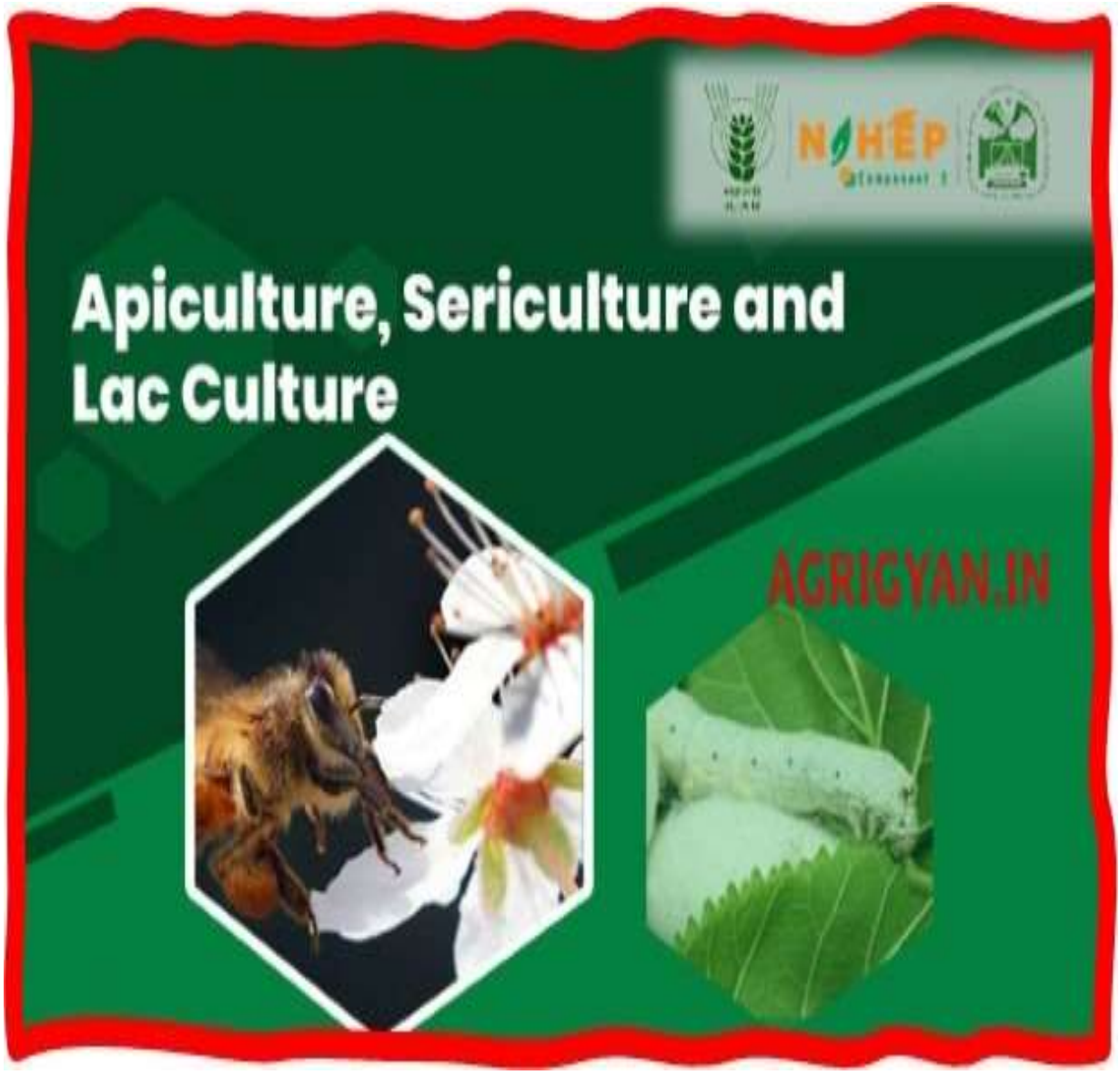

- **Content Creator:** Dr. Tamoghna Saha, Bihar Agricultural University, Bhagalpur
- **Course Reviewer:** Dr. Kalmesh Managanvi, Bihar Agricultural University, Sabour Bhagalpur

Lesson	Lesson Name

Number	
1	Introduction and importance of beneficial insects and brief history of apiculture
2	Different Species of honey bees and its morphology and anatomy
3	Life cycle, colony organization and social behaviour of honey bees
4	Beekeeping equipments, Handling of bee colony and maintenance of apiary
5	Collection and preservation of bee pasture and value added products of honey bee, their composition and uses
6	Seasonal management of honeybee colonies and queen rearing (Spring)
7	Miscellaneous management and queen rearing
8	Insect pests and diseases of honey bees and their management
9	Silkworm: History development in India, Systematic position, Life cycle and distribution of Silkworm
10	Types of silkworm, their importance and characteristics features
11	Silkworm rearing programme, egg production and rearing equipments
12	Silkworm rearing management and Cocoon characters

13	Silk and its uses and insect pests and diseases of silkworm
14	Lac insect-host plants, life cycle and its economic importance
15	Lac cultivation and their uses and enemies of Lac insect
16	Lac cultivation and their uses and enemies of Lac insect

Course Name	Apiculture, Sericulture and Lac Culture
Lesson 1	Importance of beneficial insects and brief
Content Creator Name	Dr. Tamoghna Saha
University/College Name	Bihar Agricultural University, Sabour Bhagalpur
Course Reviewer	Dr. Kalmesh Managanvi
University/College Name	Bihar Agricultural University, Sabour Bhagalpur

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1.1. Introduction of beneficial insects-scope and importance

Insects are the most dominant creatures on this earth. Normally, insects are considered harmful to man but hardly 1 per cent of insect species fall in the pest category. Benefits of insects in maintaining economy outweigh the injury inflicted. Beneficial insects provide regulating ecosystem services to agriculture such as pollination and the natural regulation of plant pests. It aims to enhance insect-derived ecosystem services from a conservation perspective (i.e. enhancing beneficial insects in agricultural landscapes that provide ecosystem services to crops.

Human cultures and civilizations have been maintained in countless ways through these beneficial insects, they regulate the pest population of many harmful pest species, produce natural products and they also dispose the waste and recycle the organic nutrients. It should be considered in thought that how much we depend on them for our survival and what kind of life would be without insects.

Importance of beneficial insects:

- As industrial importance: Honey, beeswax, bee venom, royal jelly, propolis, Silk and Shellac.
- Act as pollination: Transfer of pollens from anthers to stigma Ex. Honey bees (75-80%), butterflies, flies, beetles, thrips, etc.
- Entomophagous insects: Many insects act as predators and parasitoids.

a. Coccinellids (Coleoptera): Ex. Coccinella septempunctata, Hippodamia variegata, etc.
b. Syrphids (Diptera): Ex. Episyrphus balteatus, Metasyrphus corrollae, Ischiodon scutalaris, Metasyrphus conferator, etc.
c. Chrysopids (Neuroptera): Ex. Chrysoperla zastrowi sillemi, Mallada sp.
d. Predatory bugs (Heteroptera): Ex. Anthocoris minki, Orius spp, Blaptostethes pallescens.
e. Preying mantids (Dictyoptera): Ex. Statilia maculate.
f. Predatory wasps (Hymenoptera): Ex. Vespa spp.
g. Egg parasitoid: Ex. Trichogramma spp.
h. Larval parasitoid: Ex. Apanteles spp. Cotesia spp., Bracon sp.

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i. Egg-larval parasitoid: Ex. Chelonus blackburni.
j. Larval-pupal parasitoid: Ex. Ceromosia auricaudata (Diptera: Tachinidae).

- Improve Nutrient cycling or Soil Builders: Insects which live in soil make tunnels, creating channels for smaller organisms, water, air and roots to travel through. Insects improve soil aeration and earthworm activity can enhance soil nutrient cycle along with the soil physical properties such as soil structure and tilth and activity of other beneficial soil organisms. Examples- Beetles, ants, cut-worms, larvae of flies, crickets, termites, wasps etc.
- As human food: Over 500 spp. viz. cockroaches, silkworms, crickets, grasshoppers, beetles, caterpillars, termites are used as food by human beings in different parts of the world.
- Aesthetic value: Brightly coloured butterflies and beetles are used for various decorations.
- Study tools or research purpose: Cockroach, house fly, vinegar fly (Drosophila).
- Insect collection can be adopted as a hobby: Water beetle.
- Scavengers: Insects which feed on dead and decaying matter of plants and animals are called as scavengers. Insects (scavengers and decomposers) help in the biochemical cycling of the nutrients. Examples: Bark beetle, water scavenger beetle, termites, ants etc.
- Weed Killers: Prickly pear Opuntia dilleni feed by Dactylopius opuntiae, Congress grass or Carrot weed, Parthenium hysterophorus is controlled by Zygogramma bicolorata.
- Production of Cochineal: Cochineal pigments use in Painting: Cochineal pigment is extracted from these scale insects.

Honey bees are one of the few insects directly beneficial to man. Apiculture is the commercial production of Honey. Honey is the only sweetener, viscous fluid, produced by honeybees. It is collected from nectar from nectaries at base flowers.

- The pollens collected by pollen trap from ingoing pollen foragers is rich protein source. Bee pollen is a "complete" and good supplement in diet. It is available in health food stores.

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- The royal jelly is secreted by hypo pharyngeal gland of nurse bees when the glands are fully active (7-14 days age). It is very nutritious food and is fed to the young workers larvae and queen larvae and adult. Royal jelly is milky and light pale in color. And it is also a good ingredient of some expensive skin care products, which helps in reducing wrinkles and works as anti-aging.

1.2. Brief history of apiculture

- Honey bees and their usefulness are known to man from prehistoric times. Mention of bees are found in vedas, Ramayan and Quran.
- There was no development in beekeeping until 16th century.
- Aristotle (382-322 BC) was the first to deal with the bees in a scientific manner.
- L. L. Langstroth (1851) introduced the concept of bee space. Bee space for Indian bees is 7 mm and for European bee is 10mm. The modern bee keeping became possible after his discovery of hive with movable frames.
- This discovery was followed by subsequent innovations like comb foundation mill, honey extractor, smoker, etc., which helped in the development of modern bee keeping we see today.
- Karl Von Frisch (1953) discovered the bee dance language. He wrote a book called -The dance language and orientation of bees". He was awarded Nobel Prize in 1973 for his work on bee dance language.
- Butler (1954) identified queen substance in queen bee– Johannes Mehring (1857) invented comb foundation sheet.
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- In Himachal Pradesh modern beekeeping with indigenous honey bee A. cerana started in 1934 at Kullu and in 1936 at Kangra.
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- The exotic bee *A.* mellifera was successfully introduced for the first time in India in 1962 at Nagrota Bagwan (then in Punjab state and now in Himachal Pradesh). Because, this bee has potentials to produce more honey.
- 1962- Central bee research and training institute (CBRTI) was established at Pune.
- AICRP on Honey bee research and training is located at Haryana Agricultural University, Hissar.
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Course Name	Apiculture, Sericulture and Lac Culture
Lesson 2	Different Species of Honey Bees
Content Creator Name	Dr. Tamoghna Saha
University/College Name	Bihar Agricultural University, Sabour Bhagalpur
Course Reviewer	Dr. Kalmesh Managanvi
University/College Name	Bihar Agricultural University, Sabour Bhagalpur

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Objectives

1. To introduce different beneficial insects to the students
2. To Aquent students with brief history of apiculture along with new developments in bee keeping

1.1. Introduction of beneficial insects-scope and importance

Insects are the most dominant creatures on this earth. Normally, insects are considered harmful to man but hardly 1 per cent of insect species fall in the pest category. Benefits of insects in maintaining economy outweigh the injury inflicted. Beneficial insects provide regulating ecosystem services to agriculture such as pollination and the natural regulation of plant pests. It aims to enhance insect-derived ecosystem services from a conservation perspective (i.e. enhancing beneficial insects in agricultural landscapes that provide ecosystem services to crops.

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- National Bee Board (NBB) is located at New Delhi.

A.S. Atwal: Father of modern bee keeping in India.

Apiary: It is a place where beehives of honey bees are kept, it is also known as a bee yard.

Apiculture: The science and art of raising honey bees.

Karl Von Frisch: Father of bee keeping

Nectar: A liquid rich in sugars, manufactured by plants and secreted by nectary glands in or near flowers; It is the raw material for honey.

Nectaries: The glands of plants which secrete nectar, located within the flower or on other portions of the plant (extrafloral nectaries).

Pollination: The transfer of pollen from the anthers to the stigma of flowers.
Scavengers: Insects which feed on dead and decaying matter of plants and animals
Predators: An animal (insect) that naturally preys on other small organisms. It is usually larger than hosts.
Parasitoids: An insect whose larvae live as parasites which eventually kill their hosts. It is usually smaller than the host.

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Course Name	Apiculture, Sericulture and Lac Culture
Lesson 3	Life Cycle, Colony Organization and Social Behaviour of Honey Bees
Content Creator Name	Dr. Tamoghna Saha
University/College Name	Bihar Agricultural University, Sabour Bhagalpur
Course Reviewer	Dr. Kalmesh Managanvi
University/College Name	Bihar Agricultural University, Sabour Bhagalpur

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Objectives:

a. To get acquainted with different stages in the life cycle of honey bee castes.
b. To study organization of a honey bee colony and social behaviour of different castes.

Glossary

Cell: The hexagonal compartment of a honey comb.

Drone: The male honeybee which comes from an unfertilized egg (and is therefore haploid) laid by a queen or less commonly, a laying worker.

Drone brood or drone comb: Brood, which matures into drones, reared in cells larger than worker brood.

Drone layers: A drone laying queen or laying workers.

Drone laying queen: A queen that can lay only unfertilized eggs, due to age, improper or no mating, disease or injury.

Eggs: The first phase in the bee life cycle, usually laid by the queen; it is cylindrical, enclosed with a flexible shell or chorion.

Nurse bees or indoor bees: Young bees of less than 21 days old (up to 3 weeks), which feed and take care of developing brood.

Field bees or outdoor bees: Worker bees which are usually 21 or more days old (after 3 weeks) and work outside to collect nectar, pollen, water and propolis; also called foragers.

Laying workers: Worker bees which lay eggs in a colony hopelessly queenless; such eggs are infertile, since the workers cannot mate and therefore become drones.

Pupa (pl-ae): The third stage in the development of the bee during which it is inactive and sealed in its cocoon; the organs of the sealed in its cocoon; the organs of the larva are replaced by those which will be used as an adult.

3.1. Life cycle of honey bees

Queen deposits egg at the base of cell and fasten with mucilaginous secretion. After 3 days egg hatches and workers provide pearly white food in which “C” shaped larva floats. Cell is sealed when larva is fully grown. In the sealed cell it turns into pupa from which adult emerges. Larva sheds skin five times during development. The

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sealed cells containing worker and drone brood and honey can be differentiated on the basis of appearance.

- **Egg:** Queen lay eggs in a particular cell meant for rearing particular caste. It lay only one egg per cell. The eggs of all the three castes are white, cigarette shaped and similar in size and appearance. Incubation period is 3 days. Fecundity of Indian bee (*Apis cerana*) is 500-800 eggs per day and European bee (*Apis mellifera*) is up to 1800 eggs per day.
- **Larva / Grub:** The grubs of all castes also look alike but the queen and drone grubs are larger than workers grub in the latter half of their development. Larvae are whitish, apodous, euceuphalous, lack eyes, antennae, wings but possess simple mouth parts. Larval period is about 5 days. They undergo 4 moults and 5 instars. During larval period, the cells are uncapped and nurse bees feed the larvae with food.
- **Pupa:** Exarate pupa. Appendages are present. In drones the eyes meet on the head while in workers they are far apart. Pupal period is about 8-10 days. During pupal period, the cells are capped.
- **Adult:** The adult of various castes is variable in respect of size, colour, tongue length and size of the eyes etc.

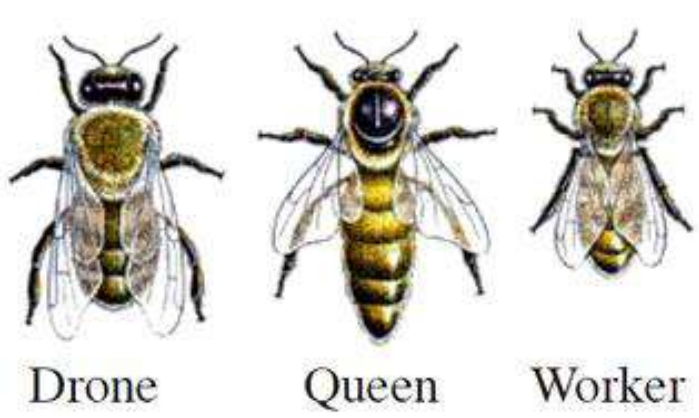

Figure 3.1 Different castes of honey bee

3.1.1. Queen:

- Queen bee is the only perfectly developed female and primary function is to lay eggs.

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- Their wings are smaller and shrivelled.
- Mouth parts for sucking food are shorter than that of workers.
- No wax glands.
- Life span varies from 1 to 3 years.
- Lay eggs at the rate of 800-1500 per day.

3.1.2. Worker:

- Worker bees are imperfectly developed females.
- They are smaller than the queen.
- They have strong wings to fly.
- They have a large and efficient proboscis (mouth parts packed together like a thin tube) for sucking nectar.
- Well-developed sting.
- Hind legs have “pollen basket” for collecting pollen.
- The workers have a life span of about 35 days. The different duties which they perform age-wise are as follows:
  a. Day 1-14 Activity inside the hive such as cleaning the hive, feeding the larvae, etc.
  b. Day 14-20 Guard duties at entrance to the hive.
  c. Day 21- 35 Foraging i.e., collecting the food (nectar and pollen from the surroundings).

3.1.3. Drone

- Drones are the male bees produced from unfertilised eggs. Their production in the hive synchronises with the production of the new (virgin) queens.
- At the age of 14-18 days the drones perform mating/nuptial flight chasing the virgin queen in the air.
- Drones can live up to about 60 days, although they are stung and killed after the mating.
- They don’t have ovipositor, pollen basket etc.

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Development: The developmental stages of honey bees are: egg, larva, pupa and the adult. Duration of life stages of different castes of honey bee varies which is given in the table 3.1 below:

3.1. Duration of life cycle of different castes of honey bees

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

- In a comb, workers rear brood in the central part where temperature can easily be maintained and honey is stored in the upper and peripheral part.
- Pollen is stored around brood area so that it is easily available for rearing brood.
- Drone brood area can be differentiated from worker brood as the sealed brood cells in the former case are raised.

3.2. Colony organization and division of labour

Honey bees are social insects and live-in colonies. A normal colony, during active season is composed of three kinds of individuals: one queen, thousands of workers (10,000 to 30,000 or even more) and few hundreds of drones, which vary in size. In addition, each colony has different developmental stages *viz*, eggs, larvae and pupae which are collectively known as brood.

3.2.1. Queen

- Only one queen is found in a colony except under supersedure or swarming instinct.

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- The mother of the whole colony producing workers and drones and is the only perfectly developed female member of the colony.
- Their function is to lay eggs. They do not have motherly instinct or ability to feed the brood. They fed lavishly by a large number of nurse bees with highly nutritious food known as royal jelly.
- A good queen can lay 1500-2000 eggs per day.
- A laying queen is the longest bee in the colony. It has larger thorax than worker and their abdomen get greatly distended during egg laying.
- The queen lays both fertilized and unfertilized eggs. Fertilized eggs produce workers and queens and unfertilized eggs produce drones (Fig. 3.2).
- A good mated queen may work satisfactorily for 2 or more years, although queens can live eight years or longer. However, in commercial beekeeping, queen is replaced every year to keep high brood rearing in a colony.
- Queen releases queen substance (pheromone) from their mandibular gland which helps in the colony organization. It acts as worker attractant and inhibits ovary development in worker bees as well as raising new queen. Absence of queen pheromone is detected after about 30 minutes of queen loss and colony may start raising new queen. The pheromones in queen substance stimulate brood rearing, comb building, hoarding and foraging in a colony and thus play important role in normal working of a colony.
- The virgin queen mates with a number of drones (5-7) within 5-10 days of emergence in the air (not inside the hive) and spermatozoa are stored in spermatheca. Stored sperms are utilized to fertilize eggs throughout her life till exhausted.

3.2.2. Worker

- Workers are imperfect females. They are unable to mate though may start egg laying if a colony remains queen less for long period.
- The workers perform all the useful work in the colony.
- **Duties of workers include:** Cleaning of the hive, feeding of larvae, raising queen cells when required, ventilate hive, guard the hive entrances, secrete bees wax, construct the combs, collect the nectar and convert it into honey, collection of pollen, water and propolis, produce a pre-digested food of royal jelly for feeding

queens and young larvae and scouting for a new nest site during swarming. The workers also feed the drones but when not needed, they are thrown out of hive.

- **The duties are related to the age of the worker**

Age of Worker Bee	Duty Site	Duties performed
a) Till 3rd day	Indoor	Maintain wax cells in sanitary state, cleaning their walls and floors after the emergence of young bees.
b) From 4-6th day		Feed older larvae with mixture of honey and pollen and making flights around the hive for getting layout of the hive (play flights or orientation flights).
c) From 7-11th day	Indoor	Hypopharyngeal glands (food glands) get developed and start secreting royal jelly and feed younger larvae.
d) From 12-18th day		The bees develop wax glands and work on building of comb, construction of cells, receive the nectar, pollen, water, propolis etc., from field gatherers and deposit in the comb cells and help in keeping the brood warm.
e) From 18-20th day		Perform guard duty.
f) From 20th day onwards	Outdoor	The worker bees take the duty of field i.e. exploring or foraging for nectar and pollen; collecting water and propolis.

Worker bees release alarm pheromone on stinging from lining of sting chamber and it assists in defence of the colony by alerting other colony members of the threat.

- A worker has an average life of only 40-50 days during honey flow season (active period) and her life may extend up to 6 months during off season.

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- **Laying workers:** Under queenless conditions for a long duration, ovaries of some of the workers start developing and they can lay even eggs but since these are unfertilized, give rise to only drones. The eggs laid by the laying workers have haphazard pattern and many eggs are laid in each cell of the comb. The colonies with laying workers ultimately perish. *A. mellifera capensis* is the exception where even from the eggs of laying workers queen and workers are raised by the bees.

3.2.3. Drone

Drones neither perform any duty inside the hive nor do they collect food from flowers. Each drone is fed by 3 to 4 worker bees. A colony rears and tolerates the drones only during breeding season when new queens are being produced and are later driven out of the colony to die of starvation. The sole function of a drone is to mate once which costs him his life. Maximum life of drone honey bee in summer is 59 days.

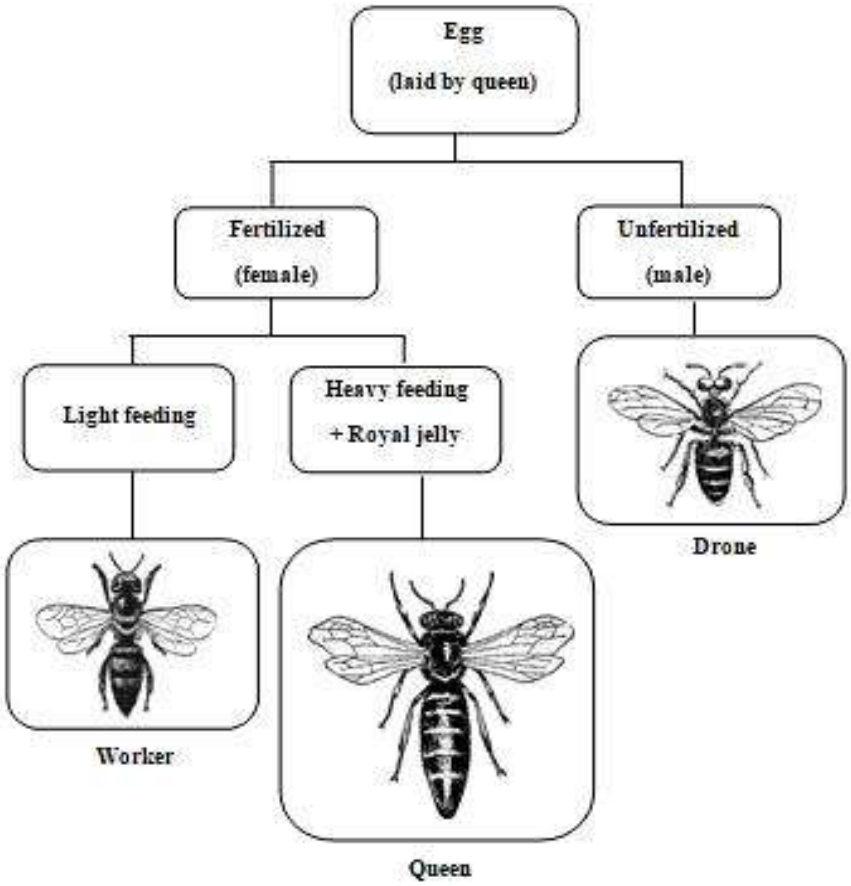

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Figure 3.2 Development of different castes of honey bees based on quality and quantity of food and whether fertilized or unfertilized (After Winston)

3.3. Social behaviour of honey bees

Among different insect orders, only eight orders have been recognized by insect taxonomists who have some communal life. Out of the eight orders only two viz. Isoptera and Hymenoptera have well developed social organization. Even in Hymenoptera, only two families namely Halictidae and Apidae of superfamily Apoidea contain fully social species. Most of other bees live solitary life.

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 behaviour in another organism in an adaptive fashion. Adaptive means that the signalling or the

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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.

3.3.1. Dances of honey bee

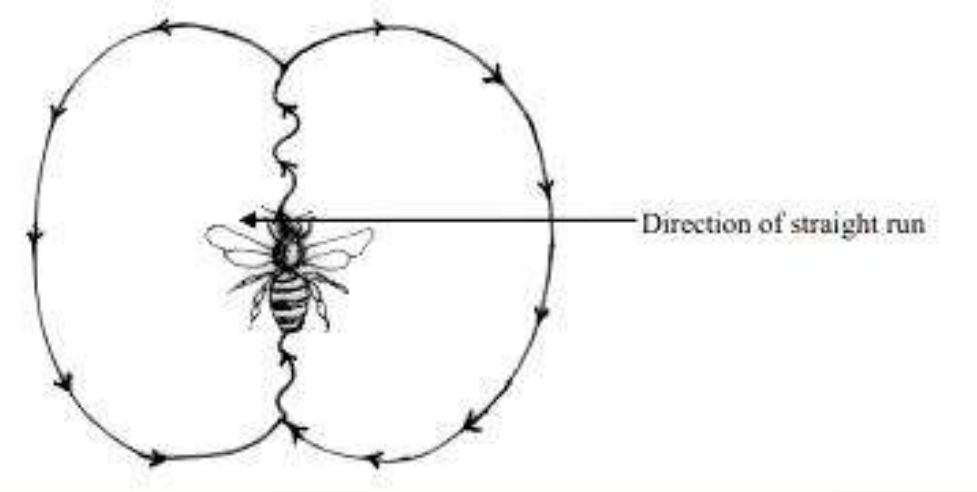
Honey bees communicate through dance language. It communicates about distance, direction and nature (quantity and quality) of food resource. Karl Von Frisch (1953) discovered the bee dance language. He worked extensively on dance language and he wrote a book called 'The dance language and orientation of bees' during 1967. He was awarded Nobel Prize in 1973 for his work on bee dance language.

Honey bees perform two major types dances either on comb surface or outside surface of the swarm.

1. Round dance
2. Wagtail (number 8 / dumble) dance

3.3.1.1 Round dance:

- Performed to communicate information of food source present at less than 100m (Fig. 3.3).
- An incoming worker (scout bee) who has discovered a nearby food source first exchange food with workers inside the nest.
- Then scout bee performs round dance repeatedly by making small circles in both clock and anti-clock wise directions for few seconds to few minutes.
- More vigorous dance consisting of a greater number of circles per second indicates the availability of more quantity and more concentrated food.



3.3.1.2 Wag-tail dance:

- Performed to communicate information of food source present at more than 100m (Fig. 3.4).
- The scout bee runs straight ahead for a short distance by shaking the body vigorously from side to side (waggling) at the rate of 13-15 times per second and also produce buzzing sound during the straight run.
- At the end of each straight run, the scout bee turns in one direction and makes a semi-circle and back to the starting point.
- It is followed by another straight run and make a semi-circle in opposite direction and back to the starting point.

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Course Name	Apiculture, Sericulture and Lac Culture
Lesson 4	Beekeeping Equipment's, Apiary and Its Maintenance
Content Creator Name	Dr. Tamoghna Saha
University/College Name	Bihar Agricultural University, Sabour Bhagalpur
Course Reviewer	Dr. Kalmesh Managanvi
University/College Name	Bihar Agricultural University, Sabour Bhagalpur

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Objectives:

a. To get acquainted with different bee keeping equipments used in modern beekeeping.
b. To get acquainted with different parameters viz. selection of good apiary site, handling of bee colonies, recording the data etc.

Glossary

Bee brush: Soft brush or whisk (or handful of grass) used to remove bees from frames.

Brood chamber: The part of the hive in which the brood is reared; may include one or more hive bodies and the combs within.

Comb foundation: A commercially made structure consisting of thin sheets of beeswax with the cell bases of worker cells embossed on both sides in the same manner as they are produced naturally by honey bees.

Hive tool: A flat metal device with a curved scraping surface at one end and a flat blade at the other; used to open hives, pry apart and scrape frames.

Movable frames: A frame constructed in such a way to preserve the bee space, so they can be easily removed; when in place, it remains unattached to its surroundings.

Queen cage: A small cage in which a queen and three to five worker bees are confined for shipping and introduction into a colony.

Queen cell: A special elongated cell in which the queen is reared. It is above an inch or more long and hangs down from the comb in a vertical position.

Queen excluder: Metal or plastic device with spaces that permit the passage of workers but restrict the movement of drones and queens to a specific part of the hive.

Uncapping knife: A knife used to shave or remove the capping from combs of sealed honey prior to extraction. These can be heated by steam or electricity.

4.1. Beekeeping equipments and their uses

Bee hive:

- L.L. Langstroth discovered the principle of bee space in 1851 in the U.S.A.

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- 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.
- Bee space is optimum distance between two surfaces in a bee hive essential for normal movement and functioning of bees.
- This principle was a big discovery for modern beekeeping. The modern hive has been designed on the bases of principle of bee space in which frames can be easily moved.
- The bee space measures 9.52 mm for *A. mellifera* and this was modified for *A. cerana* to be between 7-9 mm. Different parts of a movable frame bee hive are shown in Fig. 4.1.

Dimensions of hive:

- In general, for *A. Mellifera* Langstroth hive (named after L.L. Langstroth) and for *A. cerana*, BIS (Bureau of Indian Standard) hive A and B type are used.
- In 1995, BIS introduced C-type hive based on Langstroth hive for *A. melifera*.
- Well-seasoned wood of "Kail, "Toon", teak or rubber can be used for making good quality bee hives. Wood having strong smell is not used.
- Dimensions of different types of bee hives being used in India are given below:

Dimensions of bee hives

Hive parameters	**BIS hive C type for *A. mellifera*** (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 448x232mm Inside 428x192mm	**Type A: Modified Newton Type** Outside 230x165mm Inside 210x145mm **Type B: Modified Jeolikote**

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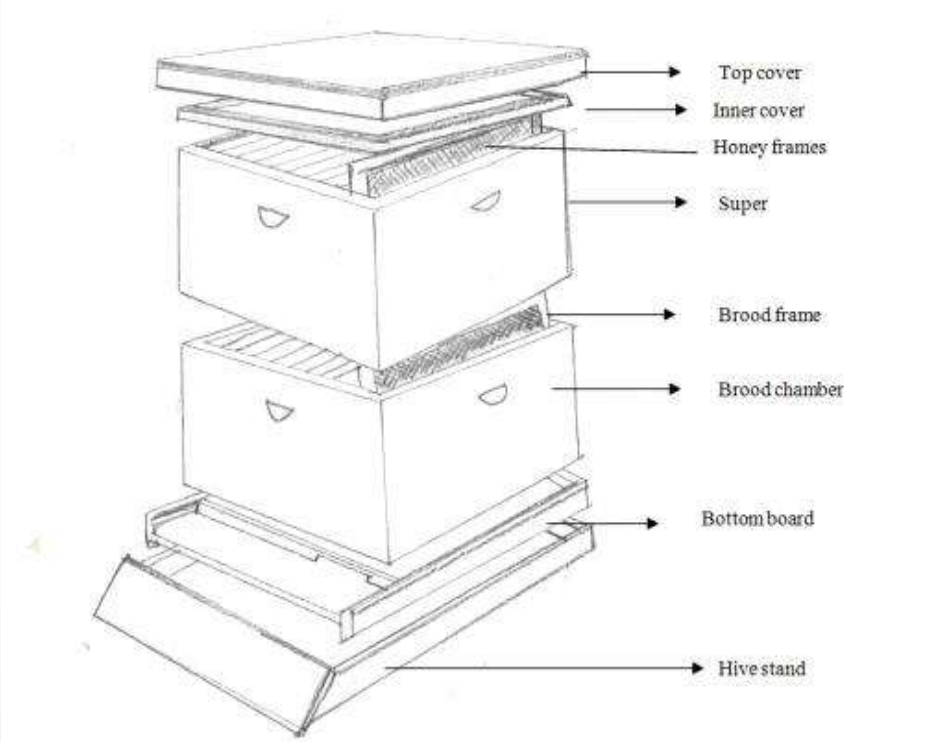

		Type Outside 300x195mm Inside 280x175mm
Bee space	10 mm	**Type A** 7 to 9 mm **Type B** 8 or 9 mm

Figure 4.1 Parts of a movable frame hive

- **Stand:** To support bottom board.
- **Bottom board:** It is floor of the hive having an entrance for bees. On this board brood chamber rests.
- **Brood chamber:** Chamber used for rearing of brood. Frames are placed in this chamber on which bees raise combs. The dimensions and number of frames vary with the type of hive. A wooden dummy board is used to limit the size of brood chamber and is placed at the end of brood frames.
- **Frame:** Each frame consists of a top bar, two sides and a bottom bar. Inner aspect of the top bar has a groove for fixing comb foundation sheet. Side bar has 4 holes for wiring the frame. The frame holds a comb.
- **Super:** Dimensions may be same as that of brood chamber or half of it (depending on type of bee hive). This is the chamber where bees store surplus honey.
- **Inner cover:** A board which acts as a partition between brood/super chamber and the roof.
- **Top cover:** A type of lid acting as roof placed over inner cover.

Other Equipment

- **Nucleus hive:** Small bee hive for keeping 4-6 frames. These are used for mating of queens and division of colonies (Fig. 4.2).
- **Observation hive:** Small hive with glass sides so as to observe movements and behaviour of bees (Fig. 4.3).

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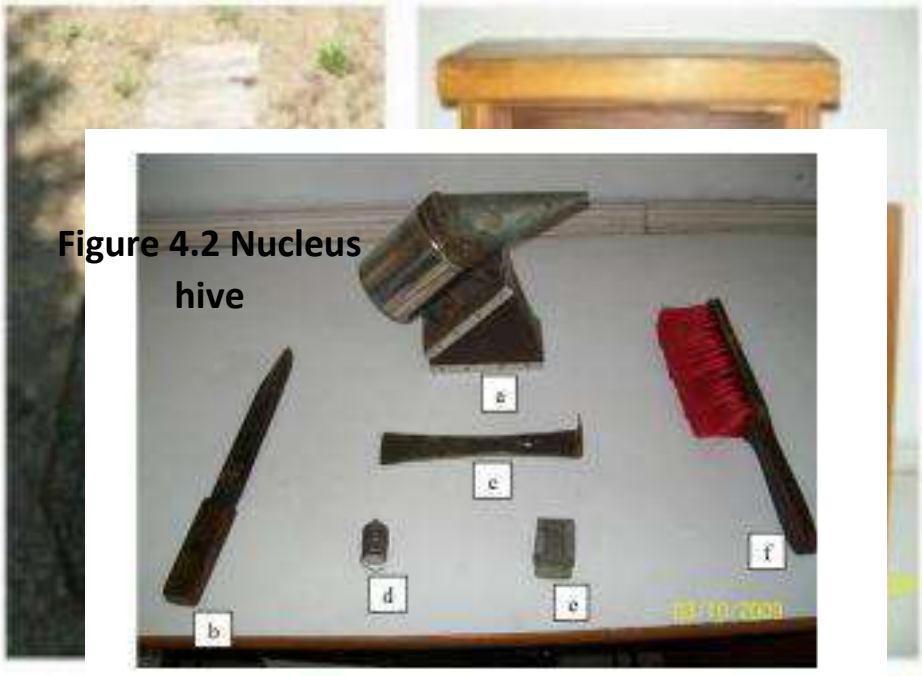

Figure 4.2 Nucleus hive

Figure 4.4 Comb Foundation

Figure 4.5 Bee

Figure 4.7 Feeders

Figure 4.8 Swarm Basket

- **Comb foundation mill:** Used to print natural cell size of desired comb foundation sheet for *A. mellifera* and *A. cerana* (Fig. 4.4).
- **Bee veil:** Used for preventing bee stings on face and neck (Fig. 4.5).
- **Smoker:** Used to calm down the bees while opening the hive (Fig. 4.6a).
- **Uncapping knife:** Large sized knife used to uncap the frames before honey extraction (Fig. 4.6b).
- **Hive tool:** An iron strip used for opening of hive and it's cleaning (Fig. 4.6c).
- **Queen cell protector:** A spring like structure for protecting queen cells (Fig. 4.6d).
- **Queen cage:** Used to introduce a queen to new colony and also to transport the queen. (Fig. 4.6e).
- **Bee brush:** To brush the bees from frames (Fig. 4.6f).
- **Feeders:** Different types of feeders are used for feeding sugar syrup to the bee colonies. (Fig. 4.7). These can be (i) slow feeder (friction top pail feeders) in which holes are made in the lid and the feeder is placed inverted inside the hive (ii) fast feeder (division board feeder) which is of the size of a regular frame and the trough contains a wooden float inside the cavity.
- **Swarm basket:** Basket to catch bee swarm (Fig 4.8).
- **Queen excluder:** Perforated zinc sheets or round wires (Fig. 4.9) assembled in such a way that workers can pass through them and queen cannot (perforation

size is 4.20mm for *A. mellifera* whereas worker thorax size varies from 3.33 to 3.50mm). It is used during honey flow season to restrict queen to brood chamber and thereby preventing egg laying in the super. It is also used in maintaining multiple queen system in a colony.

- **Honey extractor:** It is a machine to centrifuge out the honey from uncapped frames (Fig. 4.10).
- **Wax Melter:** Double walled chamber for melting of bees wax for making comb foundation sheets (Fig. 4.11).

Figure 4.9 Queen Excluder

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Figure 4.10 Honey Extractor

Figure 4.11 Wax Melter

Figure 4.12 Pollen Trap

- **Pollen trap:** For trapping corbicular pollen of returning bee foragers. (Fig. 4.12). For *A. mellifera* pollen trapping screen has holes of 4.7 to 5mm. and for *A. cerana* 3.5 to 3.7mm.

- **Bee escape:** To provide one way passage to bees (Fig. 4.13).

Figure 4.13 Two types of bee escapes (Different views)

4.2. Handling of bee colony

For management of honey bees in modern bee keeping, examination of colonies forms one of the important aspects. But whenever we talk about examination of bee colonies, there is general fear of stinging by bees. It is to be made clear here that if we are aware of bee behaviour, stinging can be prevented. Bees sting only for their own protection and after stinging they die. If all the precautions are taken before examination of colonies we can avoid stinging by bees.

Aim of examination of bee colonies: A bee colony is examined to check its working and to determine its requirements at a particular time, since these vary during different parts of the annual cycle of a bee colony. When a bee colony is opened, make the following observations:

- Whether a bee colony has sufficient food or it needs artificial feeding. Each colony, depending upon its strength, should invariably have at least 2-5kg of stores all the time.

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- Whether the queen is present or not? If present whether laying is satisfactory. If absent colony needs a new queen.
- Whether there are sufficient combs for egg laying by the queen and to store nectar or not. If not provide more frames.
- Whether there are any of the enemies or diseases in the colony. If yes, manage them accordingly.

Honey bees do not like much of interference since it affects their normal working. Therefore, the colonies should be disturbed as little as possible. It is suggested that during built-up period of the colony it is examined once a week whereas during off-seasons only once or twice a month.

Requirements for examination of bee colonies:

Hive tool, bee veil, apiary record register, measuring scale or grid, smoker.

Precautions:

- Before handling bee colonies, it is better to wear a bee veil.
- Do not wear black or dark clothing as bees are furious to black colour.
- Any kind of perfume or strong-smelling hair oils or metals like ring, watch etc which would induce bees to sting, should be removed before handling the bees.
- Do not be shaky while handling bees. Take care and avoid quick and jerking movements.
- If a bee stings, do not get nervous. Gently pull out the sting with the sharp edge of hive tool or finger nail from the base and not from the top without squeezing the venom out of it. Rub some grass on the stung area to mask the smell of alarm pheromone which otherwise induces other workers to sting in that area.
- Do not crush any bee while taking out or putting the frames back in a colony.
- Be careful about queen and avoid crushing it.
- Hive should not be opened on a windy, chilly day or the period when bees are not working outside the hive.

4.2.1 Starting of new colony and location site

Before starting the bee keeping one should know

- Acquire sufficient knowledge about the bee biology, behaviour and management through media, literature and bulletins.
- Gain experience by working with successful bee keepers.
- Attend some short training courses in apiculture/bee keeping.
- Start with few numbers of colonies and then multiply these colonies after acquired knowledge to exploit their usefulness to the maximum extent.

Season for starting beekeeping:

Suitable season for starting beekeeping coincides with mild climatic conditions and availability of bee flora in plenty. Normally, spring (February-April) and post-monsoon (September- November) seasons are the best periods to start beekeeping.

Purchase of nucleus honey bee colonies:

For starting bee-keeping nucleus colonies should be purchased in the beginning of the suitable season. A nucleus colony on four or five frame bee strength with a young, newly mated and pedigree queen bee is ideal to be purchased. Purchased colony should have sufficient amount of rightly laid eggs, worker brood (sealed and unsealed) and food reserves (honey and pollen stores) and should not have excessive amount of drone brood area. Be careful that the colonies to be purchased must be free from bee diseases and parasites.

Procuring honey bee colonies:

The colonies, if possible, should be purchased from the beekeeper near to the apiary site of the beginner, but well beyond 3 km the flight range of foragers to prevent the losses that sometimes may occur during shifting and due to bees returning back to the parent colonies if purchased from an apiary within their flight range. There are two breeding seasons for honeybees in northern plains i.e., February - April and September - October. These are the best periods to start beekeeping, the former being more suitable. The bees should be purchased early in the start of season.

The selection of site for maintaining bee hives is very important for profitable bee keeping.

- The site must be easy to get to and from in order for you to check the hives regularly.
- An apiary can house up to 20 hives depending on the availability of flowering trees in the area as bees forage up to 3 km from the apiary.
- A high hedge or fence should be put around the apiary to separate the bees from people and animals, as bees can be aggressive. The apiary should be away from human and livestock dwelling areas, road and public areas.
- It should be safe from strong direct sunshine, be shaded during the hot part of the day but have sun in the morning. Shade must be constructed if none is available at the site.
- It should be safe from strong direct wind and allow good air circulation.
- It must be near a fresh water supply; this can be a river, pond or even a dripping tap.
- It must be near food sources such as trees/nectar bearing crops, and cash crops that need pollination. Putting hives in a bee house/shed, which can be locked to prevent thieves stealing the honey, is one option. But there must be holes in the wall to allow the bees to get enough fresh air in and out of their hives.
- It is better if the apiary is away from areas where children play or any source of continual noise. Noise can disturb the bees and make them defensive.
- The apiary should be on higher ground, away from marsh or land liable to possible flooding. Humid conditions encourage fungal growth and prevent honey maturing and bees from foraging.
- The apiary must not be close to areas where pesticides are used as they may kill the bees and contaminate the honey.
- The bees will also appreciate being away from smoke, fire and unfriendly neighbours.
- There should be good water not contaminated one.
- Apiary should not be near the road.
- Should be near good plantation, flora.

4.2.2 Transferring colony

The purchased colonies or transport colony in new site should be shifted only when bees are not active i.e., at dusk or dawn and all the field force/forager bees are inside the hive. Before shifting, the colonies should be so packed as to make them properly

ventilated but bee leak proof. While shifting colonies during summer or for long distance the colonies should be packed ensuring proper ventilation without the risk of bee leakage. The vehicle having shockers should be preferred for shifting the bee colonies.

4.2.3 Combining colonies and swarm prevention

Unite/combine the colonies when two colonies are weak or unite queen less colony with weak or strong colony to achieve a strong working force of the colony during honey flow season. If uniting is done directly, the bees die due to fighting between the members of two colonies because of difference in odour and behaviour. There are two popular methods of uniting colonies.

a) Newspaper method
b) Smoking method

Newspaper method:

Take a newspaper and cut into the size of brood chamber. Smear / Sprinkle both the sides of the newspaper with honey and make small holes or punctures on the newspaper. Keep this newspaper on the brood chamber of one of the weak colonies and then keep the brood chamber of another weak colony over this brood chamber so that the newspaper is held between the brood chambers of these two weak colonies. The bees work through the newspaper and chew or gnaw the paper which is smeared with honey and get slowly mixed up due to the masking of odour. The poorer or unproductive queen is removed before uniting, if both the colonies have queen. Always uniting should be done during evening hours.

Smoke method:

Here both colonies are heavily smoked to mask the odour. As a result of masking of odour, the bees slowly get mixed up without any fighting.

4.2.4. Swarming and its management

Swarming is a natural instinct take place in honeybee colonies for reproduction, multiplication and distribution of colonies in nature. Swarming is a behaviouristic

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phenomenon in the life history of bees where in division of strong colony take place into one or more young new colonies.

Prevention / control of Swarming:

- Provide ample space for expansion of brood nest as per the requirement of bee by providing supers.
- Efforts to change old queens in early spring should be made.
- Provide proper ventilation in the hive.
- Remove the queen cells regularly.
- Clip the wings of the queen.
- Examine the hive at least once in a week during the swarming season.
- Combs with young brood can be removed and given to weak colonies and in their place an empty comb can to be placed.
- To overcome the swarming instinct, the colonies can be temporarily divided and later on united just before honey flow start.
- Use queen gate to the entrance of hive which will allow the workers bees to pass, but not the queen.
- In spite of all these precautions, if the colony issue swarm it may be caught and introduced into a new hive.

4.3. Maintenance of apiary records

Observations: Keep the record of every colony and enter your observations whenever the colony is examined. These observations can be made in the given proforma.

Periodical Colony Inspection Record

Date of Inspection	Total number of frames	Number of frames covered by bees (Bee strength)	Brood area (sq. cm.) L x B	Pollen area (sq.cm) L x B	Honey/ nectar stores (g)*	Presence of queen and its working	Remarks (date & amount of sugar feeding, drone rearing, honey extraction, temper etc.)

*Estimation based on assumption that each fully sealed Langstroth type frame of honey contains 2 kg and BIS Type A & B about 750 g of honey.

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Course Name	Apiculture, Sericulture and Lac Culture
Lesson 5	Bee Pasturage, Value Added Products of Honey Bee, their Composition and Uses
Content Creator Name	Dr. Tamoghna Saha
University/College Name	Bihar Agricultural University, Sabour Bhagalpur
Course Reviewer	Dr. Kalmesh Managanvi
University/College Name	Bihar Agricultural University, Sabour Bhagalpur

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Objectives:

a. To get acquainted with different flora used by honey bees.
b. To know about the different by-products of apiculture and their composition.

Glossary

- **Adulterated honey**: Any product labelled "Honey" or "Pure Honey" that contains ingredients other than honey but does not show these on the label.
- **Bee bread**: Pollen collected by bees and stored in wax cells, preserved with honey.
- **Bee venom**: Poisonous matter secreted by honeybees, used chiefly in defence and communicated by stinging; the poison is secreted by special glands attached to the stinger of the bee.
- **Dextrose**: Commonly known as glucose, it is a simple sugar (monosaccharide) and is one of the two main sugars found in honey; forms most of the solid phase in granulated honey.
- **Forage**: Natural food source of bees (nectar and pollen) from wild and cultivated flowers.
- **Hay fever**: An allergic condition that troubles many people; caused by various plant particles, airborne fungal spores or pollen.
- **Natural honey:** Unfiltered and unheated honey.
- **Nectar:** A liquid rich in sugars, manufactured by plants and secreted by nectary glands in or near flowers; the raw material for honey.
- **Propolis:** Sap or resinous materials collected from trees or plants by bees and used to strengthen the comb and to seal cracks; also called bee glue.
- **Royal jelly:** A highly nutritious glandular secretion of young bees, used to feed the queen and young brood.

5.1. Collection and preservation of bee pasture

- The plants that yield nectar or pollen or both for bees are called as bee flora.

- Plants which are good source of nectar are tamarind, moringa, neem, soapnut tree, eucalyptus, glyricidia.
- Plants which are good source of pollen are sorghum, sweet potato, maize, tobacco, millets, coconut, rose, castor, pomegranate, date palm.
- Plants which are good source of both pollen and nectar are banana, peach, citrus, guava, apple, sunflower, pear, mango, plum.
- Bee pasture can be designated as build up, honey flow and dearth period flora depending on period of availability with respect to development of bee colonies. The flora of an area is characteristic of its agro climatic conditions and as such varies from place to place. This flora is also a food base for large number of pollinators.

List of important bee flora

Sr. No.	Common name	Botanical name	Family	Flowering period (1-12 months)	Source for N-nectar P-pollen
1.	Stone and pome fruits	*Prunus & Pyrus spp.*	Rosaceae	2-4	N+P
2.	Bramble	*Rubus ellipticus*	Rosaceae	2-3	N+P
3.	Barberry	*Berberis lycium*	Berberidaceae	3-4	N+P
4.	Honey suckle	*Lonicera angustifolia*	Caprifoliaceae	3-4	N+P

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5.	Yellow clover	*Medicago denticulata*	Leguminosae	3-4	N+P
6.	White clover	*Trifolium repens*	Leguminosae	3-4	N+P
7.	Egyptian clover	*Trifolium alexandrinum*	Leguminosae	4-5	N+P
8.	Hirad	*Terminalia chebula*	Combretaceae	4-6	N
9.	Jamun	*Syzygium cumini*	Myrtaceae	4-5	N+P
10.	Eucalyptus	*Eucalyptus sp.*	Myrtaceae	3-5	N+P
11.	Bottle brush	*Callistemon lanceolatus*	Myrtaceae	4	N+P
12.	False acacia	*Robinia pseudoacacia*	Leguminosae	4	N+P
13.	Gulmohar	*Jacaranda mimosaefolia*	Bignoniaceae	4-5	N
14.	Bird's foot treefoil	*Lotus corniculatus*	Leguminosae	4-5	N
15.	Daru	*Punica granatum*	Punicaceae	4-5	N+P
16.	Toon	*Toona ciliata*	Meliaceae	4-5	N+P
17.	Sunflower	*Helianthus annuus*	Compositae	4-7	N+P
18.	Shisham	*Dalbergia sissoo*	Leguminosae	4	N+P
19.	Wild rose	*Rosa moschata*	Rosaceae	4-6	N+P
20.	Ber	*Zizyphus jujuba*	Rhamanaceae	5-7	N
21.	Ohi	*Albizia chinensis*	Mimosaceae	5-6	N
22.	Khair	*Acacia catechu*	Mimosaceae	5-7	N

23.	Bhang	*Cannabis sativa*	Cannabaceae	7-9	P
24.	Maize	*Zea mays*	Graminae	8-9	P
25.	Shain	*Plectranthus rugosus*	Labiatae	8-10	N+P
26.	Cruciferous oil seeds	*Brassica spp*	Cruciferae	10-4	N+P
27.	Wild cherry	*Prunus puddum*	Rosaceae	10-11	N+P
28.	Rubber	*Hevea brasiliensis*	Euphorbiaceae	-	N
29.	Soapnut	*Sapindus spp*	Sapindaceae	10-12	N

- Out of 3,52,000 species of flowering plants in the world nearly 3,08,000 species (87.5 per cent) are pollinated by animals (including insects, birds, bats, etc.). Bees pollinate a large majority of these plants.
- Honey bees collect nectar and pollen from a variety of plants which are known as bee flora or bee forage or bee pasture or nectar and pollen plants. Nectar is source of honey, meeting the carbohydrate requirements of honey bees, whereas pollen is source of protein.
- Pollination is an ecosystem service provided by the bees that is almost always taken for granted. In simple terms bees make more fruits and seeds for us by collecting nectar and pollen than the quantity of honey they make. Hence, it is essential to understand various types of bee flora and their blooming phenology in a given area to conserve bee colonies.

5.1.2. Essential honey flow sources in India

Figure 5.1 Bushes of *Plectranthus* in bloom (Autumn honey flow flora)

Figure 5.2 honey flow

Figure 5.3 *Acacia catechu*, monsoon honey flow or dearth period flora

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Figure 5.4 *Eucalyptus*, summer honey flow tree source

5.2. Value added products

The beekeepers in India domesticate bees only to produce honey and some beeswax. However, apart from honey and bees wax, many other valuable products are also obtained from honey bees like pollen, propolis, royal jelly, bee venom, queen bees, package bees, brood etc.

5.2.1. Honey

It is defined as natural sweet substance, produced by the honey bees from the nectar of blossoms or from the secretions of other parts of the plants, which honeybees collect, convert into honey and store in wax comb to ripen.

Constituent	:	Per cent
Water	:	17.20
Fructose	:	38.19
Glucose	:	31.28
Sucrose	:	1.31
Maltose and other reducing disaccharides	:	7.31

Higher sugars	:	1.50
Acids	:	0.57
Proteins	:	0.6
Ash	:	0.17
Minor components	:	21

Chemical Composition:

Uses:

- Honey is a high calorie food and one kilogram of honey contains 3150-3350 calories. Honey consumption reduces fatigue. Honey consumption is especially important for old people and children who need to build up their strength quickly.
- Honey contains some essential enzymes without which human life is not possible. It has been remarked that microelements and mineral substances present in honey have a most important biological role because their interaction with number of enzymes, vitamins and hormones affects the irritability of the nervous system, tissue respiration and circulation.
- Honey is a good preservative because of its antibiotic properties and can be used to preserve food like meat, baking bread, cakes, biscuits etc.

5.2.2. Bees wax

- Beeswax is a valuable product of beekeeping industry, produced and used by honey bees for the construction of comb.

- It is produced by young worker honeybees of 14-18 days old only as in newly emerged bees wax glands are not fully developed and in older bees (> 3 weeks old) wax glands get degenerated.
- Wax is secreted as a liquid from four pairs of specialized wax glands present on the ventral surface of the 4th to 7th abdominal segments.
- It has been estimated that to produce 1 kg of bees wax, the bees have to consume 6-8 kg of honey.

Composition: Bees wax is extremely complex material containing over 300 different substances. It consists mainly of hydrocarbons (14%), monoesters (35%), diesters (14%) and several types of acids (12%), alcohols (1%) and other substances (6%). In addition, approx. 50 aroma components have been identified.

Uses:

- Making of candles (the modern candles are made of paraffin wax, a petroleum product).
- Making pharmaceutical preparations.
- Preparation of varnishes and paints.
- Water proofing and waxing of threads.
- Formation of comb foundation (wax foundation in apiaries).

5.2.3. Propolis

Propolis is collected by bees from resinous exudates of buds, bark and wounds of plants/ trees. It is used by bees to plug the cracks and crevices in the hive, varnishing the comb surface and as a repellent against ants at the hive entrance.

Composition and Properties

The main constituents of propolis are:

Waxes	=	30%
Resins and balsams	=	55%
Etheral oil	=	10%
Pollen	=	5%

Propolis also contains flavonoids, phenolic and aromatic compounds.

Uses: Propolis is antimicrobial, antiviral, anti-inflammatory, act as topical anesthesia and has spasmolytic activity.

5.2.4. Pollen

Honey bees collect pollen from the stamens of flowers. It is the chief source of protein, lipids, amino acids, minerals, vitamins etc. in the honey bee diet. The partially fermented pollen mixture stored in the honeybee combs, also referred to as "beebread" has a different composition and nutritional value than the field collected pollen pellets and is the food eaten by young worker bees to produce royal jelly.

Composition: Each microscopic grain of pollen is a complex concentration of invaluable nutritive and curative substances, peptones, globulins, all amino acids essential to humans including proline, carbohydrates, fatty substances, enzymes, minerals and vitamins (B1, B2, B6, B12, A, E, K).

Uses: Pollen has a potential as an excellent food and can become a competitive food item in the human diets and be developed as a "Cottage industry" protein and nutritional supplement for developing nations. Pollen is formulated for human consumption into several appealing products including pastes, tablets, pollen granules, oral liquids (i.e., extracts), candy bars etc.

5.2.5. Royal jelly

Royal jelly is a creamy product secreted by young nurse worker bees for feeding to the queen, queen larvae. It is synthesized by the bees in the hypo pharyngeal glands. It is always fed directly to the queen or the larvae as it is secreted; it is not stored.

Composition:

Constituent	**:**	**Per cent**
Protein	:	13-18
Carbohydrate	:	10-16
Fat	:	6-12
Ash	:	2-3

Uses:

- Royal jelly contains acetylcholine, which dilates the blood vessels and is therefore used to treat hypertension.
- Vitamin E found in royal jelly stimulated fertility in human beings and animals. Royal jelly normalizes metabolism, has a diuretic effect can be used to prevent obesity and emaciation, builds up resistance to infections, regulates the functioning of the endocrine glands and is good for arteriosclerosis and coronary

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deficiency. It is a tonic, restoring energy and getting rid of the feeling of indisposition.

5.2.6. Bee venom

Bee venom is clear, odourless, watery liquid having somewhat sharp and bitter taste and hydrolytic blend of proteins with acidic pH. It is produced by venom glands associated with the sting apparatus of worker bees and used as a defensive agent against enemies specially predators. The worker bee injects the venom into the victim while stinging. A single worker has about 0.5 mg venom.

Composition: Bee venom contains formic, hydrochloric and orthophosphoric acids, histamine, tryptophan, sulphur and other substances.

Uses:

- In human beings, it is used for curing rheumatoid arthritis, many diseases of nervous disorders, suppressing oedema (swelling), as anti-inflammatory agent and for treatment of individuals hypersensitive to bee stings.
- Apitoxin stimulates the production of new blood (erythrocytes) and the amount of haemoglobin is raised to normal. The cholesterol level of the blood is lowered by bee venom. On the other hand, hypercholesterolemia (excess of cholesterol in the blood) may occur in cases where the effect of bee venom does not prove beneficial.

5.2.7 Method of honey extraction

The extraction of honey from combs involves the following steps

- Smoke the colony or super before removing frames.
- Remove the combs with sealed honey only. Select only those combs in which more than 70% of cells are capped. Do not select honey combs having sealed/unsealed brood.
- Shake the bees from frames or gently brush them off the comb.
- Keep the removed honey frames separately in an empty chamber and cover it.
- Honey extraction process should be done in a closed room or in a tent made of fine mesh netting away from the apiary.
- Uncap the wax seals on both sides of the honey-filled combs with uncapping knife by placing the combs in the drip tray. Knives are heated before uncapping the sealed honey in the hot water. Usually, two knives are used by putting one for heating while second one is used to uncap the wax capping. The capping can also be removed by steam operated or electrical uncapping knife.
- Cut a thin layer of wax and honey from the surface of each comb with a back-and-forth sawing movement while you hold the knife against the top and bottom bars of the frame. First uncap one side, then turn the frame and uncap the other side.
- Place uncapped honey combs in the honey extractor and rotate it to force the honey out of the combs by centrifugal force.
- To harvest honey tangential or radial types of honey extractors are used. In tangential honey extractor after extracting honey from one side, it is required to reverse the combs by hand to extract the honey from the other side of the comb. In radial honey extractors both sides of the comb are extracted simultaneously as the combs are rotated, the centrifugal force acting radially across the face of the comb.

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- Rotate the extractor slowly at first. If the extractor is turned too rapidly, the weight of the honey may break the combs. The combs should not be damaged during extraction as they are to be reused and are quite costly for man and the bees to produce.
- The extracted honey is passed through the muslin cloth or wire mesh for straining the extraneous material and wax capping.
- Combs emptied after honey extraction is given back to the honey bee colonies as many as were drawn out from every colony.

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Course Name	Apiculture, Sericulture and Lac Culture
Lesson 6	Seasonal Management of Honeybee Colonies and Queen Rearing (spring)
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Objectives

- To get acquainted with different management practices required for honey bee colonies management in spring season.
- To get acquainted with smarming behaviour of honey bees.

Glossary

- **Absconding:** The complete moving out of the bee hive by the honey bee due to the disease, wax moth, excessive heat or water, lack of resources or other reasons.
- **Dearth**: A period of time when there is no available forage for bees, due to weather conditions (rain, drought) or time of year.
- **Primary swarm:** The first swarm to leave the parent colony, usually with the old queen.
- **Robbing:** The act of bees stealing honey/nectar from the other colonies; also applied to bees cleaning out wet supers or cappings left uncovered by beekeepers.
- **Secondary swarm:** A smaller swarm which may occur after the primary swarm has occurred.
- **Supersedure:** Rearing a new queen to replace the mother queen in the same hive; shortly after the daughter queen begins to lay eggs, the mother queen disappears.
- **Swarming:** The natural method of propagation of the honey bee colony.
- **Swarming season:** The time of year, usually mid-summer, when swarms usually issue.

6.1. Spring management

The advent of spring, particularly in northern parts of the country, marks the beginning of warm weather and blooming of several tree species and cultivated crops. Following management practices are performed:

- Remove the protective covering of lightly packed hives in the early spring. But in the heavily packed colonies, the packing is removed only when daily maximum temperature has reached 16^{o}C.
- Examine the colonies on a sunny day. Check the food store and general condition of the colony. The examination should be for short duration to avoid brood chilling and robbing.
- It is a good practice to equalize the strength of normal colonies in an apiary by giving brood frames to the needy colonies.
- The colonies which do not have brood, are likely to be queen less or if queen has failed and has become drone layer, there will be predominance of drone brood. Such colonies if are weak (less than 5 frames), be united with other needy normal colonies. If these are strong, then provide a mated queen and if not available, give a frame of brood with eggs and young larvae for rearing new queen.
- Give stimulatory feeding of sugar syrup (dilute syrup; 30 per cent) to the bee colonies on the onset of spring which is indicated by the start of blooming of spring flowers. Take all the steps to guard against the robbing by bees. Bees will put their whole force during this period for brood rearing.
- Provide raised combs or frames with comb foundation sheets if raised combs are not available so that there is no shortage of space for brood rearing. But be careful not to over expand the brood in the uncertain weather conditions of early spring, which may result in chilling of brood. Once the colony is strong enough to cover the brood, there is no risk of this problem.
- Examine the colonies at least once a week on a sunny day and when conditions permit, clean the debris from the bottom boards. Provide empty frames as per needs of the colonies. Ensure that each colony always has at least 5 kg of food stores.
- During spring old bees die which are normally replaced by young bees. If mortality of old bees exceeds the rate of emergence of young bees, the colonies show sign of dwindling which is known as spring dwindling. Such colonies should

be provided with adequate stores of pollen and honey and be given 1-2 sealed brood frames from the strong colonies.

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

In warmer areas of the country, all these practices can be carried out during early summer.

6.2 What is swarming?

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

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

What causes swarming?

Swarming occurs due to:

- Overcrowding and lack of ventilation.
- Presence of old queen
- Sudden honey flow
- Lack of space for egg laying and honey storage.

Problems due to swarming:

- Loss of working force due to division of the colony.

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

Indication of swarming:

- The colonies start raising large number of queen cells usually along the lower edges of combs (Fig. 6.1). However, few emergency queen cells are also raised in the event of queen failure i.e., supersedure (Fig 6.2).
- Many bees do not go to the field creating additional crowding, resulting in clustering of bees outside the hive.

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

Catching and hiving a swarm:

- A settled swarm can easily be caught using swarm catching basket (Fig. 6.3). This basket is placed above the bee cluster and the cluster is gently pushed upwards so that the bees start ascending into the basket. Once the queen has entered, the whole swarm will follow the queen.
- The swarm in this basket can be taken to the apiary for hiving.
- To make the swarm settle properly, a hive is prepared by giving one frame each of capped brood, pollen and honey and provided with extra frames as per strength of the swarm.
- The swarm from the swarm catching basket is then shaken on the top bars of such a prepared hive and immediately covered with burlap cloth, inner cover and top cover.

- Sugar syrup is also fed to such a newly settled swarm (1 part sugar dissolved in 1 part of water).

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

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

a. Examine the brood of the colony and remove all the queen cells.

b. Remove the brood chamber from the bottom board. Place another hive body containing one comb of unsealed brood, eggs and the queen on this bottom board. Fill the remaining hive with empty combs.

c. Place queen excluder on this hive body and keep the removed brood chamber along with remaining brood and bees over it.

d. Again, inspect the top hive body after 10 days and remove all queen cells that may have been built in this interval. In 21 days, all of the brood will have emerged in the upper body and it will be used for honey storage. In this way swarming can be checked.

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

Figure 6.1 Large number of queen cells raised on lower side of the comb during swarming

Figure 6.2 One emergency queen cell (Supersedure cell) raised on upper part of comb in the event of failure of queen

Figure 6.3 Swarm of bees on tree trunk being collected using swarm catching basket

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Course Name	Apiculture, Sericulture and Lac Culture
Lesson 7	Miscellaneous Management and Queen Rearing
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Objectives

a. To get acquainted with uniting, division and shifting of colonies.
b. To get acquainted with queen rearing and its management.

Glossary

- **Absconding:** The complete desertation of the bee hive by the honey bee due to the disease, wax moth, excessive heat or water, lack of resources, or other reasons.
- **Robbing:** The act of bees stealing honey/nectar from the other colonies; also applied to bees cleaning out wet supers or cappings left uncovered by beekeepers.
- **Secondary swarm:** A smaller swarm which may occur after the primary swarm has occurred.
- **Supering:** The act of placing honey supers on a colony in expectation of a honey flow.
- **Supersedure:** Rearing a new queen to replace the mother queen in the same hive; shortly after the daughter queen begins to lay eggs, the mother queen disappears.
- **Uniting:** Combining two or more colonies to form one larger colony.

8.1. Miscellaneous management

During different seasons as described earlier, different manipulations are done. These manipulations have been described separately under miscellaneous management since these may or may not be season specific.

Colony multiplication/dividing of colonies:

- Catching of swarms is an old method to increase the number of colonies but this method should not be encouraged since the colonies raised from swarms will have the swarming instincts. Moreover, this is a time-consuming method.
- Spring is the best season for increasing number of colonies by dividing the colonies which are not as strong as others and sparing these colonies from honey production. Such colonies can be divided into nuclei with two to three frames of

bees and each nucleus is given a queen cell or new queen. These nuclei should be fed with 50% sugar syrup.

- Another method to increase the colonies is before the honey flow when colonies are having peak population. Remove 2-3 combs of brood and bees from strong colonies to make nuclei. This will not affect the strength of the strong colonies and these can avail honey flow well due to strong condition. This also reduces the chance of swarming. The nuclei are given new queen or queen cells.

Uniting of bee colonies: The colonies to be united should be brought close to each other by moving 1 metre each day so as to avoid drifting of bees. When they are near to each other (within one metre), the colonies can be easily united using newspaper method in which few small holes are punctured in the paper and placed over the brood chamber of the colony. Place the brood chamber of other colony (without bottom board) over the first colony which is now separated by punctured newspaper. The bees will gradually mingle together by gnawing the paper.

Precaution: Keep the better queen and remove poor queen before uniting.

Shifting of bee colonies:

- If colonies are to be moved within the apiary to a short distance, these should be moved 1 metre every day in the evening to the desired site.
- If colonies are to be moved to a few hundred metres in the apiary, then these should first be taken to a distance of about 5km beyond the flight range. Keep the colonies for 2-3 days, and then bring back to the apiary and place at the desired site. However, before moving the colonies, all movable parts are nailed and colonies are closed in the late evening after the bee activity has ceased.

8.2. Queen rearing

In a normal bee colony, there is only one queen and raising of new queens is inhibited by pheromones secreted by the queen. Mated queen inhibits queen raising by workers only if it is able to move freely over brood area by distributing a pheromone from its tarsi on the combs by foot pads.

- This pheromone in combination with secretions from mandibular glands inhibits raising of queen cells. When used alone, neither of these secretions inhibits construction of queen cups.
- Natural periods for colony to rear queens attributed to inadequate queen movement over brood area.
- Crowding of workers restricts queen movement.

Under natural conditions bee colonies raise queen cells during:

- Swarming period.
- If queen becomes inefficient (due to old age, injury or disease).
- If a colony becomes queen less.

Production of queen

Queen rearing can be taken up during the periods when the queens are raised naturally. For quality queen production there should be abundance of drones for mating and plenty of floral sources for bees to collect nectar and pollen.

- Spare queen cells produced during swarming season can be used but the colonies raised from these queens may have more swarming instinct, hence generally discouraged.
- Few queen cells can be raised by removing the queen from a strong colony making it queen less.
- For large number of queen cells: Doolittle (1889) method of queen rearing is used which involves transfer of young larvae from worker cells to artificial queen cups by grafting.

8.2.1. Mass queen rearing

How to proceed for mass queen rearing:

Queen transmits to the colony all the important characters like longevity, disease resistance, temperament, swarming tendency etc. Hence, selection of a breeder colony (colony providing brood for grafting and raising quality queens) is made on the basis of progeny potential of such queens like increased honey production and

other characters. For selecting breeder colony, best performing colony in the apiary is marked and brood from this colony is used for raising quality queens.

Pre-requisites to produce good queens

- Presence of well-fed larvae (24 h old or younger).
- Strong cell builder colonies to provide surplus royal jelly and proper care for queen cells.
- Large number of mature drones of desired stock near queen mating yard.
- Stimulation of cell builder colony by constant feeding during development period.
- Nucleus of adequate strength to keep ripe cell (matured queen cells) warm and proper care of emerging queen.

Requirements: Queen cell forming rod, grafting needle, beeswax, oven, bee colonies, queen cell protector, queen cell holding frames and queen storage frames, sugar, candy, feeders.

Controlled queen rearing

- Preparation of queen cups: Cell forming rod of 7.5 cm length, tapering from 9.4 mm diameter at 12.5 mm from the tip to a diameter of 6.25 to 7.8 mm at tip.
- Prepare queen cups using molten beeswax, having diameter of 9 to 10 mm and 11 to 12 mm in length for mass queen rearing of *A. mellifera*. The cup size will be different for *A. cerana* queen rearing.
- Cell builder colony: colony managed to rear queen cells. Select a strong colony with young bees having access to stored or fresh pollen. Feed continuously using friction- pail feeders.
- Strength of cell builder colony should be more than 20000 worker bees (one frame full of bees has about 1600 number of bees).
- The colony should have nine combs containing sealed brood, honey and plenty of pollen with 2 combs of young brood in the centre, next to where queen cups are to be placed.
- Breeder queens: it represents the selected stock of mother queens from which new queens are to be reared.

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Basic grafting

- Grafting is best done inside a building under bright light preferably at temperature of 30°C and 60-70 per cent relative humidity. Items required are:
  a. Bars of cell cups (Fig. 8.1a).
  b. A grafting needle (Fig. 8.1b).
  c. Frame containing (frame marked after egg laying by queen) 12-24 h old brood.
  d. Royal jelly in case of wet grafting.
- In dry grafting there is no need of priming the cells with royal jelly.
- In wet grafting, a drop of royal jelly (1:1 diluted with water) is placed in queen cup before grafting.

a

b c

Figure 8.1 (a to c) Grafting of larvae in queen caps

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Figure 8.2 Accepted queen cells after 2-4 hours of grafting

- Young larvae from the selected breeder stock (from best performing colony in an apiary) are picked up with a grafting needle from (Fig. 8.1 a-c) the brood comb.
- The grafting needle is moved down from the side of the comb cell and as it reaches under the “c” larva, it is moved up with the larva on its tip.
- This larva from the grafting needle is then dislodged at the bottom of queen cup attached on the bars without changing its position (8.1 c).
- In this way 15 to 30 queen cups can be grafted with larvae and once grafting is complete, the frame with grafted cells is immediately moved to cell builder colony.

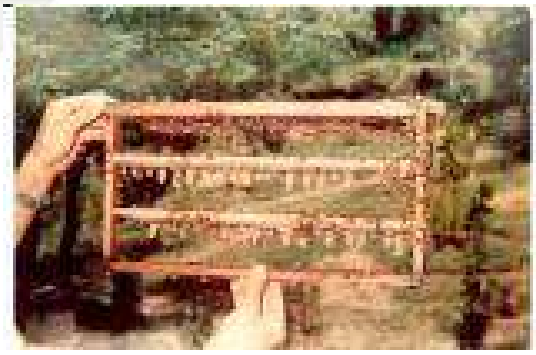

Figure 8.3 Sealed queen cells

Figure 8.4 Protected sealed queen cells

Figure 8.5 Queens in mating nuclei kept for mating

Management of cell builder colonies

- Cell builder colony needs proper management and same colony can be used to rear queen cells during entire season.
- Cell builder colony is made queen less by removing its queen. Grafted cells are accepted within few hours after making it queen less; better acceptance if dequeened in morning and first lot of cells given in afternoon or next day.
- This colony being queen less needs sealed brood or nurse bees to maintain sufficient population. For this purpose two frames of brood (1 with uncapped cells) are sufficient which should replace 2 brood less combs.
- Frame containing grafted queen cups is placed in the centre of cell builder colony and workers start raising queen cells once accepted by them (Fig. 8.2).
- Destroy any queen cell reared on other brood combs, since these queen cells are not from selected stock.
- On 10th day after grafting: shift finished queen cells (Fig. 8.3) to individual queen mating nucleus or use queen cell protectors (Fig. 8.4) to prevent cell destruction by any of the emerging queens.
- Mating nuclei can be baby nuclei (Fig. 8.5) or large 2-3 frame full depth nuclei. However, generally baby nuclei are preferred by breeders as these are easy to feed, easier to stock and easier to find mated queen.

Mating of queens

- Mating nuclei are placed in mating yard having ample mature drones from selected colonies (better performing colonies).
- Young queen mates after 5 to 10 days of emergence during mating flights in the open air with a number of drones in drone congregation areas (areas having hundreds of drones).
- Queen starts laying after 7-10 days of mating and is ready for further use.

Transportation/Mailing of queens

After successful mating of the queens, these can be transported in mailing queen cages.

- Standard wooden mailing cages are used for mailing.
- One end of each queen cage is provisioned with candy. The mated queen is placed in this cage with 3-4 attendant worker bees.
- Queens can be transported to long distances in these mailing cages.
- In many advance countries, queens are even mailed as parcels in queen mailing cages through department of posts.

Preparation of honey-sugar candy: 0.568 litre (800 g) honey & 1.82 kg sugar (1:2.27 w/w mixtures). Prepared by warming honey to 65.6^{o}C, adding powdered sugar with continuous stirring and then kneading the mass produced. This candy can be fed to the bees when queen is transported in mailing cage or introduced in to a new colony.

Course Name	Apiculture, Sericulture and Lac Culture
Lesson 8	Insect Pests and Diseases of Honey Bees and their Management
Content Creator Name	Dr. Tamoghna Saha
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Course Reviewer	Dr. Kalmesh Managanvi
University/College Name	Bihar Agricultural University, Sabour Bhagalpur

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Objectives:

a. To get acquainted with different insect pests of honey bees and their management.
b. To get acquainted with different diseases of honey bees and their management.

Glossary

- ***Acarapis woodi:*** A mite, called the Tracheal mite which infests the bees' breathing or tracheal system; sometimes called Acarine disease, this refers to bees that are heavily infested with the Tracheal mite.
- ***Bacillus larvae:*** The bacterium that causes American foulbrood.
- **European foulbrood:** An infectious brood disease of honey bees caused by *Streptococcus pluton.*
- **American foulbrood:** A brood disease of honey bees caused by the spore-forming bacterium, *Bacillus larvae* and characterized by a ropy or gummy condition of affected larvae. It is the most widespread and destructive of the brood diseases, affecting queen, drone, and worker larvae alike.
- **Sacbrood:** A brood disease of bees caused by a filterable virus which interferes with the moulting process; the dead larva resembles a bag of fluid.
- **Nosema disease:** A widespread adult bee disease caused by a one-celled spore-forming organism Nosema apis; it infects the gut lining.
- **Terramycin:** An antibiotic used to control American and European foulbrood.
- **Wasp:** A close relative of honey bees, usually in the family Vespidae; they are carnivorous, some species preying on bees (see also, Hornet).
- ***Braula coeca:*** The scientific name of a wingless fly commonly known as the bee louse.

9.1. Insect pests of honey bee and their management

Predatory wasps:

Vespa velutina (V. auraria) Nests on tree tops/buildings.

Vespa magnifica Under-ground nest.

Vespa tropica (V. cincta) Underground nest.

Vespa basalis Nest on tree top/buildings.

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Figure 9.1 Vespa velutina

Figure 9.2 Vespa mangifica

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Figure 9.3 Severe attacks of *Vespa basalis* at the hive entrance of *A. cerana*

Nature of damage:

- The wasps catch the bees at hive entrance and kill them (Fig. 9.1).
- Most serious damage in hills is caused by *V. magnifica* which cuts down bees in large number while sitting or flying at/near hive entrance (Fig. 9.2).
- Sometimes even *V. basalis* has been found causing severe damage to the colonies (Fig. 9.3).
- The weak colonies may even perish due to its attack.

Prevention and control:

- Kill the fecunded females visiting the apiary during spring by flapping.
- Burn the nests during night time.
- In fire prone places destroy the nests by spraying them with strong insecticidal solution.
- Kill the wasps in the apiary by flapping.

Wax moth: Two species are reported. Greater Wax Moth, *Galleria mellonella* and Lesser wax moth, *Achroia grisella*.

The wax moth larvae (Fig. 9.4) tunnel through the mid ribs of the comb (Fig. 9.5). It forms silken webbing in comb in which excreta is enmeshed. Also, the wax moth larvae decap cells resulting in bald brood condition.

Figure 9.4 Larvae of *Galleria mellonella* exposed from the galleries

Figure 9.5 Damage of comb by larvae of wax moth

Management:

- Maintain strong colonies during dearth period.
- Remove old black combs and uncovered combs.
- Clean bottom board regularly reduce entrance.
- Use of traps (delta sticky traps) to catch adults.
- Use of fumigants (sulphur or ethylene bromoide or ethylenedibromide).

Control in storage: Keep spare combs in empty hive bodies in tiers and close both at bottom and top. Disinfect the stack by burning sulphur @ 180 g/ cubic metre (fumigation by sulphur fumes). After fumigation, put naphthalene flakes in moth proof stacks.

Mite pests: Most important parasitic mites which attacks honey bees are,
Endoparasitic mite – Acarapis woodi
Ectoparasitic mite – *Varroa destructor* and Tropilaelaps clareae

Acarapis woodi – It is called as **acarine disease or Isle of Wight**. It attacks adult bees. Mite enters into thoracic tracheae of bees. It feeds on body fluid and breeds there. Finally, the tracheae get blocked and bees die due to suffocation.

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Symptoms:

- Large number of crawling bees in front of hive
- Fore wings and hind wings get separated developing K winged position
- Crawlers move away from hive and do not return
- Brood not covered normally but scattered clusters

Tropilaelaps Clareae: This mite feeds only on bee brood. In case of severe infestation of this mite dead brood is thrown outside the hive by workers. The bee colonies may even abscond if control measures are not adopted. The diagnostic symptoms are:

- Irregular brood pattern - perforated brood capping.
- Dead or malformed wingless bees at the hive's entrance.
- Fast running small brownish mites can also be seen on the infected brood frame.

Varroa mite:

Figure 9.6 Uncapped pupal brood due to attack of *Varroa destructor* (Photograph by Dr B S Rana)

Figure 9.7 *Varroa destructor* on a bee pupa (Photograph by Dr B S Rana)

- This mite develops and reproduces in the sealed brood cells of honey bees (Fig. 9.6) feeding on haemolymph of bee pupa (Fig. 9.7). Parasitized individual may die or develop into deformed, weak individual incapable of normal functioning.
- This mite has caused heavy losses to *A. mellifera* colonies throughout the world as it reproduces both on drone and worker brood of this species. On *A. cerana* this mite reproduces only on drone brood and is unable to complete life cycle on worker brood due to slightly shorter developmental period.

The symptoms of colony infestation with Varroa are:

- Spotty brood pattern (Fig. 7.6).
- Mite can be seen on adult bee's body as mature female mite attaches to young adult bee and also feed on haemolyph till further reproduction in the brood cell.
- Dead brood and malformed adult bees are seen near/around hive entrance.
- Colonies become weak and wounds inflicted by mites make the bees more susceptible to bacterial and viral diseases.

Management of mite pests

- Dusting synecar (powdered sugar for which chloropropylate or bromopropylate is mixed) or thymol or sulphur between frames.
- Use of evaporating agents like formic acid.
- Use of fumigants like Varostan or chlorobenzilate or folbex.

- Burn sulphur or dimite (acaricide containg potassium nitrate) in the smoker
- Place stick sheet at bottom board.

Ants: Carpenter ant (Camponotus campestris), fire ant (Solanopsis sp), red ants (Oecophylla smargdina) – They take away honey, brood, pollen, dead bodies and other debris.

Death's head moth*: Acherontia styx*: The moth enters the hive at night and sucks honey.

Wax beetles, *Platybolium alvearium, Bradymerus* sp.: Adults and grubs of these beetles are found in debris on the bottom board of the hive. Feed on wax.

Bee louse, *Braula coeca*: Wingless fly found on thorax of bee and feeds by coming near mouth close to opening of salivary glands and take the available nourishment. It is not a serious pest.

Cockroaches: Roaches live in colonies and nibble away small bits of Combs.

Robber files and Dragon files: These catch the bees in flight and feed on them.

Preying mantids: The preying mantids catch the bees when they visit the blossoms and eat them.

Termites: Odontotermes obeses: The termites damage the wooden components of the hives and other apiary appliances.

Birds: Bee eaters (Merops orientalis) and King crow (Dicurus sp) catch/picking them the bees around apiaries (Use bird scarers, repellents to avoid birds).

Monkeys: In search of honey, they topple the bee hives causing disturbance to the bees leading to desertion ultimately.

9.2. Diseases of honey bee and their management

Honey bees are attacked by a large number of diseases which are caused by different organisms including virus, bacteria, protozoan and mites both ectoparasitic and endoparasitic. The extent of damage varies from death of some brood or adults to complete loss of colonies.

The disease spreads from one colony to other through different manipulations done in the apiary as well as through robber bees, swarms and drifting bees. Brief account of symptoms and control measures is given in the tabular form below which can also help in differentiating one disease from the other.

9.2.1. Diseases of honeybee

	American Foul Brood	**European Foul Brood**	**Sac Brood/Thai sac brood**
Causative Organism	*Paenibacillus larvae* (bacteria)	*Melissococcus pluton* (bacteria)	Virus (sac brood *in A. mellifera* and Thai sac brood in *A. cerana*
Time of death	Late larval or early pupal stage	Coiled larvae in unsealed cell (usually young unsealed larvae sometime older sealed larvae)	Late larval stage; (usually older sealed larvae sometimes young unsealed larvae)
Cappings	Sunken and punctured	Dead brood in uncapped stage	Capping removed or punctured often with two holes.
Colour of dead brood	Off white to light cream to brown; coffee brown to dark brown or almost black	Yellowish white to grey or dark brown, dark brown or almost black (Fig. 9.9) as compared to glittering white in case of normal brood (Fig. 9.8)	Straw coloured, starts darkening from head
Position of dead brood	Lying flat on cell base	Coiled, twisted or collapsed	Extended with head curled upright in cells (Fig. 9.10)
Consistency of dead brood	Sticky to ropy	Soft and gummy ; rarely sticky or	Sac like with watery content

		ropy, granular	
Odour of dead brood	Glue pot, putrid faint	Slightly sour to penetratingly sour, Putrid fish	None to slightly sour; faint sour
Type of brood affected	Worker, rarely drone or queen	Worker, drone and queen	Worker only
Control	Terramycin @ 0.250 – 0.400g in 5lt sugar syrup feeding	Feed Terramycin @ 0.2g in 500ml conc. Sugar syrup	No effective cure

Figure 9.8 Healthy worker brood of *A. mellifera* (Photograph by Dr B S Rana)

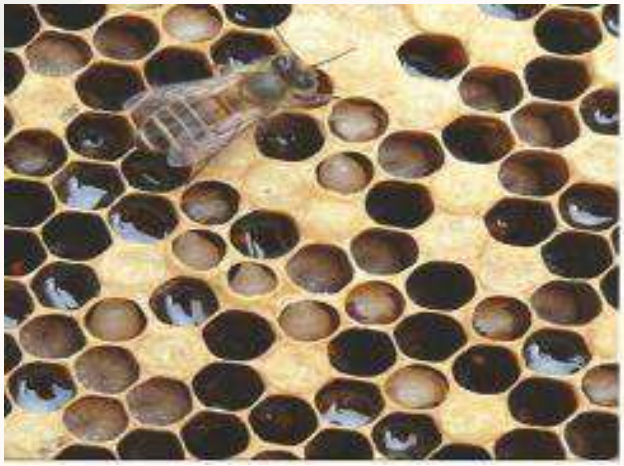

Figure 9.9 European foul brood disease in *A. mellifera* (Photograph by Dr B S Rana)

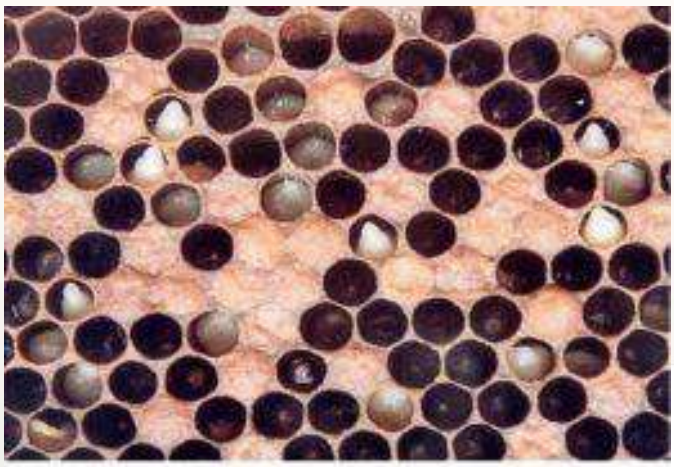

Figure 9.10 Sac brood disease in *A. mellifera* (Photograph by Dr B S Rana)

9.2.2. Adult diseases

	Nosema disease	**Acarine disease**
Causative organism	*Nosema apis* (protozoan)	*Acarapis woodi* (Endoparasitic mite)
Symptoms	Infected bees collect in front of hive, sluggish, crawlers on leaf blades, distended abdomen, dysentric (Fig. 9.11)	Bees gather in front of hive as crawler bees and unable to fly; disjointed wings having typical 'k' wing condition
Control	Feed fumigillin 200 mg in sugar syrup to each	Fumigate using folbex strips at weekly intervals or with

	colony or 0.5-3.0 mg in 100ml sugar syrup. or Two feedings at weekly interval of Dependel-M @0.5g/litre/colony	formic acid (85%) @ 10ml/colony and replenish the quantity after every 24 h for 21 days

Figure 9.11 Symptoms of nosema disease in *A. cerana* (Photograph by Dr B S Rana)

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Course Name	Apiculture, Sericulture and Lac Culture
Lesson 9	Silkworm: History Development in India, Systematic Position, Life Cycle and Distribution of Silkworm
Content Creator Name	Dr. Tamoghna Saha
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Objectives

a. To get acquainted with brief history of sericulture and organizational set of silk industry.
b. To get acquainted with different life stages, life cycle of silkworm.

Glossary

- **Life cycle:** The total time duration taken by the larvae of silkworm from egg to adult is the life cycle.
- **Silk gland (Labial gland):** The silk glands are paired modified labial glands,ectodermal in origin, cylindrical and tubular in shape.
- **CSR&TI**- Central Sericultural Research and Training Institute (Mysore, Berhampore, Pampoor).
- **Distribution:** The area where silkworm regularly found.
- **Vanya silks:** Except mulberry, other non-mulberry varieties of silks are generally termed as vanya silks.

10.1. Silkworm: History and development in India

- Silk was discovered in China by the Empress, Si- Ling and later spread to other parts of the world.
- The first authentic reference to silk is found in the Chronicles of the Chou- King of China (2,200 BC).The discovery of silk production from *Bombyx mori* occurred about 2700 BC.
- From Tibet, it spread to India in l40 BC. There is evidence in ancient Sanskrit literature.
- Silkworm eggs and the technology of making silk, was brought to India by Buddhist monks from China.
- About two and half centuries ago silk was introduced into Karnataka by Tippu Sultan, the ruler of the State. Today it is the biggest silk producing centre in India. Sericulture introduced in TamilNadu from the border area of Karnataka during early 1960. Now TamilNadu Stands number one in Bivoltine Silk production in India.

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10.2 Organization set up in sericulture industry

- Central Silk Board (CSB) established in 1949 is one of the earliest statutory bodies under Ministry of Textiles, Government of India, with its headquarters located in Bangalore.

10.2.1 The institutes under CSB are:

- Central Sericultural Research and Training Institute (CSR&TI), Mysore, Berhampore, Pampoor.
- Central Silk Technological Research Institute (CSTRI), Bangalore.
- National Silkworm Seed Organization (NSSO), Bangalore.
- Silkworm Seed Technology Laboratory (SSTL), Kodathi, Bangalore.
- Central Sericultural Germplasm Resources Centre (CSGRC), Hosur.
- Seri Biotech Research Laboratory (SBRL), Bangalore.
- Central Tasar Research and Training Institute (CTR &TI), Ranchi, Jharkhand.
- Central Muga Eri Research and Training Institute (CMER&TI), Jorhat, Assam.

10.2.2 Functions of CSB:

- Promotion and development of silk industry.
- Encouraging scientific, technological and economic research.
- Development and distribution of healthy seeds of silkworms.
- Devising improved methods of moriculture, Silkworm rearing, reeling, and spinning.
- Price fixation of silk cocoon and raw silk.
- Quality control of silk and silk products.
- Pre-shipment inspection of silk and silk products for exports.
- Advising Govt. of India on all matters related to development of silk industry including import of raw silk and export of silk products.

10.2.3 International Silk Organizations

CSB is delegate member of

a. International Sericulture Commission (ISC).
b. International silk Association (ISA).

10.3. Systematic position, distribution, lifecycles in brief, Silk glands.

Systematic position of Silkworm

Kingdom:	Animalia
Phylum:	Arthropoda
Class:	Insecta
Sub-Class:	Pterygota
Order:	Lepidoptera
Sub Order:	Ditrysia
Family:	Bombycidae, Saturnidae
Genus:	Bombyx, Antheraea

10.4. Life cycle of silkworms

The silkworm is the larva or the caterpillar of the moth Bombyx mori (popularly called the silk moth) the total life history of the moth (from egg to adult take 50 days). The different stages are as follows:

a. **Egg 10 days**
b. **Larva (4 Stages) 30 days**
c. **Pupa (Cocoon) - 10 days**
d. **adult**

a. Eggs

The eggs are round and yellowish-white, and they become grey as hatching time approaches.

b. Larvae

- The newly hatched larva is about 3 mm long and somewhat black in colour. The larvae grow in size and shed their skin (moult) four times. Each growing stage of the caterpillar consumes lot of mulberry leaves.

- The last stage full grown larva is about 7 cm long. It has a hump behind the head and a spine-like horn at the tail end.
- When full grown, the mature larva stops feeding, climbs on a twig and spins a cocoon.

c. Pupa

The full-grown larva pupates inside the cocoon. In about 10 days' time it transforms into a winged adult. The adult moth makes an opening in the cocoon and escapes through it.

d. Adult

The adult silk moth is a creamy white moth that has a flat body and a wing expanse of about 5 cms. It takes no food and seldom attempts to fly. It lives for only 2 to 3 days. After mating, the female moth lays 300-500 eggs on leaves of the mulberry tree.

10.5. Distribution of silkworm: The silkworm is mostly reared in China (65%), Japan, Italy, France, America, Tibet, Nepal, and European countries and whereas in India, Karnataka (60%), AP, Tamil Nadu, West Bengal, Assam, Kashmir, Bihar, Maharashtra, MP, UP and Orrisa.

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Silk gland (Labial gland)

- The silk glands are paired modified labial glands, ectodermal in origin, cylindrical and tubular with branched nuclei, second largest part organ in the body, each glands several times the length of the larva occupying 2/5th body weight and volume, situated from the 4th to 8th abdominal segments ventero-lateral to the mesenteron; posterior ends closed, fore ends join together to one secretary duct in the head region, opening at the spinneret of the labium; each gland divisible into anterior, middle and posterior regions; anterior region narrow, straight, middle region very thick, with two definite curves forming three division viz., fore, mid and hind division; posterior region irregular with many curves throughout; wall of the gland with three layers viz., the outer tunica propria, middle gland cells and inner tunica intima.
- The middle region of the silk gland produces sericin and the posterior region produces fibroin. The silk fiber consists of inner fibroin and outer sericin.

Except mulberry, other non-mulberry varieties of silks are generally termed as vanya silks. India has the unique distinction of producing all these commercial varieties of silk.

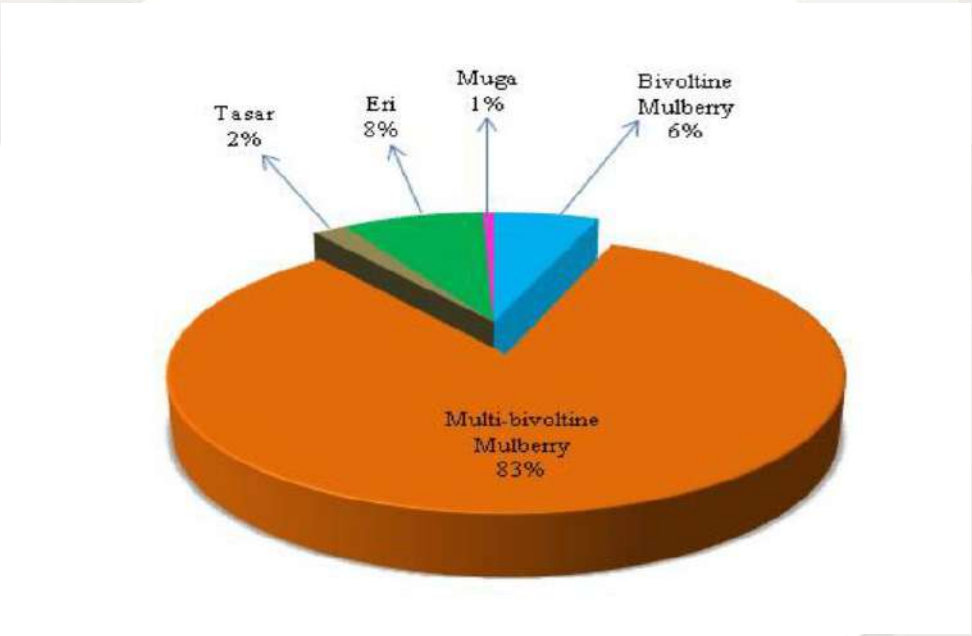

Figure. 10.5. Variety-wise share of raw silk production

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Main properties of silk

a. It is lustrous, soft and strong.
b. It is made up of two proteins: the inner core is fibroin and an outer cover is sericin.
c. It is hard wearing.
d. It can be dyed into several colors.
e. it is elastic, non-conductor of heat and electricity.
f. Silk is commonly referred as queen of textiles.
g. Silk is made up of two protiens.

- Sericin- 25% Gummy/gelatinous and hot water soluble
  Made up of Serine, Leucine and Alanine amino acids

- Fibrion – 75% It is tough, elastic and insoluble in hot water
  Made up of Glycine, Tyrosine and Alanine amino acids

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More suggetions

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Course Name	Apiculture, Sericulture and Lac Culture
Lesson 10	Types of Silkworm, their Importance and Characteristics Features
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Objectives:

a. To get acquainted with different agro-industrial activities of sericulture.
b. To understand the life cycle of mulberry silkworm.

Glossary

- **Bivoltine:** is a type of silkworm which completes two life cyclesper year in natural conditions.
- **Cocoon:** The cocoon is formed from a secretion from two large silk glands (actually the salivary glands), which extend along the inside of the body and open through a common duct on the lower lip of the mouthparts.
- **Silk:** Silk is the secretion from the salivary glands which are found on both sides of the alimentary canal of silk worm larvae and this secretion hardens into fine threads called silk.
- **Silk gland (Labial gland):** The silk glands are paired modified labial glands, ectodermal in origin, cylindrical and tubular with branched nuclei, second largest part organ in the body.
- **DFL's:** Disease free layings.
- **Brushing:** Transferring newly hatched larvae from eggs to rearing bed.
- **Grainage:** The place where the silkworm eggs are produced in a scientific way.

- **Sericulture or silk** production is the breeding and management of silk worms for the commercial production of silk. The important industry of sericulture well operated in Japan, China, India, Italy, France and Spain. At present, China is leading producer followed India and Brazil consecutively.

Sericulture is an agro based industry playing a vital role in the improvement of rural economy, which offers employment opportunity to about 8 million people in India.
The word "Sericulture" is derived from the Greek 'Sericos' meaning 'silk' and the English 'culture' meaning 'rearing'. It is a multidisciplinary programme. It involves the cultivation of host plant to produce leaf, rearing of silkworm to convert leaf to cocoon, reeling of the cocoon to obtain silk yarn and weaving to convert yarn to fabrics.

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11.1. Importance of sericulture

- Sericulture is an agro based rural industry with large labour involvement and higher income generation potential.
- India, the second largest silk producer next to China, has a unique position in the world, being the only country producing all the four commercial types of natural silk viz., Mulberry, Tasar, Eri and Muga.
- Once the plantation is established it will continue to yield for 10 to 12 years with minimum expenditure for maintenance. Therefore, maximum turnout can be obtained with minimum investment.
- It is suitable to small and marginal farmers also.
- All the sericultural activities are village based and hence prevent migration of people from rural to urban areas in search of jobs.
- Silk being an expensive commodity used mostly by the affluent society, transfer of money from rich to poor is ensured.
- Mulberry ensures higher income per unit area than that from a number of agricultural crops. Sericulture gives income 5 to 6 times a year.
- Sericulture mostly requires use of simple appliances which are easily available in rural areas.
- In drought conditions, when most of the agricultural crops do not revive even after a few showers, mulberry being a perennial crop sprout and yield leaves for rearing silkworms.
- Sericulture provides self-employment opportunities to the educated unemployed youth in the varied sectors.
- A number of by products are obtained from sericulture activities.
- Mulberry and silkworm have pharmaceutical values.
- Silkworm is used as a tool for genetic and biotechnological studies.
- Silkworm gives products which are used as human medicines.

11.2. Characteristics features of mulberry silkworm

- An adult silkworm has a wingspan of 40 to 50 mm (about 2 inches) and has a thick bristly body (the adult female is larger than the adult male).

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- It typically is blond to light brown in colour, with thin dark bands running across the body.
- The wings are cream-colored and have dark veins extending out to the margins.
- Mouthparts in adults are reduced or absent, so in their brief adulthood of two or three days, they do not eat.
- They cannot fly either. However, male perform a flutter dance, a mating ritual induced by female's secretion of a pheromone known as bombykol.
- Females lay about 300 to 500 eggs, which hatch within roughly 7 to 14 days when kept at temperatures of 24 to 29 °C (about 75 to 85 °F).

Figure1. Silkworm and cocoon

11.3. Types of silkworm and their host plant

There are four major types of silk of commercial importance, obtained from different species of silkworms which in turn feed on a number of food plants. These are:

11.3.1. Mulberry silkworm (Bombyx mori)

It is the most important silk worm and reared extensively (90%) on mulberry plant only in various part of India and domesticated.

The cocoon is creamy in color from which best quality of silk is obtained. There are several races of the mulberry silk worm which may be grouped into two categories univoltine, bivoltine and multivoltine.The univoltine has an annual life cycle while multivoltine race passes through many generations in a year.

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11.3.1.1. Host Plants of *B. mori* (Lepidoptera: Bombycidae)

Mulberry silkworm is monophagous and feeds on mulberry (Morus spp.) and it belongs to Family: Moraceae and Order: Morales. Some species of mulberry are:

White mulberry: Morus alba, Black mulberry: Morus nigra, Red mulberry: Morus rubra.

Russian mulberry: Morustartarica, Indian mulberry: Morus indica (light yellowish in colour).

Creamy mulberry: Morus serrata.

11.4. External Morphology of *B.mori*

Head: There is a pair of dark compound eyes and bipectinate antennae. Mouthparts are siphoning type with a vestigial proboscis.

Thorax: It consists of three clear segments- anterior prothorax, middle mesothorax and posterior metathorax. Each segment bears a pair of long jointed legs ventrally and meso and metathorax each bears a pair of wings dorso-laterally.

Abdomen: It is composed of 10 segments with 6 pairs of functional spiracles and also bears external genitalia on the terminal segment. There is a pair of fleshy, yellow flap-like structures called 'labin' in female, while in males there are two dark hook – like structures called 'harpes'.

11.5.Races of mulberry silkworm

A population within a species that is distinct in some way, especially a subspecies.

Indigenous- Originating in and characteristic of a particular region or country; native.

Eg: Pure Mysore, Nistari.

Exotic- Plant or animal species introduced into an area where they do not occur naturally, non-native species.

Eg: E16, Daizo etc.

Voltinism: It is the ability of many insect groups to produce from one to several generations a year.

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Univoltine races: Produce **ONE** generation per year, larval weight is comparatively higher and cocoons are heavy, Denier of the silk filament is above 2.3,they lay only diapausing eggs. All European races are univoltines.

Eg: E16

Bivoltine races: Produce**TWO** generations per year. Length of the larval stage is short. The leaf consumption to cocoon production is less, and the quality of the cocoon's inferior to that of Univoltine races.

Eg: NB4D2, NB18, KA, NB7 etc.

Multivoltine races: Produce more than 5-6 generations per year. Length of the larval duration is short. In most of the polyvoltine races the leaf cocoon ratio is high, the length of the filament is short, cocoon filament is fine and clean with little lousiness; but with more lustrous. The larvae are robust and can tolerate fluctuating environmental conditions and hence best suited for tropical climates.

11.6. Mulberry varieties cultivated in India

Variety	Region	Developed at	Origin
Kanva-2	South India Irrigated	CSRTI, Mysore	Selection from natural variability
S-36	South India Irrigated	CSRTI, Mysore	Developed through EMS treatment of Berhampore Local
S-34	South India Rainfed	CSRTI, Mysore	Selection from poly cross (mixed pollen) progeny
MR-2	South India Rainfed	CSRTI, Mysore	Selection from open pollinated hybrids.
S-1	Eastern and NE India Irrigated	CSRTI, Berhampore	Introduction from (Mandalaya) Myanmar
S-7999	Eastern and NE India Irrigated	CSRTI, Berhampore	Selection from open pollinated hybrids
S-1635	Eastern and NE India Irrigated	CSRTI, Berhampore	Triploid selection
S-146	N. India and Hills of J and K Irrigated	CSRTI, Berhampore	Selection from open pollinated hybrids

Tr-10	Hills of Eastern India	CSRTI, Berhampore	Triploid of Ber. S1
BC-259	Hills of Eastern India	CSRTI, Berhampore	Back crossing of hybrid of Matigare local x Kosen with Kosen twice
Goshoerami	Temperate	CSRTI, Pampore	Introduction from Japan.
ChakMajra	Sub temperate	RSRS, Jammu	Selection from natural variability
China White	Temperate	CSRTI, Pampore	Clonal selection

11.7. Life cycle of *Bombyx mori*:

11.7.1. Characteristics of good layings:

- There should be more than 400 eggs in each laying.
- It should be free from pebrine disease.
- Eggs should be layed side by side.
- Eggs should not be one above the other.
- All eggs should be of uniform in size.
- There should be less infertile eggs.
- Eggs should stick permly to the egg card.

Life Cycle:

- The moths copulate by keeping their mouth to opposite direction. They mate immediately after emergence during May- June.
- The eggs are laid on an average 300-400 eggs popularly called as silk seeds.
- The larva moult 5 times after every 6-7 days and becomes mature in 30-35 days.
- The caterpillar on hatching, is white to dark in color and about 3 mm in length. Young caterpillars are called chawki worms/ ants/kegs and are reared in trays on tender chapped mulberry leaves at 25-27 ^{0}C and RH of 80-90%.
- While the 3^{rd,} 4thand5th instar larvae are called late age worms and are reared either on trays or open bed method. The temperature requirement will be in the range of 23-25 ^{0}C and relative humidity of 65-80%.
- Proper care should be taken during moulting and bed cleaning of the silkworms.

- The larva pupates inside the creamy cocoon. At the end of fifth instar, the larva stops feeding and spins a cocoon around itself. After spinning the silk completely, it transforms into a pupa inside the silk cocoon. Then the adult structures are formed and the moth breaks.
- Characteristics of mature worms are 1. They reduce feeding 2. Release wet feacal matter 3. Shrink in size 4. Body becomes translucent 5. Larvae starts crawling in bed with raised head. All the above characters indicate that larvae is mature and needs to be transferred to mountages.
- They open cocoon by secreting the enzyme 'cocoonase' and comes out. Adults do not feed and only reproduce.
- For silk purpose we should take proper care that it should not break the cocoon. There should be proper drying may be in open sunlight or hot air oven so as kill the pupa inside the cocoon.

11.7.2. Mounting

Mounting is transferring mature silkworms from rearing beds to montages to start spinning.

Spinning starts 8 days after worms get into fifth (5^{th}) stage.

Signs of Maturity

- Larvae cease to feed and crawl restlessly in search of a corner to attach themselves for spinning.
- They move to corners of the rearing beds ready to spin.
- If picking of mature silkworms is delayed the worms spin on the bed and silk fiber is found on the bed.
- The worms appear cream white as they are full of silk, they appear shrank in length.

Process of Mounting

The mature worms are picked from the rearing beds and transferred to mountages. Care should be taken to put the right number of worms on the mountages to avoid overcrowding and formation of double cocoons.

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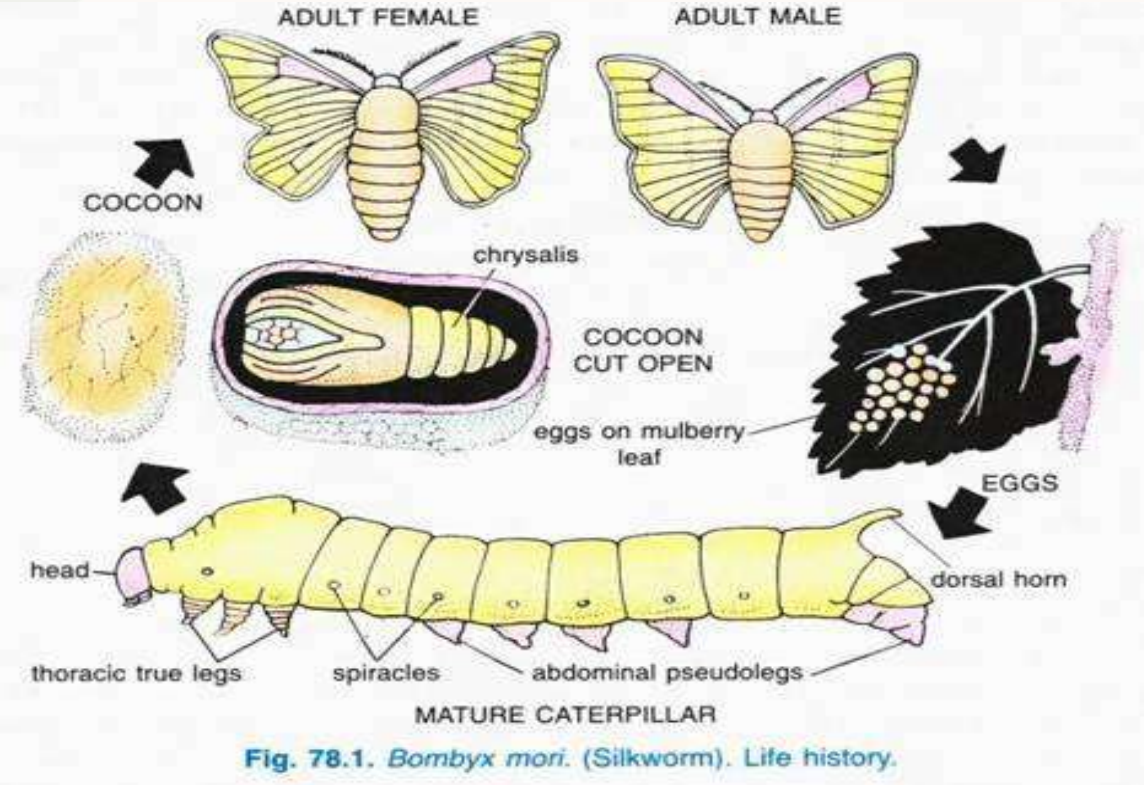

Fig. 78.1. *Bombyx mori.* (Silkworm). Life history.

Figure 2. Process of Mounting

11.1. Duration of different stages in the life-cycle of mulberry silkworm

Stage	Multivoltine (polyvoltine) breeds	Uni/bivoltine breeds
Egg	09-12 days	11-14 days
Larva	20-24 days	24-28 days
Pupa	10-12 days	12-15 days
Adult	03-04 days	06-10 days
Total	42-52 days	53-67 days

11.8. Moriculture: Cultivation of mulberry plants is called moriculture. There are over 20 species of mulberry, of which four are common: Morus alba, M. indica, M. serrata and M latifolia. Mulberryis propagated either by seeds, root- grafts or stem cuttings, the last one being most common.It is defined as the process of cultivating mulberry plants in order to obtain feed for silkworms. The following package of practices is followed for mulberry cultivation:

- Select flat or slightly sloppy, fertile, porous, loamy, sandy loam or clay loam soils, (slightly acidic PH : 6-7).
- Soil testing is to be done prior to establishment of garden.
- Rectify highly acidic or alkaline soil by application of lime and gypsum respectively.
- Apply gypsum @ 2-4 tons per ha. and mix it with the top soil by light ploughing.
- Flood the plot with good quality irrigated water. Plant Mulberry saplings in the month of April-May in rain fed condition.
- Plant Mulberry cuttings in the month of September-October in irrigated condition.
- Mulberry Varieties :- S-1635, BC-259, TR-8, TR-10, JRH.
- Sow seeds of Dhaincha, Sanhemp in the Mulberry garden in the last week of June after hoeing @ 50 kg/ha (i.e. 20.4 kg/acre).
- Harvest leaves by picking after 10 weeks of pruning. Leaf yields per acre are 6000 kg. in rainfed condition and 9000 kg in irrigated condition per year.

11.9. Tasar silkworms

- **Tropical tasar** - Antheraea mylitta
- **Temperate tasar** - Antheraea proylei
- **Chinese tasar** - Antheraea pernyi
- **Japanese tasar**-Antheraea yamamai

It is generally found in the forests of Bengal, Assam and UP and is not domesticated. The cocoon is hard light brown copper color and are reelable.

Figure 3. Host Plants of Tropical Tasar Silkworm, *Antheraea mylitta* Drury (Lepidoptera: Saturniidae)

1. Primary host plants:

Terminalia tomentosa, Terminalia arjuna, Shorearobusta

2. Secondary host plants:

Terminalia chebula, Terminalia belerica, Terminalia catappa, Terminalia paniculata, Syzygiumcumini, Eugenia jambulana, Lagerstroemia parviflora, Zizyphus jujube, Zizyphusmauritiana, Hardwickia binate.

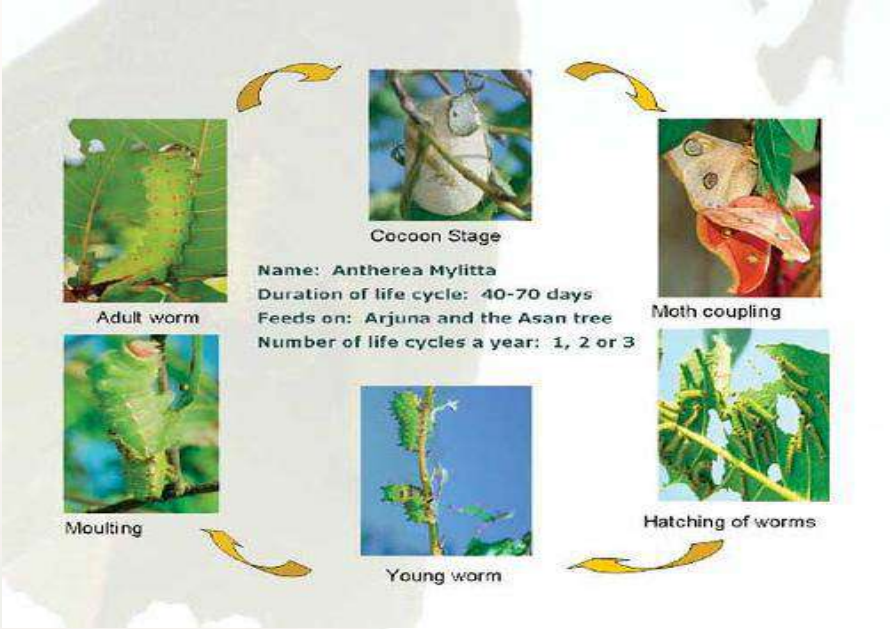

Figure 4. Life Cycle of Tasar silkworm

11.10. Eri silkworm (Samiaricini)

It feed on castor leaves and domesticated all over the country. Cocoons are white in color and not reelable.

Figure 5. Host Plants of Eri Silkworm Samiacynthiaricini (Lepidoptera: Saturniidae)

1. Primary host: Castor- Ricinus communis.

2. Secondary host: Heteropanax fragrans, Manihot utilissima, Plumeria rubra, Plumeria alba.

11.11. Muga silkworm (Antheraea assamensis)

They cannot be domesticated. The cocoons are reeled and silk of golden yellow color is obtained.

Figure 6. Host Plants of Muga Silkworm, *Antheraea assamensis*(Lepidoptera: Saturniidae)

1. Primary hosts:

Machilusbombycina – Som, Litsea polyantha – Soalu.

2.Secondary hosts:

Litseacitrata- Silva Timber, Micheliachampaka- Sampige, Tamarindus indica-Hunase.

Course Name	Apiculture, Sericulture and Lac Culture
Lesson 11	Silkworm Rearing Programme, Egg Production and Rearing Equipments
Content Creator Name	Dr. Tamoghna Saha
University/College Name	Bihar Agricultural University, Sabour Bhagalpur
Course Reviewer	Dr. Kalmesh Managanvi
University/College Name	Bihar Agricultural University, Sabour Bhagalpur

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Objectives

a. To get acquainted with mulberry silkworm rearing and rearing equipments.
b. To get acquainted with grainage activities for quality DFL production.

Glossary

- **Voltinism:** It refers to number of life cycles per year. Depending upon eco-race a typicalsilkworm may have one (Uni), two (Bi), three (Tri) or Multi (more than three) life cycles.
- **Moult:** A silkworm goes into molt phase five times in its life cycle of 30-35 days. During this process it sheds its skin and does not eat. This is because there is enormous enlargement in its size. During this process the old skin is shed and new skin comes up.
- **Grainage:** The process of production eggs in scientific way in a particular area is called grainage. It involves storage of eggs, facilitating of male female coupling, washing cleaning of eggs and disease checking.
- **Incubation:** It is process where number of eggs are going to hatching, uniformtemperature and humidity are maintained. It must also have heating and cooling devices, sufficientillumination and proper ventilation.
- **DFL's:** Disease free layings.

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12.1. Rearing house

Silkworm Rearing Programme

The programme of silkworm rearing in a farm is determined by the following considerations.

a. Conditions of mulberry growth and yield of mulberry leaf.
b. Availability of labour for rearing silkworms.
c. Facilities for rearing silkworms i.e., suitable buildings and equipment.

Rearing house

- A model rearing house is a rat proof building with a ledge all around to prevent rats from entering the building. The building has a verandah all around and glass windows and doors to provide good ventilation and light. Ventilators must be installed to ensure free circulation of air.
- The rearing house is partitioned into four convenient rooms in one of which, by maintaining high temperature and humidity, the young age silkworms are reared. The rooms are provided with an adequate number of windows and doors to ensure good ventilation for rearing older silkworms.
- The rearing houses should be located in such a manner as to maintain as far as possible ideal temperature and humidity conditions inside the rearing rooms. In temperature and sub-tropical regions, they should be constructed in a North-South direction so that maximum sunlight and heat is available to warm up the rearing rooms adequately.
- In some rearing houses, roof and side walls are made of plastic sheets or tarpaulins which prevent direct drought of cold air from outside entering the sheds. This type of shed is usually used for shoot rearing or floor rearing.In many places, there are no separate rearing houses as such, but rearing is done in the dwelling houses themselves.

Area required for one acre of mulberry:

Chawki rearing house – 150 sq.ft.

Old age rearing house - 1000 sq.ft.

12.2. Hygienic rearing

- The silkworms must be reared with the at most care since they are very susceptible to disease. Bacteria, viruses, fungi and protozoa attack the silkworms readily and any disease, once it breaks out, spreads quickly. To prevent disease, good sanitation methods and hygienic rearing technique must be meticulously followed.
- The rearing room and appliances used for rearing must be thoroughly cleaned. Dust, dirt and refuse of dead larvae found in the rearing house and on the rearing appliances should be removed and the house and appliances thoroughly washed with water and dried.

12.3. Chawki and old stage rearing silkworm

Method of Rearing

Instead of rearing stands and trays, shoot rearing racks are required. The larvae after 3rdmoult are shifted to shoot rearing shelves for shoot feeding. The ideal size of each shelf of the rack is about 5ft. width and 30ftlength. This can accommodate 20,000 larvae or 50 DFL‘s up to spinning. Such shelves can be arranged in 2 tiers with an interval of 30 inches or in 3 tiers with an interval of 27-inch distance. The rack is made of wood, bamboo or mild steel.

Chawki rearing

From hatching to its full-grown stage, the silk worms pass through five instars and the worms up to stage two are called young age worms or chawki.

As they are susceptible to infections and vulnerable to adverse weather conditions, special care is required for rearing of chawki. Hence, it is advisable to obtain silkworm reared under controlled conditions in separate chawki rearing centers.

The package of practices for chawki rearing is entirely different from late age rearing.

Old stage rearing silkworm

Rearing of late age worms begins from third instar. These worms are voracious feeders. Various practices required for rearing are indicated below:

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12.4. Methods of Disinfection and Disinfectants

Disinfection means the selective elimination of undesirable micro-organisms. In sericulture it is the destruction or inactivation of disease-causing germs.

Disinfection is an integral part of healthy and successful silkworm rearing. It aims at the total destruction of disease-causing pathogens. There are no curative methods for any of the silkworm diseases and they are best prevented than cured.

Disinfectants

- **Formalin:** It is commercially available as 36% formaldehyde in solution form.
- **Bleaching powder:** It is a white amorphous powder, with a pungent smell of chlorine. Chlorine content is 30%.
- **Slacked lime:** A very useful bed disinfectant in sericulture especially against viruses. It absorbs moisture and can be used to regulate bed humidity and maintain hygiene.
- **Chlorine dioxide:** Chlorine dioxide marketed as Sanitech is an ideal disinfectant for sericulture. The disinfectant is available at 20,000 ppm. It possesses tolerable odour and is least corrosive.

Methods of disinfection

a. 2.5% Sanitech (Chlorinedioxide) + 0.5% slaked lime or2% Formalin + 0.3 % slaked lime

Any one of the above disinfectant solution is sprayed @ 2 lit/m^2 area for disinfecting the rearing house immediately after completion of rearing and three days before brushing. This can be applied on rearing appliances also.

b. 2 % Bleaching powder

The rearing equipments are dipped in 2% bleaching powder solution and sun dried before use.

c. 5% Bleaching powder

The powder is dusted @ 200 g/m^2 around the rearing house and passages and water is sprinkled @ 2 lit/m^2 floor area.

The required quantity of disinfectant is sprayed uniformly using powerful jet sprayer/Rocker sprayer, to drench all parts of rearing house, and rearing appliances.

The rearing house is kept closed for a minimum period of 6-10 hours. After disinfection, sundry the rearing appliances are sun dried for 10-12 hours. Cow dung should not be smeared on the rearing trays.

d. Grainage acid treatment

Disinfection of grainage and implements the grainage rooms along with its appliances should be thoroughly disinfected prior to commencement of operation and kept ready to receive seed cocoons. A day before disinfection, the rooms and appliances are to be washed with 5% bleaching powder solution and the appliances are to be sun dried for 3-4 hours. A day after, the rooms and appliances should be properly disinfected with a mixture of 2 % formalin, 0.5 to 1 % lime and 0.05% detergent solutions. Room to be disinfected at the rate of 1 litter per square meter floor area.

Disinfection and maintenance of hygiene during silkworm rearing

- Avoid borrowing the rearing appliances. Do not use appliances without disinfection. Avoid overlapping rearings.
- Maintain personal and rearing hygiene throughout the rearing. Restrict the entry of persons into the rearing house.
- Surface disinfects the silkworm eggs before head pigmentation stage with 2% formalin for 10 min. and wash with water. Dry them in shade and incubate.
- At the entrance sprinkle 5% bleaching powder.
- Wash hands with 2% bleaching powder in 0.3% slaked lime solution.
- Pick up diseased / unequal/suspected diseased worms and dispose into 5% bleaching powder in slaked lime in a basin.
- Clean the silkworm rearing bed using bed cleaning net.
- Spread vinyl sheet for the collection of bed refuse and shift bed refuse into manure pit.
- Rear silkworms always on rearing seat paper (newspaper).

12.5. Package and practices of silkworm egg production

Silkworm Egg Production

Success of sericulture depends on quality silkworm eggs. Therefore, management of seed production, interalia transportation and incubation play important role on

overall return. To produce quality seed, it is very important to adopt scientific methods of egg production right from seed crop rearing to egg incubation.

Transportation of Seed Cocoons

The seed cocoons are to be always loosely packed either in perforated plastic crates or bamboo baskets and transported to respective destinations during cooler hours of day.

Pupal examination

Before selection of seed cocoons, it is very important to know the disease freeness of a lot, melt, flimsy and good cocoons are also to be separated. The gut portion is taken out and subjected to microscopic examination.

Preservation and protection of seed cocoons

Immediately after the receipt of seed cocoons, they are to be spread on trays in a single layer to facilitate good aeration. The healthy seed cocoons alone should be preserved in trays for further processing. There should be cross ventilation in the preservation room, 25 ± 1° C temperature, 75 ± 5 % relative humidity, 12-hour light and 12-hour dark conditions to be maintained in the cocoon preservation rooms. Complete darkness to be maintained on the previous day of emergence, to avoid irregular emergence of moths.

Early moth exclusion box

A simple box made up of wood and plywood sheet with a glass door having dimension 90 x 75 x 60 cm is used. The bottom is fitted with asbestos sheet. A heating element is connected to the electric main through a thermostat (0 – 60°C). On the top of the box at the centre, a 15-cm diameter ventilator covered with wire mesh is provided. It is fitted with sliding top to regulate ventilation. At the bottom of the box and on the lower portion of sidewalls, small holes are drilled to facilitate aeration. For reading the temperature, a thermometer is fixed from inside of glass door. Within the box, a portion has been made to place 4-5 plastic trays in two tiers for keeping seed cocoon inside.

For early emergence of moths, 50-60 seed cocoons are taken from individual lots and placed into an artificial eclosion box. The temperature in the box is adjusted to 32-33 ^{o} C with the help of thermostat. This accelerates the development of pupae and moth emerges early. The early-emerged female moths of respective lots are taken and subjected for microscopic examination to know the disease freeness of lots.

Black boxing:

It is a technique is subjecting the developing eggs to a totally dark condition, to synchronize the circadian rhythm of the silkworms. This ensures uniform synchronized hatching of eggs. Black boxing should be done on the 8thor 9thday i.e. on the onset of eye-spot or black head stage.

Black boxing is a management technique to physically prevent hatching for a reasonable period of time beyond which the larvae instantly hatch out. It is done by different ways;

- Black boxing using wooden/ bamboo trays.
- Use of wooden trays with fly wood cover.
- Use of wooden box.
- Cupboard for black boxing.
- Darkening of the entire room.
- Use of black colored paper.

Surface sterilization of silkworm eggs

After ascertaining the disease freeness of laying, egg sheets are dipped in 2 % formalin for 10-15 minutes. This helps in removal of pathogens adhering to the eggshell and further prevents secondary contamination. Washing of eggs in formalin solution helps in firm adherence of eggs to the sheet.

Incubation of silkworm eggs

Incubation facilities uniform development of embryo. In addition, it greatly influences the voltinism of the eggs in succeeding generation, larval growth and success of cocoon crop. Therefore, the eggs are subjected to ideal conditions of incubation.

Optimum temperature of 25 ± 1^{o} C and relative humidity of 75 ± 5 %, 16 hours of light and 8 hours of darkness are ideal. During the pinhead stage or before two days

of hatching, the eggs are black boxed to aim at uniform development of embryo and hatching of larvae at a time on a single day.

Loose egg preparation

Loose eggs are getting popular for obvious advantages such as (a) standard / uniform egg number (irrespective of the race, season, zone) (b) increased egg recovery and (c) easy and better management.

Advantage of loose eggs

- Superior quality.
- Uniform and known quantity irrespective of race / season / zone / grainage etc.
- Enables scientific evaluation.
- Increased egg recovery, hatchability andeconomical seed production.
- Efficient surface sterilization and easy acid treatment of bivoltine eggs.
- Unfertilized eggs can be eliminated (in bivoltine only).

12.6. Rearing Equipments

Shelf rearing method requires the following equipments.

a. **Rearing stands:** These are racks used to accommodate the trays. They may be made of wood or iron. The size depends upon the trays. There should be 10 tiers to accommodate 10 trays per stand (Fig.12.1 & 12.2).
b. **Rearing Trays:** The worms are reared in trays. They vary in shape and size. They commonly used rectangular wooden trays measure 3.5'x 2.5'. The diameter of the circular bamboo trays ranges from 3 to 4.5'(Fig.12.3).
c. **Cleaning nets:** Cotton or nylon nets are used for cleaning rearing beds. Usually, the following mesh sizes are used for cleaning(Fig.12.5, 12.6, 12.7& 12.8).

First and second instars - 2mm^2

Third instar - 10mm^2

Fourth and fifth instars - 10mm^2

d. **Cocoonage(Chandrike or mountage):**

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These are meant to enable the ripe worms to spin cocoons. Chandrike is a rectangular bamboo mat on which spiral bamboo tape is fixed which gives support to the ripe worms to spin the cocoons (Fig.12.14).

e. Dry and wet bulb thermometer:

This is used to record the room temperature and humidity during the rearing period. Hygrometer can also be used to record humidity (Fig.12.13).

f. Charcoal stoves, room heaters/room heating coils:

These are used in raising the room temperature whenever the temperature of the rearing room falls below the required level.

g. Room coolers: These are used in cooling the rearing room.

h. Miscellaneous requirement:

Chopping board, chopping knife, leaf preserving baskets, leaf preservation chamber, mats, leaf basins, ant wells, bird feather, feeding stands, wax coated paper, foam rubber, wash basin with stand, sand beds, exhaust fans, etc.

Figure 12.1 Iron rearing stand

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Figure 12.2 Shoot rearing stand

Figure 12.3 Feeding stand & tray

Figure 12.4 Brushing net

Figure 12.5 Cleaning net for chawki worms

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Figure 12.6 Cleaning net for 3rd instar

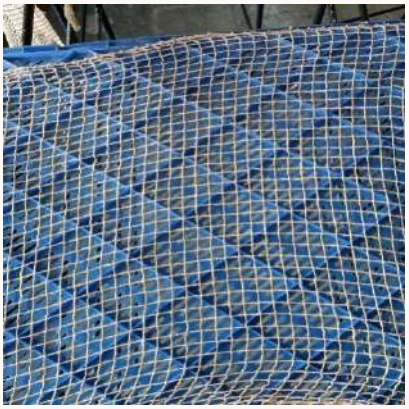

Figure 12.7 Cleaning net for 4th instar larvae

Figure 12.8 Cleaning net for 5th instar larvae

Figure 12.9 Paraffin paper

Figure 12.10 Knapsack sprayer

Figure 12.11 Hand sprayer

Figure 12.12 Deflossing machine

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Figure 12.13 Dry and wet bulb thermometer

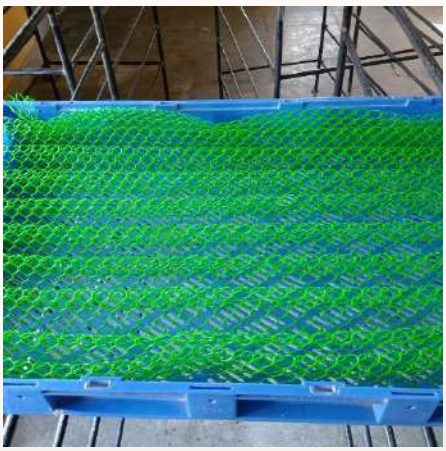

Figure 12.14 Plastic mountages

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Course Name	Apiculture, Sericulture and Lac Culture
Lesson 12	Silkworm Rearing Management and Cocoon Characters
Content Creator Name	Dr. Tamoghna Saha
University/College Name	Bihar Agricultural University, Sabour Bhagalpur
Course Reviewer	Dr. Kalmesh Managanvi
University/College Name	Bihar Agricultural University, Sabour Bhagalpur

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Objectives

a. To get acquainted with different rearing byproducts of mulberry silkworm.
b. To get acquainted with different cocoons their properties and defective cocoons.

Glossary

- **Brushing:** Transfer of the newly hatched larvae from eggs on to the wax paper or rearing bed is called brushing.
- **Bed cleaning:** Removal of the accumulated unfed mulberry leaves, faecal matter, exuvia, dead and unhealthy worms from the rearing is called bed cleaning.
- **Tray or Shelf rearing:** In this method, late age silkworms are reared in bamboo trays, which are arranged one over the other in tiers on rearing stands.
- **Harvesting:** The silkworms complete spinning in 2 to 3 days but the cocoons should not be harvested at this time as the worms inside are still in the prepupal stage. Harvesting should be done on the fifth day (7th day for bivoltine hybrids) when pupae are fully formed and hard.
- **Stifling/ Drying:**To kill the pupa in order to prevent the pupa from transforming into moth and come out of the cocoon by piercing the cocoon andto remove the moisture content in the cocoon (pupa) to an optimum level.

11.1. Rearing of silkworms

- Selected healthy silk moths are allowed to mate for 4 hours.
- Female moth is then kept in a dark plastic bed. She lays about 400 eggs in 24 hours, the female is taken out and is crushed and examined for any disease, only the certified disease- free eggs are reared for industrial purpose.
- The eggs are hatched in an incubator.The hatched larvae are kept in trays inside a rearing house at a temperature of about 20°C-25°C.
- These are first fed on chopped mulberry leaves. After 4 -5 days fresh leaves are provided. As the larvae grow, they are transferred to fresh leaves on clean trays, when fully grown they spin cocoons.

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11.1.1 Environmental requirements for different stages of silkworm

The productivity and profitability of sericulture depends upon healthy and hygienic rearing. For healthy rearing in addition to giving quality leaves, optimum environmental conditions must be maintained within the rearing room.

1. Temperature: Maintenance of optimum temperature within the rearing room is very essential because temperature affects both the growth of the larvae and the quality of the cocoons produced. **The optimum temperature for different instars is**

a. instar - 26 -28^{o} C
b. instar - 26 -28^{o} C
c. instar - 25 - 26^{o}C
d. instar - 24 - 26^{o}C
e. instar - 24 - 25^{o}C

If temperature falls below the optimum, growth and activity are retarded and larval duration is prolonged. If temperature rises above the optimum, humidity is reduced leading to drying up of the leaves in the bed and increases the activity of the larvae.

2. Humidity: Humidity plays a triple role in silkworm rearing.

- It directly affects the growth of the larvae and quality of cocoons.
- It affects the quality of leaf in the rearing bed.
- Increase of humidity induces diseases.

The optimum humidity for the various instars is given below.

a. instar - 85% RH
b. instar - 85% RH
c. instar - 80% RH
d. instar - 75% RH
e. instar - 70% RH

3. Aeration: The rearing room gets polluted by carbon dioxide, Sulphur dioxide, carbon monoxide and ammonia due to the metabolic activity of the silkworm, mulberry leaves, worker sand the fermentation process of the bed.

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4. Light: Light has varied effect on the silkworm behavior and growth. Silkworm prefers dim light of 20-30 lux. The intensity of light should be uniform throughout (16 hours a day) and darkness (8 hours a day) during night is more congenial for healthy growth of the larvae.

Feeding and bed spacing

- The quantity of leaf to be fed each time should not be more to avoid wastage of leaf. Every day before giving 10 am feeding, the bed has to be spread to facilitate drying and larval crawling onto the bed surface in addition to better aeration which helps the larvae to feed better on fresh leaf.
- The quantity of leaf required for 100 dfls is, I instar 2- 4 kg; II instar 4-6 kg.
- Silkworm is very fast growing and attains a 10,000-fold increase in weight and about 7,000-fold increase in size during larval period. As the larvae grow in size, they require more bed area.
- Overcrowding of the silkworms leads to unnecessary competition for the available food and space, which weaken the worms to a great extent.
- The spacing and feeding quantity has to be regulated for the healthy growth of the silkworm. Every day after bed spreading, optimal bed area has to be provided. Care should be taken for uniform distribution of the larvae in the bed.

13.2. Silkworm rearing/ reeling products

1. Silkworm litter:

It is used in compost making, biogas production and also for used as cattle and poultry feed. Chlorophyll paste, proteins and plastic materials cab be prepared from it.

2. Silkworm faeces:

It is generally considered as waste. It is mostly used in compost / vermi compost making as cattle feed. It can be used as aqua feed and for preparation of Chlorophyll paste.

3. Pupae:

- Silkworm cocoon consists of two major portions *viz.,* cocoon shell (12.24%) and pupae (76-88%). Dried pupae contain 28.4% oil and 51.3% protein is used for the manufacture of pupal oil, Amino acid powder, peptides / protein concentrate.
- The pupal oil which is brown in color with bad odor finds limited use in the manufacturer of industrial soap. It finds use in the preparation of cosmetics, lotions, cream and shampoo etc.

4. Pupal skin

It is available in the reeling and grainage as wastes. It is made up of chitin (3-4 % of dry weight of pupae). It is used as an additive to increase the loaf volume of wheat bread from 4.6 to 6.0 cm^3 /g.

5. Basin refuse

The last layer of cocoon attached to pupae (pelade layer) cannot be reeled. This can be used for manufacture of spun silk which will reduce the cleaning cost of pupal wastes.

6. Cut and pierced cocoons

Cut and pierced cocoons can be used for the production of hand span yarn (matka) using takli; such units are functioning in Malda, West Bengal.

7. Throwers wastes

Waste silk obtained during winding, twisting and doubling of yarn are used for production of thick fabrics /carpets.

13.3. Cocoon Characters

Cocooning

- Silk worms moult four times during their developmental period. After the fourth molt, worms begin to eat voraciously for a few days. All the internal and external

organs of the worms reach the maximum stage of development during the last larval period.

- Then, they loss their appetite and become restless to spin cocoon. They move about in search of a suitable place and settle down to exude secretion from the silk gland.
- All the ripe larvae completely give out entire intestinal mass of excreta (liquid and solid) asa prelude to set out building of cocoons shells.
- Matured, ripened worms produce hollow sound when it isrubbed between fingers.

Harvesting and Grading of Cocoons

- Harvesting at 4th day after mounting, while in bivoltines it is 5th day after mounting.
- The cocoons are harvested manually by hand and are sorted into good and defective cocoons. Later the cocoons are cleared by separating the leaf bits, sticks and other extraneous materials for improving the quality, thus enabling to get higher price in the markets.
- Cocoons will be graded based on their size, shape and compactness into different grades, viz., A, B, C, etc.

13.4. Assessment of quality of cocoons: maintenance of records cost of production etc.

Cocoon assessment:

- Next day after harvesting, deflossing of cocoons is to be carried out. Then sorting of cocoons (i.e melted, thin shelled, Uzi infested, deformed and double cocoons) is to be done.
- These defective cocoons are to be records systematically in the data sheet. After sorting, by gently shaking each cocoon for live papal sound, cocoon number (pupation rate) is to becalculated.
- The number of dead pupae cocoons is also to be recorded. Count the live cocoons byusing counter specially meant for it. Then act dual of counted cocoons weight of counted cocoonsshould be recorded.

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- The cocoon assessment is done by using electronic balance. Cut thecocoon shell weight and cocoon shell ration of both male and female separately.
- After the completion of total procedure, from the remaining half, 50 reliability cocoons in thecase of cellular batches and 300-1000 cocoons in case of hybrids should be selected at random andweight. Theses cocoons should be sent for reeling test.

Quality cocoon means the production of cocoons with uniform shape, size, less defective cocoon percentage and good reliability. These parameters could be obtained by the proper usage of technologies and packages recommended in mulberry leaf production and silkworm rearing.

13.5. Cocoon quality:

The multi-bivoltine cocoons preferably having shell ratio of 16% and above and reelability of 70% and above should be used for producing quality silk.

Further cocoons, which are having wide variation in shape and size, should not be mixed together.

Fig. 1: Multibivoltine cocoons.

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The optimum degree of drying is decided based on the shell ratio of the sample cocoons using a simple formula.

$$\text{Optimum degree of drying (\%)} = \frac{100 - \text{Shell ratio (\%)}}{4} + \text{Shell ratio (\%)} \quad (1)$$

$$\text{Shell Ratio \% (E)} = \frac{\text{Weight of cocoon shell(D)}}{\text{Weight of cocoons (C)}} \times 100 \quad (2)$$

Quality cocoon means the production of cocoons with uniform shape, size, less defective cocoon percentage and good reliability.

These parameters could be obtained by the proper usage of technologies and packages recommended in mulberry leaf production and silkworm rearing.

13.6. Defective Cocoons

1. Double cocoons: A double cocoon is spun by two worms, producing a filament, which does not unwind smoothly and tangles easily. Double cocoons may be caused by crowded mounting conditions, high temperatures, high humidity and mutation of silk species.

2. Inside stained cocoons (dead cocoons): Dead cocoons are also known as melted cocoons. In this case, the pupa is dead and sticks to the inside shell of the cocoon causing a stain. Melted cocoons are called mutes because they do not make a sound when shaken.

3. Outside stained cocoons: These are recognized by a rusty colour spot on the cocoon shell caused by absorption of intestinal fluid/urine of the mature worm formed during mounting.

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4. Printed cocoons: This defect may happen due to improper mounting frames; these are also called scaffold pressed cocoons.

5. Malformed cocoons: These are abnormally shaped cocoons, which may arise from species variation. This defect may be due to racial characteristics and breeding with mulberry leaves stained with agrochemicals.

6. Flimsy cocoons: Here, the shell is loosely spun in layers and has a low silk content. These cocoons are easily overcooked and produce waste.

7. Thin-end cocoons: One or both ends of the cocoon are very thin and risk bursting when processed. The cause of this defect may be attributed to species characteristics or improper temperature and humidity during rearing and mounting.

8. Pierced cocoons: This happens when a moth has emerged, been eaten by beetles or in the case of the emergence of a parasite. Pierced cocoons are unfit for reeling and can be used only for hand spinning or as raw material of machine spun silk yarn.

13.7. Stifling/ Drying

- To kill the pupa in order to prevent the pupa from transforming into moth and come out of the cocoon by piercing the cocoon. To remove the moisture content in the cocoon (pupa) to an optimum level.
- To provide desired restraint in reeling of filament from the cocoons Sun drying, steam stifling and hot air drying are the known methods of stifling the green cocoons. Hot air drying can be done in a batch type hot air drier or ushnakoti.

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Course Name	Apiculture, Sericulture and Lac Culture
Lesson 13	Silk and its Uses and Insect Pests and Diseases of Silkworm
Content Creator Name	Dr. Tamoghna Saha
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Objectives

a. To know different uses of silk and its by-products.
b. To get acquainted with different insect pests and diseases of silkworms.

Glossary

- **Reeling:** Raw silk reeling is a process of combining number of ends of the cocoon filaments together to form a single thread of desired denier.
- **Bleaching**: Bleaching is a process of removal of coloring matters to produce pure white material. Bleaching can be done using reducing agents.
- **Weaving:** Weaving is a process of interlacing of warp (lengthwise parallel arrangement of yarns) and weft (widthwise interlacing yarns). Weaving is done in handloom or power loom.
- **Mulberry fruits:** They are used for preparation of juice,jelly, squash and jam.
- **Silkworm litter:** It is used in compost making, biogas production and also for used as cattle and poultry feed. Chlorophyll paste, proteins and plastic materials cab be prepared from it.
- **Silkworm faeces**: It is generally considered as waste. It is mostly used in compost / vermin compost making as cattle feed. It can be used as aqua feed and for preparation of Chlorophyll paste.

11.1. Use of silk and by-products

Sericulture involves three major activities viz., production of mulberry leaves (Moriculture), rearing of silkworm and reeling and its processing activities. Certain amount of by product wastes are generated at each stage. The byproducts classified are as follow:

a. **Byproducts of mulberry:**Mulberry leaves wood, fruits and roots.
b. **Byproducts of silkworm rearing:**Silkworm litter, bed water, faeces, pupae, unused cocoons (pierced cocoon, melted cocoon, floss double / flimsy / stained cocoons).

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c. **Byproducts of silkworm reeling / post cocoon stage:**Cooking wastes, reeling wastes, pelade layer, half reeled cocoons, unreelable cocoons, pupae, charka wastes.

Use of silk:

- 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 fibresi.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.
- 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 progresson different lines of biotechnology, genetics using silkworms in Japan.
- 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.

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14.2. Economics of silk production

- Each DFL contains 200 healthy disease-free eggs.
- Each egg has the potential to become full grown cocoon. Therefore, theoretically a group of 200 DFLs can gives 40,000 cocoons.
- But actually there are hatching losses about 10% and depending upon the care taken by beneficiary losses due to predators and weather losses.
- Normally in traditional areas the output is about 50 cocoons per 200DFLs.
- Normally the price of a cocoon varies from lowest grade 30 paisa to 2 rupees. Therefore the average cost of the produce is about 1 Rupee.
- Therefore a beneficiary in one crop gets about Rs 10,000 in 45 days.
- The yield in the second crop is higher and the beneficiary may earn up to 15-25000 in second crop.
- Therefore, a beneficiary in two crops may earn between 25,000 to 50,000.
- In traditional areas some beneficiaries earn up to between 1 to 2 lacks working in family groups.
- Due to the presence of the beneficiaries the forests are protected as the income of the beneficiaries depend upon the abundance of food plants.
- The production of cocoons in the forest areas leads to development of other decentralized cottage industries like reeling, dyeing and weaving.

14.3. Insect pests and diseases of silkworm

Mulberry is prone to attack by number of pests and they cause abrupt reduction in leaf yield and deteriorate its quality. Feeding such leaves to silkworm results in adverse effect on the cocoon yield and silk quality.

14.3.1. Silkworm pests and their management

Pests of silkworm

Pests of silkworm include insects that attack silkworm larvae in rearing room and grainages.

Rearing room pests

1. Uzifly–Exoristabombycis, Tachinidae, Diptera.

2. Ants – Fire ants, Solenopsisgeminata, Formicidae, and Hymenoptera.
3. Straw itch mite –Pyemotesventricosus, Pyemotidae, Acarina, Arachnida.
4. Rodents like rate, squirrels, lizards etc.

1. Uzifly: *Exoristabombycis*Tachinidae, Diptera

Uzi fly is an endo-larval parasitoid of the silkworm. It causes loss to an extent of 10-20% to the sericulture industry.

It occurs throughout the year with maximum incidence during July -November.

Symptoms of damage:

- Presence of eggs and / or black scar on the larval body.
- Presence of maggot emergence hole in cocoons.

Silkworms are generally attacked from 3rd instars onwards by uzi flies. Silkworms parasitized in early instars are getting killed. While that parasitized in late fifth instar, spin weak cocoons and uzi maggots pierce through the cocoon and emerges out. (Uzi pierced cocoons are unfit for reeling).

Integrated management of Uzi fly

Cultural

- Collect and destroy the uzi infested silkworms.
- Remove the uzi maggots and pupae in rearing rooms and market centers.
- Keep the rearing room free from crevices / holes.
- Destroy the uzi infested cocoons.

Physical

All the windows and ventilators are to be fitted with Uzi Nets (Nylon mesh). Provide at the entrance of the rearing hall to exclude Uzi flies.

Biological

Several natural enemies have been reported on uzifly which include, Nesolynx thymus, Exoristobiaphilippinensis, Trichopriasp:Tetrastiches howardiand Dirhinus sp.

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Among the hyper parasitoids, N.thymusis highly effective indigenous ecto-pupal parasitoid of Uzi fly. N. thymus is mass multiplied and used in the control of uzifly. Release one lakh adults of N.thymus@ 8,000 during IV instars, 16,000 during Vinstars and 76,000 at one or two days after cocoon harvest. Release the parasitoids in the rearing house, places of mountage storage, near manure pits and cocoon markets.

Chemical

a. Uzi fly trap

- It is a Chemo-trap to attract and kill the Uzi fly adults. Uzi tablet (2.5 g) is dissolved in one liter water and the resultant yellow color solution is kept in a light-colored flat container.
- The Uzi traps are to be placed near the windows in the rearing houses from 3rd instar onwards. It is effective in reducing the damage by 36.0%.

b. Uzizide (Benzoic acid)

It is an ovicidal formulation. It is sprayed on the body of silkworm from 2nd day of III instar through 4th / 6th day of V instar. Dose: 4- 5 liters / 100 dfl.

Mode of action**:** Ovipositional deterrent and ovicidal action.

c. Uzi powder

It is an ovicidal dust applied on the body of the silkworm larvae on 2nd day of III instar, $2^{nd}$and 4^{th}day of IV instar and on 2^{nd}, $4^{th}$and 6^{th}day of V instar worms. Dose: 4 – 5 kg / 100 dfl.

Mode of action: Dislodges the eggs from the body of silkworm.

14.3.2. Silkworm diseases and their management

Diseases of mulberry silkworm

i. Protozoan -Pebrine – *Nesemabombycis*

ii. Viral diseases – NPV, CPV, IFV and DNV

iii. Bacterial diseases

a. Flacherie – *Bacillus, Serratia, Streptococcus, Staphylococcus spp.*

b. Sotto –*Bacillus thuringiensis.*

iv. Fungal diseases - White muscardine–Beaveriabassiana.

Green muscardine– Metarhiziumanisopliae.

Aspergillosis - Aspergillus flavus.

1. Pebrine:*Nosema bombycis,* Nosematidae, Protozoa

Pathological symptoms: Observed in egg, larval, pupal and adult stages.

Eggs:

i. Poor egg number

ii. Pebrinized egg laying – eggs are loosely adhered to substratum.

iii. Irregular laying - lack of uniformity in laying and more of unfertilized eggs.

iv. Poor and irregular hatching.

Larva

i) Poor appetite, retarded growth, irregular size/moulting and sluggishness.

ii) Presence of pepper like spots.

iii) Body wrinkled with rusty brown coloration.

iv) Transversally infected larvae die before III moult.

Pupa

Flabby pupae; swollen, lusterless pupae with softened abdomen and poor emergence.

Adult: Delayed emergence; clubbed wings; distorted antennae; improper mating; sclales easily come off; lay eggs without glue.

2. Viral diseases

a. Grasserie - NPV *Borrelinabombycis,* Baculoviridae

Pathological symptoms:

Swollen segments; milky white body colour; movement of the larvae along the periphery of rearing trays and wandering movements and characteristic: hanging down symptom.

b. Cytoplasmic polyhedrosis, Smithea virus, Reoviridae

Diagnosis: Polyhedral bodies in haemolymph are hexahedron in shape.

Pathological symptoms:

Empty headed, diarrhoea, motionless, irregular faeces and chain of whitish green excreta. Rectal protrusion is a prominent symptom in advanced stages.

3. Bacterial diseases

a. Flacherie caused by *Streptococcus sp, Staphylococcus sp, Serratia mascescens, Bacillus sp etc.,*

Symptoms

Decreased appetite; sluggish movements; straightened body; swollen thorax; shrinkage of abdominal segments; vomiting and bead like faces; loss of clasping power of legs; body becomes soft and discolored emitting foul smell on eruption.

b. Sotto:*Bacillus thuringiensis*

Symptoms

Loss of appetite; convulsion; lifting of head; spasms; tremors; paralysis, distress; sudden collapse and death. Shortly after death body is outstretched and corpse is hard to touch with a hooked head. Body turns brownish black with foul smelling dark brown fluid.

4. Fungal diseases

White muscardine*/Calcino disease* *–Beaveriabassiana,*

Green muscardine– *Metarhiziumanisopliae*

Aspergillosis - *Aspergillus flavus*

A. Muscardines

General symptoms

- Appearance of moist specks on the body.
- Loss of appetite and inactive.
- Body becomes limp; loss of skin elasticity.

Diagnosis

a. If body is covered with while mycelial growth, spores are colorless, globular and porcelain, it is due to white – White muscardine.

b. When body is covered with light greenish mycellia, slightly pointed light green oval shaped and irregularly branched conidium, it is due to Green muscardine.

B. Aspergillosis:*Aspergillus flavus*

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Symptoms

- Infects mainly first and second instar larvae of silkworm.
- Stop feeding; lethargic, show body tension.
- Restlessness; vomiting with extended head and thorax.
- Body is covered with black colored conidia and hyphae.

Integrated management of silkworm diseases

Prevention of diseases

As pebrine is trans-ovarially transmitted it requires preventive measures such as mother moth examinations and scientific method of disease free egg production.

Maintenance of hygiene

- Sun drying of rearing appliances.
- Regular disinfection of rearing room and appliances with 5% bleaching powder.
- Ensure proper ventilation for aeration and maintenance of optimum temp and humidity and aeration.
- Disinfection of rearing room, trays and discarding of diseased worms.

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Course Name	Apiculture, Sericulture and Lac Culture
Lesson 14	Lac Insect-host Plants, Life Cycle and its Economic Importance
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Objectives

a. To get acquainted with hosts plants of lac and its biology.
b. To get acquainted with different uses of lac and its by-products.

Glossary

- **Lac:** It is the resinous secretion of a number of species of lac insects, of which the most commonly cultivated is *Kerria lacca*.
- **Stick lac:** It is the coated branches on the host trees are made by lac insect cut and harvested as sticklac.
- **Seed lac:** The harvested stick lac is crushed and sieved to remove impurities. The sieved material is then repeatedly washed to remove insect parts and other material. The resulting product is known as seed lac.
- **Rangeeni and Kusmi:** Strain of lac insect *Kerria lacca.*
- **Wax:** Long waxy filaments are a striking feature of a healthy encrustation of *Kerria lacca.* These filaments produce out of the anal and branchial pore of the female lac insect.
- **Lac dye:** Lac dye present in the hemolymph and obtained through washing of lac insect.

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15.1. Brief introduction about Lac insect

Lac Insect: *Kerria lacca (or) Lacciferalacca*

- Lac is a resin secretion of insects, which are commercially cultivated through ages. Lac cultivation has its roots in India and Bangladesh, the two main Asian countries in the world and was a major source of economy to the local people.
- The natural red colour obtained on the purification of this resin was used in the coloring of items like wood and textiles. Lac insects secrete brownish resinous encrustation called as lac and lives within.
- Thecommercial product called as shellac is manufactured forms this true lac.

Lac is the only one of its kind in its origin as an animal resin and chief producer is female only.

Note: The Indian Institute of Natural Resins and Gums formerly known as the Indian Lac Research Institute, is an autonomous institute established in 1925 under the umbrella of Indian Council of Agricultural Research (ICAR) by the Ministry of Agriculture, Government of India for advanced research on lac and other natural resins and gums. The Institute is located at Namkum, Ranchi Jharkhand, India.

Distribution: Besides India, it is found in Pakistan, Myanmar, Shri-Lanka, Jawa, Malaya, China and Thiland. In India, Jharkhand (Maximum), Chhatishgarh, Bihar, MP, West Bengal, Maharastra, UP, Orissa, Assam.

Figure 1. Lac tubes created by *Kerria lacca*

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15.2. Economic importance of lac is:

- Lac is used in making toys, bracelets, sealing wax, gramophone records, bangles etc.
- It is used by the jewelers and goldsmiths as a filling material in the hollows of gold and silver ornaments.
- It in the form of shellac is used as a furniture finish.
- Waste materials produced during the process of stick lac are used for dying purpose.
- Nail polish is a good example of the by-product of lac.
- The fluid lac dye obtained by dissolving the crushed stick-lac in water is called Alakta or Alta. This dye is applied by Indian Hindu women on hands and sole of feet.
- From the stick-lac (twigs encrusted with lac), shellac is obtained after purification. Shellac is used as coating for medicines.
- In Ayurveda, Siddha and Unani system of medicine Lac is used for treatment of variety of diseases. In Ayurveda, Lac is considered astringent (Ras/taste), cool (Veerya/potency), and Pungent (Vipaka/post-digestive effect). It balances pitta-kapha dosh and promotes strength. In Unani, Lac is considered tonic for liver, stomach and intestine.

15.3. Host Plants:

Palas (Butea monosperma), Ber (Ziziphus mauritiana), Kusum (Schleichera, oleosa, S. trijuga), Ghont (Ziziphus xylopyra), Jallari (Shoreatalura), Arher (Cajanus cajan), Pipal (Ficus religiosa), Babul (Acacia arabica), Khair (Acacia catechu).

15.4. Systematic Position:

Kingdom	Animalia	**Sub-order**	Homoptera
Phylum	Arthropoda	**Super-family**	Coccoidae

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Class	Insecta	**Family**	Lacciferidae
Sub-class	Pterygota	**Genus**	*Laccifer*
Order	Hemiptera	**Species**	*lacca*

15.5. Identification and life cycle of Lac insect

Male:

They are pinkish red in colour and are of two types, winged (Only fore wing present and mostly found during dry season) and wingless.

They survive only 3-4 days and die after copulation. Head is large, mouth part vestigial, 2 pair ocelli, 3 segmented tarsi, abdomen 8 segmented.

Female: The female is pinkish in colour and about 1.5 mm in length. The ventral surface of the body is flat while dorsal surface is convex.

The female deprives of eyes, legs and wings, antennae 3-4 segmented, piercing and sucking type mouth parts.

Life cycle

- Three developmental stages are found in its life cycle, egg, nymph and adult. The eggs are laid by the female within the lac cell **about 200-500 eggs** which may be fertilized or unfertilized.
- The eggs hatch within a few hours, viviparous females. The newly emerge nymph is pinkish in colour. It possesses a pair of antennae, three pairs of leg, two compound eyes and six anal setae.
- The nymph settles on shoots and thrusts its proboscis into the bark of the twig and does not move after settlement. After one or two days of settlement, they start secreting resin from glands distributed all over the body except near the mouth parts, breathing pores and anus.
- They moult thrice before reaching maturity and after first moult the nymph loses its eyes, legs and antennae. The male nymph developed the organ after second

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moult. From male cells both winged and wingless male emerge after about two months.

- These males fertilize the females in their cells and after female secrete lac at a faster rate. Thus, the females are the chief source of the lac secretion. The lac insect usually passes through two generations in a year.

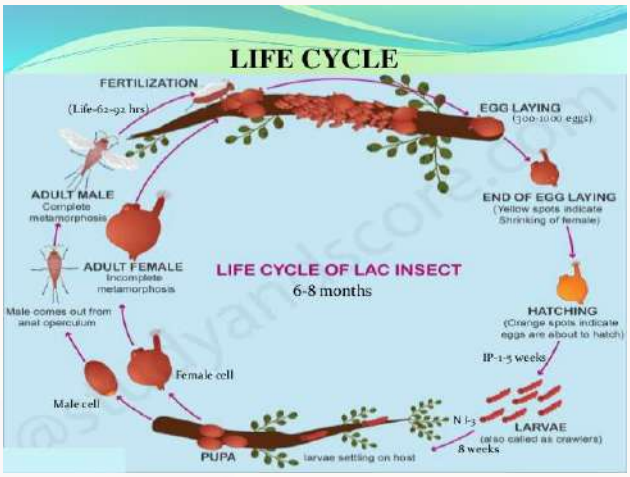

Figure 2. Life Cycle

References

- Srivastava, K.P., and Dhaliwal, G. S. (2010). *A Text Book of Applied Entomology*. Kalyani Publication New Delhi-110002.
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Course Name	Apiculture, Sericulture and Lac Culture
Lesson 15	Lac Cultivation and their Uses and Enemies of Lac Insect
Content Creator Name	Dr. Tamoghna Saha
University/College Name	Bihar Agricultural University, Sabour Bhagalpur
Course Reviewer	Dr. Kalmesh Managanvi
University/College Name	Bihar Agricultural University, Sabour Bhagalpur

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Objectives

a. To get acquainted with lac culture, strains and cultivation methods.
b. To get acquainted with different enemies of lac both in field and storage.

Glossary

- **Dust lac:** Dust lac is obtained after grinding the seed lac.
- **Pruining:** It is a technique carried out lightly and branches, more than 2.5 cm in diameter should not be cut.
- **Lac:** It is a resinous substance secreted by a tiny insect called *Lacciferalacca* (popular name "lac insect").
- **Natural enemies:** A living organisms that is harmful to the main rearing crops or insects.
- **Predator:** A predator is an organism that captures and eats another (the prey). This act is called predation. It is bigger in size, very active than its host prey.
- **Parasites:** A parasite is an organism that lives at the expense of another organism - the host. Parasites are usually smaller than their host. Parasites use both invertebrate and vertebrate hosts.

16.1. Lac growing areas in India

The lac insect lives on native trees in India, Burma (now called Myanmar) andMalaysia. In India it is chiefly grown on trees like "Kusum", "Palas" and "Ber".

The leading producer of lac is Jharkhand, followed by the Chhattisgarh, West Bengal, and Maharashtra states of India.

Lac production in India

- At present only less than 5% lac host trees are under the lac cultivation.
- The cultivation of lac on a large number of hosts of different kinds, its collection by numerous small growers, variations in the yield depending on the type and size of the host, cultivation practices and climatic conditions are the major factors influencing the estimation of lac production.
- On the basis of survey in the markets of different lac producing districts, the estimated nationalproduction of sticklac during 2015-16 was approximately 18,746 tons comprising rangeeni (7,597tons) and kusmi (11,149 tons) sticklac.

- Among the lac growing states, Jharkhand state ranks 1st followed by Chhattisgarh, Madhya Pradesh, Maharashtra and Odisha. These five states contributearound 93% of the national lac production. Contribution of Jharkhand in national lacproduction is about 53% followed by Chhattisgarh (17%), Madhya Pradesh (12%), Maharashtra (8%) and Odisha (3%).
- Among the different cropping season crops, jethwi crop was ranked 1st withthe contribution of 32% followed by aghani (27%), baisakhi (24%) and katki (17%) in total lacproduction.

16.2. Lac cultivation/ culture

There are two distinct strains of the lac insect in India, called Kusumi and Rangeeni. The former is raised mainly on the Kusum trees and later on all other lac hosts. Each of the strains produces two crops in a year, thus there are four crops.

Of the country's total production; 90% lac is obtained from the Rangeeni crops and only 10% from the Kusumi crops.

The two methods of lac cultivation are popular

1. Local cultivation
2. Modern cultivation

1. Local cultivation:

- This is the crude and unscientific method of lac cultivation in which lac is collected from the trees growing in jungles.
- The method of lac cultivation has generally failed to provide sustained supplies of brood lac for crop inoculations and optimum yield of lac.

2. Modern method:

This method was developed by Indian Institute of Natural Resins and Gums, Ranchi and is known as coupe system. To get good crop, following points should kept –

A. Selection of suitable site:-The site should be selected on the basis of host plants, where environmental conditions, suitable for host trees should be preferred. The excessive heat and cold should be avoided.

B. Pruning of host plants:

Pruning should always be carried out lightly and branches, more than 2.5 cm in diameter should not be cut. The pruning is dependent upon the type of the host plant e.g. in case of ber trees, a large number of succulent shoots are produced after pruning while palas and kusumi do not ordinarily require pruning.

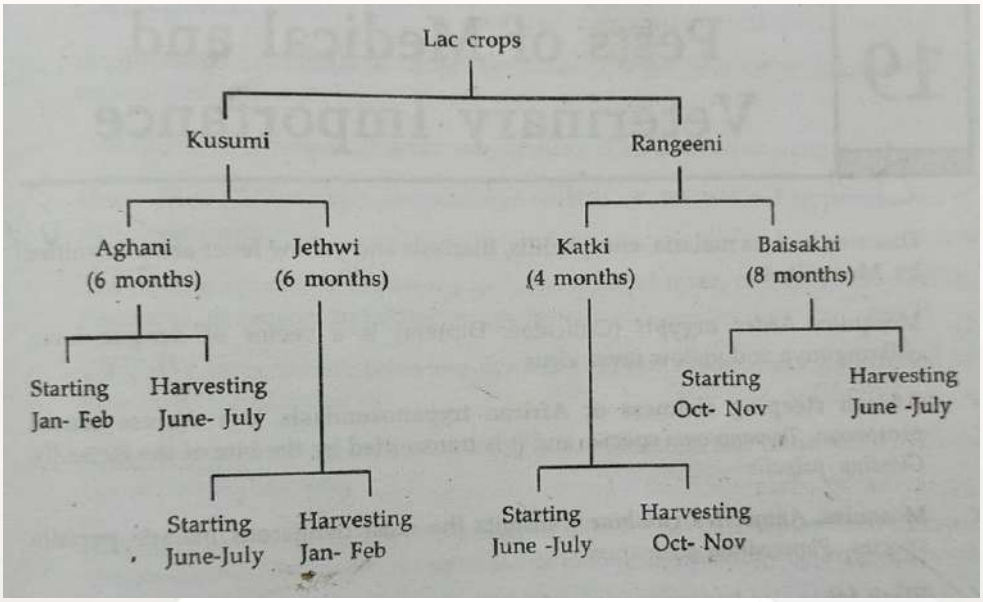

Figure 1. Lac Crops

16.3. Composition of Lac

The following constituents are found in the lac-

1. Resin	68%
2. Colored materials	10%
3. Wax	6%
4. Gum	5.5%
5. Sugar	4%
6. Debris	6.5%

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16.4. Types of Lac

Lac is a resinous substance secreted by a tiny insect called *Lacciferalacca* (popular name "lac insect").There are following types of lac:

a. Ari-lac: This is the immature lac and cutting of ari lac should be avoided.

b. Stick lac: Mature lac harvested in the form of sticks is called as sticks lac.

c. Seed lac: The lac obtained after removing and washing from the sticks is known as seed lac.

d. Dust lac: Dust lac is obtained after grinding the seed lac.

e. Shel lac: Shel lac is prepared after heating the seed lac and dust lac.

16.5. Uses of Lac

- Commonest use is in polishing wooden furniture. The granules are dissolved in spirit and then are applied in very thin layers on the wooden surfaces.
- In sealing parcels, packets and envelopes.
- As insulating material in electrical work.
- In making phonograph records (now replaced by synthetic material).
- In shoe polishes.
- In toys and jewellery.

Utilization of lac for various purposes has been very ancient in India. A "lac palace" is described in Mahabharata, which was intended to be used for burning the Pandavas alive.

16.6. Enemies of Lac insect

The insect pest attacking on the lac insect including parasitoid and predators. Some non-insect pest is also attacked the lac insect.

Parasites:

A parasite is an organism that lives at the expense of another organism - the host. Parasites are usually smaller than their host. Parasites use both invertebrate and vertebrate hosts.

Examples: Coccophagoustschirchi, Tetrastichuspurpureus, Eupelmustachardiae

Predator:

A predator is an organism that captures and eats another (the prey). This act is called predation. It is bigger in size, very active than its host prey.

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Examples: Eublema amabilis, Holocerapulverea

Eublema amabilis:

- Eublemma amabilis commonly known as white lac moth of the family Noctuidae.
- It is found in India, Bangladesh and Sri Lanka.
- The adult is white pinkish. Eggs are round and grey white.
- First instars are creamy whitish with a broad flat head. It is a major pest on *Kerria lacca*.
- The caterpillar enters the lac insect through one of the openings in the test or by tunneling a hole through the incrustation.
- Pupa obtect, adecticous and dark brown.

Holocerapulverea:

- Holcocerapulverea commonly known as black lac moth, attacking the lac insect in India.
- It causes economic loss to the lac industry, not only through its destruction of living scales but through the infestation of stored lac.
- At times the field damage reaches 25-30%.
- The eggs were laid singly on adult female scales, empty male cocoons or twigs having a heavy growth of sooty-mold fungus, produced by the scale infestation.
- Younger larvae feed on the body contents and waxy covering of scale insects.
- They move from one scale to another, building a silken tunnel or web through the mass.
- A maximum of 45 adult female scales have been found killed and the wax covering partially destroyed, by each larva during its feeding.
- There are 5 generations annually and winter is spent principally in the egg stage.
- Eggs seem to be very susceptible to changes in weather, for there is high winter mortality. Also, the majority of eggs laid during June are killed by high temperatures of the season.

Non-insect pest enemies

Some birds, monkeys, rat and squirrels also destroyed the lac insect and lac encrustations and cause considerable losses.

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Apiculture, Sericulture and Lac Culture

Lesson-16

Lac cultivation and their uses and enemies of Lac insect

Content

DESIGNED AND DEVELOPED UNDER THE AEGIS OF
NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications
ICAR-Indian Agricultural Statistics Research Institute

Course Name	Apiculture, Sericulture and Lac Culture
Lesson 16	Lac cultivation and their uses and enemies of Lac insect
Content Creator Name	Dr. Tamoghna Saha
University/College Name	Bihar Agricultural University, Sabour Bhagalpur-813210 Bihar
Course Reviewer	Dr. Kalmesh Managanvi
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Lecture-16

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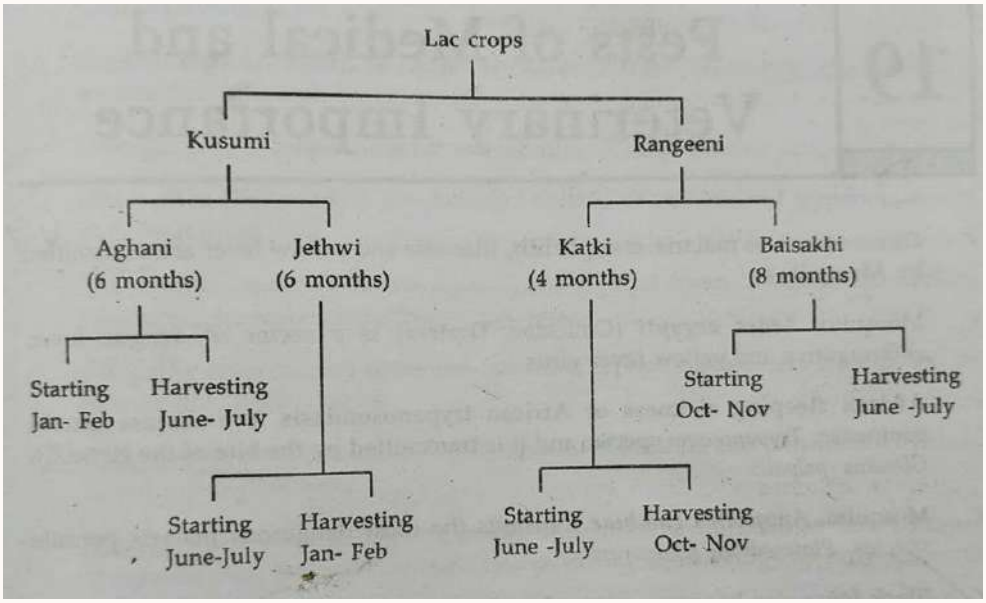

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