# Post-Graduate Degree Programme (CBCS)

# in

# ZOOLOGY

## SEMESTER-III

## ZSECT-301

## Industrial/Economic Zoology

**SELF LEARNING MATERIAL**

**DIRECTORATE OFOPEN AND DISTANCE LEARNING**

**UNIVERSITY OF KALYANI**

**KALYANI, NADIA,**

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Utmost care and precision have been ensured in the development of the SLMs, making them useful to the learners, besides avoiding errors as far as practicable. Further suggestions from the stakeholders in this would be welcome.

During the production-process of the SLMs, the team continuously received positive stimulations and feedback from Professor (Dr.) Manas Kumar Sanyal, Hon'ble Vice- Chancellor, University of Kalyani, who kindly accorded directions, encouragements and suggestions, offered constructive criticism to develop it within proper requirements. We gracefully, acknowledge his inspiration and guidance.

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Their persistent and co-ordinated efforts have resulted in the compilation of comprehensive, learner-friendly, flexible texts that meet the curriculum requirements of the Post Graduate Programme through Distance Mode.



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Director
Directorate of Open and Distance Learning
University of Kalyani

# ZSECT-301

# Industrial/Economic Zoology

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# UNIT I

# Pisciculture: History, definition, scope and significance of aquaculture

## Objective:

In this unit we will discuss about Pisciculture: History, definition, scope and significance of aquaculture.

## Introduction:

The term 'fishery' ordinarily means culture and propagation of edible and marketable fishes. This definition, however, should be restricted to pisciculture. Fishery is a vast domain.

In a broader sense it includes the judicious exploitation of natural resources of water for human consumption and benefit. The natural resources of water include all the organisms such as fishes, prawn, shrimps, crabs, sharks and rays, various molluscs, dolphins, whales, seaweeds, algae, etc.

The science of fisheries is a very complex subject. It is multidisciplinary and includes physical, chemical, biological, microbiological, hydrobiological, limnological, and meteorological sciences interacting with the biology of fish, ecology of the resources, production management, marketing, etc.

Fishery science has expanded to such an extent that today various colleges and universities are running MSc courses in Zoology with specialization in fish and fisheries or BSc, MSc courses exclusively in Fishery Science (BFSc and MFSc). Moreover, under the provision of U.G.C (University Grants Commission), a vocational course in Fishery Science or Industrial Fisheries is being run by a number of colleges and universities.

Apart from the above, a number of technological and Research Institutes, under the Indian Council of Agricultural Research (ICAR) are actively engaged in conducting research and evolving technological improvements for the betterment of fisheries.

## Research Institutes of Fishery:

**Some important Fishery Research Institutes are listed below**

(1) Central Inland Capture Fisheries Research Institute (CICFRI) with headquarter at Barrackpore (West Bengal).

(2) Central Institute of Freshwater Aquaculture (CIFA) with headquarter at Bhubaneswar (Orissa).

(3) Central Institute of Brackish water Aquaculture (CIBA) with headquarter at Chennai (Tamil Nadu).

(4) Central Institute of Fisheries Technology (CIFT) with headquarter at Cochin (Kerala).

(5) National Bureau of Fish Genetic Resources (NBFGR) with headquarter at Lucknow (Uttar Pradesh).

(6) National Research Centre on Cold Water Fisheries with headquarter at Nainital (Uttaranchal).

(7) Central Marine Fisheries Research Institute (CMFRI) with headquarter at Cochin (Kerala).

(8) Taraporevala Aquarium and Marine Research Station at Mumbai (Maharashtra).

## History of Aquaculture

Aquaculture in India appears to be an activity of ancient origin. Kautilya in his Arthashastra, written around 300 BC, mentioned how fish could be rendered poisonous in tanks during war. The method of fattening fishes in ponds has been described by the King Someshwara in an encyclopedia named "Mansoltara" written by him in 1127 AD.

- **Aquaculture Development during Pre-independence Period**

The 19th Century did not witness any significant development on aquaculture scenario except for collection and transport of carp spawn from rivers in Bihar and West Bengal and spawning of carps in wet and dry bundhs simulated natural environmental conditions of the flooded rivers and inundated fields where carps are bred during monsoon months. Construction work on railways and buildings in plains and deltaic regions of eastern states which necessitated digging for earth resulting in formation of ponds, gave a further fillip to fish culture in the country. Coastal aquaculture is also quite an ancient practice in India. The earliest forms of coastal aquaculture have been in vogue in the extensive backwaters of Kerala and the Sunderban mangrove swamps of West Bengal for several decades. These practices had been developed by the local farmers to put the low lying saline lands into productive use by raising fishes and prawns. Further, wherever possible, a rotation of agricultural and aquacrops was practised, using the extremely low saline conditions during the monsoon months for paddy cultivation and the medium to high saline period for prawn and fish cultivation.

Early in the 20th Century, with the establishment of Fisheries Departments in certain states, the aquaculture practices got extended to other parts of the country. The first scientifically designed fish farm was constructed by the then Madras Fisheries Department at Sunkesula in Krishna District (now in Andhra Pradesh) in 1911. Gradually, Fisheries Departments were established in other states of the country too.

Activities like exhaustive survey for development of aquaculture, studies on bionomics and life history processes of important fishes; aquaculture extension on scientific lines etc. were pursued. Besides food fishes, attention was also paid on culture of larvicidal fishes for biological control of mosquitoes acting as vectors for malaria, filaria, dengue etc.

In India, during pre-independence days, fisheries had been largely looked upon as a source of revenue. The government began taking keen interest in the development of fisheries only in 1944 when a Fish Sub-Committee was appointed to review the position of fisheries in the country and recommended measures necessary for their development. The recommendations of the Committee received immediate attention and, as a first step, some fisheries personnel were appointed at the center to carry out a survey and help the states (then Provincial Government) in formulating and implementing scheme of fisheries development with financial support from the Central Government. Thus, beginning on an ad-hoc basis, the First Five Year Plan (1951-56) placed the development of fisheries on a national footing.

- **Aquaculture Development during Post-independence Period**

A real spurt in aquaculture activities was witnessed soon after India gained independence when almost all the states established either a section or independent Department of Fisheries and initiated action plans on stocking various water bodies with fish seed imported from Calcutta. During those days, fish and fisheries did not .figure as a subject of study in any of the Indian universities. The central and state governments had to recruit general graduates and post-graduates of Zoology discipline for manning the managerial posts in the fisheries sector. Since such recruits had no knowledge of the 'applied fisheries, the government resorted to establishing a series of in-service training centers at various levels. Accordingly, the first move in fisheries training was made during the period of GROW MORE FOOD CAMPAIGN in the country when Government of India in 1974 started two all India fisheries training centers, one for the 'inland fisheries at Barrackpore in West Bengal and other for marine fisheries at Mandapam Camp in Tamil Nadu. While the latter dealing mainly with marine fisheries has been discontinued, the former dealing with inland fisheries is still continuing under a different set up. The next major move in fisheries development was made in 1952 when a tripartite agreement was signed between the United Nations, USA and the Government of India. The agreement enabled India to acquire costly equipments for giving face uplift to its fishing industry and start mechanized fishing operation in coastal waters. This, in turn, led to the establishment of fisheries training centers in all the maritime states of the country.

Following the expansion of fisheries development activities in the country with increasing outlay in the successive Five Year Plans, the Government of India constituted an ad-hoc committee on Fisheries Education in 1959 for assessing the manpower requirements and suggesting measures for providing trained manpower at various

levels to give a further boost to fisheries developmental activities. Finding that the existing colleges and universities in India did not provide any formal courses in fisheries, the committee suggested the establishment of a post-graduate training centre for imparting training to district level fisheries officers, deputed by various state governments. Consequently, the Central Institute of Fisheries Education (CIFE) was created by an order of the Ministry of Agriculture on 6 June, 1961 at Bombay. Following the recommendation of the Committee, one more national institute, namely, Central Institute of Fisheries, Nautical and Engineering Training (CIFNET) was established at Cochin in 1963. Besides these, under Indo-Japanese Collaboration programme, the Marine Products Processing Training Centre (MPPTC) came int-o existence at Mangalore in 1963 for imparting training to fish processing technologists for the upcoming fish processing industry of the country. Although the system of imparting training in fisheries commenced during the forties, professional programmes of higher fisheries education in the country was started only in 1961 with the establishment of the first College of Fisheries at Mangalore under the aegis of University of Agricultural Sciences, Bangalore, Karnataka. Successful performance of the college helped a great deal in convincing all concerned about the usefulness of having programmes in professional fisheries education at the degree level. Consequently, a chain of fisheries colleges were established under various State Agricultural Universities (SAUs), the total of which presently stands at twelve (Table 2.2).

In the initial moves of aquaculture in India, riverine seed or seed produced through bundh breeding used to be the only source of stocking material for fish culture. However, in 1957, a major breakthrough was made when Indian major carps were successfully bred using fish pituitary extract. This facilitated procurement of pure seed of known species for culture purposes. It was indeed a significant development which virtually brought a revolution on aquacultural horizon of the country, so much so that the use of riverine seed for aquaculture came down from over 90% to about 10 to 20%. 30 A further boost to aquaculture development was provided in I970s when the Indian Council of Agricultural Research (ICAR), instituted an All India Coordinated Research Project on Composite Carp Culture to develop and demonstrate the viability of composite carp culture technology in different states of the country. Following this, under the rural aquaculture project sponsored by the ICAR/IDRC in Orissa and West Bengal, the viability of the technology in farmers' ponds was further demonstrated.

In 1973, a major national programme of Fish Farmers' Development Agency (FFDAs) was initiated at district level. It provided administrative and infrastructural support, training of beneficiaries, mobilization of inputs and extension support to fish farmers and arranging institutional finance through bank credits. The effort helped in upgrading the technology considerably which, in turn, also helped in improving the productivity of ponds under aquaculture.

## History and Development of Aquaculture

An All India Coordinated Research Project on Brackish water Aquaculture was launched by ICAR in 1973. The project sought to develop semi-intensive technology for mono culture of shrimps (viz. *Penaeus monodon* and *P. indicus*) and fishes (*Chanos chanos, Mugil cephalus, Liza parsia, L. tade*, *Etroplus suratensis* and *Lates calcarifer*). The project yielded extremely valuable scientific data on a nation-wide basis and led to making specific recommendations on development of brackish water aquaculture in the concerned states of the country. With the launching of important social beneficiary schemes like Area Development Approach Programme (ADAP), Brackishwater Fish Farmer's Development Programme, the Bay of Bengal Programme (BOBF) of FAO, the Marine Products Exports Development Authority (MPEDA), etc. the period eighties witnessed a tremendous amount of interest in brackish water aquaculture. The role of private sector, particularly in the development of shrimp farming in the eighties was remarkable. Concurrent development of shrimp hatcheries gave a good support to shrimp farming activities during this period. However, a major problem that haunted shrimp farmers was the feed. Commercial aquaculture of shrimps (largely *P. monodon*) came to be practiced in India during early nineties when under the guidance of foreign experts some enthusiastic entrepreneurs tried to initiate the technology of shrimp farming of neighboring South-east Asian countries. With the liberalization of economy during this period, a significant rush for investing on shrimp farming ventures ensued.

The large capital investment and use of modern technology, gave a massive boost to shrimp production in India. However, in the wake of "get rich quick" race shrimp farms mushroomed along the east and west coasts of the country. Many shrimp farms built with high capital investment were stocked heavily in the hope of reaping richer harvests of shrimps. Heavy stocking necessitated intensive feeding and indiscriminate use of drugs and chemicals which ultimately led to environmental degradation. It became a cause of great worry, so much so that the Supreme Court had to intervene. The situation finally compelled all concerned to look into the possible negative impacts of large aquaculture projects (more than 20 ha water area) on environment before granting them go ahead signal. It is hopefully believed that greater degree of mass awareness will help aqua-entrepreneurs to handle the shrimp farming technology with greater degree of care and caution in coming years. Diversification in brackish water aquaculture incorporating cultivable species of fishes like mullets, sea bass and crustaceans such as crabs and lobsters is a desirable step to be taken during the ensuing century. , In spite of being gifted with seas on its three sides, Bay of Bengal in the east, Arabian Sea in the west and Indian Ocean in south, sea farming or what is also called mariculture is still in its infancy ill India. This is largely because most part of India's coastline is too straight and flat, open to surges of strong winds and heavy tidal waves, thus, making them unconducive for sea farming. However, some bays are there such as in Gulf of Kutch, Konkan coast, Goa, Northern Karnataka, Lakshadweep, Gulf of Mannar and Andaman and Nicobar Islands which could be brought into use for sea farming.

Steps like upgradation of available sea farming technologies and their transfer to coastal fisher folk through impactful extension techniques are required to be taken to popularize sea farming in India.

## Advantages of Fish Farming:

1. Fish provides high quality animal protein for human consumption.

2. A farmer can often integrate fish farming into the existing farm to create additional income and improve its water management.

3. Fish growth in ponds can be controlled: the farmers themselves select the fish species they wish to raise.

4. The fish produced in a pond are the owner's property; they are secure and can be harvested at will. Fish in wild waters are free for all and make an individual share in the common catch uncertain.

5. Fish in a pond are usually close at hand.

6. Fishes do not spend much energy on temperature regulation as they are poikilothermic in nature.

7. Fishes can convert food into body tissue more efficiently than any other farm animals. The conversion factor to flesh is high in fishes (80.9%) than chicken (64.7%) and beef (51%).

8. Effective land use: effective use of marginal land e.g. land that is too poor, or too costly to drain for agriculture can be profitably devoted to fish farming provided that it is suitably prepared.

9. Fish production can be organized according to the market demand in respect of quality, quantity, size, colour, preservation and processing.

10. Low trophic feeders (herbivores) can be raised at comparatively lower costs than those which are higher in the food chain.

**Probable questions:**

1. What do you mean Aquaculture?
2. What do you mean by pisciculture?
3. Elaborate briefly the history of aquaculture.
4. Elaborate the aquaculture development during Pre-independence Period in India.
5. Elaborate the aquaculture development during Post-independence Period in India**.**
6. State the advantages of aquaculture?
7. Elaborate the reasons why aquaculture industry developing so fast in India.

**Suggested Readings:**


1. https://courseware.cutm.ac.in/wp-content/uploads/2020/06/Unit-2-History-of-Aquaculture-2.pdf
2. Textbook of Fish Biology and Fisheries 3rd edn (PB) by Khanna S S and H R Singh; Narendra Publishing House.
3. Brief Introduction to Fisheries (Springer: Singapore), Springer, Singapore.
4. Rastogi Publications Fish and Fisheries (Z-56), 4th Revised Edition: 2018-2019.

# UNIT II

# Different aquaculture systems; Aquaculture–Problems and prospects in India

## Objective:

In this unit we will discuss about different aquaculture systems and problems of aquaculture and prospects of aquaculture in India.

## Introduction

Aquaculture may simply be referred as 'Underwater Agriculture'. Over the years, the enormous increase in the growth rate of aquaculture has been in response to declines in commercial harvests of wild stocks of fish and shellfish. Top aquaculture producers In 2008 were China with 62 percent of world aquaculture production of fish, crustaceans and molluscs (32.7 million tonnes). Other countries producing over one million tonnes in the same year are India (3.5 million tonnes), Vietnam (2.5 million tonnes), Indonesia (1.7 million tonnes), Thailand (1.4 million tonnes) and Bangladesh (1 million tonnes). Carps are the most cultured species in the world with 39 percent of production by volume. Other major groups cultured include shellfishes (oysters, clams, mussels and scallops), other freshwater fish includes tilapias, followed by shrimps, prawns and salmons. At single species value level, white leg shrimp generated the highest value (USD 9 billion) in 2008, followed by Atlantic salmon (USD 7.2 billion), grass carp (USD 4.8 billion), silver carp (USD 4.8 billion). India is a major maritime state and an important aquaculture country in the world. It is also home for more than 10% of global fish biodiversity. India has achieved considerable production increases in aquaculture, especially in the production of freshwater fishes and shrimps. While progress in research and development of new technologies have already made in mollusk culture, seaweed culture, and in culture of certain marine fishes like seabass these have not yet taken off on commercial scale. The production gap in aquaculture between China and India or other important Asian countries are very wide, so effective utilization of the diversity of our marine living resources for aquaculture, in the long coastline will increase Indian aquaculture production.

## Different systems of aquaculture

Aquaculture practices are classified in several ways, depending upon the different aspects and situations involved in the culture practice. Some major and important classifications are given below based on the different factors involved in aquaculture.

I. **On the basis of salinity**
- Freshwater farming
- Brackish water farming
- Marine water farming

II. **On the basis of intensity**
- Extensive fish farming system
- Semi-intensive fish farming system
- Intensive fish farming system

III. **On the basis of fish species**
- Monoculture
- Polyculture

IV. **On the basis of enclosure**
- Pond culture
- Cage culture
- Pen culture
- Race-way culture

V. **On the basis of integration**
- Agriculture cum fish farming
- Animal husbandry cum fish farming

## I. <u>On the basis of salinity</u>

- Freshwater Farming

Farming of aquatic animals and plants in zero saline water, mostly fresh water farming is inland based. Catla, Rohu, Mrigal, Silver carp, Grass carp, Common carp and Fresh water prawn are mainly farmed in fresh water.

- Brakishwater Farming

Brakishwater is a mixture of seawater and freshwater with a salinity less than 30ppt. All estuaries, backwaters, creeks and mangrove waterways are brakish in nature. Over 25 species of commercially important fishes, shrimps, crabs and mollusks offer a wide scope for farming in brakish water.

- Marine water farming

Farming of aquatic animals and plants in sea water is commonly known as marine water farming or mariculture. In mariculture rearing of commercially important fishes and shell fishes are done in open sea by installing cages.

## II. On the basis of intensity of inputs and stocking density

- Extensive fish farming system

In the most extensive fish farming, the fish feed entirely from the food web within the pond, which may be enhanced by the addition of fertilizer or manure. Ponds (natural or artificial) and lagoons are fertilised to promote the presence of phytoplankton (microscopic plants), zooplankton (mostly small crustaceans) and aquatic vegetation which form the base of the aquatic food pyramid. This encourages the development of marketable animals at a higher yield than that of the natural ecosystem.

Common carp and a number of other fish species are still sometimes farmed extensively in the European Union, though fish farming there is predominantly intensive. Extensive farming of carp and tilapia is common in Asia and Africa. For example, one of the most common methods of farming bighead carp (mainly farmed in China) is to grow them in small lakes and reservoirs without the use of feed or fertilizer. The bighead carp are stocked with other fish species at a stocking density of 150-750 fish per hectare (i.e. 13-67 square metres per bighead carp) which represents about 40-50 % of the total number of fish stocked. Bighead carp are also extensively reared in polyculture ponds and pens, where organic fertilizer is usually applied to increase natural food when bighead and silver carp are cultured as major species

- Semi-intensive fish farming system

In semi-intensive fish farming, the fish still obtain significant nutrition from the food web within their pond, but they are also given supplementary feed. This means the fish can grow faster and/or to a larger size or at a greater stocking density. The feed may be of vegetable origin or may include fish, fish oil and/or fishmeal.

Grass carp is the farmed fish species with the highest global production tonnage and is farmed, mainly in China, in both in semi-intensive pond systems and intensively in cages. In semi-intensive farming, the grass carp are stocked in ponds or pens with other carp species (either as a major or secondary species), where aquatic weeds and terrestrial grasses form the main feed. Commercial feeds, such as pellets, and vegetable by-products may be used instead to save labour costs, or at specific times of the year when growth of water grasses and algae is reduced. The total stocking density is 750-3,000 fish per hectare (i.e. 3-13 square metres per fish).

- Intensive fish farming system

In intensive farming, the fish are kept at too high a stocking density to obtain significant amounts of feed from their environment. Instead the fish are dependent on the feed provided and water must be replenished at a high rate to maintain oxygen levels and remove waste. The levels of feed inputs and management of the water affect the stocking density of the fish that can be supported.

## III. On the basis of number of species stocked for farming

- Monoculture

Monoculture is a fish production system in which only one fish species is reared in a culture system. The major fish varieties reared in monoculture system are trout, tilapia, catfishes, carps, shrimp etc. Monoculture of high-value, market-oriented fish species in intensive system is a common practice throughout the world. Supplementary feeding is compulsory to ensure production.

- Polyculture

Polyculture is a fish production system in which two or more different fish species are farmed or culture of fish along with some other aquatic animals like shrimp or prawn. In this system of culture species with different habitats and different food preferences are stocked together in such densities that there will be almost no competition for food or space. Polyculture practices give higher yield than monoculture under the same conditions for freshwater carp farming.

**Biological basis of polyculture**

Common fish species in Indian polyculture are catla, rohu, mrigal, silver carp, grass carp and common carp, and this system is sometimes called as composite fish culture. The biological basis of polyculture is different fish species grow together in a pond with difference in feeding and living behavour.

The principal requirements of the different species in combination for polyculture are

i. They must be different in feeding habits
ii. They should occupy different columns in a pond system
iii. They should attain marketable size at the same time
iv. They should be non predatory in behaviour

## IV. On the basis of enclosure used for culture

- **Pond culture**

It is the most common method of fish culture. In this case water is maintained in an enclosed area by artificial construction of dike/bund, where aquatic animals are stocked and grown. Ponds are usually filled by rain, canal water and by man made bores. They differ widely in shape, size, topography, water and soil qualities.

- **Cage culture**

Cage culture is rearing of fish from juvenile stage to commercial size in a volume of water enclosed on all sides including bottom, while permitting the free circulation of water. Cage culture is readily adapted to water areas which cannot be drained. Fish culture in cage is an innovative concept to exploit the potential of lakes, reservoirs and riverine pools. Cage culture of fish and other aquatic organisms is popular in many countries. Japan, South Korea, China, Philippines, Thailand, Malaysia, Germany, Norway, USA are some of the countries where cage culture is well developed. In principle, almost

every cultivable species of fish can be cultured in cages, such as carps, tilapia, trout, catfishes, etc. depending on socioeconomic, ecological and technical suitability.

**Advantages of Cage Culture**

i. Use existing water bodies
ii. Technical simplicity with which farms can be established or expanded
iii. Lower capital cost compared with land-based farms
iv. Easier stock management and monitoring compared with pond culture

**Disadvantages of Cage Culture**

i. Stock is vulnerable to external water quality problems eg. Algal blooms, low oxygen
ii. Stock is more vulnerable to fish eating predators such as water rats and birds
iii. Growth rates are significantly influenced by ambient water temperatures

- **Pen culture**

Pen culture is defined as rising of fish in a volume of water enclosed on all sides except bottom, permitting the free circulation of water at least from one side. This system can be considered a hybrid between pond culture and cage culture. Mostly shallow regions along shores and banks of the lakes and reservoirs are used in making pen/enclosure using net/wooden materials where fish can be raised.

In a fish pen, the bottom of the lake forms the bottom of the pen. Pen has the advantage of containing a benthic fauna which serves as food for the fish and polycultue can be practiced in pens as it is in ponds. The environment in fish pen is characterized by a free exchange of water with the enclosing water body and high dissolved oxygen concentrations.

## Advantages of Pen culture:

**a. <u>Intensive utilization of available space</u>:** Stocking density can be increased compared to that of a pond culture system

**b. <u>Safety from predators</u>:** Within the enclosure the predators can be excluded. In the larger pens this would be more difficult, but in smaller pens this can be done as efficiently.

**c. <u>Suitability for culturing many varied species</u>:** Due availability of more space and the natural water system

**d. <u>Ease of harvest</u>:** In the large pens the harvest may not be as easy as in cage rearing but it more controllable and easier than in the natural waters.

**e. <u>The flexibility of size and economy</u>:** When compared with the cage, pens can be made much larger and construction costs will be cheaper than that of the cages.

**f. <u>Availability of natural food and exchange of materials with the bottom</u>:** Since, the bottom of the pen is the natural bottom; the pen cultured organisms are at an advantage that they can procure food/exchange materials from the natural bottom.

## Disadvantages of Pen culture:

**a.** High demand for oxygen and water flow

**b.** Dependence on artificial feed

**c. Food losses:** Part of the feed is likely to be lost uneaten, and drifted away in the current, but the loss here would be less than in floating cages.

**d. Pollution:** Since a large biomass of fish are cultured intensively a large quantity of excrements accumulate in the area and cause a high BOD - also substances such as ammonia and other excreted materials, if not immediately removed/ recycled. They pollute the water and cause damages.

**e. Rapid spread of diseases:** For the same reason of high stocking density in an enclosed area, any disease beginning will spread very quickly and can cause immense mortality of stock and production decline.

**f. Risk of theft:** Since the fish are kept in an enclosed area, 'poaching' and thefts can take place more frequently than in natural waters, but perhaps less than those from cages.

**g. Conflict with multiple use of natural waters:** In locations where a pen is constructed, if the water is used for multipurpose like irrigation and recreational activities, such as swimming, boating etc. may lead to conflicts.

## V. Raceway

Raceway culture is defined as rising of fish in running water. It is a high production system in which fishes are grown in higher stocking density. Raceways are designed to provide a flow-through system to enable rearing of much denser population of fishes.

Raceway ponds are basically of two types:

I. Linear type: Ponds arranged in sequence. In a linear type, the volume of water entering each pond is larger and as the same water is used repeatedly from pond to pond, occurrence of disease in initial ponds may directly affect the other connected ponds

II. Lateral type: Ponds lay out in parallel. Lateral or parallel type the volume of water entering each pond is smaller but a fresh supply of water is always ensured and no transfer of disease from one pond to another.

## VI. Recirculating Aquaculture system (RAS)

A Recirculating Aquaculture System (RAS) can be defined as an aquaculture system that incorporates the treatment and reuse of water with less than 10% of total water volume replaced per day. The concept of RAS is to reuse a volume of water through continual treatment and delivery to the organisms being cultured. Water treatment components used in RAS need to accommodate the input of high amounts of feed required to sustain high rates of growth and stocking densities typically required to meet financial outcomes. Generally, RAS consist of mechanical and biological filtration components, pumps and holding tanks and may include a number of additional water treatment elements that improve water quality and provide disease control within the system.

## VII. On the basis of different farm integration

**Basic Principles of Integrated Fish Farming:**

Integrated fish farming is based on the concept that 'there is no waste', and waste is only a misplaced resource which can become a valuable material for another product (FAO, 1977). In integrated farming, the basic principles involve the utilisation of the synergetic effects of inter-related farm activities and the conservation, including the full utilisation of farm wastes.

It is assumed that all the constituents of the system would benefit from such a combination. However, in most cases, the main beneficiary is the fishes which utilises the animal and agricultural wastes directly or indirectly as food. As integrated farming involves the recycling of wastes, it has been considered an economic and efficient means of environmental management.

- **Fish farming with agriculture**

In the fish integrated agriculture system, fish culture is integrated with agricultural crops such as rice, banana and coconut, thereby producing fish and agricultural crops. Agriculture based integrated systems include rice-fish integration, horticulture-fish system, mushroom-fish system, seri-fish system.

- **Rice-Fish integrated farming/ Paddy-cum-fish culture**

Rice fields which are water-logged for 3-8 months in a year, there is always small population of fishes that gain access to such waters. This probably had given rise to the practice of deliberate stocking of fishes and harvesting. The trapping of prawns and fishes with the help of 'gamcha or dhoti' in fallow paddy-fields has been an age old practice in India.

**The objectives or advantages of paddy-field aquaculture are as follows:**

(1) Paddy-field aquaculture provides additional income to the farmers.

(2) In areas where rice and fish form the staple food, paddy-field aquaculture makes available an essential diet for the people.

(3) As paddy and fish can be grown either simultaneously or alternately in the same water mass, it requires very little extra input by way of additional costs, particularly in management and labour.

(4) It provides off-season employment to the farmers and farm labours.

(5) Combination of paddy and fish farming is mutually beneficial. Fish cultivation promotes better paddy production by way of exercising an effective control on unwanted weeds, molluscs, noxious insects and their larval stages.

### A. Fishes Suitable for Paddy-Cum-Fish Culture:

All fishes are not suitable for such a type of culture as paddy-fields provide special ecological conditions such as shallow turbid water with high temperature.

**Fishes having the following criteria are generally selected for paddy-cum-fish culture:**

(1) Fishes that can adapt to shallow waters necessary for paddy crops.

(2) Fishes that can tolerate high temperature.

(3) Fishes that can thrive on low dissolved oxygen, which is the characteristic of paddy-fields especially in tropical countries.

(4) Fishes that can tolerate fairly high turbidity.

(5) As the duration of culture is quite short, fishes that have high growth rate is to be selected, so that it can reach marketable size within these few months.

(6) Fishes that can live in confinement and do not tend to escape from the cultivated area.

Fishes that are cultured in such waters in India are *Mugil* sp., *Mystus gulio, Haplochromis mellandi* (mollusc eating fish), *Lates calcarifer, Mugil parsia, Puntius sp., Channa sp*., prawns and shrimps. In India, limited experimental works have shown the suitability of Indian carps for such integrated farming.

### B. Management of Paddy-Fields:

**To increase the utility of paddy-fields as fish ponds, the following managements are required:**

(1) A continuous flow of water in the field, with proper inlet and outlet is to be maintained.

(2) The water in the field is to be maintained at a desired level.

(3) Proper drainage of water from the field has to be made in case of flooding.

(4) At the point of entry and exit of water, some control means (such as screens) have to be provided to prevent the cultivated species from escaping and stopping the entry of wild fishes into the paddy-field.

(5) Deep pits or other devices have to be provided as shelter to the cultivated fishes at the time of distress.

**The disadvantages of Paddy-Cum-Fish Culture are:**

(1) The water depth being shallow hinders better fish rising.

(2) For fear of harmful effect on fishes, herbicides and insecticides uses in paddy-field is generally prevented which ultimately limits paddy production.

(3) Due to abrupt changes in temperature and dissolved oxygen, inadequate space and presence of piscivore birds, there is great loss of fishes which may be about 20-60%.

(4) Due to presence of piscivorous birds like herons, cormorants, etc., considerable loss of fish (20-60%) takes place.

- **Horticulture-Fish integrated farming**

The dykes and the adjoining areas of the ponds can be best utilized for horticulture crops. The top, inner and the outer dykes can be planted with dwarf variety coconut, mango and banana. And the side by land can be used for planting pineapple, ginger, and turmeric and chilly. The exchanging water can be used to water the plants which are rich in organic load. The residues from the vegetables cultivated could be recycled into fishponds, particularly when stocked with fishes like grass carp.

- **Mushroom-Fish integrated farming**

Cultivation of mushroom requires high degree of humidity and therefore its cultivation along with aquaculture tremendous scope. *Agaricus bisporus , Voloriella* spp. and *Pleurotus* spp., are commercially cultured mushrooms in India.

- **Seri-Fish integrated farming**

In this faming system silk worm is cultured along with fish. Here the mulberry leaves produced is primarily consumed by the silk worm and the faeces of the silk worm is directly applied to the fish pond to increase of natural food organism-detritus and bacteria in fishpond.

- **Livestock integrated fish farming**

Livestock integrated fish farming system includes cattle-fish system, pig-fish system, poultry-fish system, duck-fish system, goat-fish system, rabbit-fish system. In this integrated farming the excreta of ducks, chicks, pigs and cattle are used directly in ponds to increase plankton production which is consumed by fish or serve as direct food for fish. Hence, the expenditure towards chemical fertilizers and supplementary feeds for fish ponds are totally avoided reducing the production cost.

- **Cattle-Fish integrated farming**

Cow dungh is the most widely used manure, in fish ponds all over the world. A healthy cow excretes over 4,000-5,000 kg dung, 3,500-4,000 litre urine annually. For 1 ha pond 5-6 cows can provide adequate manure. An additional income is generated from milk (9,000 litres/year) and fish production ranges from 3,000-4,000 kg fish/ha/year.

- **Pig-Fish integrated farming**

In this farming system 60-100 no of pigs are enough to fertilize one hectare area fish pond. A floor space of 3-4$m^2$ is required for a single pig. Five tones of pig manure is required for manuring 1 ha fish pond for 1 year. Pigs are fed with kitchen waste, aquatic plants and crop wastes. The waste produced by 30-35 pigs is equivalent to 1 tonne of ammonium sulphate. Exotic breeds like White Yorkshire, Landrace and Hampshire are reared in this farming system. Grass carp, silver carp and common carp (1:2:1 ratio) are suitable for integrated farming with pigs.

- **Poultry-Fish integrated farming**

Chicken droppings are rich in phosphorus and nitrogen, so chicken manure is an effective fertilizer. For 1ha fish pond 25,000 chicks can be reared. Poultry shed is constructed above the pond with bamboo flooring to facilitate the direct fertilization of the pond. One chicken produces 25 kg poultry manure per year. From poultry 90,000 to 1, 00,000 eggs and 2500 kg meat can be produced and 3000 – 4500 kg of fish can be produced without any chemical fertilizer and supplementary feeding.

- **Duck-Fish integrated farming**

In Duck-fish integrated farming, ducks provide a safe environment to fish by consuming juvenile frogs, tadpoles and dragonfly in the pond. As the duck spends most of its time swimming in the pond the dropping goes directly in pond, which in turn provides essential nutrients to stimulate growth of natural food in the fish pond. The duck dropping contain 25 per cent organic and 20 per cent inorganic substances with a number of elements such as carbon, phosphorus, potassium, nitrogen, calcium, etc.

Hence, it forms a very good source of fertilizer. To fertilize 1 ha fish pond number of ducks required is between 100 and 3,000, depending on the duration of fish culture and the manure requirements. Small ruminants such as goats and sheep are integrated with fish culture is practiced, but on a very small scale. Integrated rabbit-fish farming is also practiced only on a very small scale. This system has up to now not received much attention.

## Advantages of aquaculture

i. Aquaculture is the important source of excellent quality protein and healthy oils

ii. Future for fish production is dependent on aquaculture

iii. Due to production of fish at low cost, it can be supplied at an affordable price even to poorer peoples

iv. Cultured fishes are safe from captured fish because cultured fishes are free from pollutants

v. Aquaculture provides good quality food for the growing population

vi. Increases employment opportunity

## Disadvantages of aquaculture

i. The infrastructure development for aquaculture will affect the local flora and fauna like wetlands and mangroves

ii. The untreated effluent discharged with heavy organic load will adversely affect the local ecosystem

iii. Farming of exotic species would bring with new pathogen to the new environment

iv. Disease and parasite transfer from captive stock to wild

## Problems of Aquaculture in India

The main critical gaps / challenges for fisheries development in India include the following:

i. "The biggest problem with fish culture is the **possibility of diseases**. Fish can be infected with fungal, bacterial, ulcer or worm diseases. The infected fish as they become weak and lethargic, and often come to the surface of the water to breathe. In eye diseases, for instance, their eyes become opaque. Infected fish can have open spores on the body, and can also have their scales dropping. Treatments are available in the form of treating the water with potassium permanganate solution, or with acetic acid and normal salt. Copper sulphate solution and Chloromycetin are also used to treat some other diseases.

ii. **Lack of a reliable database** relating to aquatic and fisheries resources

iii. **Limited number of species** grown / cultured, mainly due to weak linkages between research and development and fish farmers community.

iv. **Weak multi-disciplinary approach** in fisheries and aquaculture

v. **Inadequate attention** to the environmental, economical, social and gender issues in fisheries and aquaculture,

vi. **Inadequate HRD** and specialized manpower in different disciplines.

vii. **Weak marketing and extension network:** It is also mandatory to have good transportation links to main wholesale markets. These are expensive affairs and big entrepreneurs and fish co-operatives can afford it, but it is not possible fur individual farmers.

viii. Decline in fish catch and depletion of natural resources due to **over exploitation of coastal fisheries.**

ix. **Water pollution**: unscientific management of aquaculture and contamination of indigenous germplasm resources.

x. Poor yield optimization, problems in harvest and post-harvest operations, landing and berthing facilities for fishing vessels and issues in welfare of fishermen.

## Prospects of Aquaculture in India:

The government has come up with schemes in association with state governments from time to time to support fish culture. Development of Inland Fisheries and Aquaculture was one such scheme launched during the 10th Plan. Under the scheme, whose cost is borne by the central and the state governments in the ratio of 75:25, farmers are given assistance for building ponds.

A subsidy of 20% is given assuming cost for constructing a pond in plain areas is Rs. 200,000 per hectare and at Rs. 300,000 per hectare in hilly regions. For renovation of an existing pond subsidy is given at 20% assuming cost of Rs 60,000 per hectare.

The National Bank for Agriculture and Rural Development (NABARD) also refinances the banks extending loans to fisheries cooperatives or to entrepreneurs involved in fish culture. The formation of the Fish Farmers' Development Agencies (FFDAs) was another major scheme launched by the Ministry of Agriculture in the 1970s. These agencies provide financial, technical and other support to beneficiaries at district level throughout India. Training is also provided through the NFDB

India produces in excess of 3.6 million metric tons of freshwater fish, but a lot of potential lies untapped. While the area covered by rivers cannot be added, fish production through ponds can definitely be increased by several notches. India has fixed a target of over 5.5 million metric tons of freshwater fish catch by 2020.

There is a need for better resource management and community intervention in all places where fish culture is practiced or can be practiced. Rain-fed areas should also be utilized to cultivate fish. As far as markets are concerned, communication systems among fishermen's cooperatives controlling marketing need to be enhanced. This would be beneficial not only for farmers, but also for consumers.

**Probable questions:**

1. What do you mean by fresh water farming?
2. Differentiate and discuss briefly aquaculture system on the basis of fish species.
3. Discuss briefly about extensive fish farming system.
4. What do you mean by semi-intensive and intensive fish farming system?
5. What is cage culture? State the advantages and disadvantages of cage culture.
6. What is pen culture? State the advantages and disadvantages of pen culture.
7. What do you mean by Recirculating Aquaculture system (RAS)?
8. Describe the basic principles of integrated fish farming.
9. What do you mean Paddy-cum-fish culture? State the objectives of paddy-field aquaculture.
10. Which Fishes are Suitable for Paddy-Cum-Fish Culture?
11. Describe duck-fish integrated farming.
12. Differentiate and discuss briefly aquaculture system on the basis of different farm integration.
13. State the advantages and disadvantages of aquaculture.
14. State the problems of aquaculture in India.
15. Describe the prospects of aquaculture in India.

**Suggested Readings:**


1. https://courseware.cutm.ac.in/wp-content/uploads/2020/06/Unit-2-History-of-Aquaculture-2.pdf
2. Textbook of Fish Biology and Fisheries 3rd edn (PB) by Khanna S S And H R Singh; Narendra Publishing House.
3. FAO FishStat "Aquaculture Production 1950-2010 (Release date: March 2012)".
4. FAO Cultured Aquatic Species Information Programme – Hypophthalmichthys nobilis (Richardson, 1845).fao.org/fishery/culturedspecies/Aristichthys_nobilis/en.
5. FAO Cultured Aquatic Species Information – Programme Ctenopharyngodon idellus (Valenciennes, 1844). fao.org/fishery/culturedspecies/Ctenopharyngodon_idella/en.
6. Gregory N.G. (1998) Animal welfare and meat science. In: chapter 11. CAB International, November 1998. ISBN-13: 9780851992969.

7. Scientific Opinion of the Panel on Animal Health and Animal Welfare on a request from the European Commission on the Animal welfare aspects of husbandry systems for farmed trout. The EFSA Journal (2008) 796, 1-22.

# Unit-III

# Lac culture: Host plant and cultivation of Lac; recent advancement in Lac cultivation; Lac industry in India

**Objective:**In this unit you will learn about life-history of lac insect, culture method, lac processing, lac products, natural enemies of lac insect and their control

## Introduction:

Lac culture is the scientific management of lac insects to obtain a high amount of quality lac. This involves selection and maintenance of host plants, inoculation of host plants with healthy lac insects, collection and processing of lac and protection against enemies. Lac is the resinous secretion of lac insects. Two species of lac insects *Tachardialacca* and *T. chinensis* are common, of which the former one is predominant in India. India is the highest lac-producing country. Thailand is next in order.

## History:

Lac has been used in India from time immemorial for several purposes, from the epic of Mahabharat it has been recorded that Kauravas built a palace of lac for the destruction of Pandavas. We come across references of lac in the Atharvaveda and Mahabharata, so it can be presumed that ancient Hindus were quite familiar with lac and its uses. Scientific study of lac started much later. In 1709 Father Tachard discovered the insect that produced lac. First of all Kerr (1782) gave the name *Coccus lacca* which was also agreed by Ratzeburi (1833) and Carter (1861). Later Green (1922) and Chatterjee (1915) called the ac- insect as *Tachardialacca* (kerr). Finally, the name was given as *Lacciferlacca*.

## Introduction to Lac Insects:

Two strains of the lac insects are recognised in India, RANGEENI and KUSMI. The lac insects that thrive on the host plant Kusum is referred to as Kusmi whereas the Rangeeni strain generally grows on host plants other than Kusum. Each strain completes its life cycle twice a year but the seasons of maturity differ considerably.

There are four lac crops in a year that are named after the Hindi months (Table 4.2). Lac insects under the genus Kerria are generally bivoltine with two broods in a year. But few species like *K. lacca*mysorensis (host plant-Sal), and *K. sharda* (host plant-Kusum) are tri-voltine having three broods in a year. Again, species belonging to the genus *Paratachardia*(host plants-Tea, Sandal, etc.,) are all univoltine.

Table 4.2 : Strains of lac insect and their characteristics

| Characteristics | Kusmi | Rangeeni |
|---|---|---|
| Host plant | Kusum is main, others include Ber, Siris, Semialata, etc. | Rangeeni strain grows well mainly on Palas and also on a few other trees, but not on Kusum |
| Types of crop | (a) Jethwi (b) Aghani | (a) Kartiki (b) Baisakhi |
| Inoculation time | (a) Jethwi : Jan/Feb.<br>(b) Aghani : June/July | (a) Kartiki : June/July<br>(b) Baisakhi : Oct/Nov |
| Duration of life cycle | (a) Jethwi : Jan/Feb to June/July<br>(b) Aghani : June/July to Jan/Feb | (a) Kartiki : June/July to Oct/Nov.<br>(b) Baisakhi : Oct/Nov to May/June |
| Harvesting month of crop-yield | (a) Jethwi : June/July<br>(b) Aghani : Jan/Feb | (a) Kartiki : Oct/Nov<br>(b) Baisakhi : May/June |
| Quality of lac | Superior | Inferior to Kusmi lac |

## Taxonomy of Lac Insect: (After E.E.Ruppert and R.D. Barnes, 1994)

**Phylum: Arthropoda**

**Sub-phylum: Uniramia**

**Class: Hexapoda/Insecta**

**Subclass: Ectognatha**

**Order: Hemiptera**

**Family: Laciferidae**

**Genus: *Tachardia***

**Scientific name: *Kerria (Tachardia) lacca***

The first scientific account about lac insect was given by J. Kerr in 1782, published in Philosophical Transaction of Royal Society of London. The first scientific name given to it was *Tachardialacca* after the name of French Missionary Father Tachardia.

Later it was changed to *Kerria lacca.* Out of nine genera and 87 species of lac insects reported from the world, two genera and 19 species are found in India. Of these 19 species, only *K. lacca* is exploited for commercial production of lac. However, *K.*

*chinensis*in northeastern states and *K. sharcla* in coastal regions of Orissa and West Bengal are also cultivated to certain extent.

## Habit and habitat:

The lac insects have a no. of plants as a host plant. About 113 varieties of host plants have been described and 14 are very common in India. Kusum, Khair, Babul, Ber Palas and Ghont plants give better quality of lac.

**Distribution**:India has its monopoly on the production of lac. Other countries like Africa, Australia, Brazil, Burma, Sri Lanka, China, France, W. Germany, Japan, Malaya and several other countries.

## Food Plants:

The insects live as a parasite, feeding on the sap of certain trees and shrubs. The important trees on which the lac insects breed and thrive well are –

**Kusum (*Schleicheratrijuga*)**

**Palas (*Butea frondosa*)**

**Ber (*Zizyphusjujuba*)**

**Babul (*Acacia arabica*)**

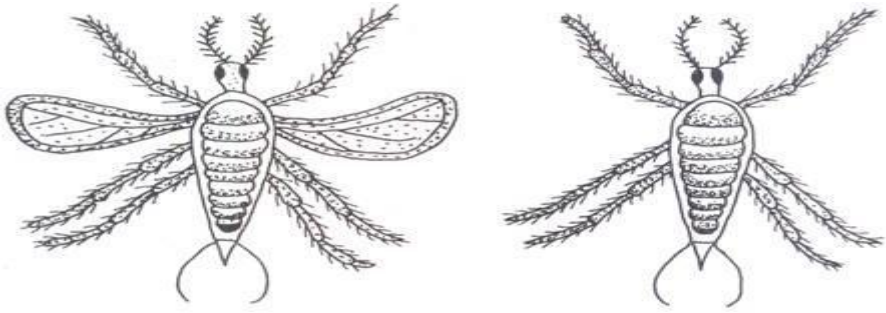
**Khair (*Acacia catcchu*)**

**Arhar (*Calanus indicus*)**

Before coming to the actual mechanism of lac secretion and its processing, it is advisable for a lac-culturist to have detailed knowledge of lac insect and its life cycle. The adult lac insect shows a marked phenomenon of sexual dimorphism. The male and female insect varies in shape, size and also in presence or absence of certain body parts.

## Structure of Male Lac-insect:

It is larger in size and red in colour. The body is typically divided into head, thorax and abdomen. The head bears a pair of antennae and a pair of eyes. Mouth parts are absent so a male adult insect is unable to feed. Thorax bears three pairs of legs. Wings may or may not be found. (Fig. 33 a, b).Abdomen is the largest part of the body bearing a pair of caudal setae and sheath containing penis at the posterior end.



(a) Male with wings (b) Male without wings

Fig. 33. Adult male lac-insect.

## Structure of Female lac-insect:

It is smaller in size. Head bears a pair of antennae and a single proboscis. Eyes are absent. Thorax is devoid of wings and legs. The loss of eyes, wings, and legs are due to the fact that the female larvae after settling down once never move again and thus these parts become useless and ultimately atrophy. Abdomen bears a pair of caudal setae. It is female lac insect which secretes the bulk of lac for commerce.

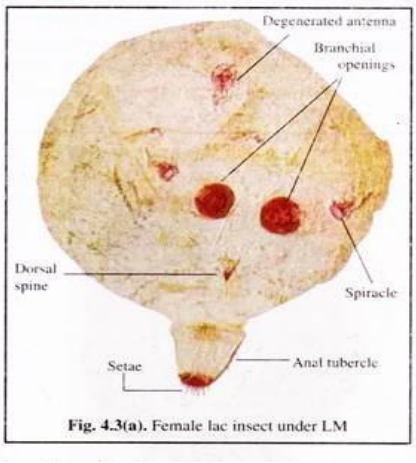



**Fig. 4.3(a).** Female lac insect under LM

**Fertilization:**After attaining the maturity, males emerge out from their cells and walk over the lac incrustations. The male enters the female cell through anal tubular opening and inside female cell it fertilizes the female. After copulation, the male dies. One male is capable of fertilizing several females. Females develop very rapidly after fertilization. They take more sap from plants and exude more resin and wax.

## Life Cycle:

**Egg:** The female lac insect is ovoviviparous in nature. So the laid eggs contain fully developed embryos within it. About 300-1000 such eggs are laid in the chambers (cell) in which the female remains encased. The egg laying period may last from 7 to 10 days. The eggs hatch within few hours of laying. But egg laying ceases if the temperature falls below 17°C in summer and 15°C in winter.

**Nymphs:**Following hatching, the first instar nymph stays within the cell for a brief period. Then the crimson red coloured nymphs, referred to as 'crawlers', come out of the cell in search of suitable host plant branch for settlement. The emergence of lac insect nymphs in huge number is commonly called swarming that continues for several weeks. Boat-shaped nymphs are very small in size (0.5 mm) and divisible into head, thorax and abdomen. Head bears antennae, ocelli and mouth. Thorax has 3 segments, each with one pair of leg and caudal setae are found at the end of abdomen.
On reaching soft succulent twigs, the nymphs settle down close together and start to suck phloem sap through their suctorial proboscis. After one day or so of settling, the nymphs start secreting lac from the hypodermal glands lying under their cuticle keeping open their mouthparts, breathing spiracles and anus. The secreted semisolid lac hardens on exposure to air and the nymph gets fully covered by the lac encasement, called as lac cell.

## Metamorphosis:

Within the cell, the nymphs moult thrice before reaching maturity. During first moult both male and female nymphs lose their appendages, legs and eyes. Following this moult, dimorphism appears in their cells. Inside the male cells, the male nymph casts off their second and third moults and matures into adults.

On maturity, the males lose their proboscis and develop antennae, legs and a pair of wings. The male brood cell is slipper- shaped. It bears a pair of branchial pores on the anterior side and a single large circular pore on the posterior side. The posterior hole remains covered by a round trap door or operculum through which adult males emerge. The female brood cell is larger, globular in shape that remains fixed to the twig. The female cell also has a pair of branchial pore and a single round anal tubular opening through which protrudes waxy white filaments (it indicates that the insect inside the cell is alive and healthy).

These filaments also prevent the blocking of the pore during excess secretion of lac. Following second and third moulting, the females retain only mouthparts but fail to develop any wings, eyes or appendages. While developing into adult, the female becomes immobile and large in size to accommodate huge number of eggs. During development, the females continuously secrete resin at a faster rate that coalesces around its body. After 14 weeks, the females shrink in size allowing light to pass into the cell.

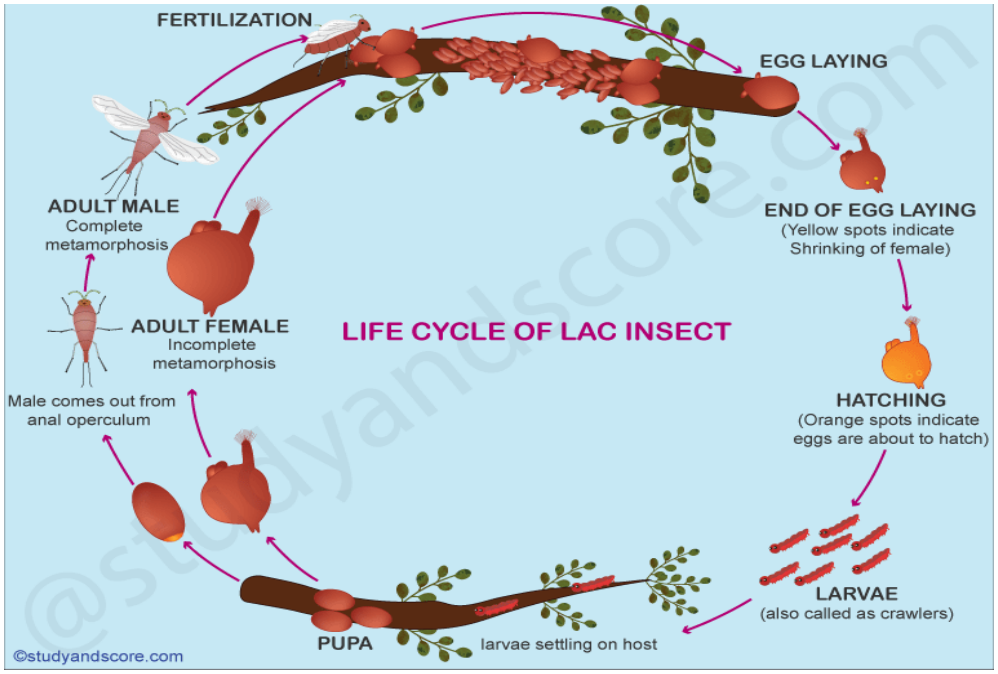
## Mating:

Following emergence, the winged males walk over the immobile females and fertilize their eggs. The males die soon after copulation. A male has life of 62-92 hours.

## Egg laying:

About the time of egg laying, two yellow spots appear at the rear end of the female cell which gradually enlarge and become orange in colour. At this time, the females contract at one end of the cell and thus vacates a space, called 'ovisac', inside the cell. Then the anal tubercle is drawn in the ovisac and the females start oviposit large number of eggs in the ovisac. The ovisac looks like orange due to presence of crimson lac dye which indicates the time of egg hatching.

Following hatching the nymphs emerge and the whole process begins all over again. After one cycle has been completed, and around the time when the next generation begins to emerge, the resin encrusted branches are harvested. From each crop, some encrusted twigs are retained for inoculation to the new host plants. Parthenogenesis: In the life history of lac insect, parthenogenesis is known to occur when unfertilised eggs are directly hatched into nymphs. It is common in Kartiki crop of Rangeeni Strain.




## Lac Secretion:

Lac is a resinous substance secreted by certain glands present in the abdomen of the lac insects. The secretion of lac begins immediately after the larval settlement on the new and tender shoots. This secretion appears first as a shining layer which soon gets hardened after coming in contact with air. This makes a coating around the insect and the twig on which it is residing. As the secretion continues the coating around one insect meet and fuses completely with the coating of another insect. In this way a continuous or semi-continuous incrustation of lac is formed on the tender shoots.

Fig. 36. Lac incrustation.

### Use of Lac:

Lac has been used for the welfare of human beings from the great olden days No doubt the development of many synthetic products have made its importance to a little lesser degree, but still it can be included in the list of necessary articles. Lac is used in making toys, bracelets, sealing wax, gramophone records etc.

It is also used in making grinding stones, for filling ornaments, for manufacturing of varnishes and paints, for silvering the back of mirror, for encasing cable wires etc., Waste materials produced during the process of stick lac is used for dying purpose. Nail polish is a good example of the by-product of lac.

### Composition of Lac:

Lac is a mixture of several substances, of which resin is the main constituent. The approximate percentage of different constituents of lac is given below:

Resin – 68 to 90%

Dye – 2 to 10%

Wax – 5 to 6%

Mineral matter – 3 to 7%

Albuminous matter – 5 to 10%

Water – 2 to 3%

## Cultivation of Lac:

Cultivation of lac involves proper care of host plants, regular pruning of host plant, infection or inoculation, crop-reaping, control of insect pests, and forecast of swarming, collection and processing of lac. The first and perhaps the most important prerequisite for cultivation of lac is the proper care of the host plant. It is the host plants on which lac insects depend for their food, shelter and for completion of their life cycle. There are two ways for the cultivation of host plants. One is that plants should be allowed to grow in their natural way and the function of lac-culturist is only to protect and care for the proper growth of plants.

Another way is that a particular piece of land is taken for the purpose and systematic plantation of host plant is made there. Regular watch is necessary in this case by providing artificial manures, irrigation facilities, ploughing and protecting the plants from cattle and human beings for which the land should be fenced. The larvae of lac insects are inoculated on host plants only after the host plants have reached a proper height.

The lac larvae feed on the cell sap by inserting their proboscis in the tender twigs. The proboscis can only be inserted in the tender young off-shoots. For this before inoculation, pruning of lac host plants is necessary. The branches less than an inch in diameter are selected for pruning. Branches half inch of less in diameter should be cut from the very base of their origin. But the branches more than half inch diameter should be cut at a distance of 1 ½ inch from the base.

## Inoculation:

The method by which the lac insects are introduced to the new lac host plant is known as inoculation. This may be of two types, namely "Natural infection" and "Artificial infection". When infection from one plant to other occurs by natural movements of insect, it is called natural infection. This may be due to overcrowding of insect population and non-availability of tender shoots on a particular tree.

Artificial infection takes places through the agencies other than those of nature. Prior to about two weeks of hatching, lac bearing sticks are cut to the size of six inches. They are called"Brood lac". Brood lacs are then kept for about two weeks in some cool place.

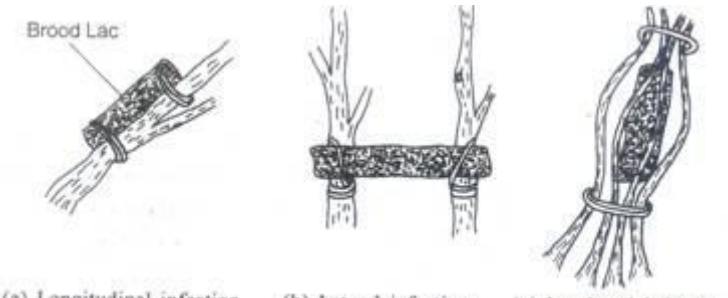


Fig. 37. Three different ways of artificial inoculation of lac.

When the larvae start emerging from this brood lac, they are supposed to be ready for inoculation. Strings can be used for tiding the brood lac with the host plant may be of different types in longitude infection the brood lac is tied in close contact with host branches. In lateral infection the brood lac is tied across the gaps between two branches. In interlaced method, brood lac is tied among the branches of several new shoots.

## Lac Crop:

The lac insects repeat its life cycle twice in a year. There are actually four lac crops since the lac insects behave in two ways either they develop on Kusum plants or develop on plants other than Kusum. The lac which grows on Non-Kusum plants is called as

"Ranjeemlac," and which grows on Kusum plant is called as "Kusumi lac. Four lac crops have been named after four Hindi months in which they are cut from the tree. They are as follows:

## Ranjeeni Crop:

**(i) Katki:**

Lac larvae are inoculated in June-July. Male insect emerges m August-September. Female give rise to swarming larvae in October-November and the crop is reaped in Kartik (October and November).

**(ii) Baisakhi**:

Larvae produced by Katki crop are inoculated in October-November, male insects emerges in February-March, females give rise to swarming larvae m June-July, the crop is reaped in Baisakh (April-May).

## Kusumi Crop:

**(i) Aghani**:

Lac larvae are inoculated in June-July, male insect emerges m September, female give rise to swarming larvae in January-February and crop is reaped in Aghan (December-January).

**(ii) Jethoi**:

The larvae produced by Aghani crop is inoculated in the month of January- February, male emerges in March-April, female give rise to swarming larvae in June- July and the crop is reaped in the month of Jeath (June-July).The time of infection with swarming larvae, the time of emergence of male insects, the time of reaping the crop, and the time of producing swarming larvae by female etc., are shown m tabular form below

| *Infection with swarming larvae* | *Emergence of male insect* | *Crop reaped* | *Female give rise to swarming larvae* |
|---|---|---|---|
| **Ranjeeni or Nankusumi Crop** | | | |
| Katki (June-July) | August | Oct.-Nov. | Oct.-Nov. |
| Baisakhi (Oct.-Nov.) | Feb.-March | April-May | June-July |
| **Kusumi Crop** | | | |
| Aghani (June-July) | September | Dec.-Jan. | Jan.-Feb. |
| Jethoi (January) | March-April | June-July | June-July |

## Scraping and Processing of lac:

Lac cut from the host plant is called as “stick lac”. Lac can be scraped from the twigs before or after the emergence of larvae. If it is used for manufacturing before the emergence of larvae, the type of lac produced is called as “Ari lac” and if it is used for manufacturing purpose after swarming of larvae has occurred, the lac is said to be Phunkilac”.The scraping of lac from twig is done by knife, after which they should not be exposed to sun. The scraped lac is grinded in hard stone mills. The unnecessary materials are sorted out In order to remove the finer particles of dirt and colour, this lac is washed repeatedly with cold water. Now at this stage it is called as “Seed lac” and is exposed to sun for drying. Seed lac is now subjected to the melting process. The melted lac is sieved through cloth and is given the final shape by moulding. The final form of lac is called “Shellac”. Colour or different chemicals may be mixed during melting process for particular need.

## Preparation of Feeding Ground for Lac Insects:

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

## Pruning:

Pruning means cutting away old, weak and diseased twigs from the host plants. It is done in January or June. It is very important for cultivation as it induces the host plants to throw out new succulent twigs. Pruning should be done with a sharp instrument to give a short and neat cut. If trees are old and have lost their capacity to produce vigorous shoots of new flush, heavier pruning is carried out to produce the new wood at the expense of the old. Such operation will bring the tree to a better shape, so that subsequent pruning will give the desired flush. Proper pruning should result in a good shape and give plenty of chances for the development of new shoots.

## Objectives of Pruning:

(1) To ensure new, good, healthy and succulent shoots.

(2) To ensure availability of large number of shoots (larger area for lac insect settlement).

(3) To provide rest to host plant for maintaining its vigour.

(4) To remove dead, diseased and broken branches.

## Types of Pruning in Lac Host Plants:

Two types of pruning have been recommended for lac culture.

**(i) Apical/ light pruning:**

Branches less than 2.5 cm diameter should be cut from base and branches more than 2.5 cm diameter should be sharply cut leaving a stump of 30-45 cm from the base. Diseased and dead portion of branches should be removed completely. Light pruning is recommended for slow growing conventional host tree species like Palas, Kusum and Ber.

**(ii) Basal / heavy pruning:**

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

## Pruning time:

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

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

## Enemies of Lac Insects and their Control:

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

**(1) Vertebrate enemies of lac insects:**

The important vertebrate enemies are squirrels and rats. In worst conditions, the damage caused by these enemies can be as serious as 50% of brood sticks. Squirrels are active during the daytime and the damage by them is more common under forest conditions. Rats are active at night-time and the damage usually occurs near about the villages.

Towards the crop maturity, these pests gnaw the mature lac encrustation on the tree, damage the brood lac tied to trees for inoculation and consume the full grown gravid female lac insects. The damage to brood lac tied to trees interferes with the inoculation, as the brood bundles and the lac encrustations drop to the ground where the larval

emergence is taking place. Besides squirrels and rats, monkeys also cause some damage to lac encrustations and to the newly developing shoots from pruned host trees by breaking them.

## Control:

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

### (2) Insect enemies of lac insect:

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

## There are two kinds of enemy insects:

(i) Parasites, and

(ii) Predators.

### (i) Parasites:

All parasites causing damage to lac insect belong to the Order Hymenoptera of class Insecta. A list of parasites associated with lac insect, *Kerria lacca* is presented in Table 4.4.

**Table 4.4 : Some important Parasites and Predators of lac insect**

| Parasite of lac insects | Family | Predators of lac insects | Family |
|---|---|---|---|
| *Anicetus dodonia* | Encyrtidae | *Eublemma amabilis* (Fig. 4.19) | Noctuidae |
| *Atropates hautefeuilli* | Encyrtidae | *E. coccidiphaga* | Noctuidae |
| *Aphrastobracon flavipennis* | Encyrtidae | *E. cretacea* | Noctuidae |
| *Bracon greeni* (Fig. 4.20) | Encyrtidae | *E. scitula* | Noctuidae |
| *Campyloneurus indicus* | Encyrtidae | *Pseudohypatopa pulverea* | Blastobasidae |
| *Coccophagus tchirchii* (Fig. 4.21) | Aphelinidae | *Catablemma sumbavensis* (Fig. 4.22) | Blastobasidae |
| *Erencyrtus dewitzi* | Encyrtidae | *Cryptoblabes ephestialis* | Blastobasidae |
| *Eupelmus tachardiae* (Fig. 4.23) | Eupelmidae | *Phroderces falcatella* | Cosmopterygidae |
| *Eurymyiocnema aphelinoides* | Aphelinidae | *Lacciferophaga yunnanea* | Momphidae |
| *Lyka lacca* | Encyrtidae | *Chrysopa madestes* | Chrysopidae |
| *Marietta javensis* | Aphelinidae | *C. lacciperda* | Chrysopidae |
| *Parageniaspis indicus* | Encyrtidae | *Berginus maindroni* | Mycetophagidae |
| *Parechthrodryinus clavicornis* | Encyrtidae | *Silvanus iyeri* | Cucujidae |
| *Protyndarichus submettalicus* | Encyrtidae | *Tribolium ferrugineum* | Tenebrionidae |
| *Tachardiaephagus tachardiae* | Encyrtidae | *Phyllodromia humbertiana* | Blattellidae |
| *Teachardiobius nigricans* | Encyrtidae | *Ishonoptera fulvastrata* | Blattellidae |
| *Aprostocetus (Tetrastichus) purpureus* (Fig. 4.24) | Eulophidae | *Dolichoderus thoracicus* | Formicidae |

Among the parasites listed, *Tachardiaephagustachardiae* and *Tetrastichuspurpureus* are the most abundant lac associated parasites. They lay their eggs in the lac cells and the grubs (larvae) after hatching start to feed on the lac insect within its cell.

**(ii) Predators:**
The predators, on the other hand, are more serious and may cause damage up to 30-35 per cent to the cells in a crop. The important predators of lac insects are listed in Table 4.4. Of the predators, *Eublemmaamabilis* and *Pseudohypatopapulverea* are the most destructive to lac insects and are in regular occurrence but their incidence may vary from season to season, place to place and crop to crop.

## Prevention and Control of Insect Enemies:

**Preventive measures:**
(a) Parasite- and predator- free brood lac should be used for inoculation.

(b) Self-inoculation of lac crops should be avoided as far as possible.

(c) Inoculated brood bundles should be kept on the host tree for a minimum period only.

(d) Phunki (empty brood lac sticks) should be removed from the inoculated trees in 2-3 weeks time.

(e) All lac cut from the tree and all phunki brood lac (after use as brood lac) not required for brood purpose should be scraped or fumigated at once.

(f) Cultivation of Kusmi strain of lac should be avoided in predominantly Rangeeni area and vice versa.

## a. Mechanical control:
Use of 60 mesh synthetic netting (brood bag) to enclose brood lac for inoculation purposes can reduce infestation of enemy insects of lac.

The emerging lac larvae easily crawl out from the minute pores of the net and settle on the twigs of the lac host plants, whereas the emerging adult predator enemies cannot move out of the brood bags and get entrapped within the net. This can check the egg laying by the predator moths on the new crop.

## b. Chemical control:
Application of 0.05% endosulphan at 30-35 days stage of crop has been identified as the most effective dose of insecticide without any adverse effect on the economic attributes of the lac insect.

## c. Microbial control:

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

## d. Biological control:

Two ant predators, viz. *Camponotuscompresus* and *solenopsis geminate*, are the most important and promising for biological control of predator enemies of lac in field condition. Egg parasitoids, viz. *Trichogrammapretiosum, T. chilonis, T. poliae, Trichogrammatoideabactrae*and *Telenomus remits*, have been found to be effective in management of many lac predators like *P. pulverea*.

Again, hyperparasitism is found to happen in some lac cultivation areas where parasites of lac insects could also be controlled biologically by hyperparasitic insects, viz., *Aprostocetus (Tetrastichus) purpureus* (Fig. 4.24) is secondary parasite of *Coccophaqustchirchii* (Fig. 4.21), and *Eupelmustachardiae* (Fig. 4.23) is a secondary parasite of *Eublemmaamabilis*.

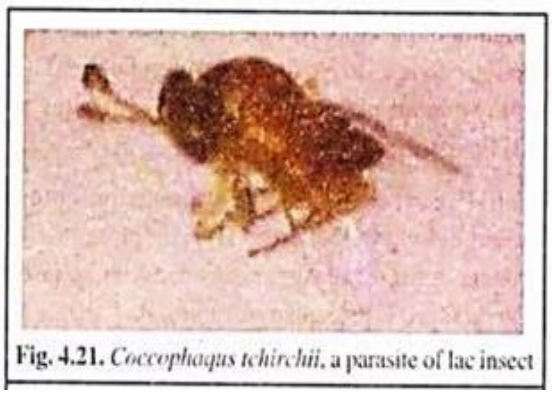


**Fig. 4.21.** *Coccophaqus tchirchii*, a parasite of lac insect

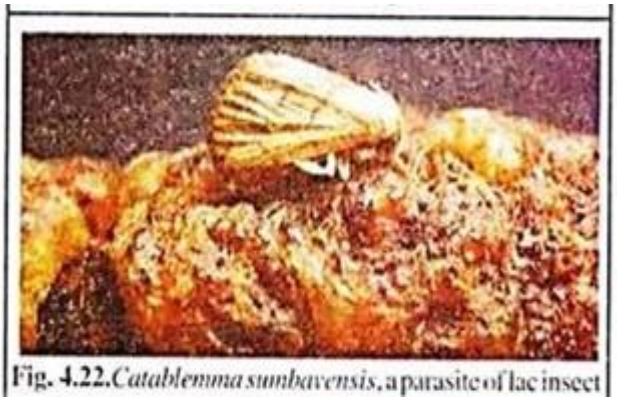


**Fig. 4.22.** *Catablemma sunbavensis*, a parasite of lac insect

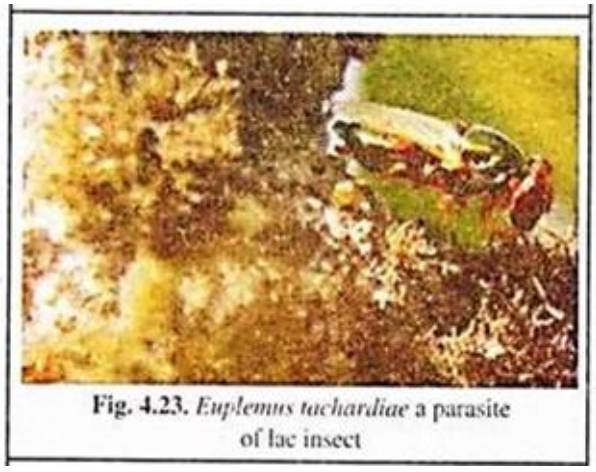


**Fig. 4.23.** *Euplemus tachardiae* a parasite of lac insect

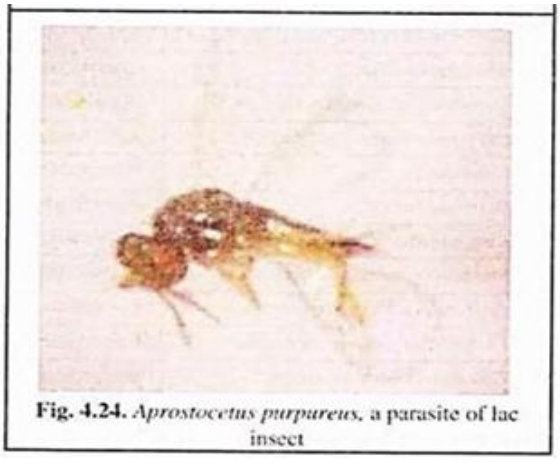


**Fig. 4.24.** *Aprostocetus purpureus*, a parasite of lac insect

## Microbial Flora Associated with Lac Insects:

Two types of microflora, viz. bacteria and fungi, are associated with the lac insects. Bacteria could be symbiotic or pathogenic. Microbial studies revealed that four species,

viz. *Micrococcus varians. M. conglomerates, Clostridium sp.* and *Bacillus subtilis*, are found in permanent association with various stages of lac insects. Presence of various symbiotic microflora is considered beneficial for good yield of lac, particularly during rainy season crop. However, on the other hand, association of fungi with lac insect is not always beneficial.

## Fungal infection in lac culture causes severe losses of lac yield by:

(1) Killing the lac insects by inhibiting respiration.

(2) Hindering mating process.

(3) Blocking larval emergence.

(4) Affecting lac host efficiency.

Lac culture during rainy season is prone to fungal attack particularly when grown on Ber and Kusum trees due to their steady and spreading crown. Three species of fungi belonging to family Eurotiaceae and Aspergillaceae, viz. *Aspergillus awamori, Aspergillus terricola* and *Penicillium citrinum,* are reported to cause maximum loss in lac crop. *Aspergillus awamori* (Fig. 4.25) and *Penicillium citrinum* are black and greenish in colour respectively, and make a continuous cover on lac insect cells and thereby blocking their breathing pores which ultimately lead to mortality of lac insects. A pathogenic fungus, *Pythium* sp. in female tests, causes a heavy mortality of the larvae which fail to enclose satisfactorily and lie dead in clusters within the female resinous cells.

Fig. 4.25. Fungal-cover on lac encrustation

## Prevention and control:

Application of fungicides, Bavistin (carbendazim 0.05%) and Dithane M-45 (mancozeb, 0.18%) by both dipping of brood lac before inoculation and spraying on standing crop gives significantly better yield of lac. Significant reduction (84% to 75%) in mortality of

2nd instar lac nymphs/larvae can be done by the application of different concentrations of carbendazim and aureofungin on Kusumi stain of lac insects.

## Present Position of this Industry in India:

Lac is produced in a number of countries including India, Thailand, Mayanmar, China, Indonesia, Vietnam and Laos. India and Thailand are the major producers, producing on the average 1700 tonnes of lac annually, followed by China. India alone, accounts for about 70/o of global lac production.

Former Bihar is the most important lac producing state of India. The Indian council of Agriculture Research has established Indian Lac Research Institute at Namkum in Ranchi district of Jharkhand.The average of different states in the total quantity of stic lac produced in this country is given below:

**Bihar – 55.5%, Madhya Pradesh – 22% ,West Bengal – 10%, Maharashtra – 7.1%, Gujrat – 2.7% , Uttar Pradesh – 1.8%, Assam – 0.6% and Orissa – 0.1%**

Total annual global production of pure lac is estimated to be 20,000 tonnes. The average total production of stick lac in India is about 24,000 tonnes, while the annual average pure lac produced in the country is 11,890 tonnes. About 6000 tonnes of pure lac produced in India is exported to different countries of the world, with an average earning of Rs. 202.38 million in term of foreign exchange. It has been estimated that 3-4 million people mostly tribals are engaged in the cultivation and several thousands in addition are engaged in the trade and manufacture of lac. Two main competitors of Indian lac are (i) Thailac, which accounts 50% of the total lac exported, and (ii) Synthetic resion, which have replaced lac in certain field. Shellac being a versatile resion, there is immense scope of increasing its utilisation in various fields and there is also scope to modify it to meet particular need.

## Probable questions:

1. What is lac? Describe its composition and uses.
2. Describe structure of a male and female lac insect.
3. Write down the life cycle of lac insect with suitable diagram.
4. What are different type of Ranjeeni crops?
5. What are different type of Kusumi crops?
6. What is prunning? What are the objectives of prunning?
7. Describe types of prunning in lac host plant.
8. What is the present status of lac culture in India.
9. Describe different parasites in lac culture. Also state their control measures.
10. Describe different predatores in lac culture. Also state their control measures.

## Suggested Readings:

1. The Insects by Chapman
2. Modern Entomology by D.B. Thembare
3. Economic Zoology by Shukla and Upadhyay
4. The Insects by Gullan and Carnston
5. Introduction to Economic Zoology by Sarkar, Kundu and Chaki.
6. A textbook of Economic Zoology by Aminul Islam

# Unit-IV

## Sericulture: Mulberry silkworm; rearing of silkworms; sericulture industry; recent efforts sericulture in India

**Objective:**In this unit you will know about sericulture: Indigenous races, pure races and commercial races of mulberry silk moth; Rearing of mulberry silk moth.

### Introduction:

Silk production has a long history. Silk was discovered by Xilingji (Hsi-ling-chi), wife of China's 3rd Emperor, Huangdi (Hoang-Ti), in 2640 B.C. While making tea, Xilingji accidentally dropped a silkworm cocoon into a cup of hot water and found that the silk fiber could be loosened and unwound. Fibers from several cocoons could be twisted together to make a thread that was strong enough to be woven into cloth. Thereafter, Hsiling chi discovered not only the means of raising silk worms, but also the manners of reeling silk and of employing it to make garments. Later sericulture spread throughout China, and silk became a precious commodity, highly sought after by other countries. Demand for this exotic fabric eventually created the lucrative trade route, the historically famous Silk Road or Silk Route named after its most important commodity. This road helped in taking silk westward and bringing gold, silver and wool to the East. With the mulberry silk moth native to China, the Chinese had a monopoly on the world's silk production. After 1200B.C. Chinese immigrants who had settled in Korea helped in the emergence of silk industry in Korea. During the third century B.C. Semiramus, a general of the army of Empress Singu-Kongo, invaded and conquered Korea. Among his prisoners were some Sericulturists whom he brought back to Japan. They helped in the establishment and growth of sericulture industry in Japan. Another story is that a Chinese princess married an Indian prince. She carried silkworm eggs/mulberry cocoons in her elaborate head dress. She disclosed the secret of raising silkworms thus, silk production spread in India. In 550A.D. moth eggs and mulberry seeds were smuggled from China by two Nestorian monks, sent by Emperor Justinian-I and silk production began in Byzantium. The technique of sericulture spread throughout the Mediterranean countries during the 7th century AD and then to Africa, Spain and Sicily. During latter part of the 19th century, modern machinery, improved techniques and intensive research helped the growth of sericulture industry in Japan. At present, Japan, China, Korea, Italy, Soviet Union, France, Brazil and India are the chief silk producing countries in the World.

## Sericulture and its components:

Commercial rearing of silk producing silkworm is called sericulture. It is an agrobased industry comprising three main components:

i) cultivation of food plants of the worms,

ii) rearing of silk worms, and

iii) reeling and spinning of silk.

The first two are agricultural and the last one is an industrial component. There are four varieties of silkworms in India, accordingly sericulture is classified into Mulberry Culture, Tasar Culture, Muga Culture and Eri Culture, and each one is described separately in the following text.

## Taxonomy:

Silk producing insects are commonly referred to as serigenous insects. Silkworm is a common name for the silk-producing caterpillar larvae of silk moths. Silk moths belong to Phylum - Arthropoda, Class - Insecta, Order - Lepidoptera, Super family - Bombycoidea. Bombycoidea comprises eight families of which only Bombycidae and Saturnidae are the two important families the members of which produce natural silk. There are several species of silkworm that are used in commercial silk production.These are:

**(i) Mulberry silk worm**

- *Bombyx mori* (Bombycidae)
- *Bombyx mandarina* (Bombycidae)

**(ii) Tasar silk worm**

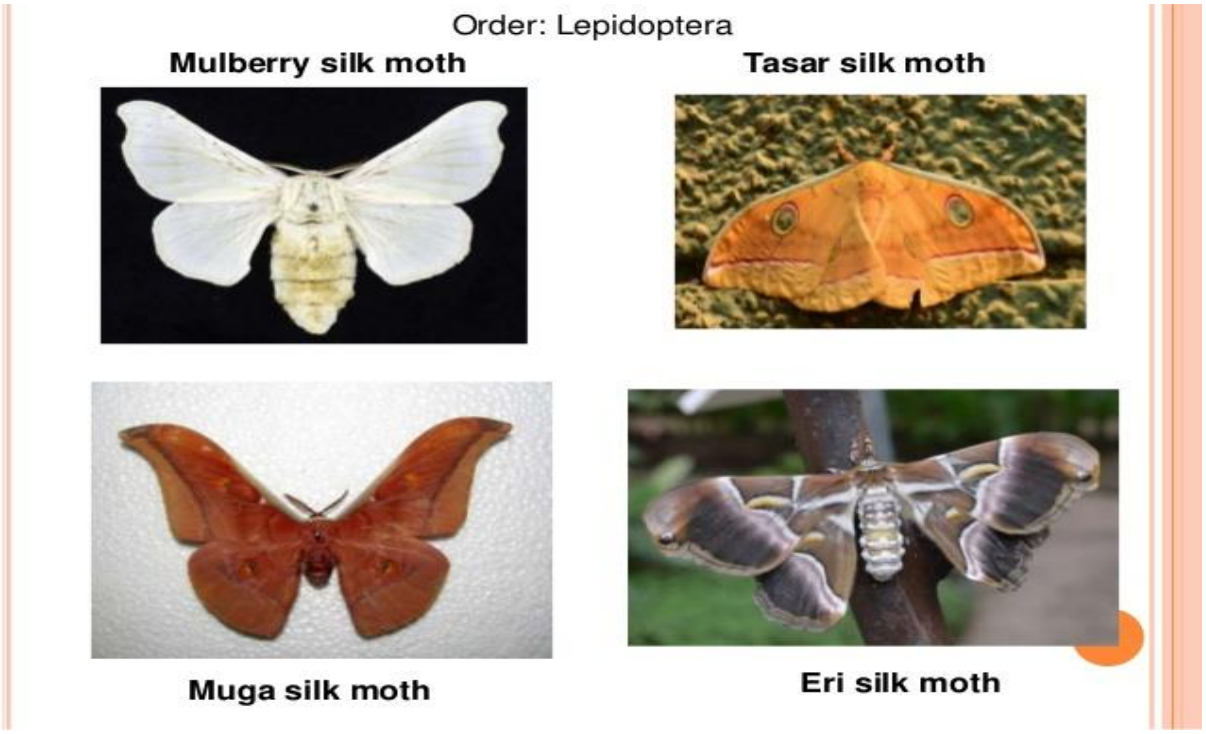
- *Antheraeamylitta*( Saturnidae)
- *Antheraeapernyi*( Saturnidae)
- *Antheraeayamamai*( Saturnidae)
- *Antheraeapaphia*( Saturnidae)
- *Antheraearoyeli*( Saturnidae)

**(iii) Muga Silkworm**

- *Antheraeaassama*( Saturnidae)

**(iv) Eri silk worm**

- *Philosamiaricini*( Saturnidae)




## Mulberry Culture :

## Biology of Mulberry Silkworm:

The insect producing mulberry silk is a domesticated variety of silkworms, which has been exploited for over 4000 years. All the strains reared at present belong to the species B*ombyx mori* that in believed to be derived from the original Mandarina silkworm, *Bombyx mandarina* Moore. China in the native place of this silk worm, but now it has been introduced in all the silk producing countries like Japan, India, Korea, Italy, France and Russia.

The races of mulberry silk worm may be identified on the basis of geographical distribution as Japanese, Chinese, European or Indian origin; or as Uni-, Bi- or Multivoltine depending upon the number of generations produced in a year under natural conditions; or as Tri-, Tetra- and Penta-moulters according to the number of moults that occur during larval growth; or as pure strain and hybrid variety according to genetic recombination.

## Life Cycle :

Life cycle of the silkworm consists of four stages i.e. adult, egg, larva, and pupa. The duration of life cycle is six to eight weeks depending upon racial characteristics and climatic conditions. Multivoltine races found in tropical areas have the shortest life cycle with the egg, larval, pupal and adult stages lasting for 9-12 days, 20-24 days, 10-12 days and 3-6 days, respectively. Seven to eight generations are produced in multivoltine races. In univoltineraces, the egg period of activated egg may last for 11-14 days; the larval period, 24-28 days; the pupal period, 12-15 days and the adult stage, 6-10 days. In

nature, uni-voltine races produce only one generation during the spring and the second generation of eggs goes through a period of rest or hibernation till the next spring. In case of bivoltine races, however, the second generation eggs do not hibernate and hatch within 11- 12 days and produce second generation normally during summer and it is the third generation eggs which undergo hibernation and hatches in the next spring, and thus producing two generations in one year.

## Egg:

Egg is round and white. The weight of newly laid 2,000 eggs is about 1.0 g. It measures 1-1.3 mm in length and 0.9-1.2 mm in width. With time, eggs become darker and darker. Races producing white cocoons lay pale yellow eggs; while races producing yellow cocoons lay deep yellow eggs. In case of hibernating eggs laid by bivoltine and univoltine races, the egg colour changes to dark brown or purple with the deepening of colour of the serosal pigments.

The eggs may be of diapause or non-diapause type. The diapause type of eggs are laid by the silkworms inhabiting in temperate regions; whereas silkworms belonging to subtropical regions like India lay non-diapause type of eggs. During diapause all vital activities of the eggs cease.

## Larva:

After 10 days of incubation, the eggs hatch into larva called caterpillar. After hatching caterpillars need continuous supply of food, because they are voracious feeders. Newly hatched caterpillar is about 0.3 cm in length and pale yellowish white. The larval body in densely covered with bristles. As the larva grows, it becomes smoother and lighter in colour due to rapid stretching of the cuticular skin during different instars of the larval stage. The skin consists of cuticle and hypodermis. Cuticle is made up of chitin as well as protein and is covered with a thin layer of wax, which is capable of being extended considerably to permit rapid growth of the larva during each instar. Nodules are found all over the surface of the body, and the distribution pattern differs according to the variety of silkworm. Larva bears four pairs of tubercles: sub-dorsal, supra-spiracular, infraspiracular and basal tubercle. Each tubercle carries 3-6 setae.

The larval body is composed of head, thorax and abdomen. The head consist of six fused segments. It carries the appendages: antennae, mandibles, maxillae and labium. Median epicranial suture, clypeus and labrum are well developed and prominent. Six pairs of larval eyes or ocelli are located a little above the base of antennae. Five segmented antennae are used as sensory organs. The mandibles are well developed, powerful and adapted for mastication. The maxillary lobe and palpi help in discriminating the taste of food. The prementum is also chitinized, and its distal part carries a median process known as spinneret through which silk is extruded out from the silk gland. The sensory labial palpi are found on both sides of the spinneret.

The thorax has three segments: prothorax, mesothorax and metathroax. Each of the thoracic segments carries ventrally one pair of true legs, which are conical in shape and carry sharp distal claws. These claws are not used for crawling but they help in holding the leaves while feeding.

Abdomen consists of eleven segments, though only nine can be distinguished, as the last three are fused together to from the apparent ninth segment. Third to sixth and last abdominal segment bear a pair of abdominal legs, which are fleshy, unjointed muscular protuberance. Eighth abdominal segment bears caudal horn on the dorsal side.

The abdominal segments carry the sexual markings on ventral side, which are developed distinctly during fourth and fifth instars in the eighth and ninth segments. In females, the sexual marking appear as a pair of milky white spot in each of the eighth and ninth segments and are referred to as Ishiwata's Fore Gland and Ishiwata's Hind Gland respectively. In males a small milky white body known as Herold's Gland appears ventrally in the centre between eighth and ninth segments. Nine pairs of spiracles are present: one pair on the first thoracic segment and eight pairs one on each side of the first to eighth abdominal segments, respectively

The larval growth is marked by four moultings and five instar stages. The full-grown caterpillar develops a pair of sericteries or silk glands. Sericteries or silk glands are modified labial glands. These glands are cylindrical and divided into three segments: Anterior-, middle- and posterior-segments. The inner lining cells are characterized by the presence of large and branched nucleus. These glands secrete silk which consists of an inner tough protein, fibroin, enclosed by a water soluble gelatinous protein, sericin. In Bombyx, the fibrinogen which on extrusion is denatured to fibroin is secreted in the posterior segment of the gland and form the core of the silk filament in the form of two very thin fibres called brins. The sericin, a hot water soluble protein, secreted by middle segment of the gland, holds the brins together and covers them. The duct from another small gland called Lyonnet's gland, that lubricates the tube through which the silk passes, joins the ducts of the silk glands. Finally, the silk is moulded to a thread as it passes through the silk press or spinneret.

## Pupa:

Pupa is the inactive resting stage of silkworm. It is a transitional period during which definite changes take place. During this period, biological activity of larval body and its internal organs undergo a complete change and assume the new form of adult moth. The mature silkworm passes through a short transitory stage of pre- pupa before becoming a pupa. During the pre-pupal stage, dissolution of the larval organs takes place which is followed by formation of adult organs. Soon after pupation the pupa is white and soft but gradually turns brown to dark brown, and the pupal skin becomes harder.

A pair of large compound eyes, a pair of antennae, fore and hind-wings, and the legs are visible. Ten segments can be seen on the ventral side, but only nine are visible on the dorsal side. Seven pairs of spiracles are present in abdominal region, the last pair being non-functional. Sex markings are prominent and it is much easier to determine the sex of pupa. The female has a fine longitudinal line on the eighth abdominal segment, whereas such marking is absent in case of male. The pupa is covered within a thick, oval, white or yellow silken case called cocoon. The pupal period may last for 8-14 days after which the adult moth emerges slitting through the pupal skin and piercing the fibrous cocoon shell with the aid of the alkaline salivary secretion that softens the tough cocoon shell.

## Adult:

The adult of *Bombyx mori* is about 2.5 cm in length and pale creamy white. After emergence the adult is incapable of flight because of its feeble wings and heavy body. It does not feed during its short adult life. The body of moth has general plan of insect body organization .The ocelli are absent. The antennae are conspicuous, large and bipectinate. The meso- and meta-thorax bear a pair of wings. The front pair overlap the hind pair when the moth is at rest.

The moth is unisexual and shows sexual dimorphism. In male eight abdominal segments are visible; while in female, seven. The female has comparatively smaller antennae. Its body and the abdomen are stouter and larger, and it is generally less active than male. The male moth possesses a pair of hooks known as harpes at its caudal end; while the female has a knob like projection with sensory hair. Just after emergence, male moths copulate with female for about 2-3 hours, and die after that. The female starts laying eggs just after copulation, which is completed within 24 hours. A female lays 400-500 eggs. The eggs are laid in clusters and are covered with gelatinous secretion of the female moth.

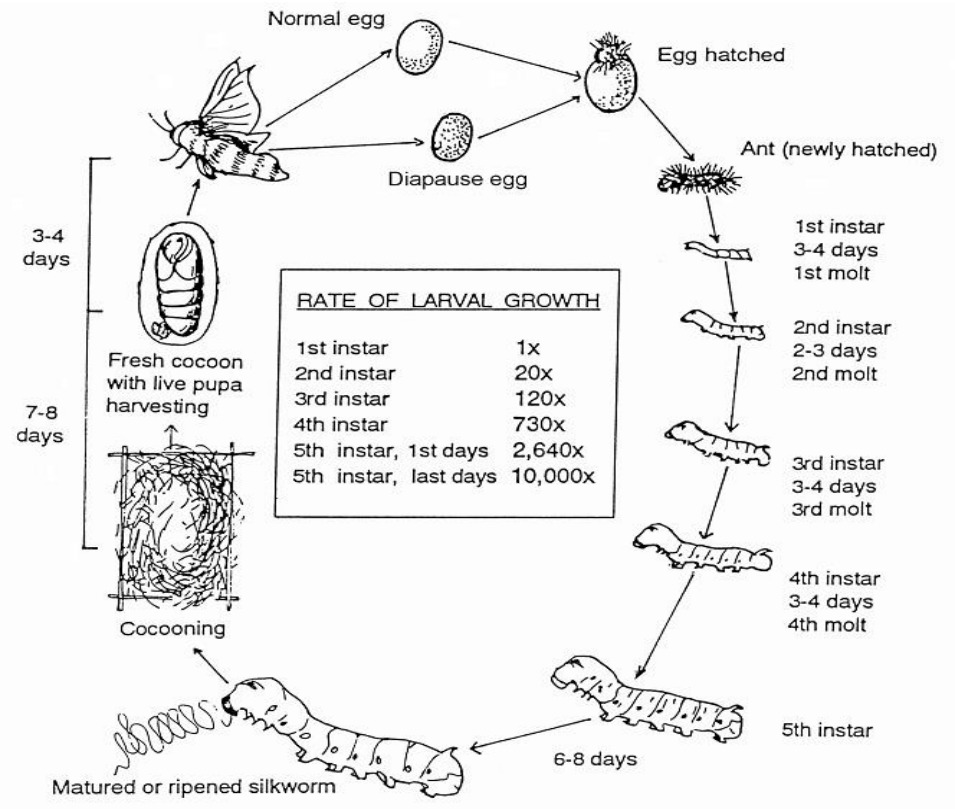



**Figure: Life cycle of *Bombyx mori***

## Rearing of Mulberry Silkworm

## Mulberry Cultivation:

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*. Mulberry is propagated either by seeds, root- grafts or stem cuttings, the last one being most common. Cuttings, 22-23 cm long with 3-4 buds each and pencil thick, are obtained from mature stem. These are planted directly in the field or first in nurseries to be transplanted later. After the plants have grown, pruning is carried out routinely which serves two purposes, induction of growth and sprouting of new shoots.

Harvesting of leaves for feeding larva is done in three ways: leaf picking, branch cutting and top shoot harvesting. In leaf picking, individual leaves are handpicked. In branch cutting method, entire branch with leaves are cut and offered to 3rd instar larva. In top shoot harvesting, the tops of shoots are clipped and given to the 4th & 5th instars. The yield and quality of leaf depend upon the agronomic practices for cultivation of mulberry. trees, namely irrigation, application of fertilizers etc. It is estimated that 20,000 to 25,000 kg of leaves can be harvested per hectare per year under optimum conditions. It has also been estimated that to rear one box of 20,000 eggs, 600-650 kg of leaves are required for spring rearing and 500-550 kg for autumn rearing in Japan. In India, to rear 20,000 eggs the quantity of leaves required is about 350-400 kg.

## Rearing Equipment:

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

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

**iii) Ant well:** Ant wells are provided to stop ants from crawling on to trays, as ants are serious menace to silk worms. They are made of concrete or stone blocks 20 cm square and 7.5 cm high with a deep groove of 2.5 cm running all round the top. The legs of the rearing stands rest on the centre of well filled with water.

**iv) Rearing tray:** These are made of bamboo or wood so that they are light and easy to handle. These are either round or rectangular.

**v) Paraffin paper:** This is a thick craft paper coated with paraffin wax with a melting point of 55o C. It is used for rearing early stages of silk worms and prevents withering of the chopped leaves and also help to maintain proper humidity in the rearing bed.

**vi) Foam rubber strips:**Long foam rubber strips 2.5 cm wide and 2.5 cm thick dipped in water are kept around the silkworm rearing bed during first two instar stages to maintain optimum humidity. Newspaper strips may also be used as a substitute.

**vii) Chopsticks:** These are tapering bamboo rods (1cm in diameter) and meant for picking younger stages of larvae to ensure the hygienic handling.

**viii) Feathers:** Bird feathers preferably white and large are important items of silkworm rearing room. These are used for brushing newly hatched worms to prevent injuries.

**ix) Chopping board and Knife:** The chopping board is made up of soft wood it is used as a base for cutting leaves with knife to the suitable size required for feeding the worms in different instar stages.

**x) Leaf chambers:** These are used for storing harvested leaves. The sidewalls and bottom are made of wooden strips. The chamber is covered on all sides with a wet gunny cloth.

**xi) Cleaning net:** These are cotton or nylon nets of different mesh size to suit the size variations of different instars of the silk worm. These are used for cleaning the rearing beds, and at least two nets are required for each rearing tray.

**xii) Mountages:** These are used to support silkworm for spinning cocoons. These are made up of bamboo, usually 1.8 m long and 1.2 m wide. Over a mat base, tapes (woven out of bamboo and 5-6 cm wide) are fixed in the form of spirals leaving a gap of 5-6 cm. They are also called chandrikes. Other types of mountage such as centipede rope mountage, straw cocooning frames etc. are also used.

**xiii) Hygrometers and Thermometers:** These are used to record humidity and temperature of the rearing room.

**xiv) Feeding stands:** These are small wooden stands (0.9 m height) used for holding the trays during feeding and bed cleaning.

Other equipment like feeding basins, sprayer, and leaf baskets may also be required.

## Rearing Practices:

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

## a. Procurement of quality seeds:

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

## b. Brushing :

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

## c. Preparation of feed bed and feeding :

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

The 4th and 5th instars are reared in wooden or bamboo trays by any of the three methods: viz., shelf-rearing, floor-rearing and shoot-rearing. In shelf rearing, the rearing trays are arranged one above the other in tiers on a rearing stand which can accommodate 10 -11 trays. This method provides enough space for rearing, but it is uneconomical as it requires large number of laborers to handle the trays. Chopped leaves are given as feed in this method. In floor rearing, fixed rearing sheets of 5-7x1-1.5m size are constructed out of wooden or bamboo strips in two tiers one meter apart. These sheets are used for rearing. Chopped leaves are given as feed. This method is economical than the first one because it does not involve much labour in handling of trays. Shoot-rearing is most economical of the three methods. The rearing sheet used is one meter wide and any length long in single tier and the larvae are offered fresh shoot or twigs bearing leaves. This method can be practiced both outdoors and indoors depending upon the weather. Each age of the silk worms could be conveniently divided into seven stages. First feeding stage, sparse eating stage, moderate eating stage, active eating stage, premoulting stage, last feeding stage, moulting stage. The larvae have good appetite at first feeding stage and comparatively little appetite at sparse and moderate eating stages. They eat voraciously during active stage to last feeding stage after which they stop feeding.

## d. Bed Cleaning :

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

## e. Spacing :

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

## f. Mounting

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

## g. Harvesting of Cocoons:

The larva undergoes metamorphosis inside the cocoon and becomes pupa. In early days, pupal skin is tender and ruptures easily. Thus, early harvest may result in injury of pupa, and this may damage the silk thread. Late harvest has a risk of threads being broken by the emerging moth. It is, therefore, crucial to harvest cocoons at proper time. Cocoons are harvested by hand. After harvesting the cocoons are sorted out. The good cocoons are cleaned by removing silk wool and faecal matter and are then marketed. The cocoons are sold by farmers to filature units through Cooperative or State Govt. Agencies. The cocoons are priced on the basis Rendita and reeling parameters. Rendita may be defined as number of kg of cocoon producing 1 kg of raw silk.

## Post Cocoon Processing :

It includes all processes to obtain silk thread from cocoon.

**a. Stifling**

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

**b. Reeling**

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

## Diseases and Pests of Silkworms:

## I. Diseases:

## a. Pebrine:

Pebrine is also known as pepper disease or corpuscle disease. The disease is caused by a sporozoan, *Nosema bombycis* (family Nosematidae). The main source of infection is food contaminated with spores. Infection can be carried from one larva to another by the spores contained in faeces or liberated in other ways by the moths carrying infection. Pebrinized eggs easily get detached from the egg cards. They may be laid in lumps. The eggs may die before hatching. The larva shows black spots. They may become sluggish and dull, and the cuticle gets wrinkled. Pupa may show dark spots. Moths emerging from pebrinized cocoons have deformed wings and distorted antennae. The egg laying capacityof the moth becomes poor.

## b. Flacherie:

Flacherie is a common term to denote bacterial and viral diseases. It has been classified into following types:-

**i) Bacterial diseases of digestive organs:** Due to the poor supply of quality mulberry leaves, the digestive physiology of the silkworm is disturbed, and multiplication of bacteria occurs in the gastric cavity. Bacteria like Streptococci, Coli, etc. have been found associated with this disease. Symptoms, like diarrhoea, vomiting, shrinkage of larval body may be seen.

**ii) Septicaemia:** Penetration and multiplication of certain kinds of bacteria in haemolymph cause septicaemia. The principal pathogenic bacteria are large and small Bacilli, Streptococci, and Staphylococci etc. Symptoms like diarrhoea, vomiting, shrinkage of larval body may be seen. Appearance of foul odour is also a common symptom.

**iii) Sotto disease:** It is caused by toxin of *Bacillus thuringensis*. The larvae become unconscious, soft, and darkish and rot off.

**iv) Infectious Flacherie:** It is caused by a virus called Morator Virus which does not form polyhedra in the body of silkworm larvae. The infection occurs mainly through oral cavity. The virus multiplies in the midgut and is released into the gastric juice and is excreted in faeces.

**v) Cytoplasmic polyhedrosis:** It is caused by a virus called Smithia which form Polyhedra are formed in the cytoplasm of the cylindrical cells of the midgut. The larva loses appetite. The head may become disproportionately large. Infection occurs through the oral cavity.

## c. Grasserie:

The disease is also known as Jaundice or Nuclear Polyhedrosis It is caused by a virus called Borrelina, which form polyhedra in the nuclei of the cells of fatty tissues , dermal tissues, muscles, tracheal membrane, basement membrane, epithelial cells of midgut and blood corpuscles. The infected larvae lose appetite, become inactive, membranes become swollen, skin becomes tender and pus leaks out from skin. The larvae finally die.

## d. Muscardine or Calcino: It is of 3 types

**i) White Muscardine:** It is caused by the fungus, *Beuveriabassiana*. The larva loses appetite, body loses elasticity and they cease to move and finally die.

**ii) Green Muscardine:** It is caused by *Metarrhiziumanisopliae*. The larva loses appetite, appears yellowish, becomes feeble and dies.

**iii) Yellow Muscardine:** It is caused by *Isariafarinosa*. Many small black specks appear on the skin. Larvae lose appetite and dies.

## II. Pests

***Tricholygabombycis*:** It is a dipteran fly of the family tachinidae, commonly known as Uzi fly. It is a serious pest of silkworm larvae and pupae. It parasitizes Mulberry and Tasar silkworm.

**Dermestid beetles:** These insects belong to the order Coleoptera, family dermestidae. This family contains many genera and a large number of destructive species. Some of them are: *Dermestescadverinus, D. valpinus, D. vorax, D. frishchi,* and *Trogoderma versicolor*. The larvae bore inside the cocoon and eat the pupa. These pests cause great damage and economical loss, as the damaged cocoons cannot be reeled.

**Mites:** *Pediculoidesventricosus* (order Acarina, class Arachnida) damage the larvae. The toxic substance produced by the mite kills the silkworms. In addition, ants, lizards, birds, rats and squirrel also cause considerable damage to silkworm larvae as well as the cocoons.

## Silk and Its Use:

## Properties of the silk:

Silk contains 70-75% fibroin and 25-30% sericin protein. The biochemical composition of fibroin can be represented by the formula $C_{15}H_{23}N_5O_6$. It has the characteristic appearance of pure silk with pearly lustre. It is insoluble in water, ether or alcohol, but dissolves in concentrated alkaline solutions, mineral acids, and glacial acetic acid and in ammoniacal solution of oxides of copper. Sericin, a gummy covering of the fiber is a gelatinous body which dissolves readily in warm soapy solutions and in hot water, which on cooling forms a jelly with even as little as 1% of the substance. It is precipitated as a white powder from hot solutions by alcohol. Its chemical formula is $C_{15}H_{25}N_5O_8$. It can be dyed before or after it has been woven into a cloth. The weight in gram of 900m long silk filaments is called a denier which represents size of silk filament.

## Silk has following peculiar properties:

1. Natural colour of Mulberry silk is white , yellow or yellowish green; that of Tasar brown; of Muga, light brown or golden; and of Eri, brick red or creamy white or light brown.

2. Silk has all desirable qualities of textile fibres, viz. strength, elasticity, softness, coolness, and affinity to dyes. The silk fibre is exceptionally strong having a breaking strength of 65,000-lbs/sq. inch.

3. Silk fibre can elongate 20% of original length before breaking.

4. Density is 1.3-1.37g/cm3 .

5. Natural silk is hygroscopic and gains moisture up to 11%.

6. Silk is poor conductor of heat and electricity. However, under friction, it produces static electricity. Silk is sensitive to light and UV- rays.

7. Silk fibre can be heated to higher temperature without damage. It becomes pale yellow at 110o C in 15 minutes and disintegrates at 165o C.

8. On burning it produces a deadly hydrocyanic gas.

## Use of silk:

## Silk is used in the manufacture of following articles:

a. Garments in various weaves like plain, crepe, georgette and velvet.

b. Knitted goods such as vests, gloves, socks, stockings.

c. Silk is dyed and printed to prepare ornamented fabrics for saries, ghagras, lehengas.

d. Jackets, shawls and wrappers.

e. Caps, handkerchiefs, scarves, dhotis, turbans.

f. Quilts, bedcovers, cushions, table-cloths and curtains generally from Erisilk or spun silk.

Parachutes and parachute cords.

g. Fishing lines.

h. Sieve for flour mills.

i. Insulation coil for electric and telephone wire.

j. Tyres of racing cars.

k. Artillery gunpowder.

l. Surgical sutures.

## Indian Scenario:

Silk is Nature's gift to mankind and a commercial fibre of animal origin other than wool. Being an eco-friendly, biodegradable and self-sustaining material; silk has assumed special relevance in present age. Promotion of sericulture can help in ecosystem development as well as high economic returns. Sericulture is practiced in India and India is the 5th largest producer of silk in the World. It has been identified as employment oriented industry. All the sections of sericulture industry, viz. mulberry cultivation, silkworm seed production, silkworm rearing, reeling and weaving of silk and collection of by-products and its processing provide a large scale employment, thereby a source of livelihood for the rural and tribal people. Sericulture industry is rated as the second largest employer in India.

Owing to this peculiar nature, the Indian planners have identified sericulture as one of the best suited occupations for ideal growth and development of rural India. Mulberry sericulture has been traditional occupation in Karnataka, Tamil Nadu, A.P. and Kashmir; Tasar one, in M.P., Chota Nagpur Division and Orissa; Muga one, in Assam, Nagaland, Tripura and Eri one in Assam and West Bengal. North-eastern part of India is the only region in the world where all four varieties of silk are produced. Central and State level Government Silk Departments are actively engaged in addressing the objective of promotion of sericulture in traditional as well as non-traditional regions. With the launching of massive developmental schemes, it is expected to gain an accelerated tempo of sericultural activities in the country, paving way for doubling the employment opportunities in phased manner, and thereby, it may set to bring a soothing touch to the burning problem of acute unemployment in rural India and thus can check the rural migration to urban areas to a certain extent. Sericulture is an agro-based cottage industry involving interdependent rural, semi-urban and urban-based activities in which estimated participation of women is about 60%. Thus, in contrast to any other agro-based profession the role of women in sericulture industry is dominating which will be helpful for improving the status of women in family enterprises. In the light of women welfare through Sericulture industry, the Central Silk Board, a statutory organization, under the Ministry of Textiles, Government of India has established a special component of assistance to Women and NGO's' into the National Sericulture Project.

## There are four major research centres for Sericulture in India:

1. Central Sericulture Research and Training Institute, Behrampur (Orissa).
2. Central Sericulture Research and Training Institute, Mysore (Karnataka).
3. Central Tasar Research and Training Institute, Ranchi (Jharkhand).
4. Central Silk Technological Research Institute, Bangalore (Karnataka).

## Probable questions:

1. Write down scientific names of Mulberry, Tasar , Muga and Eri silkmoth.
2. What is Voltinism? Name one of each type.
3. Describe life cycle of Bombyx mori with suitable diagram.
4. How mounting ids done in sericulture?
5. How cocoons are harvested?
6. Write down post cocoon processing.
7. Describe any two diseases of silkworm.
8. What is the present scenario of sericulture in India.
9. Describe the properties of silk.
10. What are the uses of silk?

## Suggested Readings:


1. The Insects by Chapman
2. Modern Entomology by D.B. Thembare
3. Economic Zoology by Shukla and Upadhyay
4. The Insects by Gullan and Carnston
5. Introduction to Economic Zoology by Sarkar, Kundu and Chaki.
6. A textbook of Economic Zoology by Aminul Islam

# UNIT-V

# Apiculture: Social organization of honey bee; selection of bees; methods of bee keeping; industrial application

**Objective:** In this unit we will discuss about honey bees, their caste system, life cycle and also different types of apiculture technique.

## Introduction:

Bees are a group of polymorphic colonial insects. They produce nutritive honey and wax; both the products are of commercial value. From very early times man knew that bees produce delicious honey that they sting, that they increase in number by swarming and that with smoke he can control honey bees. It was during the early part of the 19th century many scientific studies were conducted which revealed the biology, behaviour, life cycle and development of honey bees.

Previously man extracted honey by destroying the whole bee colony and the honey extracted was also of low quality because of the crude and unscientific way of handling. Today with the treasure of knowledge he has acquired he is able to divide a colony to start and rear new colonies.

Now sophisticated tools and new methods are available to extract honey from hives without much disturbing the hive colony and the wax combs can be reused. Pathology of honey bees are extensively studied and drugs are now available to control diseases in bees. Another leap in bee-culture technique is the artificial insemination of queens for increased honey production in colonies.

Honey bees are most familiar insects. They are best known for their labour, small saving, colonial life and division of labour. They are characterized by the presence of a highly specialized type of legs, mouth parts, membranous wings and communal behaviour. The “waggle dance” and “language of bee” is a remarkable feature. Preparation of chambered nest its hygiene and maintenance are points to be noted.In Indian subcontinent uses of bees and honey are common from the pre-historic ages. In our country, Veda, Ramayana, Koran has mentioned different uses of honey. Former Kings and Sultans used the symbol of bee as a mark of glory.

Some of the earliest evidence of gathering honey from wild colonies is from rock paintings, dating to around 13,000 BC from different countries. Since early days

honeybees are not cultured for honey, instead honey is collected from wild natural hives.

It is recorded that in 1882, artificial culture of honeybees were introduced in undivided Bengal following European methodologies. In 1883-84 the process was initiated in Punjab. In 1894, India Government first circulate details of information regarding the bee culture as promotional measure. Bee-keepers Association was established in 1907 in Punjab with its Head Office at Simla.

In 1939, All India Bee-keeping Association was established and very soon it spread its branches to most of the states and districts of India. Now it merges with ICAR (Indian Council of Agricultural Research) and has expanded its activities. In 1945, Central Bee-keeping Research Station was established. It expands its research centres to Coimbatore (Tamil Nadu), Ruptala (Andhra Pradesh), Sundar Nagar (Himachal Pradesh), etc.

## Habit and habitat:

Commonly inhabits forests, plains and protected places like mud walls, earthen pots, thick lushes, wells and walls of buildings. The honey hives are made under branches of trees and any protected place in houses.

## Distribution:

Cosmopolitan especially found in India, Canada, Australia and New Zealand.

## They belong to genus *Apis* and a variety of species are found in it. Some of them are given below:

### I. *ApisDorsata*-F. (Rock Bee):

This is the largest honey bee, about 2 cm. in length. These are the strongest and the most powerful amongst the bees. They make their combs in open areas like big branches, of trees, rocks, old forts and other such places where man cannot reach easily. These are almost similar in size and not much of difference is noted amongst the queen and worker but for the colour of the abdomen, which is much darker in queen. The comb cells are almost of uniform size and a comb can store about 20-25 kg of honey. These bees are much irritable and ferocious so their domestication is not very easy.

### II. *Apis Indica*-F. (Indian Bee):

These are smaller in size and brighter in colour than the *Apisdorsata*. These bees can be well marked by their nests as the nests are always in dark and protected places, like old forts, caves and crevices, hollow trunk of trees etc. Several combs are made parallel to each other but honey is found in only one or two combs only. Total production per comb per year is not more than 2-6 kg., under favourable conditions. These are found in hills and plains and can easily be domesticated because of their mild nature.

### III. *ApisFloria*-F. (Little Bee):

These are smallest and most gentle bees which make their nest in bushes, trees houses and other surrounding. They are docile and gentle in nature and can be domesticated easily but yield is much less and uneconomic. The comb can be removed easily and honey can be extracted without much efforts.

### IV. *A. Mellifera* – F. (European Bee):

A variety of European bees are found in general but the Italian species proves to be the best. The nature of these bees resembles with that of *A. indica*. These too make several combs parallel to each other and brood is in the central comb. The amount of honey is higher and the nature of bee is gentle. These can be domesticated and their variety can be easily improved by breeding. The queens more prolific and honey gathered varies from 5-10 kg. per comb per year. They are common in European countries.

### V. Melipona and Trigona-Spp. (Dammer Bee):

These are different from the above said honey bees. Much smaller in size and are unable to secrete wax for making the comb. They make the comb by using earthen mixture, sand and resinous substances from plants. The comb thus is a very tiny comb with 100-150 gm. of honey. Such a comb can easily be seen in the shrub and gardens close to agricultural fields. They are best for pollination of the flower.

## Caste System in Honey Bees:

The honey bee presents an example of social and organized living. The members are well defined into various castes with their special works. They are divided into: 1. Queen 2. Worker and 3. Drone.

### a. Queen:

Largest of all the bees with small legs and weak wings. Queen bee is the real ruler of the hive. She has an extended abdomen, full of eggs and the last segment is modified as an ovipositor. She has no work except eating and laying eggs. She lives for 3-3 % years and lays about 14-15,00,000. eggs during her life span. The rate of egg laying under favourable conditions may be 2,000 eggs per day.

Generally, only one queen is founding in a comb but in case when her egg laying capacity is reduced, she can be changed and replaced by another queen. In extreme cases such an old queen comes out of the hive and establishes another hive. In some of the cases a colony may have more than one queen but only one is allowed to live in the hive rest are pressed to leave the nest.

Queen is supposed to be the mother of all the drones and workers and queens (if they are) present in the comb. She lays both fertilized and unfertilized eggs which later on develop as male and workers. Some of the workers which are in real sense the females are fed with a special substance called "Royal jelly" and the larvae fed on royal jelly develops as a queen rest as workers. By the time the egg laying capacity of the queen goes slow a new larva is fed with royal-jelly and is developed as future queen.

A single fertilization is sufficient for the whole life. The queen moves from cell to cell of the comb and lays eggs. She has no special cell to live in and is always surrounded by the workers. She is generally found in the lower border of the hive. A mated queen collects the sperms in a receptacle and it is on her will to decide which batch of the eggs should be fertilized and which should not the males or drones are generally unfertilized whereas the queen and the workers develop from the fertilized eggs.

There is no difference in the organs or morphology of the worker or queen but for the size of legs and wings. The queen bee is fed with a highly nitrogenous food mixed with pollen honey and a secretion from the lateral pharyngeal glands. All these are mixed and make as Royal jelly. An egg develops as a larva in 3 days and grub into pupa in 5-7 days. The pupa emerges out after a week as an adult.

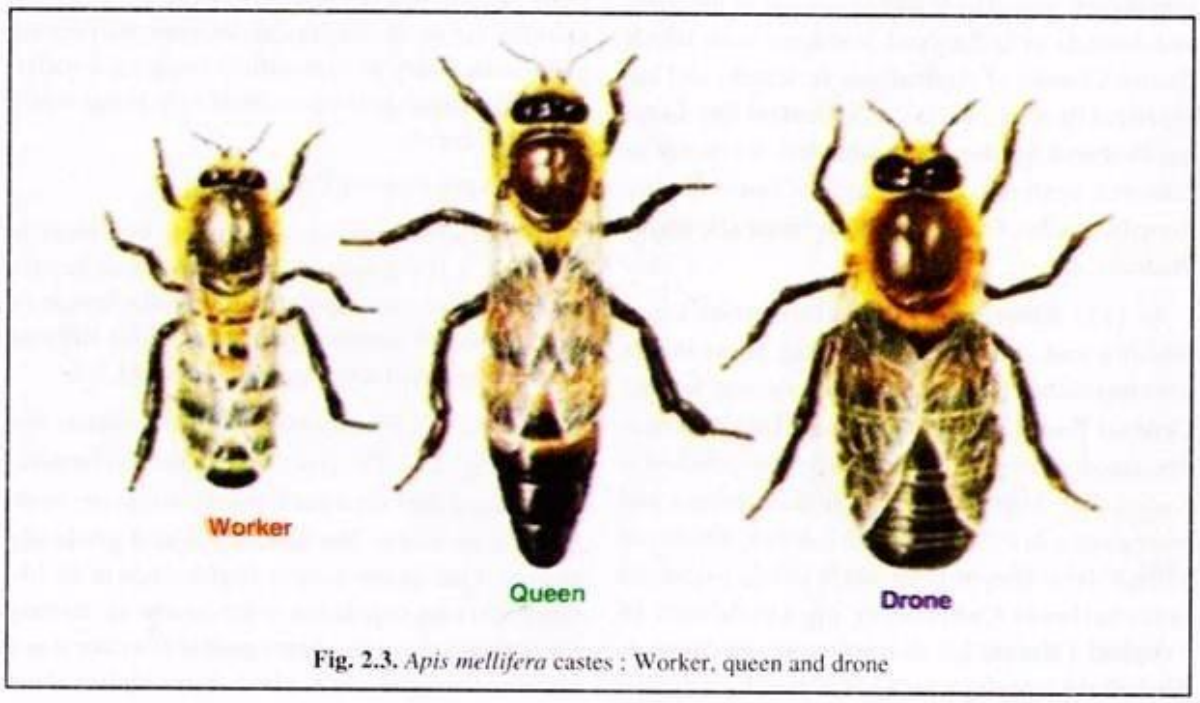


**Fig. 2.3.** *Apis mellifera* castes : Worker, queen and drone

## b. Workers:

More than 90% of the total population present in the comb consists of workers. These workers are the atrophied female which are unable to lay eggs and they sacrifice their total life in the service of queen and the hive and its residents. The longevity of a worker

depends upon the type of work and activity, generally they live for about three months in an off season but in busy seasons this is reduced to half.

The newly developed worker has weak wings, so she is employed feed the grubs, help the queen in laying eggs, feeding the queen and cleaning the hive. The work is allotted to them according to their age and they are named after their work as nurse bee, cleaner bee or builder bee.

The builder bees are provided with a wax gland in their 4 to 7$^{th}$ abdominal segments on the ventral side and these are engaged in making the nest cells whereas some of the bees produce bee glue (propolis), which is used in repairing the cracks and crevices, there are known as repairers.The duty of a nurse bee is to produce Royal jelly for die developing queen and "bee breed" for rest of the grubs. She looks after the development of the grub and before they pupate, she seals the door of the cell. Cleaning of cell, maintenance of hygienic conditions removal of debris and dead bodies are done by the cleaners.
The workers have other important job to maintain the temperature of the hive. At the time of production of honey, a fairly good amount of water is found which in later stage may spoil the honey. So to avoid the loss the worker bees assemble near the newly filled cell and deep that cell worm. The water vaporizes and level is lowered down.

On reaching a certain point the bee seals the cell and protects the honey. On the other side the temperature may not damage the egg laying capacity of the female in hot summer she is always kept cool by the workers. There are certain bees with long wings they always vibrate their wings so the temperature is lowered down: In the month of June when the sun is too hot, some of the fanner bees go out and take a dip in water and again come near the queen. This gives an air conditioning to the queen.

## In the same way they keep the queen worm during winter by assembling themselves near the queen:

Collection of food, pollen and honey is again an important work of the workers. These workers are good flier and can cover a long distance in a shorter duration. They have their own language and by dancing before other bee they tell the direction and distance of the food from the hive quantity of the food and its quality. Such bees are provided with long and powerful flight muscles and wings. Their legs are provided with pharyngeal legs. These legs are armed with big structure above the tibia called pollen basket, which helps in collecting the pollen grains.

Workers are the soldiers also they have a powerful sting in their last abdominal segment and protect the hive from outside attacks. They have a tendency to chase the enemies.

In terms of their body structure the workers are the most adapted to perform the duties in the colony.

### The adaptions are:

1. Well-developed proboscis for nectar collection.

2. Wax plates and wax glands are well formed for constructing and repairing the bee hive.

3. Very powerful sting to defend the colony.

4. Fully formed salivary and mandible glands honey stomach for jelly secretion.

Workers are the back bone of the colony. They carry out the routine chorus of the colony. The duties to be performed in the colony are divided among the worker bees based on their age.

### The major works they perform (in ascending order of age) are:

1. Cleaning the cells of the comb.

2. Secretion of royal jelly and feeding the larvae and young ones. They are called 'nurse' bees.

3. Secretion of bees wax and construction and repair of honey combs.

4. Defend against intruders and protect the colony.

5. Collect pollen, nectar and water and keep the colony cool.

6. Act as scouts in locating new food sources and lead the members during swarming.

The life span of worker bee is 3 months to one year. During active seasons they have a short life span.

### c. Drone:

The males in the colony are called drone. They develop parthenogenetically and have no stings. They depend on workers for their own food and have the sole responsibility to fertilize the queen. They are of intermediate size and pupae period ranges from 10-13 days. Total adult life span ranges from 7-8 weeks.

The reproductive organs are well developed and sometimes they die just after copulation. They are developed only at the time of breeding when a new queen is under

process otherwise they are kicked out of the colony in day of scarcity. A hive generally keeps 200 drones at a time. Drone cells are little bigger than the workers cell and smaller than the queen cells.

## Life Cycle:

The fertilized female lays eggs. Numbers of eggs laid daily vary according to the environmental condition but it may range from 1500- 2000 eggs a day. The eggs are small, cylindrical, pale yellow or white. One egg per cell is laid by the female and eggs adhere with the cell wall. Generally, three types of cells are found the Royal brood cell, Drone brood cell and Ordinary brood cell which give rise to queen, drone and the workers. The sex of the developing larva is decided by the quality and quantity of the food fed to the larvae. The eggs hatch in three days giving out of the grubs.

Grubs are yellowish or white and curved structure and develop in pupal form in 5-7 days their development depends on the food. Some of them are fed with Royal Jelly where others are fed with bee bread. Bee bread inhibits the growth of reproductive organs. So only workers come out of such larvae they pupate inside the cell and pupae come out as adult in 7-14 days. The queen, drone and workers have different life span.

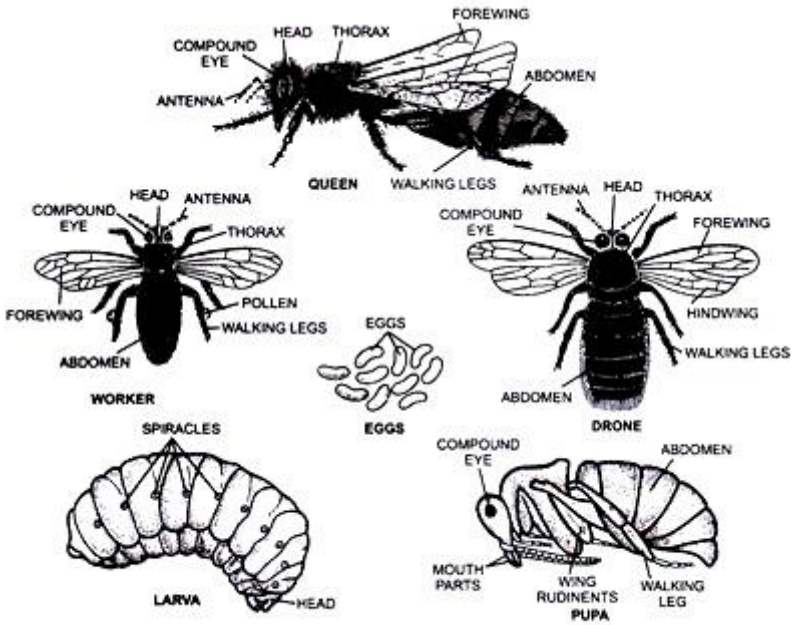



**Fig. Apis indica. Castes and stages of life history.**

## Swarming:

The process of leaving off the colony by the queen termed as swarming. It happens towards the end of spring or early summer but the real cause of swarming is still not well known. In summers when plenty of food is available and hive is overcrowded by

the bees, the queen leaves the hive on a fine fore-noon with some old drones and workers and establishes a new colony at some other place.

Now in the old hive a worker is given Royal Jelly and is converted into a new queen of the colony. This new empress of the colony never tolerates her successor, as a natural law in the hive. So she orders to kill the other sisters, if any, in the hive.

## Supersedure:

When the egg laying capacity of the old queen is lost or it suddenly dies, a new young and vigorous queen takes the position of the old queen and is called as supersedure.

## Absconding:

The migration of the complete colony from one place to another takes place due to some unfavourable conditions of life, such as destruction of the comb by termites or wax-moths and scarcity of nectar producing flowers around the hive. This phenomenon is quite different from that of swarming.

## Nuptial or Marriage Fight:

The first swarm is led by the old queen but the second swarm is led by the 7 days old virgin queen which is followed by the drones and is called marriage flight. One of the drones starts copulating with the queen in the sky and fertilizes the queen and dies during the course of copulation. The queen receives spermatophores and stores in the spermatheca. Along with the queen, died drone falls on the ground and the queen reaches the hive.

## Colonial Organisation and Division of Labour among Bees:

## Honey Comb:

Various types of bees make various types of honey combs but their lay out pattern is almost same in all the cases. They have a common partition wall having serially arranged cells on either side. These cells are hexagonal, their walled and fragile. The bee may have a separate comb as a brood chamber or may use the same hive as a brood chamber.

In most of the cases the hive is divided into certain chambers the brood chamber having eggs larvae and pupae whereas storage is done in another chamber. The size of the cell for larvae and pupae of the brood would be male and workers differ in size. The cell of a drone is large as compared with that of the worker whereas that of queen is the largest. The storage cells are small and much more in number. These are built near the margin or on the top of the hive.

## Bee Hive and Its Economic Importance:

The house of honey bees is termed as hive or comb. It consists of hexagonal cells made up of wax secreted by the worker's abdomen. These hives are hanging vertically from

rock, building or branches of trees. Each hive has thousands of hexagonal thin walled fragile cells arranged in two opposite rows on a common base. The resins and gums secreted from the plants are used for the repairing of the hives.

The young stages are generally occupying the lower and central cells in the hive which are the Brood cells. In *A. dorsata* brood cells are similar in shape and size but in other species brood cells are of 3 types viz., Worker cell kit workers, Drone cell for drones and Queen Cell for the queen.

The queen cell cannot be used again while the rest are used a number of times. There are no special cells for lodging the adults, which generally keep clustering or moving about on the surface of the comb. The cells are mainly intended for the storage of honey and pollen especially in the upper portion of the comb while those in lower part are for brood rearing.

## Honey:

Honey is produced by the bee and is of an important medicinal value. It contains a variety of minerals e.g., Ca, Fe, Silica, Mg, Mn, K, CI, S, AI, and phosphorus whereas amino acids, citric, formic, succinic, malic and acetic acids are also present in traces, pigments like Carotine, Xanthonine and Anthocynin and vitamin A, B complex and C are also reported in it. Besides all these enzymes like invertase, distage are also found.

**The chemical composition of honey constitutes as follows:**

| | |
|---|---|
| Lavulose | 38-41% |
| Dextrose | 21-35% |
| Maltose and other sugars | 8-10% |
| Enzymes and pigments | 2-3% |
| Ash | 1% |
| Water | 17% |

Pure honey gets granulated after long storage. The granulation becomes faster due to presents of air bubble pollen, and other colloid substance. It has density 1.2.

## Economic Value:

It is of great economic importance and is widely used in medicine and as antiseptic. It has its own food value and gives high calorific value and energy. It is used in candies, cakes, breads and cold drinks. Alcoholic drinks, livestock feeds and poison baits are also made from honey. It is the only substance which requires minimum energy for its digestion that is why it is given to new born infants.

## Economic Importance of Honey:

Honey is used by human beings in different ways of which the most important is as food and medicine.

## (a) Food Value:

It is estimated that 200 gm of honey provides as much nourishment as 11.5 litre of milk or 1.6 kg cream or 330 gm meat. 2.1 gm of honey provide as much as 67 K. cal of energy. Its sugars, minerals, vitamins and other vital elements are readily absorbed by the systems. Honey may be taken by healthy men as well as those who are ill. It can be taken at any time in any season and by persons of all ages even those just born. It is use in the preparation of candles, cakes and bread. In illness it is preferred over milk because more than half of the body energy is provided burning of dextrose.

## (b) Medicinal Value:

Honey is mildly laxative, antiseptic and sedative, generally used in Ayurvedic and Unani systems of medicine. It is quite helpful in building up of the hemoglobin of the blood and also used as preventive against cough, cold and fever, as blood purifier and as a curative for ulcers on tongue and alimentary canal. Its regular use is recommended after severe cases of heart attack for malnutrition, indigestion and diabetes; it is also found that typhoid germs are killed by honey within 48 hours, those of branchio-pneumonia in 4 day and of dysentery in 50 hours.

## (c) Other Uses:

Other than food and medicine, honey is used in numerous ways. It is used in the preparation of bread, cake and biscuits. It enhances their preserving quality. Much amount of honey goes in making alcoholic drinks. In poultry and fishing industries honey is widely used. In laboratory, honey is used to stimulate the growth of plants.
The bacterial culture, inoculation of seeds of cloves, in insect diet and in the preparation of poison baits for fruit flies.

## Bees Wax:

It is the most useful bi-products of the honey bee. It is secreted by the dermal glands of the abdomen from $4^{th}$ to $7^{th}$ segment and is completely soluble in ether, chloroform and other organic solvents.Brown or yellowish brown in colour it does not dissolve in water. It melts easily.It is used in manufacture of cosmetics creams, paints, ointments, plastic works, polish and a variety of lubricants.

## Economic Importance of Beeswax:

Beeswax is used in the manufacture of cosmetics, for Catholic churches, face cream, paints, ointments, insulators, plastic works, polishes, carbon paper and much other lubricant. It is also used in the laboratory for microtomy with the common wax for block preparation of tissues.

## Science of Bee-Keeping:

Bee keeping is the art of rearing honey bees, to obtain honey for human use. The honey man takes is actually excess left after the use by the bees. Other than a source of honey and bees wax, honey bees are good pollinators. (A thorough knowledge about the biology, behaviour, life history and development of honey bees must be obtained before venturing to 'Apiculture').

Wooden hives are made for keeping bees. Special tools are available these days like honey extruder, bee gloves smoker, and bee veil to protect the keeper. Artificial feeding method is also resorted to at time of food shortage.

## Bee Hives:

Man provides shelter space for the bees to set up colonies. This is called bee-hive. The hive space must be large enough for passage of bees and smaller enough to discourage comb building. In earlier days straw skep was used for bee keeping. Different models of hives were designed during the past years: the most rewarding was that of Langsworth. He designed a hive that can be opened at the top.

The modern bee hive is the movable-frame hive. It is a wooden frame box made of single or double walls the former for warm place and the latter for cool climates. The hive consists of a bottom board, brood chamber, super chamber inner cover and top cover. They are placed one above the other and fixed on a stand. All these parts can be separated. The bottom board acts as the entrance for the bees.

The brood chamber is a wooden box inside which numerous frames called "comb foundations" are fixed. Comb foundation consists of sheets of pure bee wax on which are embossed the base of cells of the honey comb. The worker bees secrete wax to extend the walls of these cells. The comb foundations help in controlling the rise of the cells and reduce the number of drone cells. These frames of combs are movable and can be lifted, hence the name for the hive "movable frame hive."

The chamber above the brood chamber is the super chamber inside which honey is secreted and stored. Queen is prevented from entering this chamber by using queen excluder. This equipment has narrow spaces of 4 mm which allows only the workers to enter the super chamber.The top cover can be lifted to inspect the state of the colony or honey formation. The wooden hive is coloured yellow or white on the outside for keeping the chambers cool and to aid easy recognition by the bees.

## Other Appliances:

Many tools are devised for proper care and maintenance of beehives. The bee veil is a device to protect the beekeeper from bee sting. The veil is made of fine nettings, with a string attached for tying. Gloves are sometimes used by keepers for protecting the hands. While inspecting the hives, smoker is an equipment to scare the bees. During

hive maintenance and honey collection the worker bee may attack the keeper in groups. The smoker released will irritate the bees and keep them away.Honey extractor is a metal drum inside which a rotor rotates in its axis. The foundation frame, on which the bees secrete their honey, is fixed on to the rotor and rotated. This creates a centrifugal force, which separates the honey without disturbing the comb frame.Other minor tools are bee brush for cleaning the combs and scrapper for collecting excess honey.

## Hive Maintenance and Management:

To obtain good yield of honey the keeper must provide ideal conditions to the bees. Maintenance and management of bees therefore is very significant for the perpetuation of the colony.

## Following are the few important points of hive management:

1. The location of the hive should be such that the flora in the surrounding area and their flowering period should suit with the f active period of the colony. The area must have good humidity, preferably protected from direct sunlight.

2. The hive may be single walled or double walled in structure based on the climatic features of the locality.

3. The keeper must be familiar with biology and behaviour of the bees.

4. Close observation of the hives condition has to be maintained. The colony should be at its peak strength at the time of nectar flow.

5. If more than one queen is formed in the colony it must be removed, otherwise it will lead to disintegration of the whole colony. Swarming must be prevented by removing excess drones and additional female queens. In cases the queen dies, immediately either a new queen is introduced or the whole members of the hive are transferred to another stock.

6. When there is dearth of food, artificial feeding may be resorted to. Artificial food is prepared by dissolving 100 gm of sugar in 150- 200 ml. of hot water, boiled and cooled. This food is kept near the hive in an open container. Sometimes during hot season, the hive may get heated up. Water is required to keep the hive cool. So water availability near to the hive must be ensured.

7. For propagation, the number of colonies may be increased by dividing the existing stock.

8. Regular inspection of the hive for honey secretion and inspection of foundation frames to check the colony settlement may be made.

9. Predators and parasites found around the hive are eliminated.

10. The colony must be always maintained in a healthy state. If bees catch diseases they may be treated with available drugs.

## Appliances for Modern Method:

1. Typical movable hive.

2. Queen excluder.

3. Honey extractor.

4. Uncapping knife.

5. Other equipment.

## 1. Typical Movable Hive:

An artificial movable hive is constructed by wooden box based on bee space theory. The size and number of frames are variable form hive to hive according to the need. A small space is enough to permit the entrance and exit of workers and drones but queen once placed in hive never comes outside the hive. The perforation size on zinc sheet is only of 0.375 cm but the thorax of the queen is 0.43 cm to 0.45 cm, so the queen can never pass through this pore.

## This typical hive consists of 6 parts as given below:

### (a) Stand:

It is the basal part of the hive on which the whole hive is constructed. The stands are adjusted to make slope for the hive. Due to this slope rainwater comes down quickly.

### (b) Bottom Board:

It is situated above the stand and forms the proper base for the hive having two gates in the front position. One gate function as an entrance while the other as exit.

### (c) Brood Chamber:

The bottom board carries the brood chamber, which is the most important part of the bee hive. It is large in size provided with 5 to 10 frames. In each frame a wax sheet bearing hexagonal frames is help up by a couple of wires in a vertical position. Along with the margin of every hexagonal mark, the bees start making will and ultimately the cells.

Here every sheet of the wax is known as comb foundation, which attracts the bees and provides the base for the comb preparation on both the sides. The frames are kept vertically in brood chamber, which is covered over by other frames having a wire meshing through which the workers can easily pass.

The comb foundation helps in obtaining a regular strong worker brood cell comb, which can be used repeatedly. The Central Bee research station at Pune arranged the manufacture of a comb foundation mill, which manufactures, different cell sizes required in several regions of the country. The brood chamber is covered by another chamber known as super.

### (d) Super:

It is also without cover and the base. Super is provided with many frames containing comb foundation to provide additional space for expansion of the hive.

### (e) Inner Cover:

It is a wooden piece used for the covering of the super. It has many holes for proper ventilation.

### (f) Top Cover:

It is meant for protecting the colony from rains. It is fitted with zinc sheet, which is plain and sloping.

### 2. Queen Excluder:

It consists for wire gauze, extrans guards and drone traps with individual wires placed 0.375 cm apart. It readily permits the workers to pass through it but keeps back the queen in the brood chamber.

### 3. Honey Extractor:

It is used for the extraction of the honey from the comb and function on principle of centrifugal force. When combs are centrifuged by his device the pure honey is thrown out without any damage to the comb.

### 4. Uncapping Knife:

When all of the combs are filled with honey they are sealed by capping with the wax. So, before such capped combs are placed in the honey extractor, the wax sealing has to be removed with the help of an uncapping knife heated by steam before use.

### 5. Other Equipment:

Most of the useful, equipment for the successful management of the bee are locally manufactured which are very cheap. As they are made locally, they may not be exactly similar to those made at another place. Thus, Indian standard Institute has standardized some very common equipment. For the production of uniform and interchangeable articles. Some materials like protective garments, gum cages, gloves, net veil, bee net, brush etc. are required for easy and well-planned handling of the bees.

### Advances of Modern Method:

In the modern method of bee keeping there are several advantages which encourage the well planned bee keeping.

1. A proper watch on the activities of the bees can be had.

2. A strong colony can be developed by providing sugar, syrup, and pollen substances to honey bees.

3. Swarming of bees is checked by modern hive.

4. The same hive is used again and again so the worker's pay their attention more for the honey and not for the hive formation.

5. Under adverse climatic conditions the hive can be transferred from one place to the other for the protection of the bees.

6. Comb can be protected from the enemies.

7. Pure honey in large quantity can be obtained.

### Precautions:

**For the proper management of bee keeping programme following precautions should be taken:**

1. The hive should not be kept more than half a mile away from the place from where the bees have to collect the nectar and the pollen.

2. People must know about the bee keeper for proper contact.

3. The boxes must be kept under shade at cool places.

4. Industry should be near the road for proper transport facilities.

5. Fresh water reservoir should be near the hive.

6. Good flora for the collection of pollen and nectar should be there

## Methods of Bee-Keeping in India:

### 1. Indigenous methods:

### a. Immovable structures:

It is practiced in villages from time immemorial. Small structures are made in secluded and protected places. During construction of dwelling houses, small permanent chambers are made in the outer wall of the house for bees to build combs. Sometimes mud chambers are constructed.

On the outer-side of the chamber a horizontal slit is made for the entry of bees, while on the inside wall a large opening is left for removal of comb.

### b. Movable structures:

Bee chambers are made up of hollow bags, empty wooden boxes, earthen pots, etc. which can be moved from place to place, and put in a suitable location for the bees. These methods are not much satisfactory, as the comb is lost in the process of extraction of honey. The quality of honey is inferior due to presence of dust, tissues of damaged bee larvae, pollen grains, etc., in it.

## 2. Modern methods:

### Beehive:

In modern apiary, Longs troth's frame hive is most suitable and used commercially for production of honey.

1. It is a two-tier structure. The chambers can be removed from or added to, as required.

2. The hive is made up of wooden box.

a. It has a basal plate or bottom board on which is placed a wooden box called brood chamber.

b. A small opening at the bottom of brood chamber permits passage for bees.

c. Inside the brood chamber several frames hang vertically from the top. These frames can be removed independently. For this arrangement, a modern hive is also called movable frame hive.

d. The distance between the two frames, the bee space is narrow and serves as a passage for the workers but small for building a comb.

e. Above the brood chamber is placed another similar chamber, but of lesser height.

f. It is meant for storage of honey only and known as honey chamber. The queen is never allowed to enter the chamber. In some cases two honey chambers are used.

3. Above the honey chamber an inner covering is placed over which lies the roof.

## Tools for Bees Keeping:

## 1. Comb foundation:

A small piece of comb is necessary to tie with one of the frames from where the bees will start comb-building.

**2. Bee gloves:**

Leather gloves are used to prevent bees from stinging during handling of the comb and bees.

**3. Bee veil:**

A bee veil is required to cover neck, face and head of the keeper during handling. Usually it is made of linen.

**4. Smoker:**

A smoker must be used while capturing bees in a hive. Smoke from paper, wood and coconut cover makes the bees inactive. There is fire box in a smoker in which smoke-producing materials and fire are put. A bellow system is fitted to blow the smoke.

**5. Hive tool:**

It is a long, narrow and flat piece of steel with a slightly bent head to scrap away dirty materials deposited by bees or some other factors.

**6. Honey extractor:**

It is used for extraction of honey from the frames without damaging the comb. It consists of a metal drum with several pockets around a rotating wheel. The frames are hanged from the pockets and the pockets are made to rotate round a central axis.

The centrifugal force created by rotation separates honey from the comb which is collected in the drum. The honey is taken out from the drum through a hole at the bottom.- The combs and frames are again placed in the hive.

## Typical Location of Apiary:

A locality for apiary must have different varieties of pollen and nector-producing plants in sufficient number within a distance of 1.5 to 2.5 km. area. Neem, Rita, Tamarind, Cheery, Apple, and Citrus, Lily, Lotus, various wild plants and crops are good sources for both nectar and honey.

## Enemies of Bees:

Enemies of the bees harm the colony in different ways so they have attracted considerable attention in the different regions of the country. The wax moths (*Galleria mellonella and Achroiagrisell*a). Wasp (*Vespa* spp. And *Palarus*sp,) black ants (*Componotuscompressus*) and bees eaters (*Meropsorientalis*) and Kingcrow

(*Dicrarusmacrocercus*) are common enemies of the honey bee's comb and honey. Man is the last but worst enemy of honey bees.

Before 1958 bees were considered to be free from the diseases though suspected cases of Nosema from Punjab and Kashmir were known. But a parasitic mite-Acarapiswoodi Rennie caused Acarine disease in the adult honeybee in Kulu valley in Punjab in 1956. It was later reported from Himachal Pradesh, Uttar Pradesh and Jammu and Kashmir.This disease was controlled by the scheme in co-operation with the United States of America at the college of Agriculture Ludhiana, Punjab. Now-a-days Indian honey bees are commonly the spread of any such disease. A strict quarantine measure is being taken to check the spread of any disease from foreign countries. But in European countries bees are commonly attacked by microsporadian, which is injurious to bees.Honey being sweet, tasty it has a number of enemies also.

Wax Moth (*Galleria mollonella* Linn) lesser wax moth (*Achroiagrisella*) are the worst enemies of honeybee. Their caterpillars creep inside the comb and feed upon the brood comb. They spoil the complete colony. Quite often the bees undergo absconding swarm and leave the hive.

Sphinged moth (*Achorontiastyx*) is a strong and powerful moth, which enters the colony and feeds upon the honey, but the bees after sometime kill them.Beside above-mentionedinsects black ants, termites, dragon flies are the powerful insects which destroy the bee hive.Not only the invertebrates but some of the vertebrate pests like lizards, catoles, king crows, birds and bear cause serious damage to the bee hive and there is no escape for the bee.The bees are subjected to bacterial diseases also like dysentery, fowl brood disease, caused by Bacillusplutan and B. alvei, Nosema and Bee paralysis. Certain mites like *Acarapiswoodii* kill the bees and damage the hive.

## Diseases of the Bees:

Bees suffer from different contagious diseases and are very often subjected to curious organic disorders. The organisms for contagious diseases are Aspergillus, viruses, mites and Protozoa.

a. Aspergillus, a fungus, causes paralysis in worker bees.

b. Virus cause paralysis and high percentage of mortality to all categories of bees.

c. Gut protozoa, particularly Nosimaapis, cause death of bees.

## Probable Questions:

1. What are different casts found in Honey bee? Differentiate queen and worker bee.
2. What are the adaptations of worker bees?
3. What are the major works of worker bees (in ascending order of age)?
4. Describe life cycle of honey bee with suitable diagram.
5. Describe structure of hive.
6. What are the composition of honey?
7. Write down economic importance of honey.
8. What is bee wax? What are its importance?
9. How hive management is done?
10. What are the modern appliances used in apiculture?
11. Describe in brief Methods of Bee-Keeping in India.
12. Name tow diseases of honey bee with their causative agent.
13. Discuss about natural enemies of honey bee.

## Suggested Readings:

1. The Insects by Chapman
2. Modern Entomology by D.B. Thembare
3. Economic Zoology by Shukla and Upadhyay
4. The Insects by Gullan and Carnston
5. Introduction to Economic Zoology by Sarkar, Kundu and Chaki.
6. A textbook of Economic Zoology by Aminul Islam

# UNIT-VI

## Animal breeding: Controlled propagation of animals, animal breeding techniques

**Objective:**In this unit we will discuss animal breeding: Controlled propagation of animals, animal breeding techniques

**Introduction:**Animal breeding is producing improved breeds of domesticated animals by improving their genotypes through selective mating.Breeding means, the manner in which selected males and females are mated. Breeding makes new combination or sequencing of genes in the individual.The breeders identify and select desirable qualities in animals for future mating and discard less desirable qualities.For the improvement of live stock (= farm animals) selection and breeding must be practised simultaneously.

Continuous selective breeding leads to homozygosity in a population resulting a loss of variability. If all the individuals are alike, the breeder cannot make progress in future. Hence, there is a need to create a variability in population. This can be achieved by breeding. Therefore, selection and breeding go hand in hand for the improvement of live stock.

### Objectives of Animal Breeding:

The main objectives of animal breeding are :

(i) improved growth rate,

(ii) increased production of milk, meat, egg, wool, etc.,

(iii) superior quality of milk, meat, eggs, wool, etc.,

(iv) improved resistance to various diseases,

(v) increased productive life, and

(vi) increased or, at least, acceptable reproduction rate.

## Methods of Animal Breeding:

Two methods of animals breeding are: inbreeding and out breeding, based mainly on breeding work with cattle.

## 1. Inbreeding:

When breeding is between animals of the same breed for 4-6 generations, it is called inbreeding. Inbreeding may be explained by taking an example of cows and bulls. Superior cows and superior bulls of the same breed are identified and mated. The progeny obtained from such mating are evaluated and superior males and females are identified for further mating. A superior female, in the case of cattle, is the cow that produces more milk per lactation.

On the other hand, a superior male is that bull, which gives rise to superior progeny as compared to those of other males. As the homozygous pure lines developed by Mendel as described in Chapter 5, a similar strategy is used for developing pure lines in cattle as was used in case of peas. Inbreeding, as a rule, increases homozygosis.Thus inbreeding is necessary if we want to develop a pure line in any animal. Inbreeding exposes harmful recessive genes that are eliminated by selection. It also helps in accumulation of superior genes and elimination of less desirable genes. But continued inbreeding reduces fertility and even productivity.

This is called inbreeding depression. In this condition, the selected animals of the breeding population should be mated with superior animals of the same breed but unrelated to the breeding population. This often helps in restoring fertility and yield.

## 2. Out breeding:

Out breeding is the breeding between the unrelated animals which may be between individuals of the same breed (but having no common ancestors) or between different breeds (cross breeding) or different species (interspecific hybridization).

**(i) Out crossing:**

It is the mating of animals within the same breed but having no common ancestors on either side of their pedigree up to 4-6 generations. The offspring of such a cross is called as an outcross. Outcrossing is the best breeding method for animals that are below average in productivity in milk production, growth rate in beef cattle, etc. Sometimes only one outcross helps to overcome inbreeding depression.

**(ii) Cross-breeding:**

In cross-breeding superior males of one breed are mated with superior females of another breed. Many new animal breeds have been developed by this strategy. It gives better breeds. Cows of an inferior breed may be mated to bulls of a superior breed to get better progeny. Hisardale is a new breed of sheep developed in Punjab by crossing Bikaneri ewes and Marino rams.

**(iii) Interspecific Hybridisation:**
In this approach, male and female animals of two different species are mated. The progeny obtained from such a mating are usually different from both the parental species.

But in some cases, the progeny may combine desirable characters of both the parents. Mule is produced from a cross between female horse (mare) and male donkey. Mules are harder than their parents and are well suited for hard work in mountainous regions.

## Controlled Breeding Experiments:

These are carried out using artificial insemination and Multiple Ovulation Embryo Transfer Technology (MOET).

**(i) Artificial Insemination (AI):**
The semen of superior male is collected and injected into the reproductive tract of the selected female by the breeder. The semen can be used immediately or can be frozen for later use. When a bull inseminates a cow naturally approximately 5 to 10 billion sperms are deposited in the vagina. However, when semen is deposited artificially, considerably fewer sperms are required to achieve conception. Therefore, artificial insemination is very economical. The spread of certain diseases can be controlled by this method.

**(ii) Multiple Ovulation Embryo Transfer Technology (MOET):**
In this method, hormones (with FSH-like activity) is given to the cow for inducing follicular maturation and super ovulation instead of one egg, which they usually give per cycle, they produce 6-8 eggs. The cow is either mated with a best bull or artificially inseminated.

The embryos at 8-32 cell stage are recovered and transferred to surrogate mothers. The genetic mother is available for another super ovulation. MOET has been done in cattle, sheep, rabbits, buffaloes, mares, etc. High milk giving breeds of females and high quality (lean meat with less lipid) meat- giving bulls have been bred successfully to obtain better breed in a short time.

## Classification of Breeding Systems:

Under the selected breeding system selected males and females are mated. The breeding system can be classified into five different ways depending on their phenotypic and genotypic relations.

**The five breeding systems are:**
(1) Random mating,

(2) Phenotypic assortive mating,

(3) Phenotypic dissortive mating,

(4) Genetic assortive mating and

(5) Genetic dissortive mating.

### 1. Random mating or Panmixia:

It is a system of mating in which each male individual has an equal opportunity to mate with the female individual and vice versa. This mating system generally takes place in nature where the number of males and females are assumed to be equal.

### 2. Phenotypic assortive mating:

In this type of mating animals which are phenotypically alike are allowed to mate among themselves. This is also called "like to like" mating.

### 3. Phenotypic disassortive mating:

Here individuals which are phenotypically unlike are allowed to mate. It is also called "unlike to unlike" mating. For example, mating of tall with short individuals.

### 4. Genetic assortive mating:

In this system individuals, which are closely related genetically are allowed to mate. This is also known as inbreeding.

### 5. Genetic disassortive mating:

This system is just opposite to the previous system where mating takes place between less closely related individuals. This is also called as out breeding.

## Breeding Methods:

There are two major breeding methods: inbreeding and out breeding.

### Inbreeding:

It is defined as "breeding of more closely related individuals (males and females) than the average relationship of the population." Depending upon the closeness among mated individuals, inbreeding are of 3 types.

**They are:**

(i) Close inbreeding (mating individuals have relationship above 0.25),

(ii) Mild inbreeding (mating of relatives beyond 2nd generation and upto 6th generation),

(iii) Line breeding (mating of relatives between 4th-6th generations).

## Advantages and Disadvantages:

## Advantages of Inbreeding:

1. Due to increase in homozygosity, the stamping ability or prepotency of inbred line increases.

2. It helps to eliminate lethals and semi lethals due to homozygosity.

3. It increases genetic variance between lines and reduces genetic variance within lines.

## Disadvantages of Inbreeding:

1. Many lines are lost due to homozygous lethals or semi lethals.

2. Due to loss of heterozygosity, the hybrid vigour is lost.

3. Inbreeding leads to lower birth weight, post natal mortality (baby death after birth), poor growth, reproductive disorder and low resistance to diseases.

## Out-breeding:

It is opposite of inbreeding where unrelated individuals are mated. The breeding individuals have relationship less than the average relationship of the population. Out-breeding results in increase in heterozygosity and decrease in homozygosity.

**Out-breeding can be classified into two major classes:**

(i) Out-breeding within a breed and

(ii) Out-breeding between two species/strain/line/breed.

## Advantages of out-breeding:

1. Out-breeding increases heterozygosity which results in hybrid vigour (increase in weight, faster growth, increased resistance to disease, low mortality).

2. It covers the defects of recessive lethals and semi-lethal genes.

3. It increases genetic variance within lines.

## Probable Questions:

1. What are the objectives of animal breeding?
2. Discuss different types of out breeding.
3. Differentiate inbreeding and out breeding.
4. Discuss different types of breeding systems.
5. What are advantages and disadvantages of inbreeding?
6. What are the advantages of outbreeding?

## Suggested Readings:

1. The Insects by Chapman
2. Modern Entomology by D.B. Thembare
3. Economic Zoology by Shukla and Upadhyay
4. The Insects by Gullan and Carnston
5. Introduction to Economic Zoology by Sarkar, Kundu and Chaki.
6. A textbook of Economic Zoology by Aminul Islam

## Disclaimer:

**The study materials of this book have been collected from various books, e-books, journals and other e sources.**