LECTURE NO. 1

INTRODUCTION TO BENEFICIAL INSECTS, IMPORTANCE AND HISTORY OF APICULTURE

Introduction to Beneficial insects:

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*, Aphid, etc.

They 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)**

IMPORTANCE OF APICULTURE:

Bee keeping is an agro based enterprise, which farmers can take up for additional income generation. Honey bees convert nectar of flowers into honey and store them in the combs of the hive. Collection of honey from the forests has been in existence for a long time. The growing market potential for honey and its products has resulted in bee keeping emerging as a viable enterprise. Honey and wax are the two economically important products of bee keeping.

Bees play an important role as pollinators in the environment. Besides providing honey and beeswax, honeybee pollination is crucial for putting on our table four out of the five foods we eat – **oilseeds, pulses, vegetables and fruits.**

While pollination can be done by a number of insects such as butterflies, bumble bees, beetles, flies and even ants, honeybees are the most efficient pollinators. It is estimated that under normal conditions a hive of fifty thousand bees pollinates half a million plants in one day – making any other kind of pollinator pale into insignificance. Honeybees of the Indian subcontinent, especially *Apis cerana indica* are found extensively in the natural environment. *A. cerana indica* is an extremely hard worker (as compared to the hybrid bee *Apis mellifera* which is commonly used by commercial beekeepers). She works long hours and even through extreme weather conditions.

Studies have pointed out benefits of increased yields through pollination.

- Bee keeping requires less time, money and infrastructure investments.
- Honey and beeswax can be produced from an area of little agricultural value.
- The Honey bee does not compete for resources with any other agricultural enterprise.
- Beekeeping has positive ecological consequences. Bees play an important role in the pollination of many flowering plants, thus increasing the yield of certain crops such as sunflower and various fruits.
- Honey is a delicious and highly nutritious food. By the traditional method of honey hunting many wild colonies of bees are destroyed. This can be prevented by raising bees in boxes and producing honey at home.
- Beekeeping can be initiated by individuals or groups.
- The market potential for honey and wax is high.
- Responsible for 1/3 of the world's food supply by pollination of more than 90--100 species of 100 species of flowering plants.
- Worldwide economic value to food production of 50-100 billion USD annually with little or no "carbon footprint"

BEEKEEPING :

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

Initially in 1953 as many as 230 beekeepers, who maintained around 800 bee colonies in modern bee boxes and were producing 1, 200 Kgs 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 burst.

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

HISTORY OF BEEKEEPING – INDIA:

Bees and honey were known to human being in India since time immemorial as their references are mentioned in epics, on murals, sculptures, etc. Vaishali Stupas in Muzaffarpur (Bihar) were built in commemoration of offering of honey to Lord Buddha by king of monkeys and his people whenever

Lord Buddha visited the place. Several references of bees have been made in the oldest scripture of India, the **Rig Veda**.

The earliest method of keeping bees was to use hollowed out tree trunks, empty pots or any other suitable receptacles smeared with wax and sweet scented leaves of *Cinnamomum iners* on the inner surface; these receptacles were kept in jungles to entice (invite) the bees during swarming seasons. When the bees had settled there, these recepticles 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 193839. 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 & 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 in 1962.

The research in beekeeping started when Indian Council of Agricultural Research (ICAR), New Delhi started funding 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 bee & other pollinators sponsored through ICAR, New Delhi with Project entitled **"All India Co-ordinated Research Project on Honey bee and Pollinators from the year 2015-16".**

SUCESSFUL 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.

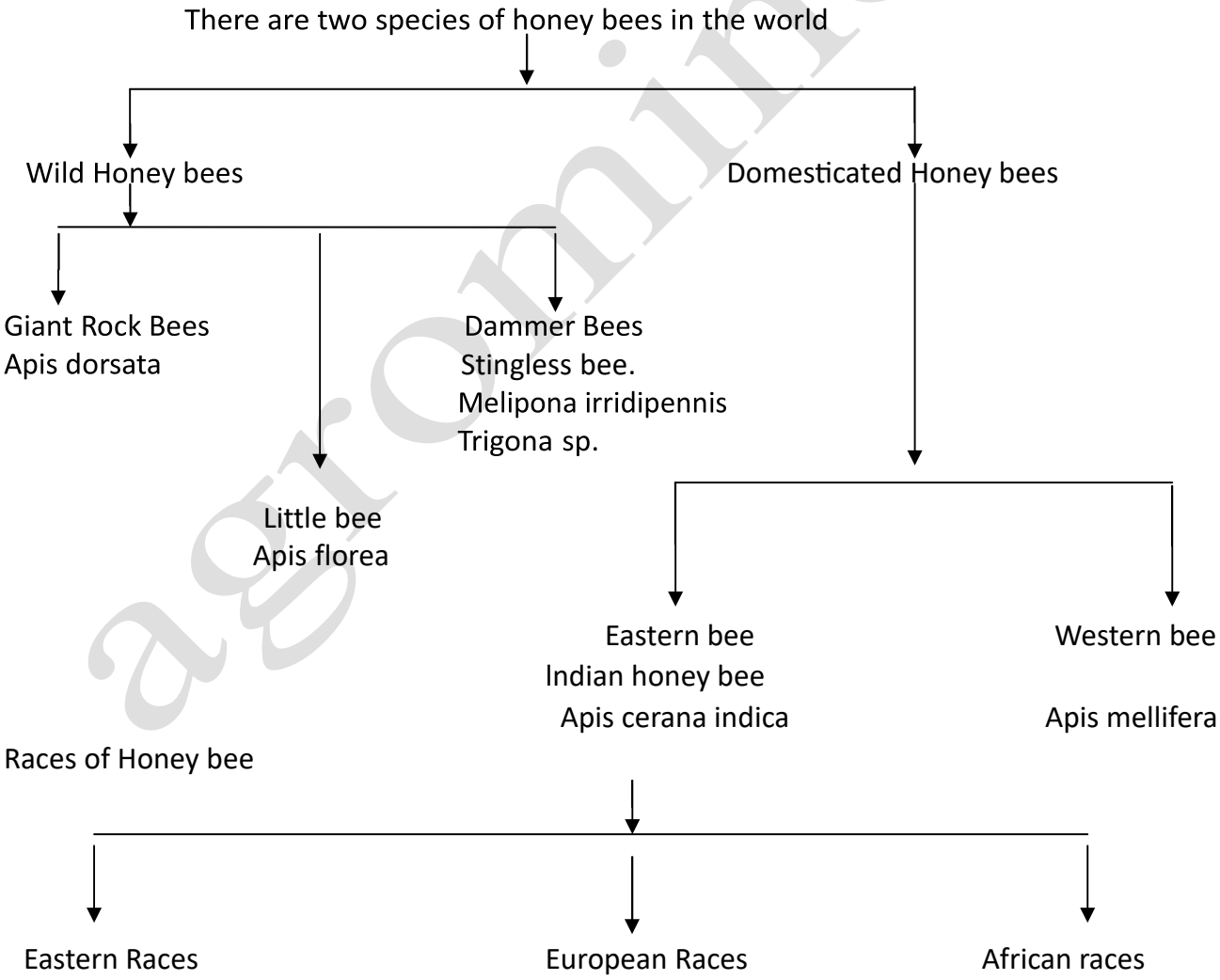
Convinced with the performance of *A. mellifera* in the Punjab, H.P. and Haryana and due to the outbreak of Thai Sac brood Viral Disease causing large scale mortality of *A. cerana* colonies during late 1970s to early 1980s in the states, practicing *A. cerana* beekeepers of many other states expressed 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**.

LECTURE NO. 2

DIFFERENT SPECIES OF HONEY BEES, MORPHOLOGY AND ANATOMY

Honey bee: Taxonomic classification:

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



1) Apis cerana cerana
(North India, HP, J.K. etc)
2) Apis cerana indica
(South India : Kerala, Karnataka , Maharashtra etc.)
3) Apis cerana himalaya
(Eastern India : Nagaland) Manipur, Meghalaya, Assam, Mizoram etc.)
4) Apis cerana japonica

1) A.m. mellifera
(Dark Dutch Germany)
2) A.m. cornica
(Carniolan bee in Southern Austria)
3) A.m. ligustica
(Italian bee)
4) A.m. coucasica
(USSR)

1) A.m. intermissa
(Morocco and Lybia)
2) A.m. iamarkii
(Egyptian restricted to Nile valley)
3) A.m. capensis
(Cape bee which rear queen from eggs laid by worker
4) A.m. adara

In India all the four species are found. *Apis mellifera* is an Exotic bee for India which was introduced in India (Nagrota : HP) for the first time successfully in 1962. In addition to four true honey bee species, more species have been found in some parts of the world. They are :

1) *Apis laboriosa* : (Nepal) resemble to *A. dorsata.*
2) *Apis vechti* or *A. kaschevnikovi* (Malaysia) resemble to *A. cerana.*
3) *Apis andreniformis* (China) resemble to *A. florea*
4) *Apis nuluensis* (Malaysia, Indonesia) resemble to *A. cerana.*
5) *Apis nigrocincta* (Indonesia) resemble lo *A. cerana*

Species : Each species is reproductively isolated from the other and these cannot be interbreed.

Races: Races are geographically isolated and these can be interbreed.

1) Giant rock bee (*Apis dorsata*, Fab) :

1) Builds a single large comb 5' wide and 2'- 4 ' long in open on tree branches, eaves of high buildings, suspended from rocks, high hedges.
2) Good honey gatherers and produces large quantity of honey. Average honey production is 36.3 kg per colony per year.
3) It can not be domesticated and has ferocious temperament, easily provoked and attack in masses on man or beast often with fetal results.
4) They are industrious, good, efficient pollinators of crops.

2) Little bee (*Apis florea*, Fab.):

1) Builds a small single comb about the size of palm of hand suspended from branches of bushes, hedges, trees, crevices of buildings but in semi dark conditions.

2) Poor honey yielder and produces 0.5 to 1.0 kg of honey per colony per year.

3) Not so prone to stinging. Prone to swarming and have 4-5 swarmings.

4) Industrious, good and efficient pollinators.

3) Indian Honey bee (*Apis cerana indica*, Fab.):

1) Widely distributed throughout India. Builds series of parallel combs inside cavities, hollow tree trunks, rocks, wooden boxes, mud receptacles etc. are common abodes used by bees.

2) Can easily be domesticated and kept in modern beehive, easy to manage.

3) Good honey yielder and yields 4 to 5 kg of honey per colony per year. Under better management it yields 10 to 15 kg honey / colony / year.

4) Prone to heavy swarming, absconding, robbing and developing large number of laying workers but can be remedied with proper manipulatory practices.

4) Dammer bee or stingless bee (*Mellipona irridipennis*, *Trigona sp.*, *T. laeviceps*):

1) Smallest bees and built their nests in hollow log of trees or rocks or in walls as sac like comb from a mixture of resins and wax held together by propolis.

2) Stingless bees (*Vestigial sting*). Poor honey gatherer and yields only 50 to170 mg Ofhoney per colony per year and difficult to extract.

3) A substance known as 'bee's dammer' or Pivenyet obtained from colonies used as varnish and for caulking boats to make them water proof.

5) European bee (*Apis mellifera* Linn.) :

1) Found all over Europe and have well recognized varieties and strains. The Italian variety is considered to be the best.

2) This bee is similar in habits to *Apis cerana* bee and builds several parallel combs in cavities, hollow log of trees etc.

3) It has many desirable traits. Prolific queen, swarm lessness, less absconding habit, gentle temperament, good honey gatherer and amenable to rear in all environmental conditions and modern bee hives. Easy to manage and multiplication.

4) Good honey yielder and yields 45 to 100 kg honey per colony per year. On an average 25 to 40 kg honey is obtained.

Identification/differentiation among different bee species:

Sr. No.	Characteristics	The rock bee, *Apis dorsata* (Giant honey bee)	The little bee, *Apis florea* (Small honey bee)	Indian hive bee/ Asian bee, *Apis cerana indica* (Asiatic honey bee)	European bee or Italian bee, *Apis mellifera* Linnaeus	Dammer bee or stingless bee *Trigona irridipennis*
1.	Body size	Largest	Smallest	Medium	Medium	Smallest
2.	Body colour	Head blackish, abdomen reddishyellow anteriorly & black at the tip	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 posteriorly	Body is reddish brown in colour
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.

Morphology of Honey bees:

1. Head : The head of honey bee is triangular with two large compound eyes and three ocelli. The drone's head is larger than that of either queen or workers and its compound eyes are contiguous on the vertex. The ocelli are located in a triangle anteriorly on the vertex in the worker and queen but lower in the face of the drone. Bee recognize objects with their compound eyes, perceive movement and distinguish colour and forms. They can distinguish only yellow, blue, blue green and ultraviolet and cannot see black, red and grey colours. The antenna is geniculate with a large scape, a small pedicel and ten flageller segments in the female (queen and worker) and 11 in the males (drone). It accommodates various kinds of sense organs, chiefly tactile and olfactory. The mouth parts are of chewing and lapping type. The mandible and labrum are of the same structure as in the chewing insects.

Structure of mouth parts :

Labrum is the upper lip which covers the mandible and closes the mouth cavity from infront. It helps to pull food in to the mouth.

Mandible are two in numbers. They are flattened and dumbbell shaped.They are not used in feeding mechanism but they are used for i) moulding the wax of honey comb cells ii) manipulating nest materials iii) grasping prey iv) eating pollen and v) holding the base of the outstretched proboscis but maxilla and labium are united to form to lapping tongue and particularly glossa has become a sucking organ.This united structure of maxillae and labium is called maxilla labial complex. This complex remains suspended partly in the mouth cavity and articulatedto the headcapsule by means of two cardines.

The chief basal plate of maxilla is the stipes and its lower end is articulated with stalk like cardo (cardine) and at the apex, stipes bear peg like maxillary palpus. Articulating with the upper extremely of the stipes, there is a blade like lobe or galea and reduced lacinia.

In the labium a large strongly sclerotized plate is the prementum and later articulate with a small triangular sclerite or mentum. The base of mentum is supported by a transverse band, the submentum or lorum whose extremities are attached to the distal end of cardo. The labial palpi are segmented, each being carried by a basal palpiger. The elongated central organ of the labium is glossa and at its base, are two lobes called paraglossae. The glossa is covered with long hairs and at the apex it bears a small spoon shaped lobe called flabellum. Hypopharynx is vestigial.

Feeding mechanism: When at rest, mouth parts are folded down beneath the head against the stipes and mentum. However, during feeding, they become straight and honey bees thrust out glossa and licks with the nectar with the tip of flabellum. The glossa thus smeared with nectar is rapidly retracted between the labial palp and the galae. As a result of which nectar is squeezed off the tongue and deposited so as to accumulate in the small cavity formed by the paraglossa at the base of the glossa.

Then by bending the labium upward near its midlength, the base of glossa is brought nearer to the mouth cavity and accumulated nectar is sucked in to the oesophagus by the action of pharyngeal pump.

2. Thorax : The thorax of the bee consists of four body segments, they are designated as prothorax, mesothorax, metathorax and propodeum. This thorax is characterized by the fusion of the first abdominal segment with metathorax. The two pairs of membranous wings in each side are coupled together during flight by a row of 25 hooks or hamuli arising from the anterior margin of hind wings.

3. Modification in legs : The leg of honey bee consists of the usual six segment viz. coxa, trochanter, femur, tibia, tarsus and pre-tarsus. The tibia is slender in fore and middle legs, but the hind tibiae are greatly elongated and flattened especially observed in workers.The tarsi have 5 segments or trarsomeres. The first tarsomere or the basitarsus is broad and flat while the other four are small. The pre-tarsus in the honey bee is a highly specialized structure consisting of a pair of lateral claws and a soft apical medium arolium.

i) Fore leg (Antenna cleaner) : In the fore legs of all the three castes of bees, brushes of stiff hairs are present on the inner surface of the basitarsus. These hairs are useful for cleaning pollen or other particles from the head, eyes and mouth. But more important feature of the fore leg is the antenna cleaner. Since the antenna have important organs, insects are careful to keep their antennae clean of all dirt. In honeybees the tibia and basitarsus of fore leg of all the three castes have undergone certain modifications for this purpose and the organ is called *antenna cleaner*. It is situated in the inner margin of the fore leg. Each antenna cleaner consists of a deep semicircular notch at the proximal end of the long basitarsus and of small spur like process of the tibia called *Fibula* that projects from the distal end of the tibia over the notch. The margin of the notch has comb like row of small hairs. The notch is first placed against the antenna and the tarsus is pressed against the Fibula and thus the notch is closed forming a circular aperture. The antenna flagellum securely held in the aperture is nowd rawn upwards and gets cleaned.

ii) Middle leg : Has two important structures **a) Pollen brush:** stiff hairs on basitarsus form pollen brush which is useful to collect pollen from middle part of their body. **b) Tibial spur :** At the distal end of tibia a movable spur is present which is useful to loosen the pellets of pollen from the pollen basket of hind legs and to clean wings and spiracles.

iii) Hind leg i.e. Pollen collecting leg: Pollen constitutes an important part of the food of both larvae and adult bees. It is a principle source of protein for the bees. Propolis (Bee glue) is a resinous substance available in the buds of trees and issued by the bees for repairing the cracks in the hives and also for strengthening the wax for comb building. Both pollen and propolis are collected and carried to the hives by the bees in the baskets in their hind tibiae. In the worker bees the hind legs are larger in size than the other two castes with broad and flat tibia and basitirsus. The smooth outer surface of

the tibia is fringed with long curved hairs forming the *Pollen brush or scopa* and the space thus enclosed is known as *corbicula* or the *Pollen basket*. The basitarsus is flat and provided with ten transverse rows or stiff spines. There is a deep notch between the adjacent ends of the tibia and the basitarsus. The tarsal tip of the notch has a small lobe known as auricle which is margined by a lobe of long hairs. The tibial tip of the notch has a row of spines forming a comb or *pesten or rastellum*. When the basitarsal brushes are loaded with pollen the leg of one side is rubbed against the other in such a manner that the bunch of hairs on the end of the tibia scrap off a small mass of pollen from the tarsal brush of the opposite legs. By repeating the process the little masses of pollen are pushed up in the *corbicula* which ultimately becomes fully loaded with pollen. With loaded pollen baskets the foraging worker bee returns to the hive, goes to a cell in the comb where pollen is to be stored, sits over the cell resting her forelegs on the cell edge with its abdomen curved and hind legs stretched in to the cell. The basitarsi of the middle legs move over the pollen basket and dislodge the pollen into the cell, breakup the pollen masses and pack them in the cells.

4) The abdomen: The first segment of abdomen or propodeum has undergone fusion,with the metathrorax and the region behind the propodeum is the gaster. The second segment in honey bee is greatly constricted at its union with the propodeum and this constricted part is called Petiole. The gaster consist of six exposed segments in thefemales and seven in males and remaining are concealed and considered modified. The ovipositor is well developed and is useful for laying eggs in queen and modified as stinging organ in worker. The drones being males lack a sting.

5) Wings of workers bee :

1) Fore wings are larger than hind wings, membranous, venation is stronger but two wings of each side work together in flight.

2) To ensure unity of action the wings are provided with a coupling apparatus formed by a series of upturned hooks on the front margin of each hind wings and a decurved fold on the rear margin of fore wings When the wings are extended preparatory to flight the fore wings are drawn over the hind wings and the hooks of the latter automatically catch in marginal folds of the former.

6) Sting of honey bee:

It is an elaborated and modified ovipositor supplied with poison and serves as an instrument of defence. The poison glands associated with sting are usual accessory glands found in other female insects but modified for secretion of venom, instead of such materials as that used for cementing the eggs to host surface or for the formation of egg cases.

The sting is accommodated in large sting chamber formed mainly by the terga and sterna of abdominal segment 7 and also by the sclerites of segments 8 and 9 which are reduced and retracted into the chamber.

The entire stinging mechanism is made up two sets of distinct and automatically different parts. One is the motor apparatus consisting of a few pairs of plates by which the sting is attached within the sting chamber and another is the piercing apparatus consisting of a long tapering shaft which alone is protracted from the abdomen during stinging. These parts are connected by a pair of curved arms, each of which is composed of two closely arranged rami.

The motor apparatus of sting has on each side a large quadrate plate, triangular plate lying before the quadrate plate and oblong plate lies below the other two. When the sting is not in action it is entirely retracted within the sting chamber of the abdomen.

Anatomy of Honey bees:

Inside the Bee's body are found all the organs and system as are found in a human body. They perform almost the same functions. The digestive tract consists of the mouth, pharynx (a muscular pump), oesophagus with a dialated portion called the honey stomach, associated salivary glands, the stomach (ventriculus) in which digestion and absorption of food takes place and the intestine consisting of an anterior portion and a rectum which opens to the exterior through the anus. The excretory organs (malpighian tubules remove the waste products of metabolism from the blood) are at the junction of the ventriculus and the hind intestine.

The circulatory system is an open one and the blood bathes the internal organs. The blood, which carries the digested food materials to the tissues and remove waste products of metabolism from them, is circulated by a tubular heart.

An elaborate respiratory system consisting of a network of air tubes connected to the exterior through breathing pores (spiracles) is there to carry oxygen to the organs needing it and to remove the waste carbon dioxide from them.

The nervous system consists of a well defined brain in the head and a ventral nerve cord with its seven pairs of ganglia extending to the posterior part of the abdomen. It sends out nerve cords which ramify the surrounding area and supervise and coordinate its activities.

The muscular system is rather complicated. The wing muscles are most powerful and enable the bee to carry a load almost equal to her own weight. The wax glands are located on the lower side of the abdominal segments of worker bees only and secrete a liquid which on contact with air solidifies into flakes. It is used in building waxen combs of a honey bee nest.

The reproductive organs are well developed in the Drone (male) and Queen (female) bees. The worker bees are female individuals but their reproductive organs are neither fully developed nor functional. The sting apparatus in the queen and worker bees is a modified ovipositor and is used by the latter as a weapon of defence unlike wasps and other stinging insects which use it for killing other creatures as prey.

Sense Organs : The honey bee is one of the insects which are most highly endowed with powers of sensory perception. Hair sensitive to touch are located on various parts of the body. On the antennae are located several thousand organs of smell. The taste organs on the mouth help the bee know if fluid is sweet, acidic, alkal or saltish. The ocelli help in differentiating between light and darkness and with the help of the compound eyes, the bee is able to perceive differences of colour, shape and form. It is able to distinguish between green, blue, yellow and ultra-violet, but is more or less, insensitive to red rays. As the compound eyes give a mosaic picture of the objects, the bee is able see moving, objects more readily. The bee also has a time sense and a memory sense as it returns to the same patch in a field visit after visit and day after day at the suitable time.

LECTURE NO. 3

BEE COLONY ORGANIZATION, SOCIAL BEHAVIOUR, LIFE STYLE AND SEASONAL MANAGEMENT

BEE COLONY ORGANIZATION, SOCIAL BEHAVIOUR AND LIFE STYLE:

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 which includes a queen, 200 – 300 drones and several thousand workers.

A] Queen:

The queen, a true mother bee, is the only female that is completely developed sexually from fertilized egg. This is a result of a total diet of royal jelly during a developmental period. It 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 spermatheea 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 -

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 duties:

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

SOCIAL BEHAVIOUR OF HONEY BEE:

Social behavior : Honey bees are among the fully social insects having overlap of many generations in the same nest. The colony is a well organized social group having division of labour in terms of laying of eggs, nursing, comb building, guarding, food collection and its storage. They have well developed communication system through different types of dances as well as trophallaxis.

Biological communication can be defined as an action on the part of one organism that alters the probability pattern of behavior in another organism in an adaptive fashion. Adaptive means that the signaling or the response or both which have been genetically programmed to some extent by natural selection.

Trophallaxis is food transmission (exchange of food) which is common between workers and also from workers to queen and drones. It is a sort of communication regarding availability of food and water and also a medium for transfer of pheromone. In honey bees, recruit communication is very important mode of communication which is defined as a communication that brings nest mates to some point in space where work is required.

Dances of Honey bees:

It was Father Spitzner in 1788 who for the first time described bee dances as method of communication among inmates of the hive about volume of honey flow and place of source of nectar. These observations remained unnoticed till Frisch (1920) published his observations. Karl von Frisch got noble prize in 1973 (under physiology & medicine, who shared it with two other animal behaviourists) on the basis of his work published in 1946.

Types of dances: In honey bees there is a well developed recruitment system to increase foraging efficiency. Some of the foraging force (5-35%) acts as scout bees/searcher bees. These bees may travel many kilometers. Average foraging radius of a colony is only few hundred metres in agricultural areas and about 2 km in forested areas. Scouts communicate distance, direction and quality of flowers through different types of dances which in turn results in recruitment of other workers to forage on the best available sources. The scout bees perform two types of dances:

i) Round dance ii)

Wag-tail dance

Round dance:

This type of dance is performed if food source is nearby (within 100 metres in case of *A. mellifera* and 10 metres in *A. cerana*). The performing bee takes quick short steps and runs around in narrow circles on the comb; once to right and then left and then repeating for several seconds. The dance excites the bees and they touch the performer with their antennae and then leave the hive in search of source of food. In this dance there is no indication of direction of food and the foragers search within 100 metres in all direction using floral odour clinging to hairy body of scout bee as cue as well as from the sips of nectar which they receive from the dancing bee.

Wag-tail dance:

This dance is performed when the distance of food source is more than 100 metres from the hive. In this dance the bee starts dancing on the comb making a half circle to one side and then takes a sharp turn and runs in a straight line to starting point. Thereafter takes another half circle on the opposite direction to complete one full circle. Again the bee runs in a straight line to the starting point. In the straight run the dancing bee makes wiggling motion with her body that is why this dance is known as wag-tail dance. Location of food is indicated by direction of straight run in relation to line of gravity. If the food is in line with the sun, bee wag-tails upwards and if away from the sun, it performs downwards. If the food source is to the left of the sun the bees dance at an angle counterclockwise to the line of gravity whereas, if it is to the right of the sun the bees dance to the right of the line of gravity.

The distance is indicated by the number of straingt runs per 15 seconds as given below

Distance of food from hives (metres)	Number of straight runs/ 15 sec.
100	9-10
600	7
1000	4
6000	2

As a social unit a bee colony maintains its hive temperature between 32-35^{o}C in the brood area. Queen substance 9-oxo-2-decenoic acid (9-ODA) from the queen bee, alarm pheromone and alarm odour from worker bees play important role in the welfare of the colony and help in the social organization.

ACTIVITIES OF HONEY BEE:

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 metres 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 queen daughter 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 queen daughter which emerges after swarming, kills the baby queen in the other cell and establishes herself as a queen mother. 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 an 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. 21.2), 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.

6. Air conditioning:

Among the living creatures, honey bees are the only organisms which make their comb airconditioned. 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.

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 accustomed 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.

SEASONAL MANAGEMENT:

(I) SPRING MANAGEMENT:

Remove the protective covering or lightly packed hives in the early spring. But in those which are heavily packed, the packing is removed only when daily maximum temperature has reached 16 ^{0}C.

Examine the colonies on a sunny day. Check the food stored and general condition of the colony. The examination should be for short duration to avoid brood chilling and robbing.

It is good practive to equalize the strength of normal colonies in an apiary by giving brood frames to the needy colonies.

The colonies which do not have brood, are likely to be queenless or if queen has failed and has become drone layer, there will be predominance of drone brood. Such colonies if are weak (less than 5 frames), be united with other needy normal colonies. If these are strong, then provide a mated queen and if not available, give a frame of brood with eggs and young larvae for rearing new queen.

Give stimulatory feeding of sugar syrup (Dilute syrup to 30 per cent) to the bee colonies on the onset of the spring which is indicated by the start of blooming of spring flowers. Take all the steps to guard against the robbing by bees. Bees will put their whole force during the period for brood rearing.

Provide raised combs or frames with comb foundation sheets if raised combs are not available, so that there is no shortage of space for brood rearing. But be careful not to over expand the brood in the uncertain weather conditions of early spring, which may result into chilling of brood.

Examine the colonies at least once a week on a sunny day and when conditions permit clean the debris from the bottom boards. Provide empty frames as per need of the colonies. Ensure that each colony always has at least 5 kg of food stores.

During spring old bees die which are normally replaced by young bees. If mortality of old bees exceeds the rate of emergence of young bees, the colonies show sign of dwindling which is known as spring dwindling. Such colonies should be provided with adequate stores of pollen and honey and be given 1-2 sealed brood frames from the strong colonies.

If all above mentioned practices are followed, the colonies will be well built up by the time of honey flow when maximum strength is needed. However, increase in strength also induces swarming.

What is swarming:

This is a natural division of colony in which some bees (may be half or more) leave the colony along with old queen and this swarm settles generally in the nearby area of the colony.

Period of swarming:

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

What causes swarming:

Swarming occurs due to :

- Overcrowding and lack of ventilation.
- Presence of old queen is also incentive to swarming.
- Sudden honey flow.
- Lack of space for egg laying and honey storage.

Problems during swarming:

- Loss of working force due to division of the colony.
- The morale of colony is not favourable for honey collection. The bees direct their efforts towards building queen cells and searching for new home sites.
- Colonies show great variations in respect of swarming. Some colonies do not swarm even after becoming quite populous yet many swarm without any apparent reason indicatin genetic variation to the instinct of swarming.

Indication of swarming:

- The colonies start raising large number of queen cells usually along the lower edges of combs.
- Many bees do not go to field creating additional crowding, resulting in clustering of bees outside the hive.

Time of swarming:

Time to issue swarms by the colonies is from 10 AM to 2.00 PM on sunny days. If weather is not favourable, swarms may be issued even earlier in the morning or late in the evening.

Catching and hiving a swarm:

- A settled swarm can easily be caught using swarm catching basket. This basket is placed above the bee cluster and the cluster is gently pushed upwards so that the bees start ascending into the basket. Once the queen has entered, the whole swarm will follow the queen.
- The swarm in this basket can be taken to the apiary for hiving.

- To make the swarm settle properly, a hive is prepared by giving one frame each of capped brood, pollen and honey and provided with extra frames as per strength of the swarm. The swarm from the swarm catching basket is then shaken on the top bars of such a prepared hive and immediately covered with burlap cloth, inner cover and top cover.
- Sugar syrup is also fed to such a newly settled swarm (1 part sugar dissolved in 1 part of water).

How to prevent and control swarming?

Depending on the internal and external factors, one colony may issue one to several swarms resulting in loss of population of the parent colony. To prevent swarming do as given below.

- Avoid overcrowding by adding empty combs for egg laying. Sealed brood can be shifted to second hive body.
- Remove the queen cells at regular interval as soon as these are made. Advanced queen cell removal is not much effective.
- Provide shade and ventilation to the colonies.
- Swarming can be prevented by removing old queen (which otherwise provides the supersedure impulse) and introduce a young laying queen. Requeening the colonies annually is also a good practice.
- Another well known method of swarm control is 'Demaree plan of swarm control' which is described below :

(i) Examine the brood of the colony and remove all the queen cells.

(ii) Remove the brood chamber from the bottom board and place another hive body containing one comb of unsealed brood and put the queen in this part and fill the remaining hive with empty combs.

(iii)Place queen excluder on this hive and keep the removed brood chamber along with remaining brood and bees over it.

(iv) Again inspect the top hive body after 10 days and remove all queen cells. In this way swarming can be checked.

- Swarming instinct of the colonies can also be overcome by temporarily dividing the colony and the re-uniting just before honey flow.

(II) MANAGEMENT DURING HONEY FLOW :

Indication of honey flow:

- By whitening of honey cells of the comb due to deposition of fresh wax.
- Appearance of large quantities of burr and brace combs (freshly prepared places of combs).
- Increase of weight of the colonies due to incoming nectar (a colony kept on a stage balance in an apiary indicates the sudden increase in weight such a colony is also known as a balance colony).

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

Supering:

With the first indication of honey flow, provide supers to the colonies. But before putting supers, examine the colonies for disease, check whether queen is present or not and whether laying satisfactorily because after the honey flow starts the beekeeper becomes too busy in putting and taking off the supers.

Place queen excluder between brood chamber and super so as to prevent laying in the super by the queen.

Keep swarming under check by avoiding congestion in the brood chamber. Provide empty combs at all the times until end of honey flow. The space can be provided by removing sealed brood to super chamber.

Super should contain drawn combs. If not available provide frames with comb foundation sheets. To attract bees for raising the foundation, super should contain one or two frames of drawn combs.

Supers can be of half or full depth. But full depth supers are more practical since frames can be exchanged among different chambers.

When first super is full and there is need to put the second one, it should be added between brood chamber and first super.

If there is shortage of drawn combs and raising of new combs is likely to lower honey production, the fully sealed and two thirds sealed honey frames can be taken out for honey extraction. Empty combs can be returned for re-use.

A strong colony can collect 4.5 to 10 kg of unripe honey in a single day during good honey flow. Therefore keep the supers ready for meeting colony demand. It is better to super at least one super ahead of needs of the colony.

Honey extraction:

Do not extract uncapped honey since it is unripe and due to higher moisture contents, it is liable to ferment.

Time to remove supers:

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

Process of honey extraction:

To remove honey combs, smoke colonies and brush off bees from the honey combs using soft bee brush or bunch of soft green grass.

Place the honey combs in bee tight hive bodies and shift to honey extraction room.

Never rob the colonies of their entire honey stores. Depending on strength, keep with each colony at least 5-15 kg of honey in case of *Apis mellifera* and 3-4 kg with *A . cerena* for summer and monsoon dearth periods.

Honey extraction room should be bee tight. After bringing the honey frames for extraction, these can be uncapped either with steam heated double walled uncapping knife or with ordinary uncapping knife by heating in boiling water.

Keep these uncapped frames in hive bodies with drip trays below, till extraction.

Put the uncapped frames in honey extracto and work at about 150 revolution per minute for 1 to 2 minutes. Then reverse the sides of the frames and repeat the extraction process.

Stock the emptied frames in hive bodies and return these to the colonies for cleaning. Shorten the hive entrance to avoid robbing.

Since fresh extracted honey is warm and easy to strain, arrangements for straining and packing should be promptly made so as to prevent subsequent heating.

Clean the appliances and the place where honey is extracted.

Beeswax collected during uncapping of honey frames should be allowed to drain of its honey. Then purify this beeswax by putting in a muslin bag and boiling in a water bath. On cooling pure beeswax will float over the surface of water and all impurities will remain in the muslin bag.

(III) SUMMER MANAGEMENT:

Honeyflow in most of the areas is generally followed by summer dearth periods. During this period bees throw out drones and colony population also dwindles due to the death of old bees who have worked hard during honey flow season. Attack of bee enemies increases and robbing activity of bees is also more. If colonies are not managed properly, they may even abscond. This tendency is more in *A. cerena* and little in *A. mellifera*. Manage the colonies as describe below.

Provide the bee colonies with shade by shifting to shady areas or placing them under open straw huts.

Provide proper ventilation by slightly raising the brood chamber or the super such that bees do not pass through these ventilations. Otherwise robbing may be induced.

Close all crack and crevices in the hive so as to prevent entry of the enemies and robbers.

Ensure that colonies do not remain broodless for longer duration. Provide sufficient food stores if the colonies have been stripped heavily of their honey stores during honey extraction.

Do not examine the colonies very frequently.

Restrict the number of frames as per colony strength. Remove extra frames and store these safely for later use.

In areas where summer temperature rises above 40 ^{0}C, gunny bags or straw packs moistened twice a day with water should be spread over the top covers of the colonies.

Since honey bees maintain their hive temperature during summer by collecting water from outside source, spilling it inside hive, evaporating it by fanning, there should be a source of running fresh water. This can easily be arranged in an apiary by hanging an earthen pitcher filled with water having a hole at its bottom and allowing drops of water to fall on sloping stones.

(IV) MONSOON MANAGEMENT:

During monsoon high humidity and high temperature cause unfavourable conditions for bees. Sometimes due to continuous rains, bees are confined to their hives for a long period. Honey bee becomes leathargic and may develop dysentery. Attack of bee enemie is also more. The colonies need following managements to keep them strong :

- Weak colonies which have become queenless, should be united with queen right colonies, since during the period due to absence of drones new virgin queen can not mate.
- Avoid broodlessness in colonies: if pollen stores and fresh pollen is not avoidable. Feed the colonies with pollen substitute or pollen supplement.
- If colonies have poor food stores (below 5 kg) provide sugar in the form of candy or dry sugar instead of sugar syrup.
- Keep in check the attack of enemies like wax moth, mites and wasps.

(V) AUTUMN/FALL MANAGEMENT :

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

During this period many colonies make preparation for superceding old queems and raise few new queen cells. The new queen on emergence replaces the old queen.

For successful overwintering, which is the on – productive season, following managements should be done.

Ensure that the colony has vigorous and productive queen. An ideal queen is one whose egg laying rate is high and continuous to lay well till late fall and thus provides population of predominantly young bees in sufficient number for wintering.

Colonies below average population or having scattered or less brood than the average colonies indicate failure of queens. Replace queens of such colonies by early fall so that these colonies produce desirable number of young bees.

Colonies for wintering should be free from disease.

Reduce the comb space by removing extra frames to such a level which can be covered by the bees well.

Under moderate climatic conditions, colonies of bees on 3-5 frames can winter successfully, if the colonies have proper food stores. Unite the weak colonies with a average to strong colonies.

If colonies have less honey stores, feed them with heavy sugar which is prepared by dissolving 2 parts of sugar in one part of boiling water and to avoid crystallization and 1 table spoon full if tartaric acid to each of 50 kg of sugar. Full this syrup in combs and exchange for empty combs in the hive.

Precaution:

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

(VI) WINTER MANAGEMENT :

After preparing the colonies in fall for wintering, protection should be produced to the colonies from winter by :

- Reducing the hive entrance.
- Plugging all cracks and crevices in the hive.
- Protecting the colonies from direct chilly winds.

Storage and protection of combs :

Protect the spare combs from attack of wax moth by fumigation in hive stacks frequently till spring when these drawn combs will be needed by the colonies again.

Wintering:

Honey bee use honey as source of energy for generating heat and to maintain hive temperature of 32-35 ^{0}C. For wintering, if insulation to hive is provided it will help in reducing of store consumption and saving energy of bees. The type of insulation depends upon the climatic zones.

Packing of hive:

- Only good colonies with young bees in large number and enough food stores should be packed.
- For packing colonies straw, sawdust, wood shavings, bean stalks or dry leaves , chopped rice or wheat straw can be used.

- Packing material should be dry since moisture will make it poor insulator.
- Packing can be given in the brood chamber beyond dummy board, as well as between inner and top cover.
- Strong colonies with young bees and good food stores with proper packing, need no care during winter and are opened only in spring.

LECTURE NO. 4

BEE KEEPING EQUIPMENTS AND TYPES OF BEE HIVES

EQUIPMENTS USED IN COMMERCIAL BEE KEEPING :

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 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 by10 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 a 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 equipment, there are several miscellaneous equipment which are required from time to time such as 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.

A TYPICAL BEE HIVE :

Langstroth discovered the principle of bee space in 1851 in USA. This space permits free passage for worker bees and is too small to build a comb by bees or too large for depositing bee glue i.e. propolis.

This principle was a big discovery for modern beekeeping. The bee space measures 9.525 mm for *Apis mellifera* and this was modified for *Apis cerena* between 7 to 9 mm. A complete bee hive has following parts.

a)	Stand	:	To support bottom board
b)	Bottom board	:	It is a floor of the hive having an entrance for bees
c)	Brood chamber	:	A box without top and bottom and this chamber have the frames. The dimensions vary with type of chamber
d)	Frame	:	Each frame consists of a top bar, two side and a bottom bar. Top bar has a groove in the middle for fixing comb foundation sheet. Side bar has two holes for wiring the frames.
e)	Super	:	Dimensions may be same as that of brood chamber of half of it (depending on type of bee hive). This is a chamber where bees gather surplus honey
f)	Inner cover	:	A board to cover brood chamber from super
g)	Top cover	:	A type of lid to cover inner cover and brood chamber from the top. In general for *Apis mellifera* we use Langstroth hive and for *A. cerena* we use I.S.I hive. A wooden dummy board is used to limit the size of brood chamber.

TYPES OF BEE HIVES :

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 *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, collected 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 shadeless 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 intruders.

The site should be free from termite and black ant infestation.

Bee Hives:

Various types of bee hives are available for beekeeping. They are wooden boxes having two parts: upper ¼ comb is super 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 (American hive)	42.2 cm x 31.1 cm	Some other familiar bee boxes. Nowadays these boxes are widely used in commercial beekeeping. Langstroth hive is suited to *A. mellifera*.
4.	Pant, Kanje and Jeolikote No.1	42.2 cm x 12.3 cm	
5.	Dadant box (Russian hive)	47 cm x 28.6 cm	
6.	Thompson box	30.5 cm x 15.2 cm	

Hive parameters	BIS hive C type For *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 232mm Inside : 428 x 192mm	**Type A: Modified Newton Type** Outside: 230x165mm Inside : 210x145mm **Type B: Modified Jeolikote Type** Outside : 300x195mm Inside : 280x175mm
Bee space	10 mm	**Type A :** 7 to 9 mm **Type B :** 8 or 9 mm

LECTURE NO. 5

REPRODUCTION IN BEES AND QUEEN REARING, BEE PASTUARAGE, BEE PRODUCTS AND THEIR USES, ECONOMICS OF BEE KEEPING

LIFE CYCLE OF HONEY BEE:

Eggs:

Eggs are laid by queen and when a colony a colony wants to produces a new queen, the special cell 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 in to pupa and after a week adults come out by biting the cap of queen cell. The adult who comes out earlier become the queen daughter and it kills the remaining pupae before their emergence.

Nuptial flight:

After 2-3 days the queen daughter 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. It mate only once in her life time. The seminal fluid (male sperms) is collected in a special receptacle (spermatheca) and used when required.

Oviposition:

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

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 cuplike 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 and form the unfertilized eggs drones are born. The grub are cylindrical and light yellow in colour, they fed with the royal jelly for 2-3 days after that they are provided honey and nectar etc. The grub period lasts for 5-6 days.

Worker bees are raised in the multipurpose, horizontally arranged cells of the comb. Future workers receive royal jelly only during the first 3 days, compared to future queens, who are fed 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 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 pupates periods lasts 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

QUEEN MANAGEMENT:

Qualities of a good queen:

- Good queen has a gentle tapering large abdomen, full along the sides.
- Evenly coloured and large thorax.
- Good egg laying capacity, lays single egg in the exact centre of the cell bottom which are slanted in the same direction.
- Eggs are laid symmetrically starting above the centre and spreading out in all directions.
- Combs are well occupied with concentric circle of brood on identical age.

Queen can also judged by the behavior of its progeny:

- Good honey producer
- Less swarming instinct

- Gentle in temperament

When to replace the queen:

Best method is to replace the poor queen whenever it is found and not on yearly basis, if reserve queens are available. Otherwise replace poor queen either during early spring or during fall.

Requeening/Queen introduction:

- To introduce a queen in a queenless colony, it is caged along with 5-10 attendant workers in a queen cage and is suspended in between the frames. The queen is released after one day.
- Young queens can easily be introduced during a nectar flow in spring or late in fall when egg laying is minimum.
- It is advised that a beekeeper should have some queens in the nucleus hives as reserve queens for replacing in an apiary as and when needn arises. For every 100 bee colonies keep atleast 10 queens in the nucleus hives.

BEE PASTURAGE :

Honey bee gather nectar and pollen from plants as their food. Nectar is a sweet secretion from the floral buds and extra floral nectaries of blossoms is the raw materials for honey. Pollen is a highly proteinaceous food for the bees. The plants that yield these two substances are collectively termed as **"Bee Pastaurage", Bee forage or "Nectar and Pollen plants".** The days when a good number of plants have nectar to be foraged by bees is called as **"Honey flow period ".** If the nectar yield is copious from a good number of plants of a particular species it is called as "Major honey flow period". When the amount of nectar to be collected is small the period is called as "Minor honey flow period". The days when there is no honey flow is called as **"Dearth period".** As nectar and pollen are the raw materials of the beekeeping industry, a good knowledge that govern production of honey, is of paramount importance.

It is interesting to note that the relationship between honey bees and plants is on a give and take basis. Many plants require visits of insects for cross pollination to attract the insects. They secrete nectar and have some highly coloured blossom parts (corolla). Insects in search for nectar, visit the flowers thoroughly. In this process pollen grains get stucked amoung their all body parts. Every few minutes, bees remove pollen from their bodies with pollen brushes and collect surplus pollen in their pollen baskets.

The honey bees help to bring the male and female parts of the flower together and thus arrange fertilization of the ovum, the blossoms give them nectar and pollen to eat. The bees make honey from nectar only and not from pollen.

Not all the blossoms are visited by the bees and some of those which are, may be insignificant. A bee keeper who want to know the nectar potentialities of a locality must ask himself the following questions.

1. What blossoming plants are found in abundance in one or two mile radius of the locality where he wants to keep honey bees?
2. How long are their blossoming periods?
3. Are the flowers visited by bees for nectar or pollen or both.
4. Are bees able to collect surplus honey from some abundant crops of flowers year after year.
5. What are the nectar secreting and flowering plants besides the major crop of the area.
6. How long a dearth period? if any, lasts?

Foraging activities of the bees:

If nectar secreting plants are available in large numbers, that is, there are one or two major honey flow periods with minor honey flow periods during other parts of the year and the dearth period is not of a long duration. Bee keeping is successful in that locality.

BEE FLORA OF MAHARASHTRA

Sr. No.	Common Name	Botanical Name	Source of Nectar or pollen
1	Banana	*Musa paradisica M. sapientum* L	N* + P*
2	Berries	*Rubus spp.*	N** + P**
3	Citrus	*Santra, Mosambi, Nimbu, Malta*	N** + P**
4	Coconut	*Cocos nucifera*	P**
5	Wild date palm	*Phoenix sylvestris*	P**
6	Guava	*Psidium guavajava* L.	N** + P**
7	Jamun	*Syzygium cumini* S	N** + P**
8	Jujuba	*Zizyphus mauritianna* L	N* + P*
9	Mango	*Mangifera indica* L	N* + P*
10	Pomegranate	*Punica granatum* L	N* + P**
11	Cashew	*Anacardium occidentale* L	N* + P*
12	Grapes	*Vitis vinifera* L	N* + P*
13	Papaya	*Carica papaya* L	N* + P*
14	Sapota	*Manilkara achrus*	N* + P*
	Vegetables: Acting as minor sources of pollen and nectar because most of them put forth blossom over prolonged periods. Bees are helpful in pollinating vegetables in seed production condition		
15	Coriander	*Coriandrum sativum* L	N* + P*
16	Cruciferous	*Brassica spp.*	N* + P*

17	Cucurbitacious		N* + P*
18	Lady's finger	*Abelmoschus esculantus* L	N* + P*
19	Onion	*Allium cepa* L	N* + P*
20	Garlic	*Allium sativum* L	N* + P*
21	Peas	*Pisum sativum* L	N* + P*
22	Radish	*Raphanus sativus*	N* + P*
23	Sweet potato	*Ipomea batatas* L	P*
24	Brinjal	*Solanum melongena* L	N* + P*
25	Potato	*Solanum tuberosum* L	P*
26	Tomato	*Lycopersicon esculentum* L	N* + P*
27	Chillies	*Capsicum annum*	N* + P*
	Ornamentals:		
28	Holly hock	*Althea rosea* L	N* + P*
29	Honey suckle	*Lonicera sempervirens* L	P*
30	Poinsettia	*Euphorbia Pulcherrima* L	P*
31	Pride of india	*Lagerstromia indica* L	P*
32	Poppy	*Papaver somnifera* L	P*
33	Portulaca	*Portulaca grandiflora* L	P*
34	Rangoon creeper	*Quisqualis indica*	N**
35	Roses	*Rosa spp.*	P*
36	Sunflower	*Helianthus annus*	N** + P**
37	Zinnia	*Zinnia spp.*	P*

BEE PRODUCTS AND THEIR USES:

(I) Honey: Honey is a natural food made by the bee with nectar, pollen and other substances. It is considered nature's most completely nourishing food as it contains nearly all nutrients required by humans.Honey is primarily composed of fructose (38%), glucose (31%), water (17%), maltose (7%), and small amounts of trisaccharides, other higher carbohydrates, sucrose, minerals, vitamins, enzymes, amino acids and proteins.

Uses of Honey:

Honey is valued everywhere as a sweet and tasty food.

Blood sugar regulation.

Pro-biotic agent (health benefit).

Beautiful and healthy skin.

Anti bacterial and anti fungal agent.

Soothes cough and suppress cough in children.

Reduce the ulcers.

Boost memory.

Helps with seasonal allergies.

Provides different nutrients.

Heals burns and treat the wounds (for topical application since Ancient Egypt).

Antioxidant agent.

Honey is a delicious, healthier alternative to sugar.

(II) Propolis (Bee glue) :

Propolis is a sticky, gummy and resinous substance collected by the bees from exudates of buds, bark and wounds of plants. The honey bees use this material for plugging the cracks and crevices and unwanted holes in the hive, varnishing on internal surfaces of the hive and comb surfaces and spreading around the hive entrance as repellant to the intruders like ants. Only European honey bee *A. mellifera* is in the habit of collecting propolis and that is why this species is less prone to attack of wax moth.

Composition:

The main constituents of propolis are:

(i) Waxes and fatty acids	:	30 %
(ii) Resins and balsams	:	55 %
(iii) Etheral oil	:	10 %
(iv) Pollen	:	5 %
(v) Flavonoids, phenolic	:	Traces
(vi) Aromatic compounds		

Uses:

- Propolis is antibacterial, antiviral, anti-inflammatory, acts as topical anesthesia and has spasmolytic activity.
- Acting as curative agent in human health in alignments like cold, sore throat, skin problems, stomach ulcers, hemorrhoids, gum diseases and wounds.
- In food technology, it is used as oxidant, antimicrobial and antifungal agent.
- Also used in post harvest treatment of fruits.
- Acts as antibacterial agent and used as animal growth stimulant and costs 2-6 $ per pound (0.45 kg).

(III) Royal jelly (Bee milk):

Royal jelly is a mixture of secretions of hypo-pharengeal glands (watery clear) and mandibular glands (milky white) in a ratio of 1:1 and is produced by the nurse worker bees for feeding it to the larvae destined to be queens and also for feeding to the adult queen bees. It is produced and directly fed to the gyne larvae and adult queen bees and is never stored. That is why it is not a traditional honey bee product. Queen larvae cannot consume the royal jelly at a rate at which it is supplied to them and so always surplus of it surrounding the larvae can be extracted at cost of queen larvae. It is most important

factor in caste determination (queen differentiation) since it is supplied to the queen larva in relatively larger quantity and greater frequency, though its composition is different than that from worker jelly. The worker larvae (1-3 days old) are fed watery clear and milky white secretions in a ratio of 3:1 or 4:1 while the older larvae are seldom fed milky white secretions. It is mainly the spectacular fertility and long life span of the queen exclusively fed on royal jelly which also produces similar effects in human beings.

Composition:

Royal jelly is a creamy milky white, strongly acidic, highly nitrogenous substance with a slight odour and some what bitter taste. It contains :

(i) Water - 50-70 %

(ii) Proteins - 17-45 % (Glycoproteins, amino acids and Enzyme peptides).

(iii) Sugars - 18-52 % (Glucose oxidase, Phosphatase and Choline esterase, Fructose, Sucrose and maltose).

(iv) Lipids - 3.5 – 19 % (Tri halese, melibiose, ribose).

(v) Minerals - 23 %

Vitamins like thimane, riboflavin, panthothenic pyridoxine etc. are present except A, D, and K.

The royal jelly is extracted from a neem cell cups 72 hours after grafting. The cells are cut to the level of royal jelly with sharp blade, the larva in the cells is through out. Then the jelly is extracted either with the help of aspirator or water vaccum pump or methorg suction.

Uses:

(1) It should be sold in its fresh state otherwise it must be cooled or freezed.

(2) Used as dietary supplement.

(3) Food products, vitamin supplements are enriched with fridge dried royal jelly. Widely used in beverages.

(4) As an ingredient in medicine products, acts as a stimulant hence it is included in medicine for its stimulatory effect.

(5) Ingredient in cosmetics.

(6) Animal nutrition, stimulate race horses, as a food for rearing mites and insects. 1 kg royal jelly costs 3300 $.

(IV) Bees wax:

Hornbostel, H.C. (1744) first time described that bees wax is synthesized by bees and secreted through four pairs of wax secreting epidermal wax glands, present on the ventral side of the fourth to seventh abdominal segment of the worker bees body. The wax is secreted by 14-18 days old worker bees. Bees after feeding on honey and pollen hang themselves in fastoons and secrete wax flakes/scales. These

wax flakes are masticated by bees into pliable pieces with saliva and enzymes and then used for comb construction and capping brood and ripened honey combs. To produce one part of wax, bees have to consume about 4-7 times as much honey.

Composition of bees wax:

Freshly produce bees wax is whitish to yellowish in colour with honey like odour. The colour may vary depending on the food of honey bees. Bees wax is soft at warm temperature and becomes brittle at low temperature. The bees wax can be obtained from cappings pure brace comb and old discarded combs of domesticated as well as wild bees and slum bees.

Uses:

- Used in several industries i.e, church candles, cosmetics, shoe polish etc.
- Coblers for car/mason polish, carbon paper, electrical and textile industry.
- In metal casting and moulding for water proofing, crayon colour industry, for scientific decorative models, for polishing optical lenses, in adhesives and links in candy and chewing gums, for musical instruments.
- For preparation of comb foundation sheets, for coating of drugs and pills. It costs about 70120 Rs/kg.

(V) Bee venom:

It is synthesized by the venom glands of worker bees (100-150 µg) and queen (700 µg). The normal recovery to 0.5 – 1.0 µl per bee). About one million stings are required to male one gram dry venom.

Composition:

Bee venom is a clear watery material having sharp and bitter taste, hydrolytic blends of proteins with basic pH and used by bee for their defense. Venon proteins exhibit various degrees of allergic reaction to the victim of stinging.

Uses: It is used for curing rheumatoid arthritis, diseases of nervous disorders, suppressing odema (swellings), as anti-inflammatory agent hypersensitivity to bee stings.

ECONOMICS OF BEE KEEPING :

Economics of Bee keeping (For 50 colonies)

Sr. No.	Non-Recurring cost		Rs.
1.	Cost of hives (Newton's Bee hive of teak wood) @ Rs.400/hive	=	20,000
2.	Cost of 10 nucleus box @ Rs. 300/hive	=	3,000
3.	Hive stand @ Rs.50 for 60 boxes	=	3,000
4.	Honey extractor, smoker and other appliances	=	1,500
	Total	=	**27,500**
	Recurring cost		

1.	Cost of sugar @2 kg/colony during death period @ Rs.15/kg	=	1,500
2.	Comb foundation sheet 2 kg @ 100/kg	=	200
3.	Interest for non-recurring amount @ 10%	=	2,750
4.	Depreciation @ 10%	=	2,750
5.	Cost of colonies @ Rs.100/colony	=	5,000
6.	Miscellaneous	=	1,000
	Total		**13,200**

Income (Rs.)

1. Realization through honey yield @ 3.5 kg/ colony and Rs.150/kg = 26,250
2. Realization through bees wax @ 5kg/50 colony and Rs.200/kg = 1,000

Total **27,250**

Net income (Rs.)

C (Income) - B (Recurring cost) = 27,250 -13,200

= **14,050**

As the subsequent years do not require any non-recurring materials, the income would be more from the second year. Besides the cash benefit through honey and bees wax, bees also render pollination service to the crop plants and help in getting increased fruit setting and yield. It is generally referred that the value of pollination service by the bees is 10 times more money value that contributed from the honey and bees wax.

LECTURE NO. 6

BEE ENEMIES AND DISEASES, ROLE OF BEES IN POLLINATION

BEE ENEMIES AND DISEASES:

1. Predatory wasps:

Vespa auraria:	Nests on tree tops/buildings
Vespa magnifica:	Under ground nest
Vespa cincta:	Under ground nest
Vespa basalis:	Nest on tree tops/ buildings

Nature of damage:

- The wasps catch the bees at hive enterance and kill them.
- Most serious damage in hills is caused by *V. magnifica* which cuts down bees in large numbers while sitting or flying at/near hive entrance.
- The weak colonies are attacked more than the stronger ones.

Prevention and control:

- Kill the fecunded females visiting the apiary during spring by flapping.
- Burn the nests during night time.
- Kill the wasps in the apiary by flapping. **2. Wax moth: *Galleria mellonella* Nature and extent of damage:**
- The attack is more prevalent during monsoon.
- The wax moth larvae tunnel through the mid ribs of the comb and there is presence of small mass of minute wax particles outside the tunnels.
- In case of severe infestation, further brood rearing is stopped, bees stop field work and colony may abscond.

Prevention and control:

- Close cracks and crevices in the hive. Reduce hive entrance.
- Remove combs not covered by bees. Keep the bottom board clean.

Control in storage:

Keep spare combs in empty hive bodies in tiers and close both at bottom and top. Disinfect the stock by burning suplhur @ 180 g/m^3 (fumigation with sulphur fumes). After fumigation, put naphthalene flakes in moth proof stacks.

3. Ectoparasitic mites:

In India, *Varroa jacobsoni* is found on *A. cerana* where as *Tropilaelaps clareae* causes severe damage to *A. mellifera* colonies.

Control:

- *Tropilaelaps clareae* Sulphur dusting on top bars @ 200 mg/frame.
- *Varroa jacobsoni* Fumigation by Apistan strip.

4. Bee louse: *Braula coeca*

Wingless fly found on thorax of honey bee and feeds by coming near mouth close to opening of salivary glands and take the available nourishment. But it is not a serious pest.

5. Other enemies:

Birds like Bee eater *Myropes orientalis* and Black drongo/king crow eat bees while they are flying. To control the menace scare them away. Attack of ants can be controlled by making the hive ant proof by putting the legs of hive stand in pots containing water. Bears and pine martines are the mammals which attack the bees for honey and bees.

BEE DISEASES:

A] Brood diseases:

Sr. No.	Particulars	American foul brood	European foul brood	Sac brood/ Thai sac
1.	Causative organism	*Bacillus larvae* (Bacteria)	*Mellissococcus pluton* (Bacteria)	Brood (virus)
2.	Time of death	Late larval or early pupal stage	Coiled larvae in unsealed cell	Late larval stage
3.	Cappings	Sunken and punctured	Dead brood in uncapped stage	Capping removed or punctured
4.	Colour of brood	Off white to light cream to brown	Yellowish to grey or brown	Snow coloured, stage darking from head

5.	Position of dead brood	Extended on cell base	Coiled, twisted or collapsed	Extended with head curled up
6.	Consistency	Show ropiness	Sod and gummy no ropiness	Sac like with watery contents
7.	Odour of dead brood	Glue pot	Sour or none	Faint
8.	Brood affected	Worker, rarely drone or queen	Worker, drone and queen	Worker only
9.	Control	Terramycin 0.25 – 0.4 g in 5 liters sugar syrup feeding	Terramycin is the only product labeled for the control of European foulbrood.	No effective control

B] Adult diseases:

Sr. No.	**Particulars**	***Nosema***	***Acarine***
1.	Causative organism	*Nosema apis* (protozoan)	*Acarapis woodi* (Endoparasitic mite)
2.	Symptoms	Infected bees collect in front of hive, sluggish, crawlers on leaf blades, distended abdomen	Bees gather in front of hive but unable to fly.
3.	Control	Feed fumigating 200 sugar syrup to each colony or Entakon – M (Tetracycline hydrochloride) 45 ppm	Fumigate using folbex VA strip with formic acid.

ROLE OF BEES IN POLLINATION:

The term pollination is defined as the mechanical transfer of pollen to the female part of the flowers. Joseph Gottlieb Koelreuter was the first to make observations on flower pollination. He pointed out that the visits of insects are necessary for pollination many flowers. Without the help of insects to effect pollination, many species of plant will not set seed or produce fruit, no matter how well they are cultivated, fertilized and protected from diseases and pests. Over a thousand blossom visiting species

of insects are known. Among important pollinators are honey bees, bumble bees, many species of solitary bees, stingless bees, wasps many kind of flies – *Syrphus, Bombylius and Sarcophaga*, beetles, black ants, thrips, butterflies and moths. Though most of these go to blossoms for nectar and pollen, quite a number are there to suck the juices of plant, eat its tissue and lay eggs in the blossoms or prey upon foraging insects. Relatively few species are constantly good pollinators. The most efficient pollinators carry plenty of pollen on their bodies, brush against stigmas of flowers transferring the pollen, visit several flowers of the same species in succession and move frequently from flower to flower and plant to plant.

Why cross pollination:

Besides, cross-pollination in crops is also brought through mechanical means i.e., by man or by wind, water, birds and animals etc. the plants require cross pollination due to the following reasons.

1. Self incompatibility among the flowers of the crops.
2. Variation in the length of anthers and stigma of flowers i.e. anthers at low height and stigma at higher.
3. Some of the plants have flowers of single sex (i.e., male or female) and require pollinizer e.g., peach, papaya and citrus etc.
4. Difference in maturity of pollen grains and stigma which leads to unsuccessful fertilization.

From the available data, it can be stated that honey bees is more valuable than the other bees as pollinator for the following reasons.

(i) Floral fidelity/constancy of bees.
(ii) Potential for long working hours.
(iii) Can be managed in sufficient population where and when required.
(iv) Division of labour, as a result worker bees collect pollen and nectar to supply to the next generation and in turn visit more flowers and pollinate them.
(v) Special body characteristics viz., coating of long hairs, long tongue and ability to warm them and to work in cool weather making them generally more efficient.
(vi) Their thoroughness with the flowers i.e, they come in contact of important floral organs namely anther and stigmas.
(vii) Never ceasing instinct to gather nectar and pollen- more highly developed than the other pollinating agents.

The principle role of honey bees is in pollination of many agricultural crops for the production of seed and fruit and honey and bee wax are merely by-products of pollination. Value of honey bees in

pollination of crops is 15 to 20 times that of the honey and wax it produces. Bee pollination makes it possible to utilize legumes for increasing the protein content in pasture land and dry storage as well as restoring nitrogen in soil. Thus honey bee is a link in the chain in the establishment of a stable agriculture programme.

In the recent times, the importance of honey bees as pollinator of crops has increased many fold due to the fact that wild bees and other pollinating insect population have diminished to the destruction of wild flora and nesting sites by the continuous intervention of man, also by the use of herbicides and pesticides. The large acerage of fruit and seed crops is now more dependent on honey bees for their pollination requirements. From an agricultural point of view it is highly desirable to foster programme of increasing of honey bee population throughout the agricultural areas.

Moving bee colonies from one place to another has always been followed by bee keepers in developed countries and the practice are also catching up in some Indian states. Renting bees for crop pollination has also started in certain areas in our country. The crops in which bees can play a predominant role by way of accomplishing cross-pollination include:

CROPS BENEFITTED BY BEE POLLINATION:

Fruits and nuts	Vegetable crops	Oilseed crops	Fodders	Other crops
Almonds	Cabbage	Toria	Berseem	Buck wheat
Apple	Cauliflower	Taramira	Lucerne	Cotton
Apricot	Carrots	Mustard	Persian Clover	Flax
Avocado	Coriander	Rape	Red clover	Poppy
Cashew	Cucumber	Sesamum	White clover	
Cherry	Ladys' finger	Safflower		
Citrus	Onion	Sunflower		
Coconut	Pepper			
Fig	Pumpkin			
Grapes	Raddish			
Guava	Rape			
Litchi	Squash			
Mango	Turnip			
Papaya				
Peach				
Plum				
Strawberry				
Watermelon				
Muskmelon				

PER CENT INCREASE IN YIELD DUE TO BEE POLLINATION

Crop	Botanical name	Per cent yield increase
Mustard	*Brassica* spp.	43
Sunflower	*Helianthus annus*	32 – 48
Cotton	*Gossypium* spp.	17 – 19
Lucerne	*Medicago sativa*	112
Onion	*Allium cepa*	93
Apple	*Malus domestica*	44

In certain fruit crops, cross pollination though remain essential for proper fruit formation (size and shape), development of colour and proper yield; there are certain fruits like apple, cherry, pear, almonds and some varieties of peaches, plum and strawberries and grapes which are selfunfruitful. In such cases, cross pollination is required with cross-fruitful varieties. Hence, suitable pollinizer varieties are required to be planted at specific intervals.

Advantages of Honey bee pollination:

1. The germination of pollen on stigma is improved and fertilization is assured.
2. The number, size, weight and quality of seed produced are improved.
3. Fruit set is better and as the seeds grow, carpels develop uniformly producing well formed fruits. The fruit drop is also reduced to the minimum.
4. The fruits formed are more nutritious and have a better flavor.
5. The seed produced have more oil content and nutrients and when sown there is a greater germination and healthier growth.
6. The plants grown from such seeds have more vigorous growth, producing more flowers and increasing the crop yield.
7. The plants grown from cross pollinated seed are observed to have greater resistance to diseases and other adverse environmental conditions.

LECTURE NO. 7

IMPORTANCE, HISTORY AND DEVELOPMENT OF SILKWORMS IN INDIA, SILK WORMS SPECIES AND THEIR HOSTS, SYSTEMATIC POSITION, DISTRIBUTION LIFE CYCLE AND SILK GLANDS

IMPORTANCE:

Sericulture is an agro based industry, the term which demotes 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 activities can provided employment to people either directly or indirectly. Sericulture improves frequent returns throughout the year with relatively less expenditure common in puts.

HISTORY OF SERICULTURE 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 2500BC, 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 DEVELOPMENT 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 Flanking the rivers Brahmaputra and Ganges the Aryans discovered the Silk worm in Sub Himalayan regions even though mulberry cultivation may have come to India from china. The silk from Kashmir became very famous in the beginning of christen era. This may be the fact that, the Arabs obtained the silkworm eggs and mulberry seeds from India during the early days of christen era. During 4th century AD, when the sericulture industry established in India and central Asia, raw silk and silk goods were exported to Persia and Rome. In 553 AD, Sericulture was spread to Constantinople. Gradually, Sericulture industry developed in Venetion 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 14thand 15thcentury, 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 was 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) deal with Mulberry sericulture.
2. Central Sericultural Research & Training Institute (CSRTI), Berhampore (West Bengal) deal with Mulberry sericulture.
3. Central Sericultural Research & Training Institute (CSRTI),GallandarPampore, Kashmir, (J&K) deal with Mulberry sericulture.

4. Central Tasar Research and Training Institute (CTRTI), PO-Piska-Nagri

   Ranchi- 835 303 (Jharkhand**)** deal with Tasar sericulture.
5. Central MugaEri Research and Training Institute (CMER & TI), P.O. – Lahdoigarh, Jorhat, Assam deal 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 SericulturalGermplasm 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, Navsariis working on silkworm under Plan scheme(Development Charges) Project entitled "Research Studies on Mulberry Sericulture in South Gujarat Region"since 1991.

During 2016-17, the total raw silk production in the country was 30,348 MT. The highest raw silk production was noticed in Karnataka (9571 MT) followed by Andhra Pradesh (by 5970 MT) during 2016-17.

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, *Antheraeamylitta*. Its silk filament is about three times heavier than that of the cultivated silkworm, *Bombyxmori*, 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, *Antheraeamylitta* and *Antheraeapernyi*. 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. myliltta* *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, *Bombyx mori*:

Systemic position:

Phylum : Arthropoda
Class : Insecta

Order : Lepidoptera

Family : Bombycidae

Genus : *Bombyx*

Species : *mori*

Silkworm passes through a complete metamorphosis from egg to adults' stage.

1. Egg:

- Eggs are laid in clusterson 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 appearingon 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, *Philosamia ricini*:

Systemic position:

Phylum : Arthropoda Class : Insecta

Order : Lepidoptera

Family : Saturniidae

Genus : *Philosamia*

Species : *ricini*

The erisilkworm 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 semicircular 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.

C. Morphology and biology of Tasar silkworm, *Antheraea mylitta* (Drury):

Systemic position:

Phylum : Arthropoda Class : Insecta

Order : Lepidoptera

Family : Saturniidae

Genus : *Antheraea*

Species : *mylitta* (Drury)

The egg : The egg is oval, dorsomventrally flat and bilaterally symmetrical aliong the anteroposterior axis. It is 3 mm long and 2.5 mm in diameter. Althouhg the egg is pale white, it appears brown due to a gummy coating. Two brown parallel lines are present along the equatorial plane.

The larva (Caterpillar) : The larva is eruciform or polypod type, with biting and chewing type mouth parts. It is dull brown-yellowish with black-head about 7 mm long weighing 8 mg. the body turns green in 2 days. It grows and undergoes four moults and the fifth instar larva is large 13 cms long and weights 50 gms. Shining white lateral spots appear on 3rd instar larva. The thorax is three segmented and bears 3 pairs of walking legs, one pair per segment. The terminal segment bears a anal flap and a pair of claspers. The fifth instar larva spins a cocoon.

The cocoon : The cocoon is single-shelled, yellow or grey pendent, oval, closed and reelable with a hard non-flossy grainy shell. At the anterior end there is a well formed dark brown penduncle with a ring. Female spins larger cocoon than the male. The larva transforms into the pupa inside the cocoon.

The Pupa : The pupa is obtect, adecticous with well defined segmental body, the dark brown pupa measures about 4.5 X 2.3 cm and weight 10.3 gm.

The Adult : The tasar insect is a very large moth exhibiting sexual dimorphism. The females are bigger with a wing-span of 18 cms. The wings are grey or yellow or light brown with patterns of red, with and black (brown) lines. Each wing has an eyespot or a circular ocellus in the centre. The male are smaller with brown wing and wing span of 16 cms. The males have a narrow abdomen with broad antennae when compared with the females.

D. Morphology and biology of Muga silkworm, *Antheraea assamensis* :

Systemic position:

Phylum : Arthropoda
Class : Insecta
Order : Lepidoptera
Family : Saturniidae
Genus : *Antheraea*
Species : *assamensis*

The moth is multivoltine, the entire lifecycle lasts for about 50 days in summer and 120 days in winter. The moth is semi-domesticated and can be raised outdoor. Muga silkworm also has the same life cycle as other silkworms i.e. egg, larva, pupa and adult.

Egg : The female moth's eggs are typically laid on the Som and Soalu trees. Hatching period 7 days in summer and 15 days in winter.

Larva: Eggs are hatched into larvae of about 2 mm long. They grow rapidly, eat voraciously and end up about 30 mm long after 4 to 5 weeks. During this time, they moult four times. At the end, they search suitable place for cocooning. Larval stage lasts for 24 to 70 days.

Pupa: The cocoon is light golden yellow in colour and elliptical in shape. Cocooning stage 3 to 7 days. Cocoon weight 4.5-8.55 g (wild stocks) and 2.90-7.70 (semi domesticated). Pupal stage lasts for 14 to 55 days.

SILK GLANDS:

The silk of silkworms is secreted by a pair of labial gland, known as silk glands. The silk glands lie ventral to the alimentary canal. In full grown larvae, these occupy most of the body cavity. The silk glands are tubular in shape with different diameters in different regions. Each gland has 3 distinct regions:

(1) Posterior region:

Blunt, highly folded tubular posterior regions of both glands remain attached to tracheal bushes of silkworm. This part secretes fibroin as fibrinogen which converted to fibroin upon extrusion.

(2) Middle region:

Most prominent and widest part of silk gland. It remains folded in a W-shaped structure and thus has 3 limbs — posterior, middle and anterior limbs. The posterior arm secretes sericin-I. It gets surrounded by serecin-II secreted from the middle limb.

This sericin again gets surrounded by sericin- III secreted from the anterior limb. The middle

region of silk gland also acts as the reservoir of fibroin where the later gets mature during the storage period.

(3) Anterior region:

The thin anterior region of silk gland has no secretory role and only transports the assembled silk to the spinneret.

Spinneret:

It is a projection of the median part of the labium, which draws the silk out in the form of fine filament. The secreted silk comes out as a thread or filament as it passes through silk press which resembles a typical salivary pump. The two filaments coming out of two sides are called brins. The sericin (gum) layer of the two brins then bind together into a single filament or bave.

Histologically the entire gland has 3 layers:

(1) The outer tunica propia with uniform thickness;

(2) The middle glandular layer with gland cells which increase in size during later instar stages of larval development and

(3) The inner tunica intima: It has varying thickness.

In the anterior region of the gland, this layer is very thick and is shed at each moult. In other regions of silk gland, it is thin and not shed at each moult.

Filippi's gland or Lyonnet's gland:

In the head region of the larvae, a pair of glands is situated which open into the anterior part of silk gland near its opening into the spinneret. It is thought that these glands contribute some waxy materials to the silk thread or lubricate the passage of silk while coming out.

LECTURE NO. 8 & 9
MULBERRY SILKWORMS - RACES, MORICULTURE – MULBERRY VARIETIES, PACKAGE OF PRACTICES

MULBERRY SILKWORM – RACES:

Silkworm breed is the most influential factor in the development of sericulture. In the long history of sericulture, many silkworm races have been recognized as valuable for practical use and the same have been preserved.

Bombyx mori silkworms are classified into Japanese, Chinese, European, Korean and Tropical races. Japanese (dumbbell cocoon shape) and Chinese race (oval cocoon Shape) are mainly used in the temperate zone. In the tropical zone polyvoltine races are used or as one of the parents crossing with Japanese or Chinese race.

Distinct features based on voltinism:

Univoltine: Suitable for cooler places, growth period of larvae is longer having big body. Cocoon and silk quality is excellent. High temperature and high humidity are not suitable. The univoltine silkworm, 'Borapolu' or 'Barpat' endemic to Assam

Bivoltine: Suitable for warmer places. Larval duration shorter compared to univoltines. Larva is robust, cocoon and silk quality is good. Moderately suitable to high temperature and high humidity.

Polyvoltine: Adaptable to warmer places, larval duration is shorter, larva is robust, small cocoon, silk quality is poor. Lays only non-hibernated eggs. 'Chotopolu' or 'Sarupat' and 'Moria' are endemic to this region.

NEW PRODUCTIVE BREEDS/HYBRIDS:

(1) CSR2: A new bivoltine breed evolved from the Japanese commercial hybrid at CSRTI, Mysore.

Egg: Newly laid eggs are yellow in colour. The egg number ranging from 450-500

Larva: Newly hatched larvae are deep brown in colour. Matured larvae bluish white in colour. Larval duration 23-24 days (in controlled condition) . Fifth age larval duration 6-7 days.

Cocoon: white, oval in shape with fine to medium grains with scanty floss. Survival 85-90%, cocoon weight 1.80-1.95g, cocoon shell weight 0.45-0.5g, cocoon shell ratio 24-26%, Raw silk % 20-22%, filament length 1000-1300mts, neatness 85-90 (points).

Moth: Spinning to moth emergence period is about 13 days. Lays hibernating eggs. No. of eggs per gram 1880.

(2) CSR4: A new bivoltine breed evolved from the Japanese commercial hybrid at CSRTI, Mysore.

Egg: Newly laid eggs are bright yellow in colour. The egg number ranging from 600-650.

Larva: Newly hatched larvae are blakish in colour. Matured larvae reddish tinge in colour. Larval duration 24-25 days (in controlled condition) . Fifth age larval duration 6-7 days.

Cocoon: white, elongated dumbbell with round end, fine to medium grains with scanty floss. Survival 90-95%, cocoon weight 1.90-2.15g, cocoon shell weight 0.45-0.5g, cocoon shell ratio 2122%, Raw silk % 16-17%, filament length 1000-1200mts, neatness 85-90 (points).

Moth: Spinning to moth emergence period is about 14 days. Lays hibernating eggs. No. of eggs per gram 1810.

(3) CSR5: A new bivoltine breed evolved from the Japanese commercial hybrid at CSRTI, Mysore.

Egg: Newly laid eggs are bright yellow in colour. The egg number ranging from 475-525.

Larva: Newly hatched larvae are blakish in colour. Matured larvae bluish with reddish tinge. Larval duration 24-25 days (in controlled condition) . Fifth age larval duration 6-7 days.

Cocoon: white, elongated dumbbell with round end, mild constriction, fine to medium grains with scanty floss. Survival 85-90%, cocoon weight 1.80-1.05g, cocoon shell weight 0.45-0.5g, cocoon shell ratio 24-25%, Raw silk % 20-21%, filament length 1000-1200mts, neatness 85-90

(points).

Moth: spinning to moth emergence period is about 14 days. Lays hibernating eggs. No. of eggs per gram 1780.

MORITULTURE:

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 *Morusalba*, *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

biofertilizers 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 hirsutus*	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 disperses*	Hemiptera	Aleyrodidae	Nymphs 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	*Glyphodes pulverulentalis*	Lepidoptera	Pyralidae	Larvae
12.	Ash weevil	*Mylloceru* ssp.	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
Sr. No.	**Common Name**	**Scientific Name**	**Order**	**Family**	**Damaging Stage**

15.	Termite/White ant	*Odonototerme* ssp.	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*

LECTURE NO. 10

REARING HOUSE AND EQUIPMENTS, DISINFECTION AND HYGIENE

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^{0}C and RH of 60-70% for the growth of silkworm at minimum operational cost. In tropical climate the house should face east-west while in temperate climate it should face northsouth 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 55^0C. 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.**

LECTURE NO. 11

GRAINAGE ACID TREATMENT, PACKING AND TRANSPORTATION OF EGGS, INCUBATION, BLACK BOXING, HATCHING OF EGGS

Management of Eggs of Silkmoth:

The most important as well as precarious stage of sericulture is the production of healthy and disease-free eggs and it plays a vital role on which the success of the industry depends. Silkworm eggs are also called seeds and for sericulture purpose the eggs are classified into two groups, *viz.,* Reproductive seed and Industrial/Commercial seed.

(1) Reproductive seeds:

The seeds from which parents of different commercial seeds are produced. These are usually pure line of both local and high yielding races and rarely F1 hybrid.

(2) Industrial/ Commercial Seeds:

These are mostly F1 hybrids, produced by crossing between local hardy pureline female race and pure- line high yielding bivoltine (generally) males.

Egg/Seed production centre of silkworm:

(1) Breeding Stations:

For maintaining racial purity, quality and disease-freeness etc., reproductive seeds are produced as well as multiplicated in number in a series of breeding centre called Breeding Stations.

(2) Breeding Centre:

The number of pure breed parents required for a grainage are too large and that cannot be obtained by a single multiplication step from the stock. So generally, a 3 or 4-stage multiplication is carried out to maintain the racial purity as well as to produce quality eggs by technically qualified personnel in a series of breeding centers in the Breeding stations like P4, P3, P2 and P1.

In India, usually 3 Tier system of seed production at P3, P2, and PI level is adopted as follows:

P4/P3 (Breeding centres) — Centres where great grandparents or the great grandparents of commercial grainage seeds are multiplied. They rear only pure breeds and no hybridisation is done here to maintain the purity of races. So each laying of each race is reared separately in different trays. These are the major germ- plasm bank and seeds produced here are called Basic or Nucleus seed (Breeder's Stock Egg).

P2 (Breeding Centres) – They receive seed cocoons from P4/P3 centres, so they rear the grandparents of commercial seeds and produce the Foundation Stock Seeds that also serve as germplasm bank.

PI (Breeding Centres) – Here the parents of commercial layings are reared. They receive the seed cocoons from P2 centres. The first hybridisation of double crosses is done here and the hybrids produced are called Foundation hybrids.

(3) Grainage:

The establishments where the disease-free commercial seeds are produced in mass to be supplied to rearers are called Grainages. These are mostly owned by Government and may also be licensed private owned.

In grainages parental seed cocoons received from PI centres are reared as well as preserved under optimum conditions. The sexes of either larvae or pupae are recognised and accordingly male and females are reared separately. Following their emergence, healthy adult male and female moths are allowed to mate and oviposit by different methods.

Egg/Seed Production Methods:

In grainages commercial eggs are produced by any of the following methods:

(a) Cellular Bag Method:

Each pairing moth is kept into a small bag of perforated parchment/paraffin paper or cloth where the female lays eggs. Mother moths are examined after oviposition for pebrine.

(b) Cellular Card Method:

Here, a card or craft paper is divided into 20 cellules or squares in 4 rows, each with 5 compartments. A moth funnel plate with 20 similar holes is placed on that paper. In each section of the hole, one coupling pair of moth is kept and covered by moth funnel.

After egg laying, mother moths are removed and placed in an exact chamber of mother moth box with similar compartments. Then the moths are examined for pebrine. Diseased moth (if detected) and its eggs are discarded. This method can produce eggs in large scale.

(c) Flat Card Method:

In this system, about 40 pairs of coupling moths are allowed to lay eggs on the rough surface of a flat card (Fig. 3.1). If pebrine is detected in any mother moth, all eggs are discarded.

(d) Loose Eggs Method:

Same as flat card method except that eggs are laid on smooth surface of paper. Healthy eggs are then loosened from the paper by soaking it in water. Unfertilised eggs which float on water are discarded. Healthy eggs are washed in water, dried and packed.

Eggs prepared by any method are treated with 2% formalin solution for disinfection. Mother moths after egg laying are also checked for the transovarial infection of pebrine spores. If infection is detected, eggs of that layer are rejected immediately.

Storage of Eggs of Silkmoth:

Silk moths lay two types of eggs:

(i) Diapausing or hibernating eggs and

(ii) Non- diapausing or non-hibernating eggs. The eggs are laid either in spring or in autumn.

Storage of Spring Eggs:

Spring eggs are stored at aestivation temperature (23-25°C) from June to August, then at room temperature till September or early October; then gradually lowered to 5°C in December for 50-60 days. This treatment awakens the embryo but arrests the development.

The eggs are kept still at lower temperature (2.5°C) for another 40-50 days where these can also be stored for any length of time. Otherwise, in March, eggs are shifted at a temperature of .10- I5°C for 4-5 days before incubation.

Storage of Autumn Eggs:

Eggs laid in autumn (August) are kept at 23-25°C for 20 days; then the temperature is gradually lowered (to 2.5°C) as for spring eggs till natural temperature is reached.

Grainage acid treatment:

In order to utilise available mulberry leaves, sometimes hibernating eggs are treated with diluted acid to break their diapause and to get more crops, Eggs are either kept in hot HC1 acid at 25°C

for 20-24 hours after oviposition or in dilute acid heated to 46°C for 5 minutes. Sometimes eggs are dipped in HCI at 15°C for about 50 minutes. After acid treatment, eggs should be washed in cold water.

Packing and transportation of eggs:

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 seeds (DFL) 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 are then made to 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 per cent formalin solution. Eggs are dried, weighed to the required standard and packed in small flat boxes with muslin covers and dispatched to buyers.

The transportation of eggs plays an important role in the development of embryo and successful crop harvest. The disease-free eggs are collected in wet handbags with proper aeration in early morning or in late evening. Transportation may be done during aestivation period, hibernation or post-hibernation period or pre-incubation period.

Incubation, Black boxing and hatching of eggs:

Incubation of eggs is done to achieve uniform hatching on a desired day by keeping the eggs at an optimum temperature of 250C and 75-80 per cent R.H. (Relative Humidity). Prior to incubation eggs should be disinfected by treating with formalin. Three methods of incubation are as follows:

(i) Constant temperature incubation where eggs are incubated at a constant temperature of 2325°C till hatching. Non-hibernating and acid-treated eggs are incubated by this method.

(ii) Raised temperature incubation where hibernating eggs are first kept at a temperature of 15°C, which is gradually increased by 0.5°C /day in the first week and then by 1 °C in the second week till the temperature is reached to 27°C where the eggs are kept till hatching.

(iii) Embryonic method of incubation where the eggs are kept during diapause at 15°C and then at 22-23°C till the revolution and then at 27°C till hatching. The incubation period varies with the races, voltinism and incubation temperature.

Black boxing - 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 90.00 per cent hatching can be obtained in one day by this method.

LECTURE NO. 12

SILKWORM REARING: YOUNG AGE (CHAWKI) REARING AND OLD AGE REARING OF SILKWORMS, FEEDING, SPACING, ENVIRONMENTAL CONDITIONS AND SANITATION, COCOON CHARACTERS – COLOUR, SHAPE, HARDINESS AND SHELL RATIO

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 25^0C.

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

Quality food:

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

Brushing:

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

into small pieces are scattered over the net. Worms start crawling over the leaves on the net; the net with worms is transferred to rearing tray.

Preparation of feed bed and feeding:

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

The 4th and 5thinstars 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. Shootrearing 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. First feeding stage, sparse eating stage, moderate eating stage, active eating stage, premoulting stage, last feeding stage, 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 cocoon*s:*

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.

COCOON CHARACTERS:

Colour: Colour is a characteristic particular to the species. It is the presence of pigments in the sericin layers, which cause the colour. This colour is not permanent and washes away with the sericin during the degumming process. There are diverse hues of colour including but limited to white, yellow, yellowish green and golden yellow.

Shape: Cocoon shape, as colour, is peculiar to the given species. At the same time shape can be affected by the execution of the mounting process, especially during the cocoon spinning stage. Generally, the Japanese species is peanut-shaped, the Chinese elliptical, European a longer elliptical and the polyvoltine species spindle-like in appearance. Hybrid cocoons assume a shape midway between the parents for example, the case of a longer ellipsoid or shallowly enclosed peanut form. The shape of cocoons assists in identifying the variety of species plus evaluating reelability.

Size: Cocoon size or volume is a critical characteristic when evaluating raw materials. The size of the cocoon differs according to silkworm variety, rearing season and harvesting conditions. The number of cocoons per litre, ranging between 60 and 100 in bivoltine species calculates size. Multivoltine species measure considerably higher.

Cocoon weight: The most significant commercial feature of cocoons is weight. Cocoons are sold in the marketplace based on weight as this index signals the approximate quantity of raw silk that can be reeled. The whole weight of a single cocoon is influenced by silkworm species, rearing season and harvest conditions. Pure breeds range from 2.2 to 1.5 g, while hybrid breeds weight from 2.5 to 1.8 g. In nature, the weight of a fresh cocoon does not remain constant but instead continues diminishing until the pupae transforms into a mother and emerges from the cocoon. This weight occurs gradually as moisture evaporates from the body of the pupae and as fat is consumed during the metamorphosis process

Hardiness: Cocoon hardness correlates to shell texture and is affected by cocoon spinning conditions. For instance low humidity during the mounting period makes the cocoon layer soft, while high humidity makes it hard. The degree of hardness also influences air and water permeability of cocoons during boiling. A hard shell typically reduces reelability (during the cocoon reeling process), while a soft-shell may multiply raw silk defects. In short, moderate humidity is preferred for good quality cocoons.

Shell ratio: As the entire cocoon including the pupa is sold as part of the raw material, it is essential to quantify the ratio of the weight of the silk shell versus the weight of the cocoon. This is calculated in the formula:

$$\frac{\text{Weight of the cocoon shell}}{\text{Weight of the whole cocoon}} \times 100$$

This value gives a satisfactory indication of the amount of raw silk that can be reeled from a given quantity of fresh cocoons under transaction. The calculation assists in estimating the raw silk yield of the cocoon and in deriving an appropriate price for the cocoons. The percentage will change based on the breed of the silkworms, rearing and mounting conditions. Percentage rates are altered based on the age of the cocoons (see cocoon weight) as the pupa loses weight as metamorphosis continues. In newly evolved hybrids, recorded percentages are 19 to 25 percent, where male cocoons are higher than female cocoons.

Raw silk percentage: This index is the most important for the value of the cocoon as it has a direct impact on both the market price of cocoons and the production costs of raw silk. The normal range is 65 to 84 percent for the weight of the cocoon shell and 12 to 20 percent for the weight of the whole fresh cocoon.

LECTURE NO. 13
DEFECTIVE COCOONS AND STIFLING OF COCOONS, USES OF SILK AND BYPRODUCTS, ECONOMICS OF SILK COCOON PRODUCTION

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.

Marketing of cocoons:

Being an alive and also perishable commodity, cocoons should be marketed as early as possible after harvesting and before the moths emerge from them. Defective cocoons have no market value as most of them are not reelable.

These include double cocoon, immature or premature and fragile cocoons, undersized or malformed cocoons, mute (with dead pupa sticking to inner shell) or black-stained cocoons, calcified cocoons, spotted and fungi-attacked cocoons and cocoons with thin middle part or thin ends.

Transport of Cocoons:

During transportation cocoons are kept in perforated containers with enough aeration. The containers are so designed to prevent jolting and crushing of cocoons. The transport should be done quickly and for short distance.

Cocoon Market:

To keep the price of cocoon uniform and moderate, all state Governments have set up centralised marketing federations. They fix the floor price of cocoons and also formulate guidelines for cocoon transactions.

USE OF SILK AND BY-PRODUCTS:

Man adores the natural fabrics from time immemorial. Silk had a prestigious place in the culture and commerce of India in the Pre-Vedic age. Silk term speaks about mulberry silk only. It is soft smooth, lustrous and holds a prestigious place among textile fibres and known as '**Queen of Textiles**'.

Raw silk is used for clothing such as shirts, suits, ties, blouses lingerie, pajamas, jackets,

Hand spun mulberry silk used for making comforters and sleeping bags. Other variety fabric materials like dupions, plain silk, deluxe, satin, chiffon, chinnons, crepe, broacades are made from mulberry silk. Carpet, furnishing, curtains, draperies, cushion covers and sofa covers wall hanging.

Knitted materials from silk fibres i.e. socks, stocking are very costly and possess good market.

The silk gut used in surgery for internal suturing is made from silk glands. The silk glands are dissected out and put in warm water and pulled at two ends to yield a fibre of uniform thickness. This protein is auto absorbable and need not be removed after wound healing. Silk grafts have been used successfully to replace cut arteries.

Silkworm can be reared in laboratory for genetic studies. This insect was proved as a good laboratory tool for any kind of experiment. Lot of research work is under progress on different lines of

biotechnology, genetics using silkworms in Japan. Silkworm is very much useful for genetic experiments in biotechnology.

Reeling waste, bad cocoons are used to make spun silk fabrics. The waste silks are hand spun into matka, katan, feshua (jatan or Jatam, Jhut) and noil yarns. Articles made from waste silk also have a good export market.

Among vanya silks tasar silk fabrics in exotic designs are produced by handlooms. They are Gicha-noil, tasar plain, cotton-tasar blend, tasar-mulberry blend, peduncle fabric.

Muga silk cloth is very largely used by the Assamese women as mekhela, riha-sador sarees.

Eri spun silk is used for dress materials and the coarse variety for making scarves, chaddar, shawls and quilts.

Trimoulters silk yarn is used as package material in pencil industry and for making talcum powder puffs.

Silk has had many industrial and commercial uses. In France 22-24 denier silk is used in tyre manufacturing to have a longer life span than rubber tyres in bicycle tires, artillery gunpowder bags. Parachutes are made from 13-15 denier silk fiber. These parachutes were used in World War-II.

Silk is used as raw material for preparing sound-free gears for making precision machinery.

ECONOMICS OF SILK COCOON PRODUCTION:

(I) Establishment costs of mulberry garden (First year):

Sr. No.	Particulars	Value (Rs.)
1	Ploughing operations	1500.00
2	Final land preparation	400.00
3	Farm yard manure (8 tones) @ Rs. 500/T.	4000.00
4	Mulberry saplings – 6000 saplings @ Rs. 0.50/ sapling	3000.00
5	Making trenches with tractor (4hr) and planting	2200.00
6	Fertilizer (100 kg Ammonium sulphate, 125 kg SSP and 35 kg MOP)	1036.00
7	Fertilizer application charges	120.00
8	Irrigation	
9	Hoeing/Weeding 3 times	1800.00
10	Miscellaneous expenditure	500.00
	Total	**16056.0**

(II) Maintenance of mulberry garden (IInd year onwards):

Sr. No.	Particulars	Value (Rs.)

(A)	**Operational costs**	
1	Farm yard manure (10 Tonnes)	4000.00
2	Fertilizer cost @ (600 kg Ammonium sulphate; 300 kg Single super phosphate and 80 kg Murate of potash)	5538.00
3	Manure and fertilizer application	1200.00
4	Irrigation water cost	5000.00
5	Irrigation	3600.00
6	Weeding	3400.00
7	Shoot harvest	7200.00
8	Pruning and cleaning of plants	600.00
9	Land revenue	50.00
10	Miscellaneous	500.00
11	Interest on working capital	621.78
	Total variable cost	**31710.58**
(B)	**Fixed costs**	
	Apportion cost of establishment of mulberry garden	1072.42
	Total leaf production cost	32781.00
	Total cost/kg of leaves	1.64

(III) Building and rearing assets for 300 dfls:

Sr. No.	Rearing building/ equipment	Number/ Quantity required	Rate (Rs.)	Value (Rs.)	Life span	Depreciation
	BUILDINGS					
1	Late age rearing house including Chawki and shoot store room (sq. ft)	1300	250.00	325000.00	30	10833.33
2	Veranda (Sq.ft)	300	50.00	15000.00	15	1000.00
	Total			**340000.00**		**11833.33**
	Equipments					
1	Power sprayer	1	6000.00	6000.00	10	600.00
2	Mask	1	2000.00	2000.00	5	400.00
3	Room heater	3	750.00	2250.00	5	450.00
4	Humidifier	3	1500.00	4500.00	5	900.00
5	Gas flame gun	1	500.00	1500.00	5	100.00
6	Egg transportation bag	1	150.00	150.00	5	30.00
7	Chawki rearing stands	2	500.00	1000.00	10	100.00
8	Wooden rearing trays	24	150.00	3600.00	10	360.00
9	Feeding stands	1	100.00	100.00	5	20.00
10	Leaf chopping board	1	250.00	250.00	5	50.00
11	Knives	1	50.00	50.00	2	25.00

12	Leaf chamber	1	1000.00	1000.00	5	200.00
13	Ant well	42	25.00	1050.00	5	210.00
14	Chawki bed cleaning nets	48	20.00	960.00	5	192.00
15	Litter basket/Vinyl sheets	2	250.00	500.00	2	250.00
16	Plastic basins	2	50.00	100.00	2	50.00
17	Leaf collecting basket	2	50.00	100.00	2	50.00
18	Shoot rearing rack (45 ft x 5 ft, 4 tier)	2	1500.00	3000.00	10	300.00
19	Nylon net	1	1500.00	1500.00	5	300.00
20	Rotary mountage	105	240.00	25200.00	5	5040.00
21	Plastic incubation frame	6	50.00	300.00	5	60.00
22	Plastic buckets	2	50.00	100.00	2	50.00
	Total			**54210.00**		**9737.00**
	Grand total			**394210.0**		**21570.0**

(IV) Cost and return structure in silkworm rearing:

Sr. No.	Particulars	Cost/revenue
A.	**Variable costs**	
1	Leaf	32781.00
2	Dfls (1500 dfls)	4200.00
3	Disinfectants	7425.00
4	Labour (@ 25MD/100 dfls)	16875.00
5	Transportation and marketing	1580.00
6	Other costs	500.00
7	Interest on working capital	305.80
	Total variable costs	**63666.80**
B.	**Fixed costs**	
	Depreciation on building and equipments and interest on fixed costs	21570.33
	Total costs	**85237.13**
C.	**Revenue**	
	Cocoon yield	60.00
	Average cocoon price	120.00
	Cocoon production	900.00
	Income from cocoon	108000.00
	Income from by-products	5400.00
	Total revenue	**113400.00**
	Net revenue	**28162.87**
	Benefit : Cost ratio	**1.33**

(Source : *Central Sericulture Research and Training Institute, Mysore*) LECTURE NO. 14

PESTS AND DISEASES OF SILKWORM AND THEIR MANAGEMENT

NATURAL ENEMIES OF SILKWORM:

A. Important pests of silkworm with their management:

Pests	Nature of Damage	Management
Uzi fly *Exorista sorbillans* (Tachinidae: Diptera) of (Endo-parasitoid 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 stage, pierced cocoon is noticed.	• 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.

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. • 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 (transovarial transmission). **Responsible factor:** • Infected seeds (eggs)	• Mother moth examination. • Use of disease free females. • Sterilization of eggs with 2% formalin. • Destruction of infected eggs and females. • Bed disinfectant: Vijetha powder
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
Muscardine disease (Fungal transmitted) **White Muscardine** (*Beauveria bassiana*) **Green Muscardine** (*Spicaria prasina*) **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 intersegmental 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

LECTURE NO. 15

LAC GROWING AREAS IN INDIA, LAC INSECTS, BIOLOGY, LAC CULTIVATION, FOOD PLANTS, PRUNING, INOCULATION, CROPPING, KINDS OF LAC, ENEMIES OF 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 inhabitants) 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 tons 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 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 in 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 300,000 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.

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: 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
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 ***Kusmi.*** 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: Strains of lac and lac crops

Sr. No.	Inoculation	Lac		Weather	Seed			
	Emergence Crop Female Time with Lac Host Inoculation of male harvested insects (In Swarming Plant insects mature month) larva and give rise to swarming larvae							
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 ra*ngeen*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.

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 commerce. 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 Yuan 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 lie 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.

Following hatching the nymphs 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 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: 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	Jammu and Kashmir
Albizia lucida	Gulwang	Kusmi	Gujarat
Cajanas 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
Shoria letura	Sal	Rangeeni	Karnataka
Samania saman	Rain tree	Kusmi	Odisha, West Bengal, Assam
Zizyphus xylopyrus	Khatber	Rangeeni	Madhya Pradesh

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.

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:

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 climate vagaries, 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 (in common parlance seed of other agricultural crops) 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 : 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	Oct/Nov
	April	6 month	Baisakhi	Oct/Nov	June/July
Ber	April	6 month	Baisakhi	Oct/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 is 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. 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.

5. 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

LAC AND ITS FORMS:

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

Ari lac	**:**	If lac crops are harvested by cutting down the lac bearing twigs a little before the larval emergence, that lac is known as ari lac (immature lac).
Phunki lac	**:**	If lac crops are harvested by cutting down the lac bearing twigs after the larval emergence is over, that is called phunki lac (empty lac).
Stick lac	**:**	It is raw lac, obtained by scrapping the lac encrustation from the dry twigs cut down before emergence of the new insect. It contains dead bodies of the lac insect, bark of the host plant, dried leaves, dust and other extraneous impurities. ***OR*** The lac encrustations is separated by knife or broken off with finger from the twig of host plants and is known is stick lac or crude lac or raw lac.
Seed lac	**:**	The semi-refined product obtained after crushing, sieving and winnowing of stick lac, followed by washing and drying is called seed lac. It contains impurities such as sand, insect debris, *etc.* ***OR*** The stick lac, after grinding and washing is called seed lac or chowri.
Shellac	**:**	It is the refined form of lac, available in the form of thin flakes. It is obtained by stretching the heat softened seed lac, freed from infusible materials. It is the commercial lac and is graded based on its colour and wax content. ***OR*** The manufactured product prepared from stick lac after washing and melting, which takes the form of yellow coloured flakes, is called shellac. Shellac is natural gum resin. It is non-toxic, hard, amorphous, brittle

		and also edible. Its colour varies from dark red to light yellow. When heated slowly, it melts at 89-90°C. It is insoluble in water, but dissolves readily in alcohol and organic acids. It is used in fruit coating, as binder for nail varnish, mascara, as enteric coating for tablets, in manufacturing of photographic materials, in preparation of gramophone records, as sealing wax, as a filling material in the hollows of ornaments, in preparation of toys, buttons, pottery and artificial leather. Apart from these conventional uses, being eco- friendly and renewable raw material, it is also used in industries like textile (as stiffeners), electrical (for insulation, capping, etc.), paint, aluminium, pharmaceuticals, confectionary, food processing, cosmetics, antique, etc.
Button lac	**:**	It is another form of heat purified lac, where the molten resin is cast into button shaped cakes instead of being drawn into sheets, as in the manufacture of shellac. The cakes are largely used for bonding mica splitting into micanite. OR After melting process, lac is dropped on a zinc sheet and allowed to spread out into round discs of about 3" diameter and 1/4" thickness is called button lac.
Garnet lac	**:**	It is prepared form 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	**:**	Lac from which wax has been removed is known as dewaxed lac. This nontoxic 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.

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

Sr. No.	Name of the parasitoid	Family
1.	*Anicetus dodonia*	Encyrtidae
2.	*Atropates hautefeulli*	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 : 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

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 0.54mm 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 11mm 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 are 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 1.35mm long whereas a mature larva is 10 to 12mm in length and 2mm 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 kusmi 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 ant predators *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.