **Seasonal activity:** Aug-Oct
Vespa basalis (Black wasp)	Brown coloured head, abdomen black; with fine hair; medium sized.	Papery round nest on top of the tree. **Seasonal activity:** Sept-Nov
Vespa velutina (auraria) (Brown wasp)	Reddish brown with fine hair; medium sized.	Papery ovoid nest atop the tree. **Seasonal activity:** July-Sept
Vespa orientalis (Yellow banded brown wasp)	Deep brown yellow bands with brown spots on abdomen; yellow frons, smaller sized.	Irregular, simple nests in hidden places in walls or hollows of trees. **Seasonal activity:** July-Dec

Management of wasp:

- Killing of gravid wasp queens, found building nest, early in the spring i.e. by sweeping in net or by thrashing.
- Nest destruction: Their nest can be traced by tying a thread to a worker wasp and following its flight and the nest can then be destroyed.
- Killing wasps by fly-flappers during peak attack hours (noon) for 30 minutes results in its reduced attack during following hours and days owing to reduced population.
- Elimination of alighting board also reduces losses due to wasps attack.
- Use of wasp traps and poisoned baits (candy, meat, rotten fish, apple, etc.) are also helpful.

- Destroying wasp nests with kerosene torches or fumigation with aluminium phosphide or spraying insecticides.
- Use of wasp barrier in front of honey bee colonies reduces the loss from the wasps.
- Use of long and narrow mud tunnels at the bee colonies' entrances prevent wasps entry into the colonies and helps in loss reduction.
- Mass poisoning of wasps by gluing poisoned jaggery filled gelatin capsules on to the thorax of foragers, about 6-12 loads sent this way are sufficient to kill the whole colony of the wasp.

C. Ants

Ants are usually not serious pests of honey bee colonies. Occasionally, however, certain species may enter colonies in search of food or establishing nesting sites. Ants are typically found between the inner and outer covers of the hive and in pollen traps.

Nature of damage:

Sometimes persistent attacks by ants trigger absconding in honey bee colonies. Even though majority of the ants' species seldom disturb the bees, but these can be a nuisance to the beekeeper in performing routine beekeeping operations.

Management of ants:

- Fill cracks and crevices in the hive.
- Maintain strong colonies.
- Keep bottom boards raised off the ground. Place the colony on stand with oil or sticky barrier. Alternatively, put legs of the stand in broad earthen bowls full of water (ant wells) to check entry of ants into the hive.
- Digs open the underground nests of the ants.
- Drench underground nests of ants with chlorpyriphos (0.2%).
- Colonies capable of defending by fanning should be selected and used as breeder colonies for mass rearing of queen bees.
- Repellents e.g. sulphur powder, borax powder, sodium fluoride, etc. can be used around the colonies against ants.

D. Birds

Several birds predate on honey bees. Important bee eaters include Green Bee-eaters (Little Green Bee-eater, *Merops orientalis* Latham and Olive Bee-eater, *Merops superciliosus* Madagascar) and Black Drongo/ King Crow, *Dicrurus ater* Hermann).

Management of birds

- Scaring (Use of sound in high pitch with different notes; Beating the drums and empty tins; Throwing pieces of stones/ pebbles through *Gulel* or hand; Use of sulphur-potash mixture for producing regular blasts. Hanging 2-3 dead bee eaters at 5m height; Producing distress call/ voice of injured bee eater by recording audio cassette and playing on the amplifier).
- Reflective tapes (Reflective tapes of different colours (lm x 3.5cm) fixed on string at a distance of 20-30 cm at height 5 m on two poles/ stems to ward off the birds)
- Keep bee hives under thick canopy of trees.
- Destroy nesting sites of bee eating birds.

D. Varroa mite or Ectoparasitic mite, *Varroa destructor* Anderson & Trueman

Adult female mite is dorso-ventrally flattened, brown to dark brown and shining in colour, shaped like a tiny crab, sideways oblong (broader than length), measuring 1155-1182 µm long

and 1730-1773 µm wide. The mite can be seen easily with the naked eye on infested bee larvae, pupae and adult bees. Adult males are yellowish with lightly tanned legs and spherical body shape measuring 791-887 µm long and 791-862 µm wide.

Symptoms of infestation:

In the infested colonies, adult mites can be seen on adults, larvae and pupae of honey bees. Two to six mites on an infested individual honey bee adult/ brood result in decline in colony size and activity. The infested brood has **perforations in their cell cappings**. The heavy infestation results in typical bald-brood symptoms. The higher number of mites in drone brood implies the preference of this mite for drone brood than the worker brood for its development.

Management strategies:

Management of the mite involves Integrated Varroa Management (IVM) for which various strategies as campaign are required to curb this menace.

Non-chemical methods:

1. **Destruction of drone brood**: Since the Varroa mite is attracted to drone brood and has higher multiplication rate on it, the destruction of unwanted drone brood by cutting out. The sealed drone brood part of the comb and its destruction or burying deep into the soil will be highly helpful in bringing down its population and carry over to the next brood cycle.
2. **Trapping Varroa on drone brood**: By putting one empty drone in the brood nest area to trap Varroa mites and restricting the queen bee on this comb and then subjecting it to freezing, heat treatment or simple destruction of sealed drone brood and burying it deep into the soil provides an effective control of the mite by shifting its population from worker brood to the drone brood and rendering the former safe.
3. **Queen arrestation**: Caging the queen bee for two weeks to create bloodlessness conditions also has adverse effect on the development and multiplication of the mite.
4. **Shook-swarm method**: Shaking bees from infested colony onto frames with comb foundation or broodless combs in another hive for about two weeks and destruction of infested brood on the original combs is also helpful to free the bees from the n However; sugar feeding has to be provided to the colony established in the second hive.
5. **Use of sticky papers**: Varroa adult mites adhering to the body of adult bees often are fallen down by grooming of the bees particularly at night. These mites fallen on the floor board climb up again and move to the bee/ brood combs. The placement of a sticky paper on floor board covered with 8 mesh plastic screen prevents the mite to return to the brood combs as the mites get stuck to these sticky papers.
6. **Use of Varroa boards**: Screened floor boards on high legged hive stands would result the mites to fall through on the ground and starved to death. This is considered to be continuous and effective control. However, the robbing and prevailing temperature conditions must be viewed while following this method.
7. **Dusting powdered sugar:** Dusting very fine (particle size <5(am) sugar @ 30 gram per 10 bee frame, uniformly between the combs though the bee space in the late evening, is also effective to check this mite menace. This method of controlling mite can be used during honey flow, when other chemical means cannot be used.

Chemical methods:

1. Slow release strip formulations like fluvalinate, flumethrin, bromopropylate and amitraz have been reported to be effective for the control of this mite abroad but these pesticides are not

registered and available in our country. Alternatively, the following chemical (generic) control measures, which are adopted and followed world-wide, are suggested:

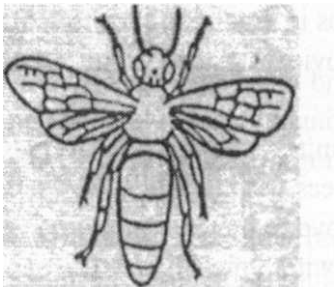
Formic acid: Formic acid (85%) @ 5 ml per day continuously for two weeks is to be administered to the infested colonies. **Oxalic acid**: This organic acid, available from chemical dealers in anhydrous form, it is effective against the mite. Its 4.2 per cent aqueous solution in 60 per cent sugar solution in water @ 5 ml of this resultant solution is to be sprayed per comb or trickled down between every two combs for this mite management.

B. Endoparasitic mite

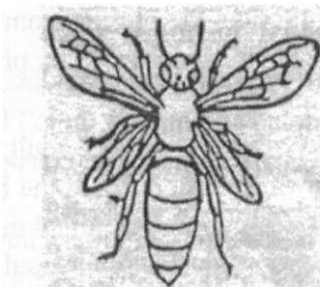
1. ***Acarapis woodi*** Rennie (Acarine mite / Tracheal mite)

This mite is internal parasite of adult bees and found in their respiratory tract (tracheae). *They* are essentially microscopic in size. They can be seen only after killing and examining the dissected out tracheae of an individual bee.

a) Symptoms of infestation



Healthy bee



K-winged bee

- Crawling bees on the ground with disjointed wings called **K-winged bees**. Such bees cannot fly.
- Infested crawling bees try to climb on a grass blade and finally fall down.
- If tracheae are dissected, irregular dark stains are initially seen on the infested tracheae which eventually blacken.
- All the three castes are equally susceptible.
- Mite can cause severe bee losses, sometimes weakening and destroying the entire colony.
- Mite attack shortens the adult bee longevity.
- The infestations diminish colony strength.

Management

Use of formic acid @ 5 ml daily for 21 days to be applied as suggested in the case of Varroa Tropilaelaps mite.

Other pests:

King crow: *Dicrunus macrocercus*: Bee eater: *Merops orientalis*

They capture bees and devour them. Since birds help in keeping down insect population, no large – scale measures against them can be recommended.

Lizards, toads and frogs: Vertebrata, All the three have sticky tongue, which helps them to capture bees. They remain on the alighting board and catch the bees.

Spiders (Aranae: Arachnida): In nature, spiders spin web nearby hives. When the bees caught in the silken web. Spiders feed them.

Diseases and their management:

I. **Bacterial Bee diseases and their management**

1. American foulbrood (AFB)

It is a bacterial disease of pupal stage caused by Gram positive sporulating *Paenibacillus larvae larvae* (White) Heyndricx *et al.* This disease results in occasionally the death of pupae in the sealed cells. Cell cappings are sunken, watery, discoloured and sometimes punctured with irregular holes. Dead pupae are dull-white and watery changing to brown ropy stage. At this stage, if a match is thrust into dead pupa and then removed, a semi fluid ropy thread is drawn. Affected colony gives a distinct fish or glue-pot like odour.

2. European foulbrood (EFB)

It is caused by the bacterium *Melissococcus plutonius* (White) Truper & De'Clari. This disease is occasionally found in both *A. mellifera* and *A. cerana* colonies in India. Larvae get displaced in their cells and die in the unsealed cells when they are only 4-5 days old. Dead larvae become soft, watery and dull yellow. Their breathing tubes are prominent at this watery stage. The affected larvae are discoloured, first creamy yellow, then turn to light brown and then dark brown and occasionally black. The infected larvae lie upright attached with side walls of the cells and sometimes appear just melted down at the base of the cells. Dead larvae finally dry to brown removable rubbery scales at the bottom of the cell.

Management of AFB:

- Feeding of sodium sulphathiazole @ 0.1 g/1, oxytetracycline (Terramycin®) @ 0.25-0.5 *gl*1 or streptomycin @ 0.05 to 0.15 g/1 in sugar syrup were recommended in some countries.
- But waiting period for the sale of the honey following such treatment has to be at least six months.
- Sterilization of combs and other hive parts with Formalin @ 150 ml/1 water for 48 h at 43 °C in fumigation chambers.
- Sterilization of combs with ethylene oxide @ 1 g/1 for 48 h at 43°C in fumigation chambers.
- Due to highly resistant spores, in European countries, burning of colonies including bees and combs and scorching of hive body

Management of EFB

- Feeding oxytetracycline @ 0.5 g per 500 ml sugar syrup or sprinkling it on bee cluster gives good bacteriostatic effect. The use of antibiotic, as above, was recommended in some countries. But waiting period for the sale of the honey following such treatment has to be at least six months.
- Sterilization o**f** combs and hive parts with formalin and acetic acid, as in case of AFB, is also recommended.
- Swarm shook coupled with provisioning of either brood alone or brood + pollen combs from the healthy colony are effective in controlling the disease.

II. PROTOZOAN DISEASES

1. **Nosema disease**

This disease is caused by *Nosema apis* Zander. It is disease of adult bees and the protozoan parasitizes all the castes. The infectious spores germinate in the ventriculus of the host. Its spores are shed in the lumen of digestive tract of the affected bee and are then excreted out. Infection spreads through ingestion of faecal matter with contaminated food. This disease is dent on *A. mellifera* colonies in the eastern part of the country.

a) **Symptoms**

i) Bees start foraging at younger age.

ii) Bees are less able to fly and fall down during their return journey.

iii) Bees crawl up the grass blades and fall down on the ground and such affected fatigued bees gather in depressions / ditches.
iv) Abdomen is distended with faecal matter.
v) Body hair are lost and bees become shiny.
vi) Mid intestine is swollen and if dissected, shows dull greyish white contents.
vii) Bees soil the hive entrance and also the ground in from of the entrance with black excreta.

b) Disease management

- Arrange the provision of fresh running water.
- Drain off stagnant water from the apiary.
- While transporting queens, select healthy attendant bees.
- Provide upward ventilation to reduce humidity.
- Use of feeding fumagillin (Fumadil) in concentrated sugar syrup is recommended in many countries. It inhibits DNA replication of the pathogen. However, in Assam where this disease is found in *A. mellifera* colonies, Antkon-M @45.5 ppm in sugar ***syrup*** is recommended for feeding to the honey bee colonies.
- Disinfect the empty hives with ethylene oxide or acetic acid fumigation @ 120 ml / hive.

2. Amoeba disease

It is caused by *Malpighamoeba mellifecae* Prell. This infection is caused by ingesting the cysts along with contaminated food. Cysts germinate, amoeba migrate to malpighian tubes and feed on cell contents. Cysts accumulate in the mid-gut / rectum. Cysts are shed in the intestine and are excreted out with faecal matter. Spring dwindling of colony strength can be experienced in such case.

Disease management:

- Ensure proper hygienic conditions.
- Scarp off the bottom board and disinfect it with 2 per cent carbolic acid.
- Disinfection of hives and equipment with acetic acid is also helpful.

C. FUNGAL DISEASES

Two fungal diseases are important *viz.* Chalk brood and Stone brood.

1. Chalk brood

This disease is caused by *Ascosphaera apis* (Maassen ex Claussen) Olive & Spiltoir. It is of very rare occurrence and is found in weaker colonies in high humid areas.

a) Brood dies and turns into hard white mummies full of mycelium.
b) Spores are formed within dark-greenish fruiting bodies when male and female mycelia unite. Then mummified larvae turn dark grey or black.
c) The mummies are heard to rattle when combs are shaken.
d) On inverting the comb, the mummies get out and fall down.
e) Its endemic infection is damaging otherwise it is a less serious disease. Old larvae (3-4 days) and those on periphery of brood area are more susceptible. The spores of fungus remain viable for 15 years.

2. Stone brood

This disease is caused *by Aspergillus flavus* Link. Its spores are ingested with food. These spores germinate in the alimentary canal. The mycelia attack the soft tissues. The spores also germinate on the cuticle and mycelia penetrate inside.

- Infected larvae and pupae when dead become hard and stony mummies.

- If infected, the abdomen of adult bees is also mummified.
- The affected adult bees show restlessness, feebleness and paralysis, abdomen gets dilated and then mummified.
- Younger bees die earlier.

Management of fungal diseases:

- These have no chemical control.
- Removal of mummies by bees results in natural control of the diseases.
- Collect and burn the mummified larvae.
- Improve ventilation of the colonies and reduce humidity.

D. VIRAL DISEASES

1. Sacbrood disease

This disease is caused by Sacbrood Virus (SBV). The virus is ingested with food. Two days old larvae are more susceptible for catching the infection. Virus multiplies in body tissues. Disease in the colony is spread nurse bees and among the colonies through swarming, drifting and robbing.

- Occasionally larva in late stage or near cell sealing and more commonly at prepupal stage dies.
- Brood is stretched on the back.
- Cell cappings are sunken and brood is patchy.
- Sometimes the infected prepupa does not have cell capping.
- Dead brood remains upright in the cell.
- Dead brood skin becomes tough.
- Its colour changes to pale yellow to brown.
- Head and thorax regions are darker.
- Brood if pulled out with a tweezer, it comes out like a sac.
- If it is held against sun, two layers of cuticle surrounding the body are visible, the outer being the molten cuticle of the last larval instar which is not shed and held along. Between the two, a thing layer of yellowish green fluid (molting fluid) will be visible which in a few seconds will start accumulating towards the lower side i.e. the rear end of the prepupa.
- Dried scale is boat shaped.

2. Chronic bee paralysis

This disease is also called hairless black bee syndrome / little black robbers. Infected bees die within a week. The causal viral particles are irregular in shape. Enzyme ribonuclease found in nectar destroys viral RNA. Bees become hairless, shiny and small.

- Bees have uncoupled wings.
- Affected bees are nibbled by healthy bees, as robbers are nibbled.
- Bees experience trembling and jerky movements.
- Sick bees gather on top bars or crawl out.
- Dead bees are seen in front of hive entrance.

3. Iridescent virus

This disease is caused by iridovirus. Its infection is serious during hot / dearth seasons. It is transmitted by nurse bees through glandular secretion (food).

- Reduced egg laying / brood rearing. Bees become sluggish and cluster.
- The infected bees crawl on the ground.
- The affected bees cease foraging, reduce honey collection, and the colony face starvation

and starts dwindling.

- Illuminated body tissue under microscope look bluish / greenish.

Management of viral diseases

For viral pathogens, there is no chemical control. The affected colonies should be isolated beyond their flight range. Adopt all the management operations to keep colonies stronger. Provide proper ventilation to reduce humidity. Cage the queen for a week and then requeen. Use sterilized equipment / combs. Check robbing, drifting and swarming. Provide supplement feeding. Feeding oxytetracycline hydrochloride @ 0.5-10 g per colony is recommended in many countries to protect the colonies against secondary infections.

General management practices for the management of diseases

- Maintain strong and vigorous colonies through appropriate management/ by uniting weaker ones.
- Provide supplementary sugar, pollen or pollen substitute feeding during their dearth or shift colonies to areas with good bee pasturage.
- Never transfer combs between colonies, without first checking for the signs of brood disease.
- Isolate the disease suspected colonies and do not exchange its combs and other hive part; with healthy colonies. Burn if the diseased colonies are a few and very high incidence of infection is detected in early stages.
- Sterilize the beekeeping equipment used for diseased colonies using formalin and carbolic acid. Take appropriate measures to check robbing, drifting, etc. in the apiary. Never leave combs or honey exposed to robbing bees.
- If a colony dies out at any time, seal the hive to prevent the remaining stores being robbed out, pending examination of the brood combs for signs of disease.
- Be suspicious of the swarms of unknown origin as these might carry the infection. Hive them on foundations rather than drawn combs, and inspect them for diseases once they have become established.
- Dequeen the colonies for a few days followed by requeening with healthy and vigorous queens. The bees relieved of brood care activity will clean out the infected brood.
- Select colonies showing disease resistance or hygienic behaviour for their use as breeder colonies for requeening or multiplication of stock or for sale purpose.
- To prevent spread of bee diseases, safe distance has to be maintained among apiaries at migration site. Furthermore, before migration, all the colonies should be inspected and the diseased colonies should not be moved along with the healthy apiary. Inspect your colonies every spring and autumn, specifically to check for the diseases. If you are unsure, seek the expert advice immediately.

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Part-II: Silkworm

INTRODUCTION:

Sericulture is an agro based Industry, the term which denotes production of Silk through silk worm rearing or in other words commercial production of Silk through silkworm rearing. Sericulture is a labour intensive agro industry ideally eradicates unemployment. Further improves their economic standards of rural poor. "Silk" the queen of textiles has a great importance ever before pre Vedic era. The term 'Silk' was mentioned in Rig-Veda, Ramayana and Mahabharata. It is estimated that one of mulberry and its allied activates can provided employment to people either directly or indirectly. Sericulture improves frequent returns throughout the year with relatively less expenditure and some common inputs.

HISTORY OF SILKWORM IN WORLD:

Today there are more than 29 countries in the world are practicing Sericulture; Historical evidence shows that, silk was discovered in China and later the industry spread to other parts of the world. The earlier reference to silk was found in the chronicles of Chou – King (220 BC).The discovery of silk is legend that during 2500 BC, one day in the garden. She saw some tiny insects feeding on some kind of leaves. Few days later she found the worms to have grown very big, and the curious queen continued to observe the process till the cocoons were spun by the worms. After the formation of cocoons, the queen collected them and preserved till moths have evolved. One day accidentally she dropped some cocoons into hot tea cup, when she tried to remove them from the cup; a fine lustrous yarn came out of the cocoons. Historical evidence reveals that sericulture was practiced in the China long back and preserved the secrete for more than 3000 years and the Chinese maintained the monopoly about 3000 years and they built a prosperous silk trade with the rest of world. The Chinese emperor ruled that, revealing of worm eggs or mulberry seed was bound to meet the very severe punishment. However 500 years later there is a reference in mulberry cultivation in 'Seminyojutu' such as mulberry layings, seedlings. During this period only mulberry cultivation technique appeared to have been taken up very seriously.

HISTORY OF SERICULTURE IN INDIA:

According to western historians, mulberry cultivations spread to Indian about 140 BC from China through Tibet. The mulberry cultivation and Silk industry first began in the areas beside the rivers Brahmaputra and Ganges the Aryans discovered the Silk worm in Sub Himalayan regions even though mulberry cultivation may have come to India from china. The silk from Kashmir became very famous in the beginning of christen era. This may be the fact that, the Arabs obtained the silkworm eggs and mulberry seeds from India during the early days of christen era. During 4^{th} century AD, when the sericulture industry established in India and central Asia, raw silk and silk goods were exported to Persia and Rome. In 553 AD, Sericulture was spread to Constantinople. Gradually, Sericulture industry developed in venation Republic and was able to meet the entire demand of silk in European by eleventh century. Silk from Kashmir and Bengal was exported to the European markets during the 14^{th} and 15^{th} century, from 1761 to 1785 the export of Bengal silk to the European markets. East India Company started to modernize the silkworm rearing and silk reeling techniques. In 1771, the Chinese Silk was introduced with the object of the quality of Cocoons. Between 1717 and 1775, the Haitian methods of rearing were introduced by East India. The attempt to replace indigenous breeds of Silkworm by the new varieties of mulberry plant without scientific study eventually is the whole industry to chaos. Louis Pasteurs (1870) discovery of the method of mother moth examination could control pebrine disease. A silk conference was called for by the British Govt. in 1942 at Delhi. The Government

launched an ambitious project called 'Silk Expansion scheme'. In 1948 the Country was divided in to India and Pakistan. As result some silk Producing areas have gone to Pakistan and East Bengal. During 19th century when the silk industry was at peak in France, the epidemic of pebrine wiped out the sericulture industry not only in France but also in Europe and Middle East. This disease was reported in Bengal during the 19th century.

RESEARCH AND TRAINING INSTITUTES ON SERICULTURE IN INDIA

Central Silk Board (CSB), Ministry of Textiles, Govt. of India, Bangalore (Karnataka) is nodal agency: The main Research & Training Institutes of the CSB provide scientific and technological support for enhancing production and productivity for sustainable sericulture through innovative approaches. The main institutes working under CSB are as follows:

1. Central Sericultural Research & Training Institute **(CSRTI), Mysore** (Karnataka) deals with Mulberry sericulture.
2. Central Sericultural Research & Training Institute **(CSRTI), Berhampore** (West Bengal) deals with Mulberry sericulture.
3. Central Sericultural Research & Training Institute **(CSRTI),** Gallandar Pampore, **Kashmir**, (J&K) deals with Mulberry sericulture.
4. Central Tasar Research and Training Institute **(CTRTI),** PO- Piska-Nagri **Ranchi**- 835 303 (Jharkhand**)** deal with Tasar sericulture.
5. Central Muga Eri Research and Training Institute (**CMER & TI**), P.O. – Lahdoigarh, **Jorhat**, Assam deals with Muga and Eri sericulture.

Regional Sericulture Research Stations (RSRS/RTRS/RMRS) for Mulberry and Vanya sericulture have been functioning for the development of region specific technology package and dissemination of research findings as per regional needs. Besides, a network of Research Extension Centre (RECs) & its sub units for mulberry and vanya silk are also functioning to provide extension support to sericulturists. In order to provide R&D support in post cocoon sector, the Board has established a **Central Silk Technological Research Institute (CSTRI) at Bangalore.** In addition, the CSB has also set up **Silkworm Seed Technology Laboratory (SSTL) in Bangalore (Karnataka), Central Sericultural Germplasm Resource Centre (CSGRC) at Hosur (Tamil Nadu) and Seri-Biotech Research Laboratory (SBRL) at Bangalore (Karnataka).** In Gujarat, Department on Entomology, N.M. College of Agriculture, Navsari Agricultural University, Navsari is working on silkworm under Plan scheme (Development Charges) Project entitled **"Research Studies on Mulberry Sericulture in South Gujarat Region"** since 1991.

During 2017-18, the total raw silk production in the country was 31906 MT. The highest raw silk production was noticed in Karnataka (9322 MT) followed by Andhra Pradesh with 6778 MT.

Glossary of Silk/Silkworm:

1. *Antheraea mylitta*, *Antheraea pernyi* and *Bombyx croesi* – Species of wild (undomesticated) moths that produce silk fibre. The silk filament is about three times heavier than that of the cultivated (domesticated) silkworm and is a coarser fibre. It is called tussah.
2. Artificial silk – Material that is similar in look to genuine silk, but is made from man-made fibres such as polyester, nylon or acetate.
3. *Bombyx mori* – The native (domesticated) variety of silkworm that produces Thai silk.
4. Cellule - A plastic black conical cup used to cover paired moths and female moth during ovi position.

5. Cocoon – The small, egg-shaped enclosure that a silkworm spins around itself, by creating silk filaments, to allow it to metamorphose inside to emerge as a moth.
6. De-gumming – The process of washing raw silk in warm soapy water to remove the sericin. This process can reduce the weight of the silk by as much as 25%. De-gummed silk is creamy white in colour and quite soft.
7. Denier – A unit of measurement of the fineness of silk and other fibres. One denier is equivalent to the weight of a single strand of silk thread of 9,000 meters in length, usually equal to one gram.
8. Dupion (or dupioni) – Yarn made from "double" cocoons that are spun by two silkworms simultaneously.
9. Fibroin – The protein that makes up the fibre of silk filaments.
10. Floss – Low-grade silk from the outer part of the cocoon. It can also refer to a soft silk yarn without any twist that is often used in embroidery.
11. Loom – A device for weaving threads together to make fabric. Hand-looms are usually made mostly of wood. Looms usually have a number of peddles to raise and lower alternate warp threads.
12. Mulberry – The tree whose leaves are the staple diet of silkworms. Approximately 200 kilograms of mulberry leaves will be eaten to produce one kilogram of raw silk.
13. Mulberry Silk – Another name for silk produced by *Bombyx mori* silkworms because they eat mulberry leaves.
14. Polyvoltine – The term used to describe silkworms that can be harvested several times a year. The native variety of silkworm in Thailand is polyvoltine.
15. Raw Silk – Silk thread that has been reeled from cocoons and is still in its natural state. It consists mainly of fibroin (the filament) with about 10-25% sericin (a gluey secretion). Raw silk is golden yellow in colour and somewhat stiff.
16. Reeling – The process of unwinding raw silk filaments from cocoons to produce a raw silk thread.
17. Sericin – A gluey protein secreted by silkworms that holds silk filaments together in a cocoon.
18. Sericulture – The process of rearing silkworms to the cocoon stage where they can then be reeled.
19. Silkworm – The larval stage of the *Bombyx mori* moth that produces silk fibres.
20. Skein – A coil of silk thread.
21. Slub – Tiny irregularities in the silk thread created by hand-making the thread.
22. Throwing – The process of taking raw silk threads and twisting them together to form skeins of silk yarn that will eventually be used for weaving. Different throwing techniques are used to produce warp and weft threads.
23. Tussah – Silk produced by wild silkworms; for example, *Antheraea mylitta*. Its silk filament is about three times heavier than that of the cultivated silkworm, *Bombyx mori*, and is a coarser fibre.
24. Weaving – The process of using a loom to interlace weft and warp threads to produce lengths of finished fabric.
25. Weighted silk – Silk that is coloured with dye and to which metallic substances have been added during the dying process. This adds back weight which is lost during de-gumming and also adds body to the fabric. If weighting is not done properly, it reduces the life of the fabric. Pure-dye silk is considered superior.

26. Wild Silk – Silk made by wild silkworms; for example, *Antheraea mylitta* and *Antheraea pernyi*. Also called tussah.
27. Yarn – Silk thread that is ready to use for weaving.

Types of silkworm, voltinism and biology of silkworm:

Sericulture:

The practice of rearing silkworms for production of silk is called **Sericulture**. Silk producing insects are commonly referred to as serigenous insects. Silkworm is a common name for the silk-producing larvae of silk moths. Silk is the secretion from the salivary glands which are found on both sides of the alimentary canal of silkworm larvae and this secretion harden into fine threads called silk. The cocoons with which pupae are covered by the worms are utilized for silk production.

Types of silkworms:

There are four kinds of natural silk, which are commercially known and produced. Among them, mulberry silk is the most important and contributes as much as 95% of world production. The other non-mulberry silks are eri silk, tasar silk and muga silk.

Characters	Mulberry silkworm	Eri silkworm	Tassar silkworm	Muga silkworm
Species	*Bombyx mori*	*Philosamia ricini* *P. cynthia*	*Antheraea pernyi* *A. mylilta* *A. yamamai*	*A. assama*
Family	Bombycidae	Saturniidae	Saturniidae	Saturniidae
Host plants	Mulberry	Castor	Terminalia, Dalbergia, Shorea, Zizyphus, Ficus, *etc*.	Som *Machilus bombycina*; Soalu, *Litsaea polyantha*
Cocoon	Silvery white in colour. Continuous and uniform type with high silk production.	White or brick red in colour. Neither uniform not continuous type with moderate silk production.	Brown in colour. Continuous and uniform type with high silk production.	Lustrous golden yellow in colour. Continuous and uniform type with less silk production.
Domestication feasibility in India	Easy and economical	Rare	The moths do not mate and so cannot be domesticated	Rare and confined to Assam

A. Mulberry silkworm: The maximum quantity of silk about 95% produced in the world is the mulberry silk.

Classification of mulberry silkworm is based on:

1. Geographical distribution:

- **Japanese:** Uni- or bivoltine, produces green, yellow or white coloured cocoon, larval phase is prolonged, silk is thick, short length and are better adapted in unfavourable conditions. They usually produce double cocoons.
- **Chinese:** Uni-, bi- or multivoltine; larval growth rate high, feeding rate is high, cocoon is oval, white or golden, yields much longer fine silk with less diameter.
- **European:** Univoltine, eggs are larger, cocoon is long, or oval, white or yellow coloured, yield much longer silk. Larvae are with higher feeding rate, larval phase is prolonged, can't endure higher temperature and humidity.
- **Indian:** Multivoltine takes less time to complete life cycle; cocoon is small, elliptical, yellow or green coloured and yields silk of considerable length.

2. Number of generation per year (Voltinism):

- **Univoltine:** It refers to organisms having one brood or crop or generation per year. Their larvae are of robust size and consume much more food. These produce larger sized cocoons having 200–300 mg shell weight. Such cocoon yields 800 – 1200 m silk. They show diapause.
- **Bivoltine:** It refers to organisms having two broods or crop or generations per year. Their larvae are comparatively of moderate size. Shell weight of the cocoon is 150 – 200 mg. They yield 600 – 800 m silk.
- **Multi or Polyvoltine:** It refers to organisms having more than two broods or crop or generations per year. Their larvae are comparatively of small size. Shell weight of the cocoon is 100 – 150 mg. They yield 300 – 400 m silk.

3. Number of moults:

- **Trimoulter:** Their larvae moult three times in their larval period. The weight of cocoon, shell ratio, the length of silk obtained from their cocoon is much less.
- **Tetramoulter:** Their larvae moult four times in their larval period. The weight of cocoon, shell ratio, the length of silk obtained from their cocoon is comparatively better.
- **Pentamoulter:** Their larvae moult five times in their larval period. The weight of cocoon, shell ratio, the length of silk obtained from their cocoon is of higher quality.

4. **Genetic nature:** Pure strain, hybrid strain, mono hybrid and poly hybrid.

Morphology and biology of mulberry silkworm: Silkworm passes through a complete metamorphosis from egg to adults' stage.

1. Egg:

- Eggs are laid in clusters on the under surface of mulberry leaves during night time.
- A female lays about 300-400 eggs popularly called as silk-seeds measuring about 1 to 1.3 mm in length and 0.9 to 1.2 mm in breadth.
- The eggs are small, ovoid, flat, ellipsoid or oval pale, white or yellow and seed like in appearance.
- At the time of hatching, it become black and hatch within 10-12 days during summer and 30 days during winter. In the univoltine race, the eggs do not hatch during winter and undergoes into hibernation.
- One generation is completed in univoltine race/year whereas 2-7 generations completed in multivoltine race/year.

2. Larva:

- The newly hatched larva is white to dark in colour and measures about 3 mm in length.
- There are 3 pairs of thoracic and 5 pairs of abdominal legs which are situated on the 3,4,5,6 and 10^{th} abdominal segments.
- On the dorsal side of the eighth abdominal segment, the larva carries the caudal horn.
- The larva moults 4-5 times and becomes mature in 30-35 days.
- The full grown larva is creamy white in colour and measures about 75 mm in length.
- In the female, a pair of milky white spots is appearing on each of the eighth and ninth segments.
- In male, a small milky white body appears at the centre of the ventral side between the eighth and ninth segments.
- Cocoons formation takes place within 25 hours.

3. Pupa:

- The cocoon measures about 38 mm in length and 19 mm in breadth. Oval in shape and white or yellowish in colour.
- The larva pupates inside the cocoon which is made up of a single thread.
- The pupa inside the cocoon is reddish-brown in colour and measures about 25 mm x 7 mm.
- The pupal period lasts for 10-15 days.
- At the time of emergence of adult, it secretes an alkaline fluid which pierces the cocoon and adult comes out.

4. Adult:

- The moth of silkworm is a creamy white colour measuring about 30 mm in length and a wingspan of about 40-50 mm.
- The female is bigger and less active than male.
- The head is small and bears a pair of black compound eyes and bipectinate antennae.
- The mouth parts are vestigial; therefore the moth does not take food and lives only for about 2 to 3 days.
- The anterior portion of thorax is narrower than the posterior.
- The fore wings are provided with dirty dark coloured stripes and the body is covered with hairs.

B. Morphology and biology of eri silkworm:

The eri silkworm is multivoltine and reared indoors about 5-6 times in a year. The required optimum weather conditions are 24-28^{0}C temperature and 85-90% humidity.

1. Eggs:

- The colour of eggs turns dark when they are about to hatch.
- The little black spot can be seen on egg as it is the heads of the emerging silkworms.
- The incubation period is about 9.0 to 10.0 days in summer and 10 to 15 days in winter season.

2. Larvae:

- Larvae are covered with tiny hairs.
- Larvae are very imposing and looking with all those spiky knobs but they are quite soft.
- Total larval period lasts for about 20-25 days.

3. Pupa:

- The cocoons are whitish in colour.
- It is loose type of cocoon.

- Pupa is brown in colour.
- The pupal duration is about 15 to 18 days during summer and 35 to 40 days during winter.

4. Adult:

- Adult moths are large with wings spanning about 10 cm.
- The wings are greyish brown in colour.
- Adult moths emerge during morning hours to mid day; males emerge earlier than the females. After an hour of emergence, mating occurs and continues till evening.
- Males are then separated.
- Both male and female have brown (chocolate), black or green coloured wings with white semi-circular markings and woolly white abdomen.
- The male is smaller than female and bear bushy antennae and narrow abdomen.
- About 400 to 500 eggs are laid by each gravid female during her lifespan.
- Eri silkworm completed its life cycle in 6 weeks during summer and 12 weeks during winter season.

CULTIVATION OF SILKWORM FOOD PLANTS

Components of sericulture:

Sericulture is an agro based industry comprising three main components, *viz*. cultivation of food plants of the silkworms, rearing of silkworms, and reeling and spinning of silk. The first two are agricultural and the last one is an industrial component.

I. Mulberry cultivation:

Moriculture: The cultivation of mulberry plants for silkworm rearing is called Moriculture as the plant belongs to the family Moraceae. Among 20 species of mulberry, the most common are *Morus alba*, *M. indica*, *M. serrata* and *M. latifolia*, while the local *M. indica* offers certain good features like quick growing, hardiness, flush remains throughout the year but with comparative low yield.

Soil and climate:

The soil should be deep fertile, well drained clayey loam. Saline and alkaline soils are not preferred. Mulberry can be grown up to 800 metre MSL, Mulberry can be grown in a rainfall ranged from 600mm to 2500mm.

Plantation season:

Mulberry cuttings can be planted in the month of September-October under irrigated condition. While in rainfed condition, saplings can be planted in the month of April-May.

Mulberry varieties:

Irrigated: S-30, S-36, S-41, S-54, S-1635, JL-1, C-776, TR-10, VR-9 and Kanva-2, etc

Semi-Irrigated: Kanva-2 and MR-2, etc

Rainfed: S-13, S-34, RFS-135, RFS-175 and S-1635, etc

Selection of planning material:

The mulberry plants are raised from semi-hard wood cuttings. The cuttings are selected from well established garden of 8 - 12 months old. The length of cuttings should be 15 - 20 cm with 3 - 4 active buds.

Nursery:

Select red loamy soil of 800 sq. m. for raising sapling for planting one hectare of main field. Apply FYM @ 20 t/ha as a basal dose in the nursery area. Size of raise nursery beds should be of 3 m x 1.7 m size.

Pre-treatment of cuttings and planting:

Cuttings are treated with biofertilizer, *Azospirillium* @ 1 kg/40 litres of water for 30 minutes before planting for inducement of early rooting. Apply VAM @ 100 g/m^2 of nursery area. Irrigate the nursery bed. Plant the cuttings in the nursery at 15cm x 7cm spacing at an angle of 45^0. Ensure exposure of one active bud in each cutting. Irrigate the nursery once in three days. The saplings are ready for transplanting in the main field after 90-120 days of planting.

Planting method and spacing:

Planting method	Irrigated		Rainfed	
	Spacing (cm)	No. of cuttings/ha.	Spacing (cm)	No. of cuttings/ha.
Ridges and furrows	60 x 60	27780	90 x 90	12350
Pit systems (45 x 45 cm pit)	90 x 90	12350	90 x 90	12350

Manure and fertilizers for main field:

Apply FYM @ 20 t/ha for the irrigated crop and 10 t/ha for rainfed crop during last ploughing. Apply organic manure (FYM) or compost 1.25 kg/pit in case of pit system is adopted.

1. Irrigated / Semi irrigated:

Particular	Row system (Kg/ha)			Pit System (Kg/ha)		
	N	P	K	N	P	K
Recommendation	300	120	120	280	120	120
Split doses						
First dose	60	60	60	60	60	60
Second dose	60	-	-	40	-	-
Third dose	60	60	60	40	-	-
Fourth dose	60	-	-	60	60	60
Fifth dose	60	-	-	40	-	-
Sixth dose	-	-	-	40	-	-

2. Rainfed:

Particular	N (Kg/ha)	P (Kg/ha)	K (Kg/ha)
Recommendation	100	50	50
First dose	50	50	50
Second dose	50	-	-

Bio-fertilizers:

Apply *Azospirillium* @ 20 kg/ha in five split doses along with phosphobacterium @ 10 kg/ha in two equal splits. Mix the bio-fertilizers with 50 kg FYM for uniform distribution. Apply the bio-fertilizers once in six months. Ensure irrigation after application. Do not mix bio-fertilizers with inorganic fertilizers.

Irrigation:

1. Ridge and furrows method:

It is most efficient method of irrigation. Comparatively less amount of water is required. These furrows can be used as drainage channel during rainy season.

2. Flatbed method:

Rectangular beds can be prepared. Water runoff is relatively less. This is labour intensive method. Better crop growth can be maintained in this method.

Weed management: Operate country plough after pruning in the interspaces. Use Grammoxone @ 2-3 lit/ha as post-emergence weedicide. Apply the weedicide immediately after pruning or within 2-3 days after pruning. Remove the weeds by hand hoe.

Pruning of mulberry plants:

Pruning is the process of removing the branches of mulberry plant with the objective to give a convenient shape and size to increase the leaf yield and to improve its feeding value. Pruning of mulberry plant is also useful in adjusting the production period to synchronize with the leaf requirement for silkworm rearing and also to extend the leaf production period throughout the year.

1. Bottom pruning: Plants are cut at ground level leaving 10-15 cm stump above the ground once in a year.

2. Middle pruning: Branches are cut at 40- 60 cm above the ground level. After bottom prunings, subsequent cuts are made at 45-50 cm height.

3. Kolar or Strip system: Branches are cut at ground level every time in closely planted area. Thus, it receives five pruning every year. This type of severe pruning requires heavy fertilization and irrigation.

Harvesting of mulberry leaves:

There are three methods of harvesting mulberry leaves *viz*., (1) Leaf picking (2) Branch cutting and (3) whole shoot harvest.

1. Leaf picking: Picking starts at 10 weeks after bottom pruning and subsequent pickings are done at an interval of 7-8 weeks with harvesting of individual leaves with or without petiole.

2. Branch cutting: Entire branches are cut and fed to the worms. Before that, toping is done to ensure uniform maturity of the lower leaves.

3. Whole shoot harvest: Branches are cut at ground level by bottom pruning. Shoots are harvested at an interval of 10-12 weeks and thus five harvests can be made in a year.

Time of harvest: It is preferable to harvest the leaves during morning hours.

Preservation of leaves: Use wet gunny bags to store the leaves or cover the bamboo basket with wet gunny bags to keep it cool and fresh.

Mulberry leaves yield:

The yield of irrigated varieties are about 40 tonnes leaves/ha/year while rainfed varieties can yield about 15 to 20 tonnes leaves/ha/year with proper cultivation practices.

Major insect pests and diseases of mulberry crop:

1. Major insect pests of mulberry crop:

Sr. No.	Common Name	Scientific Name	Order	Family	Damaging Stage
1.	Pink mealy bug	*Maconellicoccus hirstus*	Hemiptera	Pseudococcidae	Nymphs and adults
2.	Jassid/ leaf hopper	*Empoasca flavescens*	Hemiptera	Cicadellidae	Nymphs and adults
3.	Black Scale	*Saissetia nigra*	Hemiptera	Coccidae	Nymphs and adults
4.	Red Scale	*Aondiella auranti*	Hemiptera	Diaspididae	Nymphs and adults
5.	Spirallling whitefly	*Aleurodicus*	Hemiptera	Aleyrodidae	Nymphs

Sr. No.	Common Name	Scientific Name	Order	Family	Damaging Stage
		disperses			and adults
6.	Thrips	*Pseudodendrothrips mori*	Thysanoptera	Thripidae	Nymphs and adults
7.	Tobacco leaf caterpillar	*Spodoptera litura*	Lepidoptera	Noctuidae	Larvae
8.	Moringa hairy caterpillar	*Eupterote mollifera*	Lepidoptera	Eupterotidae	Larvae
9.	Tussock caterpillar	*Euproctis fraterna*	Lepidoptera	Erebidae	Larvae
10.	Brown hairy caterpillar/Tussock moth	*Porthesia scintillans*	Lepidoptera	Lymantriidae	Larvae
11.	Leaf webber	*Glyhodes pulverulentalis*	Lepidoptera	Pyralidae	Larvae
12.	Ash weevil	*Myllocerus sp.*	Coleptera	Curculionidae	Grubs
13.	Grasshopper	*Neorthacris acuticeps nilgriensis, Cytocanthacris panacea*	Orthoptera	Acirididae	Nymphs and adults
14.	Stem girdler beetle	*Sthenias grisator* L.	Coleoptera	Cerambycidae	Grubs and adults
15.	Termite/White ant	*Odonototermes sp*.	Isoptera	Termitidae	Workers
16.	White grub	*Holotrichia spp*.	Coleoptera	Melolonthidae	Grubs
17.	Mango stem borer	*Batocera rufomaculata*	Coleoptera	Cerambycidae	Grubs
18.	Bark eating caterpillar	*Indarbela quadrinotata*	Lepidoptera	Metarbelidae	Larvae

2. Major diseases of mulberry crop:

Sr. No.	Common Name	Causal organism
1.	Leaf spot	*Cercospora moricola*
2.	Powdery mildew	*Phyllactinia corylea*
3.	Leaf rust	*Cerotelium fici*
4.	Root rot	*Macrophomina phaseolina, Fusarium solani, F. oxysporum*
5.	Violet root rot	*Rhizoctonia bataticola*
6.	Stem canker	*Lasidiplodia* (*Btryodiplodia*) *theobromae*
7.	Bacterial blight	*Pseudomonas mori*
8.	Root knot nematode	*Meloidogyne incognita*

II. Castor cultivation (*Ricinus communis* L.):

The silk produced by *Philosamia ricini* is called Eri silk. Eri silkworm is a polyphagous insect feeds primarily on castor leaves. However, Kesseru (*Heteropanax fragrans* Seem) is used as an alternative food plant during the scarcity of castor leaves. Besides these, some other alternative plants *viz*., Tapioca or Cassava (*Manihot esculenta*), Papaya (*Carica papaya*), Payam (*Evodia flaxinifola*) and Plum, *Plumeria acutifolia* can be used as food plants. Among all, castor is well known and suitable food plant of worm for the successful growth and development.

Soil and climate:

Highly susceptible to water logged conditions. Red loam soils or light alluvial soils are suitable. It cannot tolerate alkalinity of soil but withstand slight to moderate acidity of soil. Moderately high temperature (20 to 27^0C) with low humidity, 80-100 mm rainfall, clear warm sunny days are found suitable for better growth of the crop.

Varieties:

Non-bloom varieties are found suitable for growth and yield of eri silkworm *viz*., NBR-1. High leaf yielding varieties like GCH-3, GCH-4, GCH-6 and GCH-7 can be raised.

Field preparation:

Castor being a deep-rooted crop requires deep summer ploughing. Disc harrowing should be done followed by ploughing to break clods, level the seedbed and destroy weeds.

Sowing time:

Irrigated crop - 1st July to 15th August. Rainfed crop - 15th June.

Seed rate:

Irrigated crop - 5 to 6 kg/ha - by dibbling method. Rainfed crop - 10 to 12 kg/ha.

Seed treatment:

Seeds should be treated with Carbendazim @ 1g or Thiram @ 3 g /kg of seeds for controlling seed and soil borne diseases.

Spacing:

Irrigated crop - 90 cm x 60 cm, Fertile soil - 120 x 60 cm. Rainfed crop - 90 cm x 20 cm. The seeds may be sown at 8 cm depth behind the plough or maize planter.

Manures and fertilizers: FYM or compost @ 25 cart loads/ha

Rainfed crop:			
Stage of application	**N kg/ha**	**P_2O_5 kg/ha**	**K_2O kg/ha**
As basal application	20	40	0
At flowering stage i.e. 45 DAS	20	0	0
Total	**40**	**40**	**0**
Irrigated crop:			
As basal application	37.5	50	0
At flowering stage i.e. 45 DAS	37.5	0	0
Total	**75**	**50**	**0**

Bio- fertilizer: Seed treatment with Azospirillum or Phosphorus Solublizing Bacteria @ 50 gm /kg seed.

Sulphur application: Apply **s**ulphur @ 20kg /ha through gypsum to oil seeds crop only.

Irrigations:

Irrigated crop: 3-4 irrigations at an interval of 15 to 20 days.

Weeding and interculturing: Two hands weeding, one at 30 days of crop growth and the other after 60 days of crop growth should be given. Incorporation of Pendimethalin 0.9 kg a.i./ha immediate after sowing but before sprouting in the soil.

Crop rotation and inter cropping:

Crop rotation: Castor – Wheat/ Mustard/ Onion, Castor – Pearl millet - Groundnut/ Cluster bean

Crop sequences: Castor – Groundnut, Castor – Sorghum, Castor – Vegetables, Castor – Pearl millet.

Intercropping: Castor + Sun flower (1: 2), Castor + Soybean (1: 1), Castor + Cluster bean (2:1), Pearl millet – Groundnut bunch (1: 3)

Nipping of axillary buds: If all axillary buds on the main shoot are nipped soon after emergence of the primary spike and thus a single main spike is allowed to develop, not only the duration of the crop is reduced but also yields are increased substantially. This practice is followed for local varieties only.

Capsules harvesting: It takes 145-180 days to mature. Harvesting is done when capsules turn yellowish for capsule yield.

Castor leaves yield:

Pluck tender leaves for young age worms and semi-mature/matured leaves for 4^{th} and 5^{th} stage worm. The optimum quality castor yield is about 12-14 tonnes leaves/ha/year.

Major insect pests and diseases of castor crop:

1. Insect pests of castor crop:

Sr. No.	Common Name	Scientific Name	Order	Family	Damaging Stage
1.	Capsule and Shoot borer	*Conogethes punctiferalis*	Lepidoptera	Pyraustidae	Larvae
2.	Castor semi-looper	*Achaea janata*	Lepidoptera	Noctuidae	Larvae
3.	Slug caterpillar	*Parasa lepida*	Lepidoptera	Cochilididae	Larvae
4.	Hairy caterpillar	*Euproctis fraterna*	Lepidoptera	Lymantriidae	Larvae
5.	Hairy caterpillar	*Portrhesia scintillans*	Lepidoptera	Lymantriidae	Larvae
6.	Tussock caterpillar	*Notolophus posticus*	Lepidoptera	Lymantriidae	Larvae
7.	Hairy caterpillar	*Dasychira mendosa*	Lepidoptera	Lymantriidae	Larvae
8.	Castor butterfly / spiny caterpillar	*Ergolis merione*	Lepidoptera	Nymphalidae	Larvae
9.	Leaf hopper	*Empoasca flavescens*	Hemiptera	Cicadellidae	Nymphs and adults
10.	Whitefly	*Trialeurodes ricini*	Hemiptera	Aleyrodidae	Nymphs and adults
11.	Thrips	*Retithrips syriacus*	Thysanoptera	Thripidae	Nymphs and adults
12.	Castor gall fly	*Asphondylia ricini*	Diptera	Cecidomyidae	Maggots

2. Diseases of castor crop:

Sr. No.	Common Name	Causal organism
1.	Seedling blight	*Phytophthora parasitica*
2.	Rust	*Melampsora ricini*
3.	Leaf blight	*Alternaria ricini*
4.	Brown leaf spot	*Cercospora ricinella*

5.	Powdery mildew	*Leveillula taurica*
6.	Stem rot	*Macrophomina phaseolina*
7.	Bacterial leaf spot	*Xanthomonas campestris pv. ricinicola*
8.	Wilt	*Fusarium oxysporum*

Rearing techniques of silkworm

I. Equipments used in Sericulture Unit:

1. Rearing house:

The rearing house should meet certain specification, as the silk worms are very sensitive to weather conditions like humidity and temperature. The rearing room should have proper ventilation, optimum temperature and proper humidity. It should be ensured that dampness, stagnation of air, exposure to bright sunlight and strong wind should be avoided.

General specification of rearing house:

- Rearing house should be built depending on the brushing capacity and the method of rearing. The rearing area of 2 sq. feet per DFL (Disease Free Laying, about 400-450 eggs are present in one DFL) for floor rearing and 3 sq. ft per DFL for shoot rearing is the general criteria. About 480 sq. feet area is required for rearing 100 DFL.
- The rearing house should have sufficient number of windows to permit cross ventilation.
- It should be well high (9 – 10 feet) from the ground.
- It should be surrounded by open verandah (7 feet wide).
- Doors and windows should be made up of glass. Its roof should be made up of straws and wood.
- The number of ventilators should be of considerable number.
- The house should be divided into five rooms; the first room - chawki room (10 feet × 14 feet) should contain 1^{st}, 2^{nd} and 3^{rd} instar larvae, the next room (12 feet × 16 feet) should contain 4^{th} and 5^{th} instar larvae, the 3^{rd} room can be used as laboratory and the 4^{th} room should be used for leaf preservation. Before entering the first room there must be an anteroom (8 feet × 8 feet).
- Temperature and humidity of the house must remain under control.
- Rearing house has to be built in such a way to provide optimum temperature of 26-28^0C and RH of 60-70% for the growth of silkworm at minimum operational cost. In tropical climate the house should face east-west while in temperate climate it should face north-south direction.
- Doors and windows must be protected by fine net to check pest infestation.
- Provision should be made to make it airtight for proper disinfection.
- Rearing house must avoid damp condition, stagnation of air, direct and strong drift of air, exposure to bright sunlight and radiation.
- Growing trees around rearing house will help to maintain favourable environment.
- Rearing house should have facilities for disinfection, washable floor, etc.

2. Rearing stand:

Rearing stands are made up of wood or bamboo and are portable. These are the frames at which rearing trays are kept. A rearing stand should be 2.5 m high, 1.5 m long and 1.0 m wide and should have 10 shelves with a space of 20 cm between the shelves. The

	trays are arranged on the shelves, and each stand can accommodate 10 rearing trays.
3.	**Ant well:** Ant wells are provided to stop ants from crawling on to trays, as ants are serious menace to silk worms. They are made of concrete or stone blocks 20 cm square and 7.5 cm high with a deep groove of 2.5 cm running all round the top. The legs of the rearing stands rest on the centre of well filled with water.
4.	**Rearing tray:** These are made of bamboo or wood so that they are light and easy to handle. These are either round or rectangular.
5.	**Paraffin paper:** This is a thick craft paper coated with paraffin wax with a melting point of 55^0 C. It is used for rearing early stages of silk worms and prevents withering of the chopped leaves and also helps to maintain proper humidity in the rearing bed.
6.	**Foam rubber strips:** Long foam rubber strips 2.5 cm wide and 2.5 cm thick dipped in water are kept around the silkworm rearing bed during first two instar stages to maintain optimum humidity. Newspaper strips may also be used as a substitute.
7.	**Chopsticks:** These are tapering bamboo rods (1cm in diameter) and meant for picking younger stages of larvae to ensure the hygienic handling.
8.	**Feathers:** Bird feathers preferably white and large are important items of silkworm rearing room. These are used for brushing newly hatched worms to prevent injuries.
9.	**Chopping board and Knife:** The chopping board is made up of soft wood it is used as a base for cutting leaves with knife to the suitable size required for feeding the worms in different instar stages.
10.	**Leaf chambers:** These are used for storing harvested leaves. The sidewalls and bottom are made of wooden strips. The chamber is covered on all sides with a wet gunny cloth.
11.	**Cleaning net:** These are cotton or nylon nets of different mesh size to suit the size variations of different instars of the silk worm. These are used for cleaning the rearing beds, and at least two nets are required for each rearing tray.
12.	**Mountages:** These are used to support silkworm for spinning cocoons. These are made up of bamboo, usually 1.8 m long and 1.2 m wide. Over a mat base, tapes (woven out of bamboo and 5-6 cm wide) are fixed in the form of spirals leaving a gap of 5-6 cm. In hindi they are also called ***chandrikes***. Other types of mountage such as **centipede rope mountage**, **straw cocooning frames** etc. are also used.
13.	**Feeding stands:** These are small wooden stands (0.9 m height) used for holding the trays during feeding and bed cleaning.
14.	**Hygrometers and Thermometers:** These are used to record humidity and temperature of the rearing room.

15.	**Feeding basins, sprayer, and leaf baskets may also be required.**

II. Rearing techniques of various silkworms:

A. Rearing of mulberry silkworm:

Silkworms must be reared with utmost care since they are susceptible to diseases. Therefore, to prevent diseases, good sanitation methods and hygienic rearing techniques must be followed. The appliances and the rearing room should be thoroughly cleaned and disinfected with 2-4% formaldehyde solution. Room temperature should be maintained around 25^0 C.

Growth and feeding rates of different larval instars of *B. mori*.

Instar	Weight increase (mg)	Duration (Days)	Leaf consumed (gm)
I	1 time (0.45 mg)	3-4	17
II	13 times	2-3	80
III	17 times	3-4	320
IV	70 times	5-6	2200
V	10000 times	7-8	20000

Procurement of quality seeds:

The most important step in silkworm rearing is the procurement of quality seeds free from diseases. Seeds are obtained from grainages, which are the centres for production of Disease Free Layings (DFL) or seeds of pure and hybrid races in large quantities. These centres purchase cocoons from the certified seed cocoon producers. These cocoons are placed in well-ventilated rooms with proper temperature (23-25^0 C) and humidity (70-80 %), and emergence of moth is allowed. Grainage rooms may be kept dark, and light may be supplied suddenly on the expected day of emergence to bring uniform emergence. Emerging moths are sexed and used for breeding purposes to produce seed eggs. Three hours of mating secures maximum fertilized eggs. The females lay eggs on paper sheets or cardboard coated with a gummy substance. Egg sheets are disinfected with 2% formalin, and then washed with water to remove traces of formalin and then dried up in shades. The eggs are transported in the form of egg sheet. However, it is easy to transport loose eggs. To loosen the eggs, the sheets are soaked in water. The loose eggs are washed in salt solution of 1.06-1.10 specific gravity to separate out unfertilized eggs and dead eggs floating on surface. Prior to the final washing, the eggs are disinfected with 2% formalin solution. Eggs are dried, weighed to the required standard and packed in small flat boxes with muslin covers and dispatched to buyers.

Quality food:

Younger larvae (I and II stage) instars are to be given tender succulents leaves with high moisture content and whereas older instars fed with mature but soft leaves with lesser moisture content.

Brushing:

The process of transferring the silkworm to rearing trays is called brushing. Suitable time for brushing is about 10.00 am. Eggs at the blue egg stage are kept in black boxes on the days prior to hatching. The next day they are exposed to diffused light so that the larvae hatch uniformly in response to photic stimuli. About 90% hatching can be obtained in one day by this method. In case of eggs prepared on egg cards, the cards with the newly hatched worms are placed in the rearing trays or boxes and tender mulberry leaves are chopped into pieces and sprinkled over egg cards. In case of loose eggs a net with small holes is spread over the box containing the hatched larvae and mulberry leaves cut into small pieces are scattered over the net. Worms start crawling over the leaves on the net; the net with worms is transferred to rearing tray.

Preparation of feed bed and feeding:

After brushing, the bed is prepared by collecting the worms and the mulberry leaves together by using a feather. The bed is spread uniformly using chopsticks. The first feeding is given after two hours of brushing. Feed bed is a layer of chopped leaves spread on a tray or over a large area. The first and second instar larvae (Up to 2^{nd} moult) are commonly known as **chawki worms**. For chawki worms, paraffin paper sheet is spread on the rearing tray. Chopped mulberry leaves are sprinkled on the sheet and hatched larvae are brushed on to the leaves. A second paraffin paper sheet is spread over the first bed. In between two sheets water soaked foam rubber strips are placed to maintain humidity.

The 4^{th} and 5^{th} instars are reared in wooden or bamboo trays by any of the three methods: *viz*., **shelf-rearing, floor-rearing and shoot-rearing**. In **shelf rearing**, the rearing trays are arranged one above the other in tiers on a rearing stand which can accommodate 10 -11 trays. This method provides enough space for rearing, but it is uneconomical as it requires large number of labours to handle the trays. Chopped leaves are given as feed in this method. In **floor rearing**, fixed rearing sheets of 5-7x1-1.5m size are constructed out of wooden or bamboo strips in two tiers one meter apart. These sheets are used for rearing. Chopped leaves are given as feed. This method is economical than the first one because it does not involve much labour in handling of trays. **Shoot-rearing** is most economical of the three methods. The rearing sheet used is one meter wide and any length long in single tier and the larvae are offered fresh shoot or twigs bearing leaves. This method can be practiced both outdoors and indoors depending upon the weather.

Each age of the silk worms could be conveniently divided into seven stages:

1. Feeding stage, 2. Sparse eating stage, 3. Moderate eating stage, 4. Active eating stage, 5. Premoulting stage, 6. Last feeding stage and 7. Moulting stage. The larvae have good appetite at first feeding stage and comparatively little appetite at sparse and moderate eating stages. They eat voraciously during active stage to last feeding stage after which they stop feeding.

Bed cleaning:

Periodical removal of left over leaves and worms' excreta may be undertaken and is referred to as bed cleaning. It is necessary for proper growth and proper hygiene. Four methods are adopted: conventional method, husk method, net method, and combined husk and net method.

Moulting:

Remove the paraffin paper. Larvae should be evenly spread in the rearing bed 6-8 hrs before settling the moulting. Provide proper ventilation to avoid excess humidity in rearing room. Provide charcoal stove/heater to raise the room temperature during winter season. Apply lime powder 60 minutes before resumption of feeding daily during rainy and winter season to avoid Muscardine disease infection.

Spacing:

Provision of adequate space is of great importance for vigorous growth of silkworms. As the worms grow in size, the density in the rearing bed increases and conditions of overcrowding are faced. Normally it is necessary to double or triple the space by the time of moult from one to other instar stage, with the result that from the first to third instar, the rearing space increases eight fold. In 4^{th} instar, it is necessary to increase the space by two to three times and in 5^{th} instar again twice. Thus, the rearing space increases up to hundred folds from the time of brushing till the time of maturation of worms.

Mounting:

Transferring mature fifth instar larvae to mountages is called mounting. When larvae are fully mature, they become translucent, their body shrinks, and they stop feeding and start searching for suitable place to attach themselves for cocoon spinning and pupation. They are picked up and put on mountages. The worms attach themselves to the spirals of the mountages and start spinning the cocoon. By continuous movement of head, silk fluid is released in minute quantity which hardens to form a long continuous filament. The silkworm at first lays the foundation for the cocoon structure by weaving a preliminary web providing the necessary foot hold for the larva to spin the compact shell of cocoon. Owing to characteristic movements of the head, the silk filament is deposited in a series of short waves forming the figure of eight. This way layers are built and added to form the compact cocoon shell. After the compact shell of the cocoon is formed, the shrinking larva wraps itself and detaches from the shell and becomes pupa or chrysalis. The spinning completes within 2-3 days in multi-voltine varieties and 3-4 days in uni- and bi-voltine.

Harvesting of cocoons:

The larva undergoes metamorphosis inside the cocoon and becomes pupa. In early days, pupal skin is tender and ruptures easily. Thus, early harvest may result in injury of pupa, and this may damage the silk thread. Late harvest has a risk of threads being broken by the emerging moth. It is, therefore, crucial to harvest cocoons at proper time. Cocoons are harvested by hand. After harvesting the cocoons are sorted out. The good cocoons are cleaned by removing silk wool and faecal matter and are then marketed.

The cocoons are sold by farmers to **filature units** (a place where silk is obtained from silkworm cocoons) through Cooperative or State Govt. Agencies. The cocoons are priced on the basis Rendita and reeling parameters. **Rendita** is defined as number of kg of cocoon required for the production of 1 kg of raw silk.

Post cocoon processing:

It includes all processes to obtain silk thread from cocoon.

Stifling:

The process of killing pupa inside cocoon is termed as stifling. Good-sized cocoon 8-10 days old are selected for further processing. Stifling is done by subjecting cocoon to hot water, steam, dry heat, sun exposure or fumigation.

Reeling:

The process of removing the threads from killed cocoon is called reeling. The cocoons are cooked first in hot water at 95-97^{0}C for 10-15 minutes to soften the adhesion of silk threads among themselves, loosening of the threads to separate freely, and to facilitate the unbinding of silk threads. This process is called **cooking**. Cooking enables the **sericin protein** to get softened and make unwinding easy without breaks. The cocoons are then reeled in hot water with the help of a reeling machine. Four or five free ends of the threads of cocoon are passed through eyelets and guides to twist into one thread and wound round a large wheel. The twisting is done with the help of **croissure**. The silk is transferred finally to spools, and silk obtained on the spool is called the **Raw Silk** or **Reeled Silk**. The Raw silk is further boiled, stretched and purified by acid or by fermentation and is carefully washed again and again to bring the luster. Raw Silk or Reeled Silk is finished in the form of skein and book for trading. The waste outer layer or damaged cocoons and threads are separated, teased and then the filaments are spun. This is called **Spun silk**. **Denier** is a unit of measurement that is used to determine the fiber thickness of individual threads or filaments. Denier expresses weight in grams of 9000 meter length of the material.

B. Rearing of eri silkworm:

Disease free seed cocoons are obtained from **Grainages** or Agencies and reared fully indoors. Healthy cocoons are spread on bamboo trays in cool dark room. On hatching, active males are separated from passive females and are then allowed to mate in quiet dark room. Fertilized females are then tied to '***kharikas***' (Egg laying device) by passing a thread around the shoulder joint of the right wings. *Kharikas* are then suspended from a string. Eggs are laid within 25 hours on *Kharika* are normally selected for rearing. The eggs are white, oval and covered with a gummy substance, which makes them adhere to one another. The eggs are disinfected with 2% formalin solution and then washed thoroughly with water. Eggs are incubated at 26^0 C, the colour changes to blue on the day prior to hatching. Hatching takes place in the morning after ten days of incubation. The newly hatched larvae are yellow with black segments. These larvae are brushed to rearing trays over which few tender leaves are spread and crowding is avoided. As the worms are advance in age, older leaves can be given as food at four hours interval for four to five times.

Rearing house for Eri culture:

Eri silkworms are reared indoor. The plinth area 10 m x 5 m size rearing house having tin or thatch roofing with 1.5 m *varandah*/passage all around is ideal for accommodating 100 dfls for commercial silkworm rearing per crop. Rearing house should be well ventilated and fly proof.

Disinfection and prophylactic measures:

Disinfection made before and after each rearing is considered as the key for a successful cocoon harvest. Disinfect the rearing house at least 7 days before and soon after the rearing. Disinfection should be carried out on bright sunny days. Wash the rearing houses and appliances with 5 % bleaching powder solution before rearing. Sprinkling of 2 % bleaching powder-lime mixture in the surroundings of the rearing house is equally effective. Fumigate with 5% formaldehyde solution under high humid condition. Open the room after 24 hours. Thereafter, windows and ventilators should be kept open for proper aeration and free circulation of air.

Season:

Rearing can be done throughout the year. However, March-April and September-October are the best seasons for rearing of silkworm.

Egg incubation:

Incubate the DFLs at 24-26°C temperature and 75-85% relative humidity.

Brushing:

Hands should be washed with 2% formalin solution and then with water. Brush newly hatched worms on tender leaves during morning hours. Use paraffin paper and water soaked foam pad in rearing tray to maintain temperature and humidity.

Feeding:

Feed 1^{st} instar worms on tender, 3^{rd} and 4^{th} instar on semi-matured and 5^{th} instar on matured leaves. Feed the worms with minimum 4 times a day.

Bed cleaning:

This work is carried out at regular interval in the same way as adopted for the mulberry silkworm. The growing worms undergo four moults and have five instar stages. Resort to bed cleaning daily. **Nylon net** can be used for easy bed cleaning. The 5^{th} instar mature larvae stop feeding and start searching for a proper place to spin the cocoon. At this stage, the mature worms are picked up and transferred to **mountages (*Chandrikes*)**. In wild race, cocoons are spun between folds of leaves. The spinning is completed within 2-3 days. The cocoons are open mouthed, white or brick red, 5 cm long in case of female and 4.6 cm in male, tapering at one end

and flat rounded at open end, flossy and without a peduncle. The silk filaments are not continuous.

Late stage rearing:

Rear maximum 300 number of 5th instar worms per 3 feet x 3 feet diameter tray. Low cost bamboo platform rearing equipment is the best for rearing late stage worms considering the limited rearing space and frequent bed cleaning. The structure with 6ft (L) x 5.5 feet (H) x 3 feet (W) dimensions can accommodate 25-30 DFLs.

Ripe (Mature) worm collection:

Ripe worms become yellowish white and start roaming for selection of site for cocoon formation. In mulberry silkworm larvae become yellowish in colour. It is ready for cocooning. While picking up the matured worms and rubbing in between fingers, **a sound of hollowness is produced in eri silkworm.** Mature worms are collected and put for the cocoon formation on mountages. Besides traditional net/*Jali*, bamboo *Chandrikes*, bamboo stripe type mountage and plastic collapsible mountage are used for cocooning.

Harvesting of cocoons: As per mulberry silkworm.

Post cocoon processing:

Stifling is done by spreading and exposing the cocoons to sun for 1-2 days. For degumming, cocoons are tied in a cloth sac and dipped in boiling soda solution. After sufficient boiling, the cocoons are taken out, washed with water several times to remove soda, squeezed to remove water and then spread on mats to dry. Being open mouthed, the thread of the cocoons is discontinuous. So, the thread can only be spun and not reeled. Traditionally spinning is done in wet condition on **Takli** and in semi dried condition on a **charkha**. Improved spinning machines like **N.R. Das type charkha** and **Chaudhury type charkha** are also available for spinning of silk from Eri cocoons.

NATURAL ENEMIES OF SILKWORM:

A. Important pests of silkworm with their management:

Pests	Nature of Damage	Management
Uzi fly *Exorista sorbillans* (Tachinidae: Diptera) (Endo-parasitoid of silkworm)	• The flies lay eggs on grown up larvae of silkworm and maggots on hatching feed the body contents of caterpillar. • Mature maggot causes reduction in yield of cocoons and cocoon quality. • Also causes death of silkworm larva. • Presence of creamy white oval eggs on the skin of larvae in the initial stage. • Presence of black scar on the larval skin. • Silkworm larvae die before they reach the spinning stage (if they are attacked in the early stage). In later	• Prevent fly's access to silkworms by mechanical means. • Fly proof rooms/doors/ventilators. • All crevices of the rooms should be closed to prevent maggots pupating in the soil. • Dusting of China clay @ 3g/100 on spinning larvae before mounting.

Pests	Nature of Damage	Management
	stage, pierced cocoon is noticed.	
Beetles *Dermestes cadeverinus* (Dermestidae: Coleoptera)	• The adults and grubs are attracted to smell of the cocoons. • They eat the cocoons, enclosed pupae and often the eggs of silkworms. • The females lay eggs in the crevices, organic matter and wooden boards. • Grubs and adults bore into the cocoons and eat the dried pupae, attack pierced and melted cocoons stored within the grainage. • Presence of small holes (pierced cocoons) in the pupae and abdominal parts are damaged in the adult moths.	• Closure of cracks and crevices. • Thorough cleaning of rearing room. • Fumigation of rooms with methyl bromide. • Store the pierced cocoons in a separate room. • Avoid long storage of pierced cocoons. • Sun dry the pierced cocoons once in a week.
Ants (Hymenoptera)	The ants attack silkworms in rearing trays.	• Legs of the rearing stands should be dipped in ant wells (water + kerosene). • Use of ash or kerosene at the handles of the mountages at the time of spinning.
Lizards, birds, rats and squirrels	• They feed on silkworms. • Mammals predate on pupae by biting open the cocoons.	• Rearing rooms should be kept free from lizards. • Setting of traps for rat and squirrel control. • Scaring of birds from the vicinity.

B. Important diseases of silkworm with their management:

Diseases and Causal organism	Susceptible stages/Mode of infection	Damage symptoms	Management
Pebrine disease (Protozoa transmitted) **(***Nosema bombycis*)	Eggs, Larvae, pupae, adults Mode of infection: Ingestion of spores	• It is a chronic disease. • Eggs laid by moth are fewer and do not firmly attach to the egg sheet. • Peeper like black spots. • Laying of unfertilized and dead eggs. • Diseased larvae have poor appetite, retarded growth, undersized and flaccid. • Larvae are comparatively paler, translucent and delays to moult.	• Mother moth examination. • Use of disease free females. • Sterilization of eggs with 2% formalin. • Destruction of infected eggs and females. • Bed disinfectant: *Vijetha* powder

Diseases and Causal organism	Susceptible stages/Mode of infection	Damage symptoms	Management
		• Silk gland will have white pustules on its surface. • Dead larvae remain rubbery for some time and then turn black. • Diseased pupa may develop black markings on the surface. • Moth appears malformed. • The wings are stunted and crippled • The infection spreads to successive generation through eggs of diseased moth (TOT: Transovarial Transmission). ***Responsible factor*:** • Infected seeds (eggs)	
Flacherie disease (Bacteria transmitted) (*Bacillus bombysepticus)*	Larvae Mode of infection: Ingestion of spores	• Loss of appetite, semisolid excreta, becomes lethargic. • Skin becomes flaccid body purification and emission of foul smell. • Larvae vomits gut juice and develop dysentery. ***Responsible factor*:** • Bad rearing condition (High temperature and humidity). • Poor ventilation, over crowding • Bad leaves and over feeding	• Proper incubation of eggs. • Proper rearing conditions. • Disinfectant: Slaked lime solution 0.3% • Bed disinfectant: *Vijetha* powder
Grasserie disease (Virus transmitted) (Nuclear Polyhedrosis Virus) Milky disease	Larvae Mode of infection: Ingestion of polyhedra (Chrystal virus particle)	• Swelling of inter segmental region and easy rupture of skin. • The integument will be fragile and breaks easily oozing turbid milky fluid. • Body fluid becomes thick and cloudy and they die. • The larvae do not settle for moult and their integument become shining ***Responsible factor*:** • Bad rearing condition (High temperature and humidity). • Poor ventilation, over crowding • Bad leaves and over feeding	• Avoidance of injury. • Disinfection of seed production unit, appliances, silkworm rearing house surroundings and silkworm egg surface. • Disinfectant: Slaked lime solution 0.3% • Bed disinfectant: *Vijetha* powder

Diseases and Causal organism	Susceptible stages/Mode of infection	Damage symptoms	Management
Muscardine disease (Fungal transmitted) **1. White Muscardine** (*Beauveria bassiana*) **2. Green Muscardine** (*Spicaria prasina*) **3. Yellow Muscardine** (*Iscaria farinosei*)	Larvae/ pupae/ adults Mode of infection: Penetration of skin by germinating spores of conidia	• Larvae loose appetite, become inactive and flaccid on death. • Hyphae come out from inter-segmental membranes. • Body becomes too hard. • Mummified larvae vomit and shows diarrhea like symptoms. ***Responsible factor*:** • Bad rearing condition (High temperature and humidity). • Poor ventilation, over crowding • Bad leaves and over feeding	• Proper rearing conditions. • Sterilization. • Formalin 3% or bleaching powder 2% or Slaked lime solution 0.3% as disinfectant. • Bed disinfectant: *Vijetha* powder

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Part-III: Lac Insect

INTRODUCTION

Lac is a natural resinous substance of profound economic importance in India. Besides silk and honey which are commercial products of insect origin, lac is also a product of a beneficial insect *Kerria lacca* (Kerr.). Millions of these sessile lac insects sustain their life on specific host plants, secreting resin as their body covering, which eventually harvested in the form of resin, dye and wax of commercial importance. It is the only resin from animal origin lending itself to diverse applications e.g. as a protective and decorative coating in the form of thin films, adhesives and plastics. It makes a small but significant contribution to the foreign exchange earning of the country, but the most important role of lac is considered to be an important cash crop by the poor cultivators (usually the tribal peoples) in almost all the major lac-growing states i.e. Jharkhand, Chhattisgarh, Odisha, West Bengal, Madhya Pradesh, Maharashtra and UP. The lac plays in the economy of the country is that roughly 3-4 million tribal people, who constitute the socio- economically weakest link of Indian population earn a subsidiary income from its cultivation.

India is the major producer of lac, accounting for more than 50% of the total world production. It virtually held a monopoly in the lac trade during the period of the world war-I, producing nearly 90% of the world's total output. Today an average of about 20 -22 thousand tonnes of stick lac (raw lac) is produced in the country per year.

Most of the lac produced in our country is from homestead land, wasteland and rural areas, a large number of poor cultivators producing lac in very less quantity. For them, there is hardly any investment, except in years of adverse conditions. They either own a few lac hosts or take them out on lease or rental basis, and generally only part-time family labour is employed. When the lac matures, it fetches them ready cash. Usually host trees standing on **Raiyati lands** (A person who hold the land for the purpose of cultivating it by himself or by members of his family) are used for lac cultivation and in some areas trees on Government land are taken on lease or rental basis.

Why lac cultivation?

- A good source of livelihood resource for poor farmers.
- Assured source of income during drought years.
- Require meager inputs (like water, pesticides *etc*.)
- Most suitably grown on marginal and degraded land.
- No competition with other horticultural, agricultural crops for land and farm operation.
- Do not harm host tree health neither other flora nor fauna.
- Avoids migration of rural population to urban areas.
- Increases opportunities for women for better occupation and returns.

HISTORY OF LAC:

Lac is a resinous exudation from the body of female scale insect. Since Vedic period, it has been in use in India. The term "Lac" synonyms Lakh in Hindi which itself is derivative of Sanskrit word "*Laksha*" meaning a hundred thousand and is suggestive of the large number of

insects involved in its production. It would appear that Vedic people knew that the lac is obtained from numerous insects and must also know the biological and commercial aspects of lac industry. The description of the insect and its host plant (Food plant) – Palas (*Lakshataru*) is recorded in the ***Atharva Veda***. It is mentioned in the **Mahabharata** that *Kauravas* built the highly inflammable ***Lakhagriha* or *Jadugriha* (Lac house)** with a motive of physically eliminating *Pandavas* by setting the lac palace on fire. It is also worth to mention that a ***Laksh Griha*** would need a lot of lac which could only come from a flourishing lac industry during that period.

The Ain-i-Akbari of 16th Century records the use of pigmented lac varnishes for painting screens. Since ancient times, Greeks and Romans were familiar with the use of lac. The cultivation of lac insects has a long history in Asia, with some suggestion that it is as old as 4000 years in China where its cultivation accompanied the development of the silk industry. Increasing demand of lac products after World War-II has received attention in the present century. In order to increase the production of lac by scientific methods, an association named **Indian Lac Association (ILA)** was formed in 1921, **Lac Research Institute (LRI)** was established at Namkum, Ranchi in 1924, with a view to have greater participation of the Government. In 1930, the **Indian Lac Cess Committee (ILCC)** was formed and the committee took over the **Indian Lac Research Institute (ILRI)** in 1957. Then the need for a Lac Extension wing was felt and thereafter a **Lac Extension Wing (LEW)** under the **Indian Lac Cess Committee (ILCC)** was created. The **Indian Lac Research Institute (ILRI)** was taken over by the **Indian Council of Agriculture Research (ICAR)** in 1966.

Responding to the opening up of economic policies, globalization of industries and agricultural enterprises, the **Indian Lac Research Institute (ILRI)** has undergone a structural change. Besides research and development on all aspects of lac; processing and product development of other natural resins and gums have been brought under the ambit of research. Therefore, ILRI has been upgraded as **Indian Institute of Natural Resins and Gums (IINRG),** Namkum (Ranchi) from the September 20, 2007. The **IINRG** is a nodal Institute at national level for research and development on all aspects of natural resins, gums and gum-resins including LAC, such as production, processing, product development, training, information repository, technology dissemination and national / international cooperation.

Recently in Gujarat, Department on Entomology, N.M. College of Agriculture, Navsari Agricultural University, Navsari has initiated research on lac insect and its cultivation under Tribal Area Sub-Plan plan (TASP) Development Charges (Plan Scheme) Project entitled **"Strengthening Research on Sericulture and Lac Culture" since 2017-18.**

Lac is Nature's gift to mankind and the only known commercial resin of animal origin. It is the hardened resin secreted by tiny lac insects belonging to a bug family. To produce 1 kg of lac resin, around 3,00,000 insects lose their life. The lac insects yields resin, lac dye and lac wax. Application of these products has been changing with time. Lac resin, dye etc. still find extensive use in Ayurveda and Siddha systems of medicine.

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

TAXONOMY OF LAC INSECT

Scientific study of lac started much later. In 1709 Father Tachard discovered the insect that produced lac. In 1782 a detail study was made by J. Kerr and named as *Coccus lacca* which was published in Philosophical Transaction of Royal Society of London (vol. 71, pp. 374-382). In 1815 *Coccus lacca* was put in new genus *Laccifer* by Oken. Later *Coccus lacca* was synonymized as *Tachardia lacca* following the name of French Missionary Father 'Tachardia'. It was later changed to *Laccifer lacca* (Kerr.) The other name given to it has been *Kerria lacca* (Kerr.) in 1883 by Blanched. Presently a total nine genera and 87 species have been described worldwide in which two genera and 23 species are reported from India (Sharma and Ramani, 2011).

A number of species of lac insects are known, of this ***Kerria lacca*** is by far the most important and produces the bulk of the lac for commercial use. It belongs to—

Phylum	:	Arthropoda
Class	:	Insecta
Order	:	Hemiptera
Super-family	:	Coccoidea
Family	:	Kerriidae
Genus	:	*Kerria*
Species	:	*K. lacca*

Lac is a natural, biodegradable, non-toxic, odourless, tasteless, hard resin and non-injurious to health. Lac is in fact a resinous protective secretion of tiny lac insect, *Kerria lacca* (Kerr.) which belongs to the family Lacciferidae in the super family Coccoidea of the order Hemiptera which includes all scale insects. Scale insect is a common name for about 2000 insect species found all over the world. Scale insects range from almost microscopic size to more than 2.5 cm.

The lac insect is a pest on a number of plants both wild as well as cultivated. These insects attach themselves in great numbers to plants. The mouth part of these insects is piercing and sucking type. They can be very destructive to tree-stunting or killing twigs and branches by draining the sap. The tiny red–coloured larvae of lac insect settle on the young succulent shoots of the host plants in myriads and secrete a thick resinous fluid which covers their bodies. The secretion from the insects forms a hard continuous encrustation over the twigs. The encrusted twigs are harvested and the encrusted twigs scraped off, dried and processed to yield the lac of commerce which is regarded as Non Wood Forest Product (NWFP) of great economic importance to India.

There are six genera of lac insects, out of which only five secrete lac and **only one, i.e. *Laccifer* secretes recoverable or commercial lac**. The commonest and most widely occurring species of lac insect in India is *Laccifer lacca (*Kerr.) which produces the bulk of commercial lac. However, *K. chinensis* in northeastern states and *K. sharcla* in coastal regions of Orissa and West Bengal are also cultivated to certain extent lac insect of South East Asia is referred to as *K. chinensis*.

DISTRIBUTION

Since the lac insects thrive and feed on certain species of the tropical trees it is found distributed in South-East Asian countries. Lac insects are concentrated in tropical and sub-tropical regions between 400 latitude above and below the equator on both Hemispheres (Varshney, 1976). Lac is currently produced in India, Myanmar, Thailand, Malaya, Lao and Yunan province of China. India and Thailand are main areas in the world while India has prime position in relation to lac production. Lac cultivation is introduced into Thailand from India.

Over 90% of Indian lac produced comes from the states of Bihar, Jharkhand, West Bengal, Madhya Pradesh, Chhattisgarh, Eastern Maharashtra and northern Orissa. Some pockets of lac cultivation also exist in Andhra Pradesh, Punjab, Rajasthan, Mysore, Gujarat and Uttar Pradesh.

LIFE CYCLE OF LAC INSECT

Lac insect is a minute crawling scale insect which inserts its suctorial proboscis into plant tissue, sucks juices, grows and secretes resinous lac from the body. Its own body ultimately gets covered with lac in the so called 'CELL'. Lac is secreted by insects for protection from predators. The life cycle of lac insect mainly depends on the ecological factors of the region like the temperature, humidity and the host plant species. It includes three stages; egg, nymph and adult. The eggs reached the adult stage within six months. The following are the stages involved in the reproduction of lac insects.

Egg

After fertilization, the females grow rapidly until it begins to lay eggs. By the same time female starts to lay the eggs, its body contracts to the ventral side and gradually vacating the place for the eggs to be accommodated inside the resin cell. After egg laying the female secretes the lac resin at a faster rate. After about 14 weeks, female shrinks in size, allowing the light to pass into the cell and onto the eggs.

At this stage, two yellow spots appear at the rear end of the resin cell. These spots gradually enlarge and turn orange in colour. This indicates the completion of egg laying by female. A female is capable of producing about 1000 eggs (average 200-500). The egg laying period may last from 7 to 10 days. After egg laying female dies. Now the resin cell with eggs is called 'ovisac'. The ovisac appears orange in colour due to crimson fluid called lac dye. This indicates that eggs are about to hatch in a week. After six weeks, the eggs are hatched into first instar larvae called crawlers.

Nymphs

Following hatching, the first instar nymph stays within the cell for a brief period. Then the crimson red coloured nymphs, referred to as '**crawlers'** come out of the cell in search of suitable place for settlement generally larvae prefer succulent shoots. The larvae emerge out in very huge numbers; this emergence is termed as '**swarming'** that continues for several weeks. **Boat shaped** nymphs are very small in size (0.5 mm) and divisible into head, thorax and abdomen. Head bears a pair of antennae, a pair of simple eyes and a single proboscis. All three thoracic segments are provided with a pair of walking legs. Thorax also bears two pairs of spiracles for respiration. Abdomen is provided with a pair of caudal setae.

On reaching soft succulent twigs, the nymphs settle down close together and start to suck phloem sap through their suctorial proboscis. After one day or so of settling, the nymphs start secreting lac from the hypodermal glands lying under their cuticle keeping open their mouthparts, breathing spiracles and anus. The secreted semi-solid lac hardens on exposure to air and the nymph gets fully covered by the lac encasement, called as '**lac cell'**. Within the cell, the nymphs moult thrice before reaching maturity. Larvae moult in their respective cells. During first moult both male and female nymphs **lose their appendages, legs and eyes**. Following this moult, dimorphism appears in their cells. The second stage larva undergoes pseudo-pupation for a brief time, whereby it changes into adult stage. Inside the male cells, the male nymph casts off their second and third moult and matures into adults.

Adult

The sex can be determined even during the early stages of development. As in case of males the growth is more on the longitudinal axis and in females the growth is more in vertical axis. The life span of the female is longer than that of the males. **Most of the lac is secreted by the females.**

On maturity, the **males lose their proboscis and develop antennae, legs and a pair of wings.** The male brood cell is **slipper shaped**. It bears a pair of **branchial pores** on the anterior side and a single large **circular pore** on the posterior side. The posterior hole remains covered by a round trap door or **operculum** through which adult males emerge.

The adult male is red in colour and smaller in size than the female insect. The length is about 1.2-1.5 mm. Head bears reduced eyes and ten segmented antennae. Mouth parts are similar to that of the females. Thorax has three pairs of legs. The male lac insect may be either winged with one pair of hyaline wing on its thorax or wingless (apterous). The eight segmented abdomen ends into a short chitinous prominent sheath containing penis. A pair of white elongated caudal seta or filament is present on either side of this sheath.

The female brood cell is larger globular in shape that remains fixed to the twig. The **female cell also has a pair of branchial pore** and a single round anal tubular opening through which protrudes waxy white filaments (it indicates that the insect inside the cell is alive and healthy). These filaments also prevent the blocking of the pore during excess secretion of lac. Following second and third moulting, the females retain only mouthparts but **fail to develop any wings, eyes or appendages.** While developing into adult, the female becomes immobile and large in size to accommodate huge number of eggs.

The **female lac insect has a pyriform body** measuring about 4-5 mm in length. The body is indistinctly divided into head, thorax and abdomen. Head bears **a pair of degenerated antennae.** Eyes are absent. Mouthparts are of piercing and sucking type. Posterior to mouth lies a pair of spiracles which ensures smooth breathing of the insect during lac secretion. Thorax has degenerated legs and lack wings. At the posterior part of the body is triangular in shape which consists the anal tubercle encircling and setae. Near to it two branchial openings and one small chitinous spine called dorsal spine are present.

Fertilization

Lac insects are **ovoviviparous types of fertilization**. The females get attached to the host plant inside the resinous mass. After attaining the maturity, males emerge out from their cells and walk over the resinous covering of the female. The male enters the female cell through anal tubular opening and inside female cell it fertilizes the female. **After copulation, the male dies.** One male is capable of fertilizing several females. A male has life of 62-92 hours. Females develop very rapidly after fertilization. They take more sap from plants and exude more resin and wax. **Parthenogenesis:** In the life history of lac insect, parthenogenesis is known to occur when unfertilized eggs are directly hatched into nymphs. It is common in Kartiki crop of Rangeeni Strain.

After hatching, the nymphs are emerge and the whole process begins all over again. After one cycle has been completed and around the time when the next generation begins to emerge, the resin encrusted branches are harvested. From each crop, some encrusted twigs are retained for inoculation to the new host plants.

LAC AND ITS FORMS

Based on the methods of collection and processing various forms of lac known in commerce are as follows:

Ari lac	**:**	If lac crops are harvested by cutting down the lac bearing twigs a little before the larval emergence, that lac is known as **ari lac (immature lac).**
Phunki lac	**:**	If lac crops are harvested by cutting down the lac bearing twigs after the larval emergence is over, that is called **phunki lac (empty lac).**
Stick lac	**:**	It is **raw lac**, obtained by scrapping the lac encrustation from the dry twigs cut down before emergence of the new insect. It contains dead bodies of the lac insect, bark of the host plant, dried leaves, dust and other extraneous impurities. OR The lac encrustations is separated by knife or broken off with finger from the twig of host plants and is known is stick lac or crude lac or raw lac.
Seed lac	**:**	The semi-refined product obtained after crushing, sieving and winnowing of stick lac, followed by washing and drying is called **seed lac**. It contains impurities such as sand, insect debris, *etc.* OR

		The stick lac, after grinding and washing is called seed lac or chowri.
Shellac	**:**	It is the refined form of lac, available in the form of thin flakes. It is obtained by stretching the heat softened seed lac, freed from infusible materials. It is the commercial lac and is graded based on its colour and wax content. OR The manufactured product prepared from stick lac after washing and melting, which takes the form of yellow coloured flakes, is called **shellac**. Shellac is natural gum resin. It is non-toxic, hard, amorphous, brittle and also edible. Its colour varies from dark red to light yellow. When heated slowly, it melts at 89-90°C. It is insoluble in water, but dissolves readily in alcohol and organic acids. It is used in fruit coating, as binder for nail varnish, mascara, as enteric coating for tablets, in manufacturing of photographic materials, in preparation of gramophone records, as sealing wax, as a filling material in the hollows of ornaments, in preparation of toys, buttons, pottery and artificial leather. Apart from these conventional uses, being eco- friendly and renewable raw material, it is also used in industries like textile (as stiffeners), electrical (for insulation, capping, etc.), paint, aluminium, pharma-ceuticals, confectionary, food processing, cosmetics, antique, etc.
Button lac	**:**	It is another form of heat purified lac, where the molten resin is cast into button shaped cakes instead of being drawn into sheets, as in the manufacture of shellac. The cakes are largely used for bonding mica splitting into micanite. **OR** After melting process, lac is dropped on a zinc sheet and allowed to spread out into round discs of about 3" diameter and 1/4" thickness is called **button lac.**
Garnet lac	**:**	It is prepared from **inferior seed lac or kiri** by the solvent extraction process. It is dark in colour and comparatively free from wax.
Bleached lac	**:**	A major portion of lac consumed in the world today is in the form of **bleached lac** or **'White Lac'.** It is prepared by dissolving shellac or seed lac in Sodium carbonate solution, bleaching the solution with sodium hypochlorite and precipitating the resin with sulphuric acid. Bleached lac deteriorates quickly and should be used within 2-3 months of manufacture. It is non-toxic and physiologically harmless and thus is widely used in food industries, food packaging and allied industries. It is also used in binding and adhesive drying-related works. Besides, it can also be used in industries related with flexographic printing, confectionary, stamping ink, coating for processed food and dry flowers, textiles; cosmetics, wood finishing, fireworks and pyrotechnics (as binder for fireworks, match sticks etc.), grinding wheels, rubber and plastic, electronics, *etc*.
Dewaxed	**:**	Lac from which wax has been removed is known as **dewaxed** lac. This non-

Lac		toxic shellac is a bit harder and brighter than other shellac. It is completely free from wax and has high gloss and excellent adhesive quality to various substrates. It can safely be used in cosmetics (hair sprays, shampoo, perfumes, lipsticks, nail polish, eyeliners, etc.), confectionary (coating of cakes, eggs, chewing gums, cheese, fruit coating), etc. Shellac aleuritic acid is now being used in synthesis of glucose mono-aleuritate (a non-toxic, non-hemolytic water soluble compound), an isocaloric substitute for dietary tripalmitin. Aleuritic acid esters are used in plastic, fibre materials and perfume industries also.
Lac Wax	**:**	Lac wax is a mixture of higher alcohols, acids and their esters. It can be used in preparation of polishes to be applied on shoes, floor, automobiles, etc. It is also used in food and confectionary, drug tablet finishing, crayons, lipsticks, *etc*.
Lac Dye	**:**	Lac dye is traditionally used to colour wool, silk, food and beverages. Being eco- friendly in nature, it is nowadays used as a colouring material. Its demand has made it rival to other synthetic colouring agents.
Lac resin	**:**	It is an ester complex of long chain hydroxy fatty acids and sesquiterpenic acid.

COMPOSITION OF LAC

The major constituents of stick lac or crude lac are resin, sugar, protein, soluble salt, colouring matter, wax, volatile oils, sand, woody matters and insect bodies. The resin is always associated with an odoriferous principle, a wax and a mixture of three dyes. Removal of both wax and dye results in a marvelous colourless and transparent resin having all the characteristic properties of the resin.

Chemical analysis has revealed that the resin is made of at least six major chemical components of different molecular complexities.

The approximate percentage of different constituents of lac is given below:

Composition of stick lac		
Lac resin	-	68 to 90%
Lac wax	-	5 to 6%
Lac dye	-	2 to 10%
Mineral matter	-	3 to 7%
Albuminous matter	-	5 to 10%
Water	-	2 to 3%

PROPERTIES OF LAC

The important properties of lac are as follows;

- Lac is soluble in alcohol and weak alkalis but insoluble in water.
- It has capacity of forming uniform durable film.
- It possesses high scratch hardness.

- Resistance to water and Heat soluble, at 80°C it melts.
- It is good adhesive in nature.
- Ability to form good sealers, undercoat primers.
- It has a capacity to allow quick rubbing with sandpaper without slicking or gumming.
- It is non-conductive and non-toxic.

No other single resin, both natural and synthetic, possesses so many desirable properties and so lac is also termed as multipurpose resin.

LAC HOSTS

Lac insects thrive on twigs of certain plant species and get settled upon it, suck the plant sap and grow. The plants preferred for feeding and development are called **host plants**. Although lac insect is natural pest on host plant, these insects enjoy the privileged position not being treated as pest. This is because: i) They yield a useful product, ii) The host plants are economically not so important and iii) The insects cause only temporary and recoverable damage to the host plants. About 113 species of host plants are found to be as lac host plant, but only few of them are found to be commercially important for lac culture in India. Of these host plants, *Butea monosperma* (**Palas**), *Schleichera oleosa* (**Kusum**) and *Ziziphus mauritiana* (**Ber**) are of major importance. These host plants contributes about 90 % of total national lac production. In addition to these host plants, a bushy host plant species, ***Flemingia semialata*** **Roxb. (Leguminosae: Papilionaceae),** has been identified and field tested as a potential fast growing host for intensive lac cultivation during winter season **lac crop of Kusmi strain (Aghani)** for increasing lac production to match with the growing global demand of lac. However, *Prosopis juliflora* (in Gujarat areas) are expected to enhance Kusmi lac cultivation.

Table-1: Common lac host plants in India

Host plant	Common name	Suitable for strain	Distribution
Major (Traditional)			
Butea monosperma	Palas	Rangeeni	All major lac growing states
Schleichera oleosa	Kusum	Kusmi	All major lac growing states
Zizyphus mauritiana	Ber	Kusmi/ rangeeni	All major lac growing states
Major (Emerging)			
Flemingia macrophylla	Bhalia	Kusmi	All major lac growing states
Flemingia semialata	Van chhola	Kusmi	All major lac growing states
Minor (Regional)			
Acacia auriculiformis	Akashmani	Kusmi	West Bengal, Jharkhand
Acacia catechu	Khair	Kusmi	J&K
Albizia lucida	Gulwang	Kusmi	Gujrat,
Cajanus cajan	Pigeon-pea	Rangeeni	Assam
Ficus benghalensis	Bargad	Rangeeni	West Bengal, Jharkhand
Ficus religiosa	Peepal	Rangeeni	West Bengal, Jharkhand
Grewia letiaefolia	Dhaman	Kusmi	Assam
Grewia disperma	--	Kusmi	Assam
Grewia serrulata	Pansaura	Kusmi	Assam

Shorea letura	Sal	Rangeeni	Karnataka
Samanea saman	Rrain tree	Kusmi	Odisha, West Bengal, Assam
Zizyphus xylopyrus	Khatber	Rangeeni	MP

ESSENTIAL CHARACTERISTICS OF A LAC HOST

The factor that determines whether the lac insect will flourish on a particular host species or not is the character of the sap of host plant. It is believed that the sap reactions of a good lac host should be near about neutral or slightly acidic (e.g. pH values between 5.8 and 6.0) and that the sap density of good lac host plants in lower than that on non-lac hosts. The sap reactions of non-lac hosts show distinct acidity or alkalinity.

LAC PRODUCTION IN INDIA

India and Thailand are the two major producers of lac. The main lac producing states in India are Chhattisgarh, Jharkhand, Madhya Pradesh, West Bengal, Uttar Pradesh, Orissa, Maharashtra and Gujarat. The cultivation of lac is at present mainly confined to the conventional lac hosts trees of Palas, Ber and Kusum. At present total annual average production of stick lac in India is approximately 20-22 thousand tons which forms the raw material for lac industries. Chhattisgarh ranks 1st position among the states followed by Jharkhand, Madhya Pradesh Maharashtra and West Bengal. These five states contribute around 95 % of the national lac production. Nearly 75-80% of the finished product is exported and only a small portion nearly 20 to 25 % is consumed within the country.

Table-2: State wise lac producing districts in the country

Sr.	State		Districts
1	Jharkhand	:	Palamau, Latehar, Garhwa, Ranchi, Lohardaga, Gumla, Simdega, Saraikela, Hazaribagh, Chatra, East Singhbhum & West Singhbhum
2	West Bengal	:	Purulia, Bankura, Midnapur, Murshidabad & Malda
3	Madhya Pradesh	:	Balaghat, Mandla, Hoshangabad, Shahdol, Jabalpur, Indore, Chhindwara, Rewa & Seoni
4	Chhattishgarh	:	Bilaspur, Raipur, Sarguja, Bastar, Rajnandgaon, Durg,,Kanker, Dhamtari, Korba & Raigarh
5	Maharashtra	:	Bhandara, Chandrapur, Gharchiroli, Gondia
6	Orissa	:	Mayurbhanj, Kendujargarh, Sundargarh, Kalahandi, Bolangir, Koraput, Sambalpur, Nabrangpur, Keonjhar, Balasore
7	Gujarat	:	Vadodara, Panchmahal, Sabarkantha and some part of The Dangs
8	Uttar Pradesh	:	Mirzapur, Sonebhadra
9	Bihar	:	Gaya
10	Assam	:	Karbi Anglong, North Silchar Hill, Nagaon
11	Andhra Pradesh	:	Adilabad, Nizamabad
12	Meghalaya	:	Khasi hills, Garo hills

STRAINS OF LAC AND LAC CROPS

Two strains of the lac insects are recognized in India, the ***Rangeeni*** and ***Kusumi*.** Each strain completes its life cycle twice a year but the seasons of maturity differ considerably. In Mysore, the Rangeeni strain completes their life cycle in 13 months on Jallari (*Shorea talura).*

There are four lac crops in a year that are named after the *Hindi* months. The following table summarizes the information about four lac crops.

Table-3: Strains of lac and lac crops

Sr	Inoculation with Lac Swarming larva	Lac Host Plant	Weather	Seed Inoculation	Emergence of male insects	Crop harvested	Female insects mature and give rise to swarming larvae	Time (In month)
A.	**RANGEENI CROPS**							
i	Katki crop (June –July)	Palas	Rainy Season	June-July	Aug-Sept	Oct-Nov	Oct-Nov	4
ii	Baisakhi crop (Oct – Nov)	Palas	Summer	October - Nov	Feb-March	April-May leaving a certain amount of lac on trees to mature and act as brood in July	June-July	6-8
		Ber	Summer	October - Nov	Feb-March	May-June	July-Aug	6
B.	**KUSUMI CROPS**							
i	Aghani crop (June-July)	Ber	Winter	June-July	September	Dec-Jan	Jan-Feb	6
ii	Jethwi crop (Jan-Feb)	Kusum	Summer	January-February	March - April	June –July	June –July	6

Lac is not always left on the trees until it matures fully, particularly in case of *Baisakhi* crop. When it is not mature, it (*Baisakhi – ari)* is cut, leaving a certain amount on the tree to act as brood for the next crop. In *Rangeeni*, three crops can be obtained from the host tree such as Jalari (*Shorea talura*) mostly found in Karnataka (Mysore region) and Rain tree (*Samanea saman*), mostly located in coastal region of West Bengal. These crops are commonly known as Trivoltine crop in which the lac insects pass through three life cycles in thirteen months.

CROP WISE LAC PRODUCTION

Regarding share of different crops, *Katki-33.39%* (rainy season crop of *Rangeeni)* contributed the most in national lac production followed respectively by *Baisakhi*- 27.35% (summer season crop of r*angeen*i), *Jethwi* 19.50% (summer season crop of *Kusmi*) and *Aghani* 19.42% (winter season crop of *Kusmi*).

Traditional cultivation practices of lac

The cultivation practices followed by the lac cultivators are essentially the same throughout India except for slight deviation here and there to suit local conditions. It consists of taking repeated partial lac crop on the same tree after allowing a few shoots, carrying lac for self-inoculation every time or when the crop is harvested. Keeping the trees under continuous lac inoculation and heavy pruning of brunches repeatedly to collect lac crop, leads to general loss of vitality of the trees. Also the self inoculation of the trees lead to over-infection on the twigs and this quite often results in whole sale mortality of the crop in season of extreme summer. Besides, this helps multiplication of enemy insects of lac resulting in failure of crops, which ultimately forces the cultivator to abandon cultivation on most of the lac host trees. In such seasons brood lac is not readily available for purchase and if at all, a very high price has to be paid which the cultivator cannot afford to pay. The cultivator usually purchases his brood to the extent he can afford at that time and puts it on a few trees and start cultivation cycle afresh. In favorable seasons, he reaps his crops and inoculates more of his trees and continues the self inoculation repeatedly till the crop fails again.

Thus production is unsteady and usually a bumper crop is obtained in cycles of 3 to 4 years. Being a subsidiary crop, lac cultivation is carried on a casual manner and the cultivator is generally satisfied with whatever he gets.

SCIENTIFIC METHOD OF LAC CULTIVATION

To start lac cultivation, two things are mainly to be taken into consideration:

a. The suitable host plant on which the lac insect thrives
b. Availability of healthy brood lac in time

MAJOR LAC CULTIVATION OPERATIONS/PRACTICES

1. Selection of suitable host plants
2. Infestation of lac hosts (inoculation)
3. Removing of used-up broodlac sticks (*Phunki*)
4. Insect pest management
5. Harvesting
6. Scraping of lac from twigs

1. SELECTION OF SUITABLE HOST PLANTS:

Selection of suitable host plants for lac cultivation is of paramount importance because quality and yield of lac depend on this. Under systematic working, the host plants are cultivated and rested in turn in **coupe system**. The host trees should be properly pruned to put forth young succulent shoots before inoculation. Only natural enemy free brood lac should be used for inoculation. Lac crops being highly sensitive to change in local weather conditions, care has to be taken to provide optimum conditions for successful results.

Selected lac hosts should have the following salient features:

- Fairly fast growing.
- Lower sap density.
- Well adapted to pollarding.

Selection of suitable site for lac cultivation

As lac can grow only in open areas, the sites for lac host plantation should be in such a place where free circulation of air around the host is assured. Cultivation should not be attempted at places where fire susceptibility is there. When starting cultivation in new areas having lac host. It is always desirable to prune them before infection to ensure good lac production.

Coupe System: a sustained yield basis of lac cultivation

The coupe system has been developed for lac production on sustained yield basis. If the same tree is continuously inoculated, its vitality suffers and the yield of crop progressively diminishes. It is therefore, important that host plants are given periodic rest. The coupe system of cultivation provides for a maximum use of host plant resources consistent with their vigor and well being.

In Rangeeni farms, *two coupe systems* with equal number of palas (*Butea monosperma*) trees in two coupes having six months rest is adopted for raising *Baisakhi-cum-Katki* crops in alternate seasons. The trees are inoculated with about 500g of *rangeeni* brood lac per tree, in the month of Oct.-Nov. Harvesting is done after a year, after allowing self-inoculation in June-July by partial harvesting and then harvesting the combined *Baisaki-cum-Katki* crop in next Oct. Nov.

In the *Kusumi* farms, Kusum (*Schleichera oleosa*) is the major lac host plant species of *Kusumi* stain of lac insect. *Five coupe system* with equal number of trees in each coupe having 18 months rest in between pruning and inoculation is adopted. The trees are pruned 18 months prior to inoculation. Thereafter in the subsequent crops, harvesting will serve the purpose of pruning. The harvesting of crop is done after six months of inoculation.

Preparation of feeding ground for lac insects

To get a good quality lac through cultivation, it is necessary to ensure proper type of feeding ground to the lac insects. The insects have to be provided with succulent shoots, as it cannot drive its slender proboscis through thick bark. For getting a good number of requisite succulent shoots the most essential operation is pruning.

Pruning Operation

Pruning at proper time is one of the important operations where the branches/ twigs are cut in order to get the maximum numbers of succulent shoots to facilitate feeding of the lac insects. Improvised scientific method of pruning which is done in the brood lac farms is as follows:

Pruning is done lightly, because light pruning avoids stunted growth and allows gradual increase in the frame of the tree. Branches more than 2.5 cm in diameter (more than thickness of one's thumb) are not cut. Branches 1.25 cm or less in diameter are cut flush with a branch or trunk from where they arise. Branches between 1.25 cm to 2.5 cm in diameter are cut, so as to leave behind a stalk of about 30-45 cm in length. Dead and diseased branches are removed, split or broken branches are cut below the split.

If trees are old and have lost their capacity to produce vigorous shoots of new flush, heavier pruning is carried out to produce the new wood at the expense of the old. Such operation

will bring the tree to a better shape, so that subsequent pruning will give the desired flush. Proper pruning should result a good shape and give plenty of room for the development of new shoots.

Objectives of Pruning

- To ensure new, good, healthy and succulent shoots.
- To ensure availability of large number of shoots (larger area for lac insect settlement).
- To provide rest to host plant for maintaining its vigour.
- To remove dead, diseased and broken branches.

Types of pruning in lac host plants

Two types of pruning/ coppicing have been recommended for lac culture.

1. Apical/ light pruning: Branches less than 2.5 cm diameter should be cut from base and branches more that 2.5 cm diameter should be sharply cut leaving a stump of 30-45 cm from the base. Diseased and dead portion of branches should be removed completely. Light pruning is recommended for slow growing conventional tree host species like palas, kusum and ber.

2. Basal / heavy pruning: Branches having less than 7 cm thickness should be removed from the base, whereas thicker branches should be cut at a place where it has a diameter of 7 cm. In quick growing bushy host, pruning should be done at a height of 10-15 cm from the ground level e.g. *Flemingia macrophylla, F. semialata.*

Pruning time

After several years of investigation at Indian Lac Research Institute (presently I.I.N.R.G.), Ranchi, Jharkhand, it has been found that the best results are obtained by **pruning in February for raising the Katki crop and in April for raising the *Baisakhi* crop in the case of major *Rangeeni* host, ber and palas.** Pruning in these months will give shoots four and six months old respectively for the lac larvae to feed on.

In case of **kusum, pruning is best done in the month of June-July and January – February.** These months coincide with those in which the crops mature and so harvesting of the mature crop serves the purpose of pruning also. Pruning time will, however need to be adjusted to suit local conditions.

Pruning instruments

Most of the lac cultivators do pruning with axes. Proper pruning cannot be done with the axe. If branches are cut with axe, they will either break or split. In both the cases damage to tree will be caused at cutting place in form of scraping of bark or splitting, giving opportunity for insect pest attack. The ideal pruning instruments are **secateurs** and long handled **tree pruners**. Of these instruments, the most valuable are the long handled tree prunners. There are two types of secateurs. These are Roll cut secateur and the French secateur. The former is better and easier to use but is easily damaged by careless handling

Pruning is also done with **pruning knife** and Dauli. The use of pruning shear and pruning saw fitted in long handle makes the operation easier as the pruning is done directly by standing on ground and climbing is avoided.

2. INFESTATION OF LAC HOSTS (INOCULATION):

Brood lac is mature lac from where the young insects are ready to come out within the time specified. For getting the best result out of lac cultivation, the work should be planned on systematic basis. Such planning will aim at a sustained annual yield and also ensure that area under cultivation acquires self sufficiency of brood lac.

Collection of brood lac

Lac sticks, having mature female insects ready to give rise to the next generation are called *brood lac*. As the female lac insect is capable of giving rise to a large number of larvae and to get the maximum benefit, it is essential that the brood should be cut at the proper time, so as to secure the emergence of the maximum possible number of larvae from it.

For quality of brood lac, lac crops should be harvested only when mature. The cutting of brood lac should be taken up at the correct time keeping in view the swarming period i.e. the expected date of larval emergence. The ideal time of cutting would be that which will result in the swarming, starting immediately or within a couple of days of tying the brood on the host plant.

Selection of brood lac

After the brood lac has been cut from the plants, it is necessary to subject it to proper examination, so that only healthy lac with the minimum signs of predator and parasitoid damage is selected for use as brood lac. This is necessary to minimize the chances of propagation of the insect enemies of lac insects.

Inoculation of brood lac

This operation includes **putting of bundles of brood lac** (*lac sticks containing gravid females*) in the host twigs for allowing young lac larvae (*crawlers*) to come out of their mother cells and settle on the host plant.

Following aspects should be taken into consideration during inoculation operation:

- Pest -free healthy brood lac should be used.
- The leaves and unwanted portion of the shoot from broodlac sticks should be removed.
- Cut broodlac sticks preferably 15 -20 cm in length.
- Weigh about 1 kg broodlac and divide into approximately into 10 equal parts.
- Bundles of brood lac (about 100g by weight) are to be prepared and put these bundles **inside 60 mesh nylon netting bags** (approx. size 30 x 10 cm.). These will entrap all the predators and parasitoids but allow the lac larvae to come out.
- The brood lac bundles are tied onto the branches parallel to shoots.
- One meter long brood lac is sufficient to inoculate 10-15m long shoots of equal length.
- During the period of inoculation, there are chances of brood bundles falling off and one should go round the inoculated trees in each branch and put such bundles back on the tree.
- Attempts should be made to see that the brood lac bundles are not kept on the tree for more than the minimum period required for complete inoculation. Ordinarily, this period will be two to three weeks. If the brood lac is kept even after the lac larvae have

completely emerged, there is the danger of a larger number of enemy insects emerging from the **empty (phunki) brood lac sticks** and infesting the field heavily.

- While inoculating kusum trees, prefer to inoculate the trees with broodlac on outer side for *Aghani* and inner side of the host crown for raising *Jethwi* crop.

Table-4: Host pruning and lac inoculation schedule for different host plant

Host	Pruning	Waiting period	For raising	Inoculation	Maturity
Kusum	Jan/ Feb	18 Month	Aghani	June/ July	Jan/Feb.
	June/July	18 Month	Jethwi	Jan/Feb.	June/ July
Palas	Feb/March	6 Month	Katki	June/July	October/Nov.
	April	6 Month	Baisakhi	October/Nov.	June/July
Ber	April	6 Month	Baisakhi	October/Nov.	June/July
Flemingia semialata	Jan/ Feb	6 Month	Aghani	June/ July	Jan/Feb.
	June/July	6 Month	Katki	Jan/Feb.	June/ July

3. REMOVING OF USED-UP BROODLAC STICKS (*Phunki*):

Used up broodlac sticks after complete emergence of lac larvae from female cells are called ***phunki***. This operation should be done to prevent access of the insect predators and parasitoids of lac insect to new lac crop and to avoid wastage of lac after drying up of phunki and prevent its falling on ground. It should be done as soon as emergence of lac crawlers is over. Generally the emergence of lac larvae from the brood lac ceases after three weeks. The phunki lac so removed is scrapped off thereafter in the brood lac for more that three weeks from the start of larval emergence to avoid emergence of enemy insects. Phunki bundles are pulled down from the trees with the help of pole mounted phunki hook or by climbing on trees.

4. PEST MANAGEMENT PROGRAMME:

There are many natural enemies of lac insects which include vertebrates, invertebrates (insect predators and parasitoids) and microbial flora.

Vertebrate enemies of lac insects

The important vertebrate enemies are squirrels and rats and the damage caused by those enemies can be as serious as 50 per cent of brood sticks in worst condition. Squirrels are active during the day time and the damage by them is more common under forest condition. Rats are active at night time and the damage usually occurs near about the villages.

Towards the crop maturity, these pests both gnaw the mature lac encrustation on the tree or the brood lac tied to trees for inoculation, and consumes the full grown lac female insects with plenty of eggs inside them. The damage to brood lac tied to trees interferes with the inoculation, as the brood bundles and lac encrustations drop to the ground while the larval emergence is taking place. Besides squirrels and rats, monkeys also cause some damage to lac encrustations and to the newly developing shoots from pruned trees by breaking them.

Control

It is difficult to control the squirrels and rats under the open field conditions where lac is cultivated. However scaring away of these animals or poisoning them may be adopted to keep the rodents under attack.

Insect enemies of Lac insect

It has been estimated that on an average, up to 30 to 40 per cent of the lac cells are destroyed by insect enemies of lac crop. At times, the enemy attack can be so serious as to result in crop failures.

These are two kinds of insect enemies:

1. Parasitoids: All parasitoids causing damage to lac insect belong to the order hymenoptera of class Insecta.

Table-5: List of parasitoids associated with lac insect, *Kerria lacca*

Sr. No.	Name of the parasitoid	Family
1.	*Anicetus dodonia*	Encyrtidae
2.	*Atropates hautefeuilli*	Encyrtidae
3.	*Aphrastobracon flavipennis*	Encyrtidae
4.	*Bracon greeni*	Encyrtidae
5.	*Campyloneurus indicus*	Encyrtidae
6.	*Coccophaqus tchirchii*	Aphelinidae
7.	*Erencyrtus dewitzi*	Encyrtidae
8.	*Eupelmus tachardiae*	Eupelmidae
9.	*Eurymyiocnema aphelinoides*	Aphelinidae
10.	*Lyka lacca*	Encyrtidae
11.	*Marietta javensis*	Aphelinidae
12.	*Parageniaspis indicus*	Encyrtidae
13.	*Parechthrodryinus clavicornis*	Encyrtidae
14.	*Protyndarichus submettalicus*	Encyrtidae
15.	*Tachardiaephagus tachardiae*	Encyrtidae
16.	*Teachardiobius nigricans*	Encyrtidae
17.	*Aprostocetus(Tetrastichus) purpureus*	Eulophidae

Among the parasitoids listed above, ***Tachardiaephagus tachardiae*** and ***Tetrastichus purpureus*** are the most abundant lac associated parasitoids. They lay their eggs in the lac cells and the grubs (larvae) hatching out feed on the lac insect within its cell.

2. Predators

The predators on the other hand are more serious and may cause damage up to 30 to 35 per cent to the lac cells in a crop.

Table-6: Table: List of predators associated with lac insect, *Kerria lacca*

Sr. No.	Insect Predator	Order	Family
1.	*Eublemma amabilis*	Lepidoptera	Noctuidae
2.	*E. coccidiphaga*	Lepidoptera	Noctuidae
3.	*E. cretacea*	Lepidoptera	Noctuidae
4.	*E. scitula*	Lepidoptera	Noctuidae
5.	*Pseudohypatopa pulverea*	Lepidoptera	Blastobasidae

6.	*Catablemma sumbavensis*	Lepidoptera	Blastobasidae
7.	*Cryptoblabes ephestialis*	Lepidoptera	Blastobasidae
8.	*Phroderces falcatella*	Lepidoptera	Cosmopterygidae
9.	*Lacciferophaga yunnanea*	Lepidoptera	Momphidae
10.	*Chrysopa madestes*	Neuroptera	Chrysopidae
11.	*C. lacciperda*	Neuroptera	Chrysopidae
12.	*Berginus maindroni*	Coleoptera	Mycetophagidae
13.	*Silvanus iyeri*	Coleoptera	Cucujidae
14.	*Tribolium ferrugineum*	Coleoptera	Tenebrionidae
15.	*Phyllodromia humbertiana*	Dictyoptera	Blattellidae
16.	*Ischonoptera fulvastrata*	Dictyoptera	Blattellidae

Among the above mentioned predators, ***Eublemma amabilis*** and ***Pseudohypatopa pulverea*** are the most destructive key pests of lac insects and are in regular occurrence but their incidence may vary from season to season, place to place and crop to crop.

Eublemma amabilis:

It is the most destructive predator of lac insect and causes most damage during *Katki* and *Aghani* lac crops *i.e.* during the rainy season in comparison to the other two crops.

Life history

The female moth lays grayish-white, flat round eggs, deposited in the center with beautiful sculpturing on the chorion. The eggs are laid singly on cell of the lac insect. Newly emerged larva is about 0.51 to 0.54 mm in length. It is creamy-white and pinkish in colour. The larva enters the lac insect either through the openings in the cell or by tunneling hole through the encrustation. Mature larva measures about 9 to 11 mm in length and dirty yellowish-white in colour. Head is dark brown in colour and partly retractable in the prothorax. A single larva can destroy 40 to 60 lac insect cells in its whole larval period. It has six generations in a year and the duration of the generations is about 37, 45, 42, 125, 80 and 40 days, respectively. Attacked lac cells can easily be identified because of its pinkish colouration due to presence of pink coloured discs of excreta inside the hollow lac cells. Pupa is on obtect, adecticous type and dark brown in colour. Adult is white-pinkish in color.

Pseudohypatopa pulverea

It is also destructive predator of lac insects and found in all lac growing areas of the country. It feeds on the live and dead lac insects and found in large numbers in stored lac and so it is responsible for the qualitative and quantitative deterioration of stored lac.

Life history

It lays oval (0.5 mm x 0.3 mm) colourless eggs on the cell of lac insects singly. Normally larvae pass through five instars but the hibernating larvae have nine instars. The newly hatched larva is about 1.35 mm long whereas a mature larva is 10 to 12 mm in length and 2 mm in breadth. Larva feed on the lac larvae and spins a loose web. A single larva is capable of destroying 45 to 60 mature lac cells.

Management of insect enemies:

Preventive measures:

- Only healthy, **pest-free brood lac** should be used for inoculation.
- The twigs for inoculation should be cut just before swarming to get healthy brood.
- Entire crop should be harvested at the maturity.
- Self inoculation of lac crops should be avoided as far as possible.
- Inoculated brood bundles should be kept on the host tree for a minimum period only.
- Phunki (empty brood lac sticks) should be removed from the inoculated trees within 2 to 3 weeks.
- All lac cut from the tree and all phunki should not use for brood purpose, it should be scraped or fumigated or immersed in water to kill the pest.
- Stick lac should be scrapping as soon as possible and should be processed immediately to convert into seed lac.
- Infected stick lac should be treated with fumigant insecticide along with predators and pests.
- Remove eggs of Chrysoperla from the plant or lac cells time to time.
- Regular monitoring is necessary for observation of any deformity or attack of insect pest.
- Cultivation of kusumi strain of lac should be avoided in predominantly rangeeni area and vice- versa.

Mechanical control:

Uses of 60 mesh synthetic netting (brood bag) to enclose brood lac for inoculation purposes which can reduce infestation of insect enemies of lac insect. The emerging lac larvae easily crawl out from the minute holes of the net and settle on the twigs of the lac host plants, whereas the emerging adult predator cannot comes out of the brood bags and get entrapped within the net. This can check the egg laying by the predator moths on the new crop.

Chemical control:

- Spraying should be done on the culture of lac insect settled on shoot and not over leaves or shoot without lac insect. Avoid pesticide spry at male emergence.
- First spray should be done at one month after inoculation with ethofenprox 10EC with 0.02% or cartap hydrochloride 50SP with 0.05%.
- Second spray after one month from the first spray, if necessary.
- Spraying should be done only before male emergence period or when fertilization is completed.
- For summer crop of *Rangeeni (Baisakhi)*: cartap hydrochloride 50SP with 0.05% (10g in 10 liter of water) or ethofenprox 10EC with 0.02% (20ml in 10 liter of water) at one month of inoculation sometimes in November and second spray in January or March (no spray between 105 to 125 days during *Baisakhi* and 42 to 58 days of inoculation for *Katki* crop.
- Summer crop of *Kusmi (Jethwi)*: ethofenprox 10EC with 0.02% (20ml in 10 liter of water) on one month and two month after inoculation or larval emergence (No spray between 65 to 90 days of inoculation).

- Winter crop of *Kusmi (Aghani)*: cartap hydrochloride 50SP with 0.05% (10g in 10 liter of water) or ethofenprox 10EC with 0.02% (20ml in 10 liter of water) + carbendazim 50WP with 0.01% (2g in 10 liter of water) on one month after inoculation. Repeat same after one week (second spray) and third spray on two month after inoculation, if lac crop is attacked by *Chrysoperla sp*. and fungi (No spray between 40 to 58 days of inoculation).
- Spray carbendazim 50WP with 0.01% (2g in 10 liter of water) only, especially in rainy season or during cloudy weathers at the interval of 15 days but not during mating period.
- For *Chrysoperla* spray dichlorovos 76%EC with 0.03% (4 ml in 10 liter of water).

Microbial control

Use of biopesticide, Thuricide (*Bacillus thuringiensis*) at 30 to 35 days stage of crop is the effective microbial control measure for important enemy insects of lac in field condition.

Biological control

Two predatory ants *viz*. *Camponotus compresus* and *Solenopsis geminate rufa* are the most important and promising for biological control of predator enemies of lac in field condition.

Egg parasitoids *viz*. *Trichogramma pretiosum, T. chilonis, T. poliae, Trichogrammatoidea bactrae* and *Telenomus remus* have been found to be effective in management of lac predators.

5. HARVESTING:

Harvesting is the process of collection of lac from host trees. Two type of harvesting process is used in most of the regions; Ari lac harvesting and mature harvesting. It is done by cutting the lac encrusted twigs when is crop is mature. It may be of two types:

A. Ari lac harvesting

Immature harvesting and collection of lac before swarming is known as 'Ari lac'. The immature harvesting has drawbacks, as the lac insects may be damaged at the time of harvesting. However, in case of rangeeni lac it is found that ari lac gives better production. Hence, ari lac harvesting is recommended in case of rangeeni only.

B. Mature harvesting

In mature harvesting lac is collected after swarming. The lac obtained is known as mature Lac. To know the exact date emergence and swarming of nymph a simple visual method is adopted. **A yellow spot develops on the posterior side of lac cell towards crop maturity**. This spot spread forwards until it covers half of the cell. Cutting of twigs for harvest can be done at any time between the stages while yellow spot occupies one third to one half of the cell area. It is sometimes desirable to wait till the emergence of the first few nymphs. The harvesting periods of different crops are different. The katki crop is harvested in Oct. /Nov.; baisakhi in May/June; Aghani in Jan/Feb.; and Jethwi in June/July.

Mature lac harvesting is of two types in practice as:

a. Partial harvesting: This harvesting is performed when surplus brood lac is on the tree and sufficient branches are available on the tree for next generation.

- It should be done in the month of January/February or June/July whenever larval emergence starts from kusum tree.

- One should harvest lac encrusted shoots from places where there is no further space for the insect settlement.
- While harvesting leave lac encrusted twigs at places where space for lac insect settlement is available.

b. Complete harvesting: In this process lac is fully harvested from the plant and plant is pruned and left for new shoot emergence.

Following consideration are recommended for harvesting:

- Lac crop should be harvested only when mature. Immature or Ari lac cutting should be avoided, though it is recommended in case of rangeeni. Secateur should be preferred for harvesting of broodlac.
- A mature crop is said to be the one from which nymphs will emerge in 7 to 10 days. So, the crop should be harvested within the above said days prior to nymphal emergence. If cutting earlier there is a chance of nymphs dying. If cutting is late the nymphs may already have emerged before inoculation is adopted.
- Attempt should be made to reap the entire crop if self inoculation is not required. In the case of *rangeeni* crop only lac encrusted twigs are cut, while in the case of *kusumi* one, reaping should combine with pruning.
- The brood sticks harvested should be utilized for inoculation as soon as possible. If storage is needed these have to be stored in a well ventilated room or under shade in open prevented from rain and heat.
- Harvesting of lac crop at maturity can solve the crisis of brood lac dearth to a large extent without affecting the quality of lac obtained as phunki lac. This will also reduce the loss of brood lac and enhance the yield.
- The pruning should be done as per pruning methodology described earlier while harvesting from kusum.

6. Scrapping

Removal of lac resin incrustation from lac host stick is called scraping. After harvesting of matured lac and sometime immature lac is need to be scraped as primary processing for long time storage. This practice is done with the help of scraping knife. Scraping of stick lac has following benefits:

- Help for quick dry and minimize the moisture content
- Save the lac loss from lac predators
- Easy storage
- Escape from fungal attack
- Hidden insect stages can be killed and removed
- Increases the storage life

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Part-IV: Predators and Parasitoids
(Predators and parasitoids used in pest control programme)

Introduction:

A large numbers of predators, parasitoids, bacteria, fungus, and viruses regulate the population of insect pests under natural field condition. Biological control came into prominence in recent times owing to some spectacular success achieved in various parts of the world. Biological control is a process in which one species population lowers the numbers of another species by mechanisms such as predation, parasitism, pathogenesis or competition or Biological control involves use and manipulation of natural enemies by man.

History of biological control:

- 900 AD- First use of red ant, ***Oecophylla smaragidna*** to control leaf chewing insects on mandarin trees.
- 1200 AD- Ants were used for control of date palm pests in Yemen (south of Saudia Arabia). Usefulness of ladybird beetles recognized in control of aphids and scales.
- 1602 - Aldrovandi noted the hymenopteran parasite, *Apanteles glomeratus* laying eggs in the pupae of the cabbage butterfly, *Pieris brassicae.*
- 1726- The first insect pathogen was recognized by de Reaumur. It was a *Cordyceps* fungus on a noctuid.
- 1762 - Indian mynah bird, *Gracula religiosa* exported from India to Mauritius to control red locust, *Nomadacris septemfasciata.*
- 1776- Control of the bedbug, *Cimex lectularius*, was successfully accomplished by release of the predatory pentatomid ,*Picromerus bidens* in Europe.
- **In 1868 Cottony cushion scale, *Icerya purchasi Maskell,*** was introduced into California in ca. around the Menlo Park (CA) area (near San Francisco) by 1887 it spread to southern California. C. V. Riley (Chief of the Division of Entomology, USDA) employed Albert Koebele and D. W. Coquillett in research on control of the cottony cushion scale and found no methods to control.
- In 1888- Koebele was sent to Australia to collect natural enemies of the scale, He sent ca. 12,000 individuals of *Cryptochaetum iceryae* and 129 individuals of *Rodolia cardinalis* (the vedalia beetle)
- **1888- Vadalia beetle, *Rodolia cardinalis*** was brought from Australia and introduced into California (Control) cottony cushion scale, *Icerya purchasi* on citrus. It's a first well planned and successful classical biological control attempt made Overview of The Cottony Cushion Scale Project.
- 1898- Austalian *Cryptlaemus montrouzieri* in India on *Coccus viridis.*
- 1902- The Lantana Weed Project in Hawaii (1902) first published work on BC of weeds.
- 1911- Berliner described *Bacillus thuringiensis as causative agent of* bacterial disease of the Mediterranean flour moth.
- 1919- USDA laboratory for biological control established in France.
- 1920 - A parasitoid *Aphelinus mali introduced from England into India to control* Woolly aphid on Apple, *Eriosoma lanigerum.*
- 1927- The Imperial Bureau of Entomology created the Farnham House Laboratory for BC work in England.

- **1929-31 - *Rodolia cardinalis* imported into India (from USA) to control cottony cushion scale *Icerya purchasi* on Wattle trees.**
- 1930 to 1940- Peak in BC activity in the world (57 different natural enemies established) World War II caused a sharp drop in BC activity with switch to pesticide research.
- 1947- The Commonwealth Bureau of Biological Control (CBBC) was established.
- 1951- CBBC renamed as Commonwealth Institute for Biological Control (CIBC). Headquarters are currently in Trinidad, West Indies.
- 1955- The Commission Internationale de Lutte Biologique contre les Enemis des Cultures (CILB) was established.
- 1958-60 - Parasitoid *Prospatella perniciosus imported from China.*
- 1960 - Parasitoid *Aphytis diaspidis imported from USA* both parasitoids used to control Apple Sanjose scale *Quadraspidiotus perniciosus.*
- 1962- The CILB changed its name to the Organization Internationale de Lutte Biologique contre les Animaux et les Plants Nuisibles. Also known as the International Organization for Biological Control (IOBC).
- 1964 - Egg parasitoid *Telenomus sp. imported from New Guinea to control Castor* semilooper *Achaea janata.*
- **1964- Paul DeBach** and Evert I. Schliner (Division of Biological Control, University of California, Riverside) published an edited volume titled "Biological Control of Insect Pests and Weeds".
- 1965 - Predator *Platymeris laevicollis* introduced from Zanzibar to control coconut Rhinoceros beetle, *Oryctes rhinoceros.*

Classical biological control achieved in India

Definition: Classical biological control (CBC) is defined as the introduction of a natural enemy of exotic origin to control a pest, usually also exotic, aiming at permanent control of the pest.

Successful examples of examples:

- 1795- Cochineal insect, *Dactylopius ceylonicus* was introduced from Brazil against carmine dye producing insect, *D. coccus*.
- 1921- the agromyzid seedfly, *Ophiomyia lantanae* against *Lantana camara* from Hawaii (origin: Mexico) and released in south India.
- 1926- The coccinellid beetle, *Rodolia cardinalis* against cottony cushion scale, *I. purchase*
- 1941- Tingid lace bug, *Teleonemia scrupulosa,* against *L. camara* from Australia.
- 1951- *C. Montrouzieri* against mealy bugs.
- 1963-The gallfly, *Procecidochares utilis* against Crofton Weed, *Ageratina adenophora* from New Zealand to Nilgiris (Tamil Nadu), Darjeeling and Kalimpong areas (West Bengal).
- **1979 to 1982- An ectoparasite, *Epiricania melanoleuca* Fletcher was introduced from Ravalgaon (Maharashtra) and Karnal (Haryana) against of *Pyrilla perpusilla* Walker in South Gujarat of India. Now, this parasitoid is well established in sugarcane ecosystem.**
- 1982- Three exotic natural enemies were introduced *viz*., hydrophilic weevils – *Neochetina bruchi* (Ex. Argentina) and *N. eichhorniae* (Ex. Argentina) and galumnid mite *Orthogalumna terebrantis* (Ex. Sout h America) against water hyacinth.
- 1983-1984- Exotic weevil, *C. Salviniae* from Australia against water fern, *Salvinia molesta* in a lily pond in Bangalore.

- 1983- The encyrtid parasitoid *Leptomastix dactylopii* against *Planococcus citri* and *P. lilacinus* from Trinidad, West Indies.
- 1983-A chrysomelid beetle ***Zygogramma bicolorata*** **against parthenium from Mexico**.
- 1988- The coccinellid predator, *Curinus coeruleus* against *H. cubana* from Thailand.
- 2010-Three exotic encyrtid parasitoids viz., *Acerophagus papayae, Anagyrus loecki* and *Pseudleptomastix mexicana*, against papaya mealybug, *Paracoccus marginatus.*

RESEARCH AND TRAINING INSTITUTES ON BIOLOGICAL CONTROL IN INDIA

National Bureau of Agricultural Insect Resources (NBAIR), formerly **National Bureau of Agriculturally Important Insects (NBAII) is located in Bangalore**, Hebbal in the same premises at which The Commonwealth Institute of Biological Control (CIBC), Indian Station was established in 1957. The advent of CIBC marked the beginning of organized and systematic biological control research in India. During this period, our knowledge of natural enemies of crop pests and weeds increased manifold. CIBC Indian station was closed during 1987 and All India Coordinated Research Project on Biological Control of Crop Pests and Weeds (AICRP-BC&W), which was launched in 1977 under the aegis of the Indian Council of Agricultural Research was shifted to the same campus in 1988. The centre was named as Biological Control Centre and the entire programme functioned under the administrative/financial control of the National Centre for Integrated Pest Management (ICAR). In the eighth five-year plan, the project was elevated to an independent Project Directorate of Biological Control, with its headquarters in Bangalore during 1993. PDBC was the nodal agency in the country that organizes biological control research at the national level with 16 centres spread across the country. The Directorate at Bangalore carried out basic research on the biosystematics of important groups of insect bioagents. The reference collection maintained at PDBC was catalogued in the form of a technical bulletin on and also available in a retrievable, electronic format. Besides, work on strain development, molecular characterization, mass production technologies, semiochemicals, biopesticides work for insect and disease management was intensified. During 11th plan, PDBC was upgraded as National Bureau of Agriculturally Important Insects (NBAII) to act as a nodal agency for collection, characterization, documentation, conservation, exchange and utilization of agriculturally important insect resources (including mites and spiders) for sustainable agriculture. In the twelfth five year plan the Bureau is now re-named as National **Bureau of Agricultural Insect Resources (NBAIR)** and the bureau's activities are divided in three divisions.

In Gujarat, Department on Entomology, N.M. College of Agriculture, Navsari Agricultural University, Navsari is working on biological control of crop pests under Plan scheme (Development Charges) Project entitled **"Strengthening Research in Biological Control of Crop Pests"** since 2007-08. Moreover, at AAU, Anand (Gujarat) is working on ICAR sponsored **"All India Coordinated Research Project (AICRP) on Biological Control of Crop Pests and Weeds"** since 1977.

Definitions of biological control:

1. H. S. Smith (1919) defined First used term "**biological control**" to signify the use of natural enemies (whether introduced or otherwise manipulated) to control insect pests.
2. **Biological control** is defined as the action of parasites, predators, or pathogens in maintaining another organism's population density at a lower average than would occur in their absence (Paul DeBach, 1964).

3. Van den Bosch *et al.* (1982) defined the **applied biological control** as the "manipulation of natural enemies by man to control pests. They further noted **natural biological control** as that "control that occurs without man's intervention.

Important terminologies:

Biological control: Biological control is a process in which one species population lowers the numbers of another species by mechanisms such as predation, parasitism, pathogenesis or competition or Biological control involves use and manipulation of natural enemies by man.

Biological control practices involves three major techniques (Three pillars)

1. **Introduction or classical biological control**: It is the deliberately introduction and establishment of natural enemies to a new locality where they did not occur or originate naturally. When natural enemies are successfully established, it usually continues to control the pest population.
2. **Augmentation:** It is the rearing and releasing of natural enemies to supplement the numbers of naturally occurring natural enemies. There are two approaches to augmentation.
   - **Inoculative releases:** Large numbers of individuals are released only once during the season and natural enemies are expected to reproduce and increase its population for that growing season. Hence control is expected from the progeny and subsequent generations and not from the release itself.
   - **Inundative releases:** It involves mass multiplication and periodic release of natural enemies when pest populations approach damaging levels. Natural enemies are not expected to reproduce and increase in numbers. Control is achieved through the released individuals and additional releases are only made when pest populations approach damaging levels.
3. **Conservation:** Conservation is defined as the actions to preserve and release of natural enemies by environmental manipulations or alter production practices to protect natural enemies that are already present in an area or non use of those pest control measures that destroy natural enemies.

Important conservation measures are: Use selective insecticides which are safe to natural enemies. Avoidance of cultural practices those are harmful to natural enemies and use favorable cultural practices. Cultivation of varieties those favour colonization of natural enemies. It will provide the alternate hosts for natural enemies. Preserve the inactive stages of natural enemies. Provide pollen and nectar for adult natural enemies.

- **Predator:** A predator is free living organism throughout its life, it kills and prey, is usually larger than its prey and require more than one prey to complete its development. e.g. *Chrysoperla zastrowi sillemi*.
- **Parasitoid:** A parasitoid is a specific kind of parasite which is often about the same size as its host, kills its host and requires only one host (prey) for development in to free living adults. e.g. Braconids wasp.
- **Parasite**: A parasite is an organism which is usually much smaller than its host and a single individual usually doesn't kill the host. Parasite may complete their entire life cycle (eg. Lice) or may involve several host species. OR Parasite is one, which attaches itself to the body of the other living organism either externally or internally and gets nourishment and shelter at least for a shorter period if not for the entire life cycle. The organism, which is attacked by the parasites, is called hosts.
- **Parasitism:** Is the phenomena of obtaining nourishment at the expense of the host to which the parasite is attached.

- **Microbial Control:** When microbial organisms or their product (toxin) are employed by man for the control of insects, animals and plants in particular area, is referred as microbial control e. g. Virus, Bacteria, Protozoa , Fungi, etc.

Qualities of a Successful Parasitoid in Biological Control Programme:

A parasitoid should have the following qualities for its successful performance. It should be adaptable to environmental conditions in the new locally. It should be able to survive in all habitats of the host. It should be specific to a particulars species of host or at least a narrowly limited range of hosts. It should be able to multiply faster than the host. It should have more fecundity. Life cycle must be shorter than that of the host. It should have high sex ratio. It should have good searching capacity for host. It should be amendable for mass multiplication in the labs. It should bring down host population within three years. There should be quick dispersal of the parasitoid in the locality. It should be free from hyperparasitoids.

Some successful examples of biological control of insect pests:

1. Control of cottony cushion scale, *Icerya purchasi* on fruit trees by its predatory Vidalia beetle, *Rodolia cardinalis* in Nilgiris. The predator was imported from California in 1929 and from Egypt in 1930 and multiplied in the laboratory and released. Within one year the pest was effectively checked.
2. For the biological suppression of Water Fern, *Salvinia molesta*, the weevil, *Cyrtobagous salviniae*, was imported from Australia in 1982. Exotic weevil, *C. salviniae* was released for the control of water fern, *S. molesta* in a lily pond in Bangalore in 1983-84. Within 11 months of the release of the weevil in the lily pond the salvinia plants collapsed and the lily growth, which was suppressed by competition from salvinia resurrected.
3. Biological Control of Water Hyacinth, *Eichhornia crassipes*, three exotic natural enemies were introduced in India *viz*., hydrophilic weevils - *Neochetina bruchi* and *N. eichhorniae* (Argentina) and galumnid mite, *Orthogalumna terebrantis* (South America) in 1982 for the biological suppression of water hyacinth.
4. Apple woolly aphids, *Eriosoma lanigerum* in Coonor area by *Aphelinus mall* (parasitoid).
5. Control of shoot borers of sugarcane, cotton bollworms, stem borers of paddy and sorghum with the egg parasitoid, *Trichogramma australicum* @ 50,000/ha/week for 4-5 weeks from one month after planting.
6. *Centrococcus isolitus* on brinjal; Pulvinaria *psidi* on guava and sapota; *Meconellicoccus hirsutus* on grape and *Pseudococcus carymbatus* on citrus suppressed by *Cryptolaemus montrouzieri.*

Parasites can be grouped as furnished below;

I. Depending upon the nature of host,

Zoophagous	**:**	that attack animals (cattle pests)
Phytophagous	**:**	that attack plants (crop pests)
Entomophagous	**:**	that attack insects (parasites)
Entomophagous insects	**:**	parasitoids

II. Based on the specialization of the site of parasitisation

1. **Ectoparasites:** they attack its host from the outside of the body of the host. The mother parasite lays its eggs on the body of the host and after the eggs are hatched the larvae feed on the host by remaining outside only. E.g. *Epiricania melanoleuca*, etc.

2. **Endoparasite**: They enter the body of the host and feeds from inside. The mother parasite either lays its eggs inside the tissues of the host or on the food material of the host to gain entry inside. Eg. Braconids and Icheneumonids, *Apanteles flavipes* on sorghum stem borer larvae.

III. Specialization based on the stage of the host

Eg. Host: Coconut black headed caterpillar, *Opisina arenosella*

1. Egg parasite : *Trichogramma australicum*
2. Early larval parasite - *Apanteles taragama*
3. Mid larval parasite - *(Micro) Bracon hebtor*
4. Prepupal parasite - *Goniozus nephantidis*
5. Prepupal parasite - *Elasmus nephantidis*
6. Pupal parasite -*Stomatoceros sulcatiscutellum, Trichospilus pupivora, Testrastichus israeli,*

IV. Depending upon the duration of attack

1. **Transitory parasite**: It is not permanent but transitory parasite which spends a few stages of its life in one host and other stages on some other species of hosts or as a free living organism. Eg. Braconids and Ichneumonids.
2. **Permanent parasite:** This spends all the stages of its life on the same host. Eg. Head louse.

V. Depending upon degree of parasitization

1. **Obligatory parasites:** Parasite, which can live only as a parasite and cannot live away from the host even for shorter period. E.g. Bird lice, Head louse.
2. **Facultative parasite:** Parasite, which can live away from the host at least for a shorter period E.g. Fleas.

VI. Depending upon the food habits

1. **Polyphagous:** develops on number of widely different host species E.g. *Bracon sp*. *Apanteles* sp on lepidopteran caterpillars.
2. **Oligophagous:** which has very few hosts (more than one host) but all the hosts are closely related. E.g. *Isotema javensis* on sugarcane and sorghum borers.
3. **Monophagous**: which has only one host species and can't survive in another species i.e. host specific. E.g. *Goniozus nephantidis* on *Opisina arenosella.*

Kinds of Parasitism

I. **Parasite:** A parasite is an organism which usually much smaller than its host and a single individual usually does not kill the host.

II. **Super parasitism:** It is type of parasitism where more individuals of the same species are present in a single host and that can complete development in a normal way. Generally survive one per host. Phenomenon of parasitization of an individual host by more larvae of single species that can mature in the host. E.g. *Apanteles glomeratus* on *Pieris brassica, Trichospilus pupivora* on *Opisina arenosella.*

III. **Multiple parasitisms:** It is the type of parasitism where the host is attacked by two or more species of parasitoids. Usually death results in the death of less aggressive species of parasitoids. Phenomenon of simultaneous parasitization of host individual by two or more different species of primary parasites at the same time. E.g. *Trichogramma, Telenomous* and *Tetrastichus* attack eggs of paddy stem borer *Scirpophaga incertulas.* Super parasitism and multiple parasitisms are generally regarded as undesirable situations since much reproductive capacity is wasted.

IV. **Hyper parasitism:** It is type of parasitism in which a parasitoid attacks another parasitoid. Secondary parasitoids is harmful, while tertiary useful. When a parasite itself is parasitized by another parasite.E.g. *Goniozus nephantidis* is parasitized by *Tetrastichus israeli,* Most of the Bethylids and Braconids are hyper parasites.

V. **Simple parasitism** irrespective of number of eggs laid the parasitoid attacks the host only once. E.g. *Apanteles taragamae* on the larvae of *Opisina arenosella, Goniozus nephantidis.*

Hierarchy of parasitism:

1. **Primary parasite**: A parasite attacking an insect which itself is not a parasite (Beneficial to man.).
2. **Secondary parasite**: A hyperparasite attacking a primary parasite (Harmful to man)
3. **Tertiary parasite:** A hyperparasite attacking a secondary parasite (Beneficial to man)
4. **Quaternary parasite**: A hyperparasite attacking tertiary parasite (Harmful to man)

A primary parasitoid becomes harmful in case of productive insects like silkworms, *Bombyx mori* and lac insect *Kerria lacca.*

Predators and Predatory mechanism:

A predator is one which catches and devours smaller or more helpless creatures by killing them in getting a single meal. It is a free living organism throughout its life, normally larger than prey and requires more than one prey to develop.

Insect predator qualities:

A predator generally feeds on different species of prey, thus being a generalist or polyphagous nature. A predator is relatively large compared to its prey, which it seizes and devours quickly. Typically individual predator consumes large number of prey in its life time E.g. A single coccinellid predator larva may consume hundreds of aphids. Predators kill and consume their prey quickly, usually via extra oral digestion. Predators are very efficient in search of their prey and capacity for swift movements. Predators develop separately from their prey and may live in the same habitat or adjacent habitats. Structural adaptation with well developed sense organs to locate the prey. Predator is carnivorous in both its immature and adult stages and feeds on the same kind of prey in both the stages. May have cryptic colourations and deceptive markings. Eg. Preying mantids and Robber flies.

Predatory mechanism:

Based on the degree of use fullness to man, the predators are classified as on entirely predatory, E.g. lace wings, tiger beetles lady bird beetles except *Henosepilachna* genus. Mainly predator but occasionally harmful. E.g. Odonata and mantids occasionally attack honey bees. Mainly harmful but partly predatory. E.g. Cockroach feeds on termites. Adult blister beetles feed on flowers while the grubs predate on grass hopper eggs. Mainly scavenging and partly predatory. E.g. Earwigs feed on dead decaying organic matter and also fly maggots. Both ways, it is helpful. Variable feeding habits of predator, E.g. Tettigonidae: omnivorous and carnivorous but damage crop by lying eggs. Stinging predators. In this case, nests are constructed and stocked with prey, which have been stung and paralyzed by the mother insect on which the eggs are laid and then scaled up. Larvae emerging from the egg feed on paralyzed but not yet died prey. E.g. Spider wasps and wasps, etc.

1. Parasitoids Order:

A.	**Order: Hymenoptera** The ovipositor originates and protrudes ventrally from the abdomen and is used to

	insert eggs into their hosts. There are three super families.
a.	**Super Family: Ichneumonoidea** • Possess long and filiform antennae. • Wings are veined.
1.	**Family: Ichneumonidae** • Eg. *Eriborus trochanteratus,* a larval parasitoid on coconut black headed caterpillar, *Opisina arenosella*. • Antennae longer with more than 16 segments. • Trochanter two segmented. • Possesses two recurrent veins and rarely one. • Abdomen three times as long as the rest of the body. • Ovipositor longer than the body. • Large slender black, yellow or reddish yellow insects. • Larvae are endo or ecto parasitic on many groups of insects and spiders.
2.	**Family: Braconidae** • Eg. *Bracon brevicornis,* a larval parasitoid on *O. arenosella*, *Chelonus blackburni,* egg larval parasitoid on cotton spotted bollworms, *Earias* spp. • Adults are relatively small; body is stouter than ichneumonids. • Abdomen is about as long as the head and thorax combined. • Not more than one recurrent vein. • Adults not as bright as ichneumonids. • Mostly endoparasitic on lepidopteran larvae.
b.	**Super Family: Chalcidoidea** • Mostly smallest parasitoids and gregarious. • Antennae geniculate. • Abdomen very short or globular with very slender propodeum. • Wings without veins.
1.	**Family: Chalcididae** • Eg. *Brachymeria nephantidis* a larval parasitoid on *O. arenosella*. • Minute insects. • Abdomen humped. • Hind femur enlarged and toothed. • Wings are not folded longitudinally when at rest. • Ovipositor straight and short. • Parasitic on Lepidoptera, Diptera and Coleoptera.
2.	**Family: Trichogrammatidae** • Eg. *Trichogramma chilonis,* an egg parasitoid on many lepidopterous pests. • Mostly egg parasitoids. • Minute insects (0.40 to 0.70 mm long) with three segmented tarsi and broad and elongated forewings with rows of microscopic hairs on them. • Hind wings reduced with hairs.
3.	**Family: Eulophidae** • Eg. *Trichospilus pupivora* and *Tetrastichus israeli,* pupal arasitoids on *O. arenosella.*

	• Adults have four segmented tarsi. • Many have brilliant metallic colouring. • Males of many species have pectinate antennae. • Mostly parasitic on aphids and scales and some are on pupae of Lepidoptera.
c.	**Super family: Bethyloidea** • Smaller than ichneumonoidea and larger than Chalcidoidea.
1.	**Family: Bethylidae:** • Eg. *Parasierola (= Goniozus) nephantidis,* a larval parasitoid on *O. arenosella.* • Small to medium sized, usually dark coloured wasps. • Females of many species are wingless and antlike in appearance. • In a few species, both winged and wingless forms occur in each sex. • Parasitic on Lepidoptera and Coleoptera.
B.	**Order: Diptera**
1.	**Family: Tachinidae** • Eg. *Sturmiopsis inferens,* a larval parasitoid on sugarcane shoot borer, *Chilo infuscatellus.* • Large bristle flies. • Eggs may be macrotype or microtype. • Macrotype eggs are laid directly on the host's body usually attached to the neck region by a glutinous secretion. • Eg. *Spoggosia bezziana* on *O. arenosella.* • Microtype eggs are laid on the host plant and the host larvae feeding on the plant tissue ingest them.
C.	**Order: Lepidoptera**
1.	**Family: Epiricanidae** • Eg. *Epiricania melanoleuca*. • Parasitic on nymphs and adults of sugarcane leafhopper, *Pyrilla perpusilla.*

2. Predators Order:

A.	**Order: Odonata**
a.	**Sub order: Anisoptera** Eg. Dragon fly **Sub order: Zygoptera** Eg. Damsel fly • Relatively larger sized insects. • Immature stages are aquatic (naiads) feeding on aquatic insects. • In naiads, labium is modified into a prehensile organ called mask for catching the prey. • Adults feed on midges, mosquitoes, flies and small moths. • Adults are capable of catching prey during flight with the help of basket shaped legs.
B.	**Order: Dictyoptera**
1.	**Family: Mantidae** • Preying mantids are large elongate insects. • Nymphs and adults are cryptically coloured with long prehensile raptorial forelegs. • Highly predaceous feeding on variety of insects like flies, grasshopper and many caterpillars Eg. *Mantis religiosa.*

C.	**Order: Hemiptera**
1.	**Family: Reduviidae** • Assassin bugs or cone nose bugs or kissing bugs. • Usually blackish or brownish in colour. • The beak or proboscis is short and three segmented. • Most are predaceous and some are blood sucking. • Both nymphs and adults are predaceous. • Eg. *Harpactor costalis* on the red cotton bug *Dysdercus cingulatus.*
2.	**Family: Pentatomidae** • Stink bugs. • Bugs are shield shaped with 5 segmented antennae. • Some of the species are predaceous on lepidopterous larvae. • Both nymphs and adults are predaceous. • Eg. *Eucanthecona furcellata* on the larvae of red hairy catepillar, *Amsacta albistriga* and gram caterpillar, *Helicoverpa armigera.*
3.	**Family: Belostomatidae** • Giant water bug. • Elongate oval and somewhat flattened with raptorial forelegs. • Feed on variety of aquatic insects.
4.	**Family: Miridae** • Elongated soft bodied insects. • A few species are predaceous. • Eg. Green mirid bug, *Cyrtorhinus lividipennis* feeds mainly on the eggs and early stage nymphs of green leaf hopper (GLH), brown plant hopper (BPH) and white backed plant hopper (WBPH) in rice.
5.	**Family: Veliidae** • Ripple bugs. • Aquatic insects living on the surface of water. • Brown or black in colour. • Eg. *Microvelia atrolineata* feeding on the first instar caterpillar of lepidopteran pests and GLH, BPH and WBPH in rice ecosystem.
D.	**Order: Neuroptera**
1.	**Family: Myrmeliontidae** • Ant lions • Larvae construct pit falls and remain buried in the soil. • Feed on the ants and other insects that fall into the pits. • Feed by inserting the mandibulo-suctorial mouth parts into the prey and sucking the internal contents.
2.	**Family: Chrysopidae** • Aphid wolfs aphid lions or green lace wings. • Adults are green in colour with golden or copper colored eyes. • Feed on more than 18 families of insects. • The larvae are predaceous mainly on aphids and also on eggs of lepidopteran insects,

	psyllids, coccids, thrips and mites. • Larvae have sharp mandibles. • The eggs of aphid lions are stalked (pedicellate).
E.	**Order: Diptera**
1.	**Family: Asilidae** • Robber flies • Adults are mostly elongate with tapering abdomen. • Body is covered with dense hairs. • Legs are long, strong and well developed. • Adults are predaceous and attack a variety of insects like wasps, bees, grasshoppers, flies etc. • Mouth parts are piercing type. They feed by sucking the body fluid of the prey.
2.	**Family: Syrphidae** • Hover fly adults are brightly coloured and resemble various bees and wasps. • Good pollinators. • Maggots are green in colour and feed on aphids by sucking their body fluids.
F.	**Order: Coleoptera**
1.	**Family: Coccinellidae** • Lady bird beetles • Beetles are small, oval, convex and often brightly coloured. • Grubs are elongate, somewhat flattened and covered with minute tubercles or spines. • Adults and grubs feed on aphids, coccids, mealy bugs, whiteflies and other soft bodied insects. • Except one or two species in the family all are predaceous. • Eg. *Rodolia cardinalis* on cottony cushion scale, *Icerya purchasi.*
2.	**Family: Carabidae** • Ground beetles. • Dark in colour and shiny and somewhat flattened. • Most of them feed on caterpillars. • Eg. *Anthia sexguttata, Ophionea indica.*
3.	**Family: Cicindelidae** • Tiger beetles. • Beetles are very active and brightly coloured. • They run and fly rapidly. • Both adults and grubs are predaceous. • Adults capture the prey with sickle shaped mandibles. • Eg. *Cichidela* spp.
4.	**Family: Staphylinidae** • Rove beetles. • Eg. *Paederus fuscipes* feeds on rice leaf folder.
G.	**Order: Hymenoptera**
1.	**Family: Vespidae** • Wasps collect various insects and feed their larvae with them.

	• Mud wasps construct nests made of mud and provide caterpillars for the young ones in the nest.
2.	**Family: Sphecidae** • Digger wasps construct nests made of mud and feed its young ones with insect caterpillars.
3.	**Family: Formicidae** • About half the members of the family are predaceous upon insects.
H.	**Order: Lepidoptera**
1.	**Family: Pyralidae** • Eg. *Dipha aphidivora.* • Feed on nymphs and adults of sugarcane wholly aphid, *Ceratovacuna lanigera.* • A single larva of *D. aphidivora* consumed on an average 6000 sugarcane woolly aphids during its 25 days of total larval period.

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PART-IV: PREDATORS AND PARASITOIDS
(MASS PRODUCTION TECHNIQUES OF BIOAGENTS)

Mass production technology:

[1]. Methodology for mass production of *Trichogramma chilonis* Ishii

A large number of Trichogramatids are reported as egg parasitoids of 200 insect species belonging to 70 families and 8 orders in diverse habitats of the world. In India about 26 *Trichogramma* species are recorded of which *T. chilonis, T. japonicum* and *T. achaea* etc. are widely distributed and are key mortality factors for many crop pest. These parasitoids attack eggs of many lepidopterous pest such *viz*., *Chilo* spp., *Scirpophaga excerptalis, Scirpophaga incertulas, Helicoverpa armigera, Agrotis* spp. *Pectinophora gossipiella, Earias* spp., *Chilo partellus* etc. The **Trichogramatids are minute parasitic wasps measuring 0.40 to 0.70 mm in length.** It completes its developments in about 8-10 days. For mass production of Trichogramatids, rice moth, *Corcyra cephalonica* is used as laboratory host in India. However, in many European countries, Angoumois grain moth, *Sitotroga cerealella* is used as factitious host for its mass production.

Mass production of *Corcyra cephalonica* (Stainton)*:*

Materials required: Round iron or galvanized trays or rectangular wooden trays, broken grains for sorghum or maize, yeast powder, muslin cloth, oviposition cage provided with an inlet to introduce the moths and the bottom fitted with 40 mesh wire net, moth collecting glass tubes with funnel mouth, plastic tube, wooden racks, petri dishes, oven, honey solution, etc.

Methodology: Broken sorghum or maize grains are first sterilized at 70^0C for 2 hours in a hot air oven. Thereafter, the same grain should be conditioned (keep grains for overnight in laboratory) before use. The sterilized grains are mixed with dried yeast powder @ 2 g/kg and 2.5 kg grains are kept in each tray. One cc eggs of *Corcyra* are sprinkled in each tray and kept for development. The tray are covered with a thick cloth or kept open in a low roofed rearing room. After emergence larvae feed on the grains and pupate inside the tray itself. The moth emergence starts from 30^{th} day onwards. The moths are collected daily and in oviposition cages for deposition. The moths lay most of the eggs within 3 days after emergence. The eggs are collected from the oviposition cages early in the morning and are used for the multiplication of *Trichogramma.*

Mass production of *Trichogramma chilonis* Ishii

Materials required: Glass jar/plastic bottles for keeping (exposed/parasitized) egg cards, egg cards, petri dishes, measuring cylinder, sieves, plastic trays, microscope, UV chamber, gum, camel hair brush, etc.

Methodology: The *Corcyra* eggs are obtained by confirming the moths in an oviposition cage. The eggs collected are passed through 25, 30 and 40 mesh sieves and run over a slope of paper to eliminate dust particles and scales of *Corcyra.* The eggs are exposed to ultra violet rays (15 Wt UV tube) for 30 minutes in UV chamber to kill the embryo. The sterilized egg are filled in plastic vial (9x5 cm) and closed with a lid of wire mesh (40 mesh) for uniform spreading on cards pasted with a thin layer of dilute gum, *Acacia.* The eggs are glued to Trichocards of 15 x 10 cm size which are perforated to obtain 10 pieces (measuring 2.5 cm) leaving uncovered one end to facilitate stapling. The cards are placed in plastic bottles in which freshly emerged parasitoids are present or place the parasitized egg cards from which adult emergence is expected in a day. Host parasitoid ratio of 6:1 is to be maintained to avoid super parasitism. The jars/bottles are kept at 27± 2° C. Normally the eggs are exposed for parasitization for 24 to 48 hours. Parasitized eggs

start turning black on 3rd day after parasitization. Normally 80 to 90 % parasitization is expected in healthy culture. Parasitized egg cards can be stored in refrigerator at 12-15°C for 10 to 15 days. Prolonged storage will impair emergence, longevity and fecundity of the progeny. Only freshly laid eggs are preferred by *Trichogramma* female for oviposition.

Transport of egg cards:

The parasitized egg cards can be easily transported in the pupal stage (3 days after parasitization) by folding the cards and kept in polythene bags.

Release of *Trichogramma* in field:

The parasitoid may be released in the field as adults or the parasitized egg cards and it may be stapled to the underside of the leaves of crop plant by keeping eggs side on ground direction. The egg card can also be kept in plastic release boxes fitted with wire mesh at the bottom for adult emergence. The boxes may be either fixed on wooden poles or hung on host plant. The trichocards may be cut in to pieces through markings and hanged under plastic cup tied in inverted manner below plant twig.

Precautions:

It is advisable to observe the following precautions during packaging and release of *Trichogramma* for better results.

- Trichocards should be packed keeping the surface with the parasitized eggs on the inner side.
- Emergence date should be specified on cards for the guidance of the end user.
- Cut pieces of Trichocards should be stapled on the inner side of leaf to avoid direct sunlight.
- Card pieces should be stapled in morning hours just before emergence to avoid predation.
- If adults of *Trichogramma* are to be released, the farmers should open the jar containing adult trichogrammatids and go on tapping the jar till all the adults fly out while walking in the field.
- Refrain from using pesticides for a week in the field where *Trichogramma* are released. If need arises use botanical or selective/safer insecticides.

[2] Methodology for mass production of *Chrysoperla zastrowi sillemi*:

Sucking pests cause serious losses to many field, plantation and horticultural crops. Green lace wing (Aphid lion), *Chrysoperla zastrowi sillemi* is a potent predator of many sucking pests. The mass production technique of a predator is given below:

Materials required: *Corcyra cephalonica* rearing unit for the egg production, nucleus culture of *Chrysoperla spp.*, rearing trays, plastic jars, slotted angle iron racks, working tables, weighing balance, scissors, brushes, cotton wool, forceps, tissue paper, brown paper separators, Foam sheet, sponge, acrylic sheet, Fructose, protinex, honey, yeast, castor, pollen, etc.

Methodology: Steps involved in mass rearing of *Chrysoperla zastrowi sillemi*

- Conceal 200 pairs of adults in oviposition case, measuring 75 x 30 x 30 cm. The sides of the cage are lined with smooth nylon wire mesh (not preferred for egg laying) and the sliding top cover is fitted with **black cloth for obtaining eggs**. To prevent damage to the eggs, the top is slides over a comb fitted on both the sides of the cage. The sliding top cover is replaced on alternate days starting from 4th day onwards. The oviposition cage is kept for 30 days and the dead adults are removed every alternate day.

- The adults in oviposition cage are fed on alternate days on cotton wool swabs soaked with the ingredients in a proper way *viz*., Drinking water, Honey 50% solution, Protinex mixture (equal quantity of protinex + fructose + powdered yeast dissolved in small quantity of water). Two swab of each of the three liquid should be hanged in case with the help of thread and thin iron wire. If sometime such case is not available, the emerged adults may be kept in desiccators or plastic jar containing honey solution soaked cotton wicks and closed with black cloth. Keep in side cotton leaves or tissue paper or brown paper or black paper for oviposition.
- One day old eggs (Egg chorion gets hardened) are dislodged from the black cloth top cover of oviposition cage by gently moving a piece of sponge. Thus, eggs collected can be used for further multiplication.
- Since the larvae of chrysopids are cannibalistic, rear them individually in plastic louvers/vials or in hexagonal cells. Place a foam sheet of the convenient size in the plastic rearing tray. Then, put the paper separators having hexagonal cells on the foam. Sprinkle about 300 to 400 *Corcyra* eggs (already inactivated by exposure to 15 W UV light for an hour) in each hexagonal cell. Introduce 3 day old 1-2 Chrysopid eggs / hexagonal cell. The cover may be secured with the help of lid of the tray. Small opening at the centre of the lid should be provided with wire mesh for aeration.

Utilization for field release and dose: Normally Chrysopids are released in the fields in its 1st instar larval stage against different field crops at the rate of 50,000 to 1, 00,000 larvae/ha or 10-20 larvae/fruit plants. Depending upon pest saturations, 2 releases at fortnightly interval are recommended for control of sucking pests and early instar larvae of Lepidopteran pests.

Methods of release: The *Chrysopid* larvae can be released in the field by;

- Broadcasting larvae with saw dust on thick crop canopy.
- Stapling of Chrysopa card as per the methodology suggested for Trichocards.
- Dropping 1 or 2 larvae per plant on leaves or 10-20 larvae/tree placing corrugated paper strip on the plants/trees or the eggs mixed in saw dust are dropped on crop canopy.

Precautions:

- Rear the grub stage individually to avoid cannibalism.
- Release should be made in early morning hrs to settle larvae on crop canopy.
- Avoid to release freshly laid eggs as they may be parasitized or predated in more numbers in the field.
- Do not use pesticides in the field where the predators are released: otherwise use selective/safer pesticides after or before 10-15 days of release following strip or staggered spray method.

[3] Methodology for mass production of *Cryptolaemus montrouzieri* Mulsant:

C. montrouzieri has been introduced from Australia for the control of *Coccus viridis* on coffee. But the predator has established on many species of mealy bugs and green shield scale. In the field its practical use for the suppression of mealy bugs *viz*., pink mealy bug, *Maconellicoccus hirsutus*, citrus mealy bug *Planococcus citri*, tailed mealy bug, *Ferrisia virgata* and mealy scale *Pulvinaria maxima* on citrus, coffee, grapes and several other fruit crops and ornamentals has been demonstrated. Use of *C. montrouzieri* is the breakthrough in applied classical biological control.

Production procedures of predator:

In the laboratory, the life cycle is completed within approximately 30 days. The pre-mating and pre-oviposition periods are about 5 and 10 days, respectively. The oviposition is about 10 days. Eggs are laid from late evening to early morning. They are pale yellowish white, the surface being smooth and shiny. It is oval to cylindrical, both the ends beings smoothly rounded. Incubation period ranges from 5 to 6 days but extended in winter months. Viability of eggs is 90-100%. The newly hatched grub is sluggish but becomes active after 3 to 4 hours. The tiny grub is pale grayish with white lines across the body along intra segmental regions. These white lines become prominent after few hours and white wax strands develop after a day. The grub has four larval instars, and the larval stage occupies about 20 days. They feed on all stages of mealy bugs. Duration of first, second, third and fourth instar grubs are 3-4, 4, 4-5 and 7-8 days, respectively. Grownup grubs are entirely covered with white wax strands. When the grub is disturbed, it exudes a yellow fluid from the dorsal surface of the body for defensive purpose. The pre-pupal period is 2 to 4 days when it suspends feeding activities. The pupal period varies from 7 to 9 days.

The adult spends about one day in the pupal case before it emerges. It is covered with a white powder like substance for a day. The male could be distinguished from the female by the colouration of first pair of legs. The first pair of legs in the case of male is brown and the latter two pairs being black, whereas in the female all the three pairs are black. Male to female ratio is 1: 1. Adults are also known to attack and feed the mealy bugs. Longevity of adults ranges from 50 to 60 days and the fecundity is about 200-220 eggs.

Feeding behaviour:

Both adults and grubs are predating almost all stages of the mealy bug. However the grubs are voracious feeders. The coccinellid grub consumes a total of 900 to 1500 mealy bug eggs in its development. A single grub can eat as many as 30 nymphs or 30 adult mealy bugs. Fourth instar grub is the most voracious feeder of the mealy bugs. After 15 days of infestation of pumpkins with bugs they are exposed to a set of 100 beetles for 24 hrs. After exposing, the pumpkin is kept back in a cage as described for under production of *M. hirsutus*. The beetle during the period of exposure feed on mealy bugs as well as deposits their eggs singly or in groups of 4-12. The grubs are visible in such cages within a week of exposure to beetles. The young grubs feed on eggs and small mealy bugs but as they grow they become voracious and feed on all stages of mealy bugs. For facilitating the pupation of grubs dried guava leaves or pieces of papers are kept at the base of each of the cages. The first beetle from the cages starts emerging on 30^{th} day of exposure to *C. montrouzieri* adults. The beetles are collected daily and kept in separate cages for about 10-15 days to facilitate completion of mating and pre-oviposition. The beetles are also fed on diet containing agar powder (1 g), sugar (20 g), honey (40 cc) and water (100 cc). The adult diet is prepared by boiling sugar in 70 ml of water, adding 1 g agar, diluting 40 ml honey in 30 ml of water and adding to the sugar and agar mixture when it comes to boiling point. The hot liquid diet is kept on small white plastic cards in the form of droplets which get solidified on cooling. Such cards containing adult diet can be fed not only to *C. montrouzieri* but also to many other species of coccinellids. From each cage about 175 beetles are obtained. The emergence of the beetles is completed within 10 days. Beetles can also be reared on *Corcyra cephalonica* eggs but empty ovisacs of *Planococcus citri* are to be kept for inducing egg laying by the beetles.

Precautions:

All due precautions should be taken to avoid scarcity of food for the grubs to avoid cannibalism by grubs. All the pumpkins showing signs of rotting should be properly incinerated.

Storage of lady bird beetle:

Eggs/larvae are not advisable for storage.

Adult: Keep them in transparent container of about 2 l capacities. Keep artificial diet in the container. Store under refrigerator conditions at 7± 1º C temperature. A total of 150-200 adults can be stored in one container.

Transportation:

Larvae: Keep the larvae in specially made plastic capsules having some diet and minute holes for aeration. Take all required precautions/cares.

Handling, storage and transportation of important bio-agents:

Care requires: A material of bio-agents should be live, it should not be adversely affected by other biotic factors and it should fulfill requirement of farmers. Bio-agents should be taken care of for taxonomical studies, educational studies, bio-assaying studies. It should be capable of introduction/inundative/inoculative releases. It should be re-cultured and capable of redistribution.

Shipment of bio agents: To dispatch of bio-agents from one place to another place is known as introduction. For insects which are produced from the laboratory or collected from the field are usually shipped. The insects collected from field in mass usually used for rearing/mass multiplications. Insects are transported or sent in a plastic/paper container with good perforation. If the insects are transported in plastic container keep some pieces of tissue papers to provide crawling surface and to absorb excess moisture.

General cares while transporting bio-agent: Provide crawling surface by adding creased/crumpled tissue paper or towel. Remove excess moisture from containers. Provide adequate ventilation by creating punch holes on lids with pin/needle for breathing. Predators like spider/ants should not be trapped while sorting/packaging in the containers. Do not expose bio agents to heat above 80 °F, keep container at cool places and out of direct sunlight. Provide sugar cubes/honey soaked moist sponge when adults are shipped. Containers should be sealed with adhesive tape to avoid entry of ants. Container/packets to be labeled with red bold letter with red pen as **HANDLE WITH CARE, DON'T EXPOSE TO SUN' INSECTS OF GREAT SCIENTIFIC VALUE.** To be sent by personal message through courier/private vehicle or speed post or air-mail or any other fast mode of transport. If it is sent out side India a custom clearance certificate is requires pasting on container/consignment. It should be sent through quarantine department. There should not be presence of any hyper parasite in the container.

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PART-IV: PREDATORS AND PARASITOIDS….continue

(IDENTIFICATION OF OTHER IMPORTANT POLLINATORS, WEED KILLERS AND SCAVENGERS)

I. Pollinators:

A pollinator is the biotic agent (vector) that moves pollen from the male flower to the female flower to accomplish fertilization.

Role of pollinators:

- Pollination refers to the transfer of anther to stigma in flowering plants for sexual reproduction.
- An insect plays great role in cross-pollination of fruits, vegetables, ornamentals, cotton, tobacco, sunflower and many other crops.
- Insect pollination helps in uniform seed set, improvement in quality and increase in crop yield.

Entomophily refers to cross pollination aided by insects

Pollination	Type of insects
Melitophily	Bees
Cantharophily	Beetles
Cantharophily	Syrphid and Bombylid flies
Sphigophily	Hawk moths
Phalaeophily	Small moths

1. Honeybees as pollinators

- All bee species aid in pollination
- Value of honey bees in pollination is 15-20 time higher than that of the honey and wax it produces.

Crop	Per cent increase in yield due to bee pollination
Mustard	43 %
Sunflower	32-48 %
Cotton	17-19 %
Lucerne	112 %
Onion	93 %
Apple	44 %
Cardamom	21-37 %

2. Hoverflies *Syrhus sp*. (Syrphidae: Diptera)

- Brightly coloured flies
- Body is striped or banded with yellow or blue
- Resemble bees and wasps
- Larval stage predatory, adults are pollinators
- Crops pollinated – carrot, cotton, pulses

3. Carpenter bee, *Xylocopa sp*. (Xylocopinae: Anthophoridae)

- Robust dark bluish bees with hairy body
- Dorsum of abdomen bare, pollen basket absent
- Adults are good pollinators
- Construct galleries in wood and store honey and pollen

4. Digger bees, *Anthophora sp*. (Anthophoridae: Hymenoptera)

- Stout, hairy, pollen collecting bees
- Abdomen with black and blue bands

5. Fig wasp, *Blastophaga psenes* (Agaonidae: Hymenoptea)

- Fig is pollinated by fig wasp only.
- There is no other mode of pollination.
- There are two types of fig **CAPRI FIG and SMYRNA FIG.**

CAPRI FIG	SMYRNA FIG
• It is a wild type of fig-not edible • Has both male and female flowers • Pollen is produced in plenty • Natural host of fig wasp	• It is the cultivated type of edible fig • It has only female flowers • Pollen not produced • Not the natural host of fig wasp

In fig wasps males are wingless, present in Capri fig and females winged. Female wasp lays eggs in Capri fig, larvae develops in galls in the base of the flowers. Male mates with female even when the female is inside gall. Mated female wasp emerges out of flower (Capri fig) with lot of pollen dusted around its body. The female fig wasp enters Smyrna fig with lot of pollen and deposits it on the stigma. But it cannot oviposit in the ovary of smyrna fig which is deep seated. It again moves to Capri fig for egg laying. In this process Smyrna fig is pollinated. Capri fig will be planted next to Smyrna fig to aid in pollination.

6. Oil palm pollinating weevil: *Elaeidobius kamerunicus* (Curculionidae: Coleptera)

- Aid in increasing oil palm bunch weight by 35 per cent and oil content by 20 per cent.

7. Other Pollinators

- Butterflies (e.g. *Deilaphila* spp.) and moths (*Acherontia* spp.)
- Ants, flies, stingless bees, beetles, etc.

II. Weed Killers:

Few insects are feed upon unwanted weeds. Because they damage the noxious and menacing weeds, these insects are considered helpful or friendly to man. In many cases the occurrence of these insects has contributed much towards eradication of the weed or at least keeping it in check.

Insects as agents for weed control:

From the year 1902, when eight species of insects were introduced into Hawai from Mexico for the control of *Lantana camera*, insects have been principal agents used in biological control of weeds. These insects feed on various parts of the weed plants and destroy them. Important groups of insects which have been successfully used for weed control are:

Lepidoptera	Phycitidae, Trotricidae
Hemiptera	Coreidae, Tingidae, Coccidae
Coleoptera	Cerambycidae,Chrysomelidae, Buprestidae, Cuurculiionidae, Galeuricidae
Diptera	Agromyzidae, Trypetidae

Action on weeds:

Insects often destroy weeds through direct destruction of vital parts. Ex: Action of *Cactoblastic cactorum* on Opuntia. The weed may die quickly or die during the next season. Insects also attack weeds indirectly through creating favorableness to infection by plant pathogens. Affecting the competitive advantage of the weed.

Desirable attributes of a weed killer:

1. It should not be a pest of cultivated plants (as *Orthezia insignis*) and should not even at a later date turn to attack useful crops, which is often the case with weed killing insects.
2. It should be effective in damaging and controlling the weeds.
3. It should preferably be a borer or internal feeder of the weed. Leaf feeders have also been found to be equally effective in checking weeds.
4. If should be able to multiply in good number without being affected very much by parasitoids and predators.

Examples of biological control of weeds with insects:

1. **Lantana weed, *Lantana camara*:** It is a perennial shrub, native of Central America; is used extensively throughout the world as an ornamental plant. *Ophiomyia lantanae* was introduced into India from Hawaii for the control of Lantana. But an introduced coccid (scale insect) *Orthezia insignis* besides its failure to effectively check the weed began to infest economic plants like citrus, coffee, cinchona and tomato.
2. **Prickly pear, *Opuntia* spp:** The prickly pear, *Opuntia inermis* (*O. stricta*) got accidentally introduced into country by 1840. The cactus spread was so rapid that in the year 1925, 24 million hectares of cultivable land were rendered useless. Control of this weed by chemical and mechanical means was not feasible and was too costly. In 1925 the moth borer, *Cactoblastis cactorum* (Pyralidae: Lepidoptera) was introduced from Argentina and the plants were killed by damaging them into papery structures. Within few years the weed population was reduced to a very great extent that Opuntia was no more a problem.

In India, *Opuntia dilleni* was wrongly introduced in 1780 in the place of *O. cccinellfera* for the cultivation of the commercial cochineal insect *Dactylopius coccus* valued for its dye. The cactus got established and spread rapidly assuming a serious proportion as a noxious weed. *Dactylopius tomentosus* was introduced from Sri Lanka in 1926 and within two years the insect effected a striking control of *Opuntia dilleni* in about 1,00,000 acres.

3. **Crofton weed,** *Eupatorium adenophorum* in Nilgiris and Palani hills was controlled by introducing an exotic Tephritid fly, *Procecidochares utilis* from New Zealand.
4. **Water hyacinth,** *Eichhornia crassipes* was successfully controlled with *Neochetina eichhorniae*, *N.brunchi* and mite *Orthogalumna terebrantis* in Kerala and Karnataka.
5. **Water fern,** *Salvinia molesta* was successfully controlled with *Cryptobagus cingularis* (Curculionidae) in India.
6. **Siam weed,** *Chromolaena odorata* by release of *Parenchaetes pseudoinsulata* (Arctiidae) has been found promising in Kerala and Karnataka.
7. **Congress grass,** *Parthenium hysterophorus* (Carrot weed, white top) has been successfully controlled in Karnataka by Mexican beetle, *Zygogramma bicolorata* (Chrysomelidae).

III. Scavengers:

Insects which feed on dead and decaying plant and animal matter are called scavengers. Remove decomposing material and prevents health hazard. Convert complex material into simple substances e.g. dung roller.

- Rove beetles (Staphylinidae: Coleoptera): Adults and larvae feed on decaying matter.
- Chafer beetles (Scarabaeidae: Coleptera); Bark beetles (Tenebrionidae: Coleoptera); Nitidulids (Nitidulidae: Coleoptera); Water scavenger beetle (Hydrophilidae: Coleoptera); Daddy long legs (Tipulidae: Diptera); Muscid flies (Muscidae: Diptera)
- Termites (Isoptera); Ants (Hymenoptera) – live and feeds upon dead animal and decaying vegetation.

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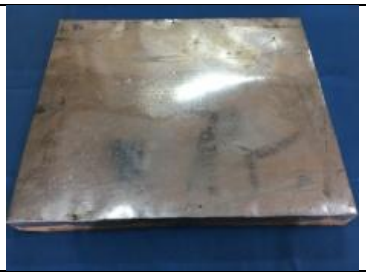
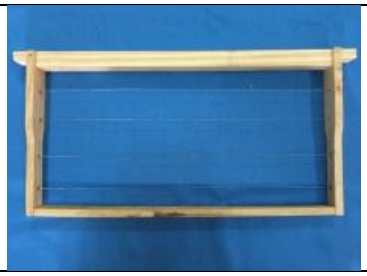
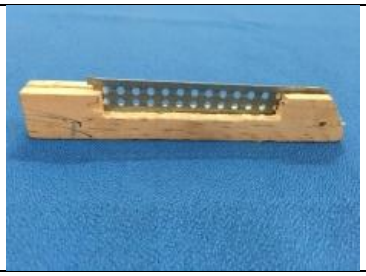
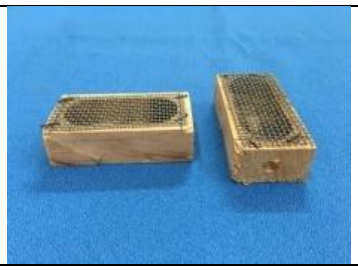
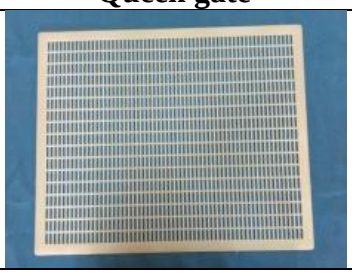
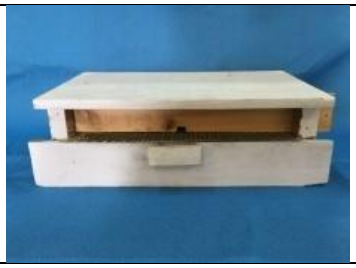
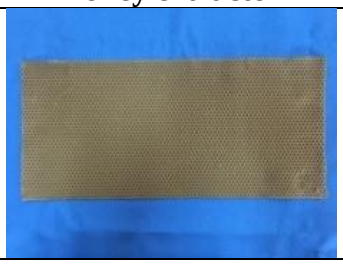
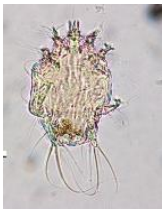
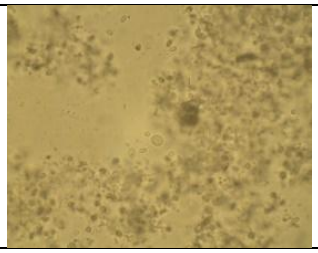
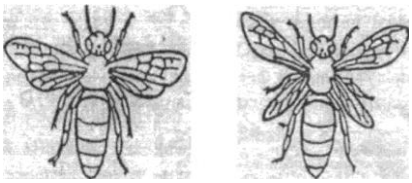
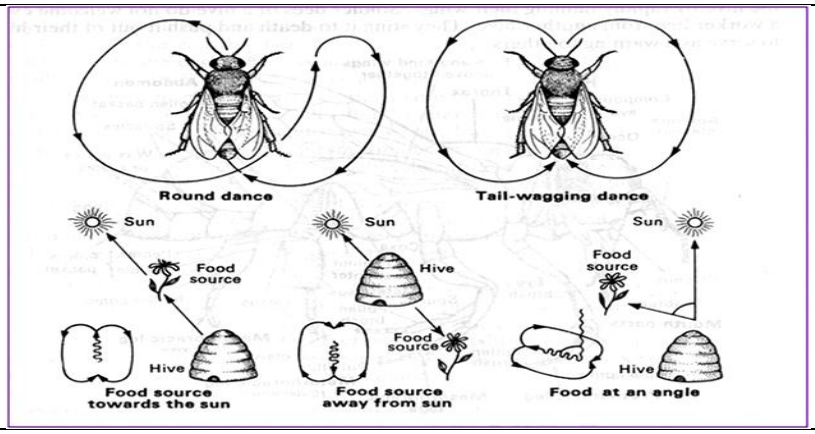
Apis dorsata	***Apis cerana indica***	***Apis florea***
		
Apis mellifera	***Trigona iridipennis***	**Hive stand**
		
Bottom board	**Brood chamber**	**Super chamber**
		
Hive cover/ Top cover	**Hive frames**	**Dummy or division Board/ movable wall**
		
Wooden bee feeder	**Plastic bee feeder**	**Queen gate**
		
Queen cage	**Queen cell protector**	**Queen excluder**

		
Plastic pollen trap	**Wooden pollen trap**	**Hive tool**
		
Bee veil	**Gloves**	**Boots**
		
Bee brush	**Smoker**	**Decapping knife/ uncapping knife**
		
Honey extractor	**Travelling screen/net**	**Comb foundation frame**
		
Comb foundation wax sheet	**Queen cage**	**Embedder**
		
Stingless bee hive	**Greater wax moth**	**Lesser wax moth**

		
Wax beetle	**Yellow banded hornet**	**Bee hunter wasp**
		
Beeeater	**Ectoparasitic mite, *Varroa destructor***	**Endoparasitic mite, *Acarapis woodi***
		
American foul brood	**European foul brood**	**Thai sac brood**
		
Nosema	**Amoebic**	**Healthy bee (L) K-winged bee (R)**
		
	***Apis dorsata* comb**	***Apis cerana indica* comb**
		
Overalls (Protecting wear)	***Apis florea* comb**	***Apis mellifera* comb**



Bee comminication

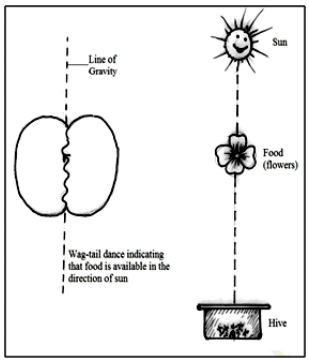


Fig. 1: Direction indication in wag-tail dance when food is in the direction of sun

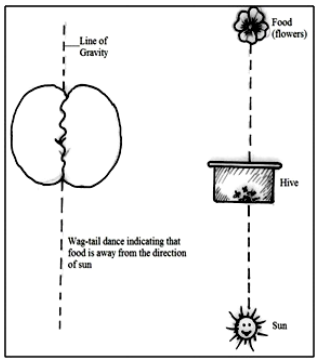


Fig. 2: Dance when food is away from direction of sun

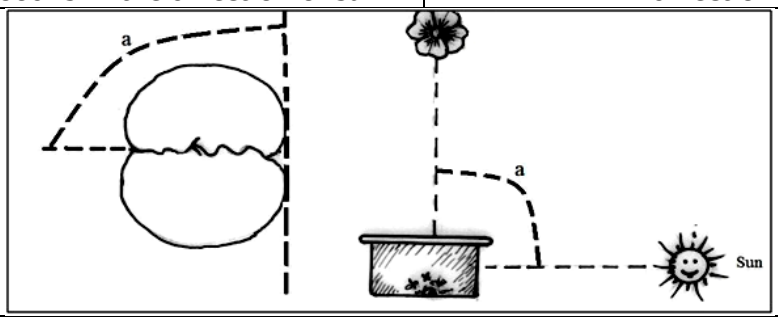


Fig. 3: If food is to the left of the sun, bee dances at an angle counterclockwise to the line of gravity

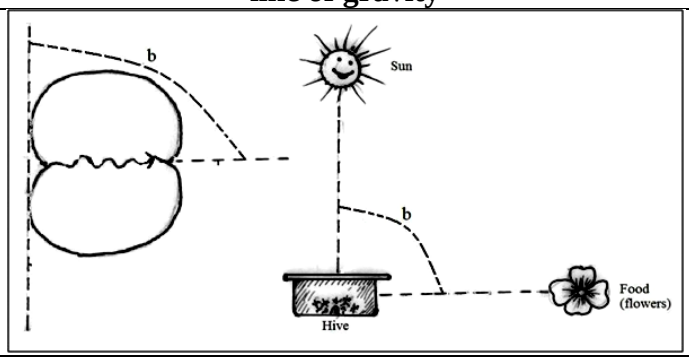
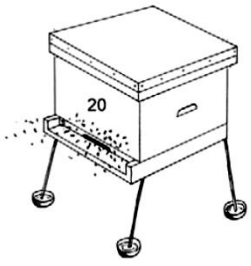


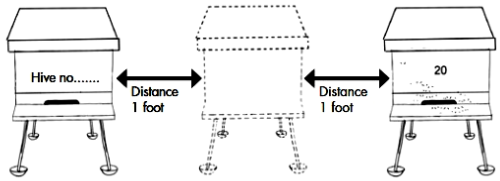
Fig. 4: If food is to the right of the sun, bee dances to the right of the line of gravity

Methods for colony division

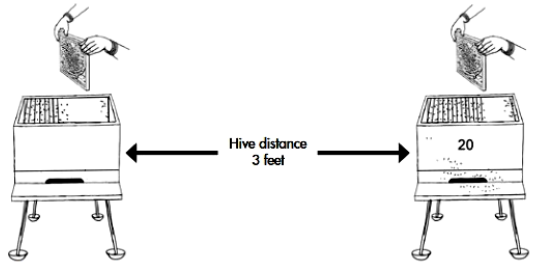


Step 1: Inspect the colonies

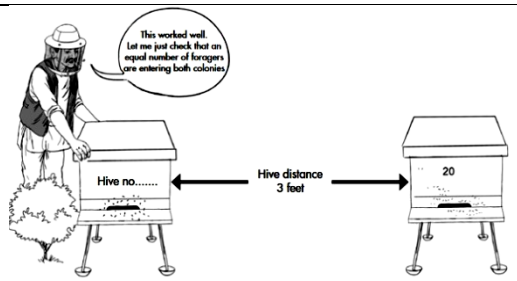
Step 2: Select the best mother colony



Step 3: Move the mother colony 1 ft (30 cm) to the left and place an empty hive 1 ft (30 cm) to the right of the previous mother colony position. The hives are a hive width plus 2 feet apart

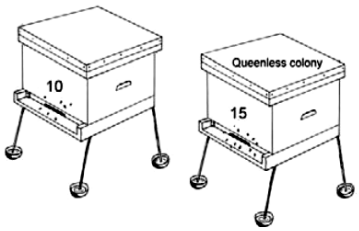


Step 4: Put 4 to 5 brood frames with the queen in the new hive

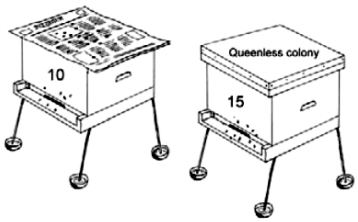


Step 5: Check the colony division is balanced and close the hives with the covers

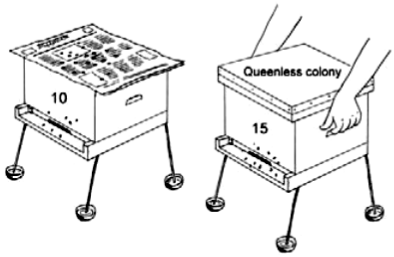
Uniting honeybee colonies by newspaper method



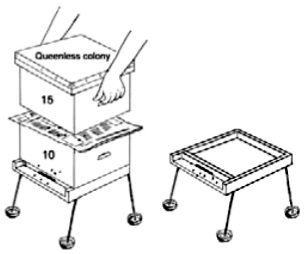
Step 1: Queen-right and queenless colonies moved close together



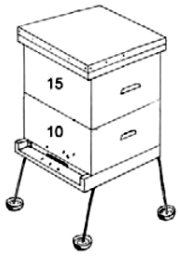
Step 2: Covers of queen-right colony removed and replaced with a sheet of perforated paper smeared with syrup or honey



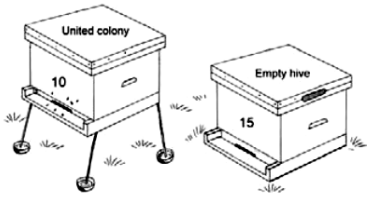
Step 3: Queenless colony lifted from bottom board



Step 4: Queenless colony placed on sheet of paper above queen-right colony

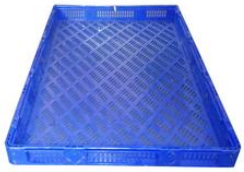
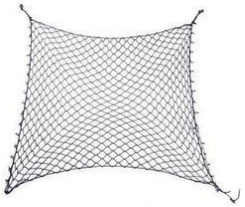


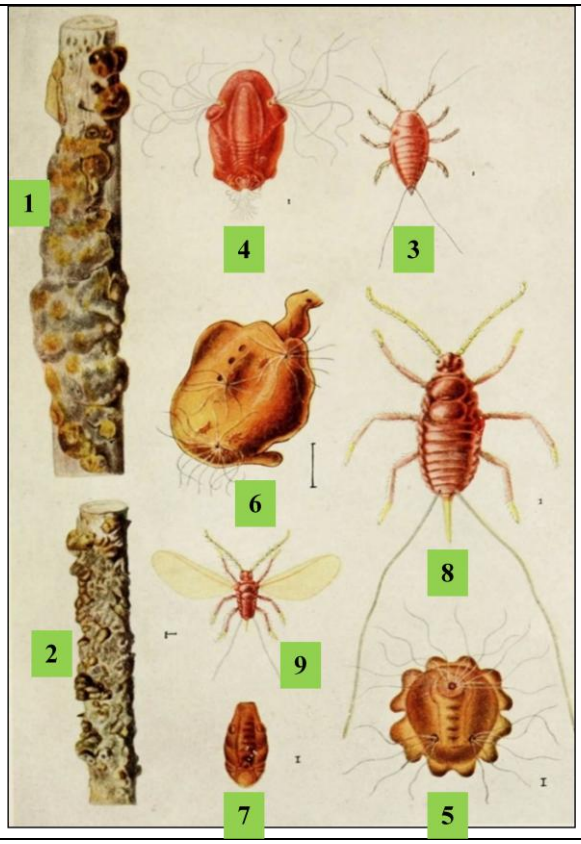
Step 5: Pheromones of colonies allowed to unite while bees chew the paper



Step 6: After 2 days bees and frames from upper chamber transferred to lower chamber and covers replaced on the united colony

			
Eggs	**Larvae**	**Cocoons**	**Adult**
Mulberry silkworm*, Bombyx mori*			
			
Eggs	**Larvae**	**Cocoons**	**Adult**
Eri silkworm, *Philosamia ricini*			
			
Mulberry cultivation	**Castor cultivation**		
			
Rearing house (Sericulture Unit)	**Rearing stand (Tray method)**		

		
Ant well	**Rearing tray**	**Paraffin paper**
		
Foam rubber strips	**Chopsticks**	**Feathers**
		
Chopping board and Knife	**Cleaning net**	**Mountages**
		
Reeling machine	**Rearing/feeding stands**	***Kharikas***
		
Uzi fly	**Dermestid beetle**	**Pebrine disease**
		
Flacherie disease	**Grasserie disease**	**Muscardine disease**

<table>
<tr>
<td> 
</td>
<td>1. Healthy lac cells
2. Diseased lac cells
3. Crawler (40X)
4. Female cell (4 weeks after inoculation (35X)
5. Female cell (13 weeks after inoculation (15X))
6. Emergence of crawlers from female cell (4X)
7. Male cell (13 weeks after inoculation (15X))
8. Wingless male (12X)
9. Winged male (40X)</td>
</tr>
<tr><td colspan="2">Various stages of lac insect</td></tr>
<tr>
<td>  </td>
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<tr>
<td>Semialata plant</td>
<td>Kusum</td>
<td>Brood lac</td>
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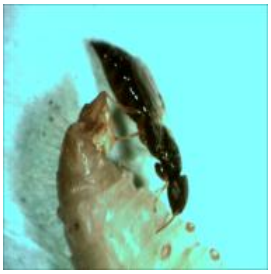
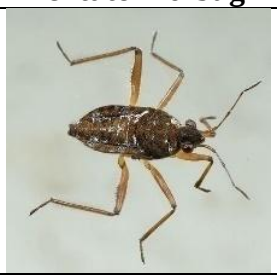
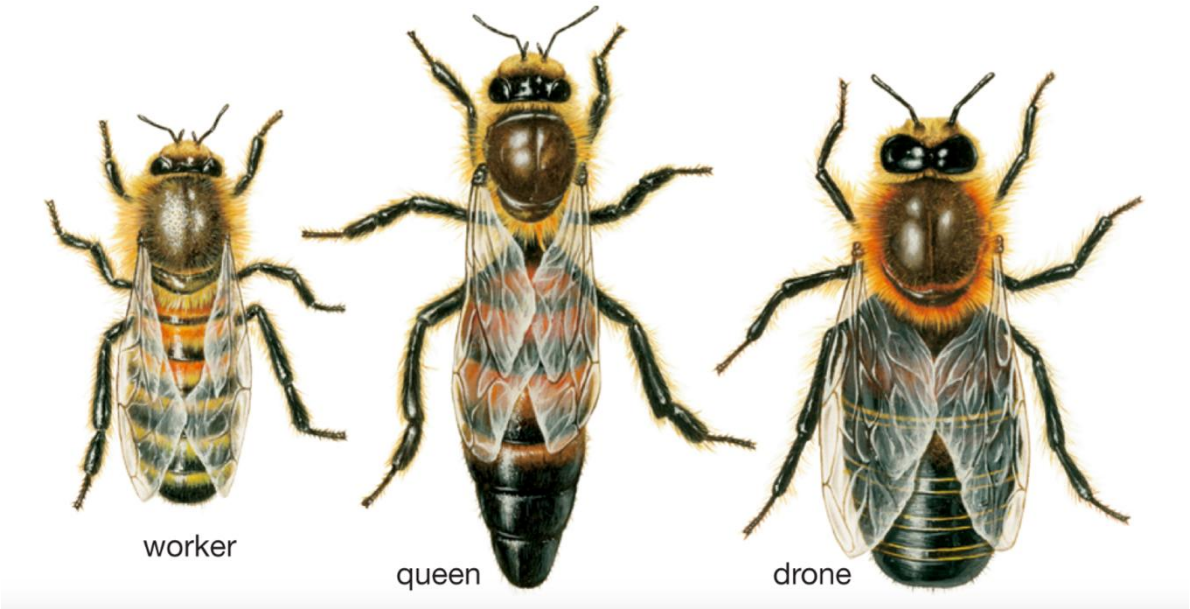
<tr>
<td>Palas</td>
<td>Ber</td>
<td>Inoculation of brood lac</td>
</tr>
</table>

		
Settlement of crawlers	**Lac encrustation**	**Lac encrustation**
		
Larva of *Eublemma amabilis*	**Adult of *Eublemma amabilis***	**Damage of *Eublemma amabilis***
		
Net covering of lac insect	**Phunki**	**Scrapping of lac encrustation**
		
Ichneumonid wasp	**Braconid wasp**	**Chalcidoid wasp**
		
Trichogramma wasp	**Eulophid wasp**	***Goniozus nephantidis***

		
Tachinid fly	***Epiricania* (*Fulgoraecia*) *melanoleuca***	**Dragon fly**
		
Damsel fly	**Preying mantid**	**Reduviid bug**
		
Pentatomid bug	**Giant water bug**	**Mirid bug**
		
Ripple bugs	**Ant lion**	**Green lace wing**
		
Robber fly	**Syrphid fly**	**Lady bird beetle**
		
Ground beetle	**Tiger beetle**	**Rove beetle**

		
Wasp	**Digger wasp**	**Red ant**
		
Fig wasp	***Neochetina eichhorniae***	***Neochetina bruchi***
		
Oil palm pollinating weevil ***Elaeidobius kamerunicus***	**Mexican beetle** ***Zygogramma bicolorata***	**Lantana weed killer** ***Cactoblastis cactorum***



Honey bee castes

Langstroth bee hive