Dr. Vinod Kumari
Associate Professor
Department of Zoology, University of Rajasthan, Jaipur

Module: Sericulture

Quadrant I

CONTENT

4.3.7. Selection of leaves
4.3.8. Preparation of feed bed
4.3.9. Bed cleaning
4.3.10. Spacing
4.3.11. Moulting
4.3.12. Mounting
4.3.13. Harvesting of cocoons
4.3.14. Post harvest processing of cocoons
4.3.14.1. Stifling
4.3.14.2. Cocoon boiling/cooking
4.3.14.3. Brushing
4.3.14.4. Reeling
4.3.14.5. Re-reeling
4.3.14.6. Raw silk testing
4.3.14.7. Spinning (spun silk yarn production)

5. Problems related to sericulture (Diseases and enemies)
6. Sericulture in India
7. Sericulture research centres in India

1. INTRODUCTION

Sericulture is the combination of two words ‘sericos’ a Greek word meaning silk and ‘cultura’ meaning rearing. Sericulture therefore is a scientific method of rearing silkworms to procure silk which is known as ‘Queen of textiles’. Around 4000 years ago, a Chinese Empress named Si-Ling-Chi, wife of great Emperor Hoang-ti, accidently dropped a silkworm cocoon brought from her garden in a hot cup of tea. The tea softened the threads which were recovered and weaved into silk. Thus, was born silk which the Chinese called ‘Si’ in honour of the Empress and the Empress Si-Ling-Chi herself was regarded as the Seine-Than or ‘deity of the silkworm’. Evidences of primitive silk loom were found from Hemudu culture in Yuyao, Zejiang (4000 BC), Yangshao culture in Quingtaicum, Henan (3630 BC) and Liangzhu culture in Qianshanyang, Huzhou, Zhejiang (2700 BC). Initially silk was used by emperors and their close relatives in clothing, decorations, bonds and luxury paper (rag paper). But later, the value of silk became more that it was measured in length equivalent to weight of the gold and was used as taxes paid by farmers, as rewards for good services. Its manufacture was kept a secret for centuries and to leak the secret was punishable by death. For three millennium, it was confined to China until famous ‘silk road’ a longest highway from Eastern China to the Mediterranean Sea was opened. The sericulture thus reached Korea, Japan. In 522 AD, sericulture reached westwards through smuggling by Persian monks. The 'monks' discovered the secret and smuggled out silkworms (larvae) and cocoons in the hollows of their staff. The silk thus reached Europe where the first silk factory was established in the middle of the 6th century A.D. at Constantinople (in Turkey, now called Istanbul). At present Japan, China, Korea, Italy, Soviet Union, France, Brazil and India are the chief raw silk producing countries. In 1905 Lefroy introduced sericulture in India at the Pusa Institute, Delhi.

Sericulture, mulberry or non-mulberry, is an agro-based export and labour oriented cottage industry comprising three main components cultivation of food plants of the worms, rearing of silkworms and reeling and spinning of silk. The first two are agricultural and last one is an industrial component. The importance of this industry lies in: (i) low investment, (ii) low water requirement and (iii) high income output from a unit area. Interestingly, India is the only country in the world where both kinds of sericulture (resulting in 4 kinds of silk) are found and since mulberry sericulture constitutes the major silk industry in the country, greater attention will be paid to it in the present chapter.

2. MAJOR SILK PRODUCING SPECIES

All moths (as also butterflies) belong to the insect order Lepidoptera. They are nocturnal, dull coloured, with tapering or feathery antennae and both pairs of wings spread while sitting. In contrast, to the butterflies which are diurnal, beautifully coloured, with clubbed-tip antennae and wings drawn vertical to the back while sitting. While all Lepidoptera secrete silk, only some moths weave their silk into cocoons to protect their vulnerable pupae from weather and predators. Only five such moths, listed in the table 1, can be exploited for commercial silk production.

TABLE. 1: Silk producing moths of India

S. No.		Family & silkworm	Main host plant(s)	Domesticated or wild	Cocoon & silk	Producing states
1		Bombycidae: Mulberry silk-worm (*Bombyx mori* L.)	Mulberry (*Morus alba*, *M. indica*, *M. multicaulis*, *M. bombycis*)	Domesticated	Reelable, white or creamy	West Bengal, Karnataka, Andhra Pradesh, Tamil Nadu, Jammu & Kashmir, Himachal Pradesh, Uttaranchal,
2	i	Saturnidae: Tasar silkworm *Antheraea mylitta* Drury *A.* royeli M.R. *A. yamamai* G. M.	Asan (*Terminalia tomentosa*) *Arjun* (*Terminalia arjuna*) *Shorea robusta*	Wild	Reelable, brown or coppery	Bihar, Orissa, M.P., Jharkhand, Chhattisgarh, West Bengal, Andhra Pradesh
	ii	Muga silkworm (*Antheraea assamaensis* W. W.)	Som (*Machilus bombycina*) Soalu (*Litsaea polyantha*)	Semi-domesticated	Reelable, golden-yellow	Assam, Meghalaya, Arunachal Pradesh, Mizoram, West Bengal

			Persea bombycina			
	iii	Eri silkworm [*Philosamia* (=*Attacus*) *ricini* Boisduval *(=Samia cynthia ricini)*] *A.* (atlas) = *minor*	Castor (*Ricinus communis*) Kasseru (*Heteropanax fragrans*) *Manihot utilissima*	Domesticated	Unreelable, red creamy white	Assam, Bihar, West Bengal, Manipur, Orissa, Nagaland, Andhra Pradesh
	iv	Oak Tasar silkworm *Antharaea pernyi* G. M. *A. proyeli* Jolly	*Quercus serrata* *Q. incana* *Q. himalaya*		Finer variety of tasar	Manipur, Mizoram, Nagaland, H.P, Uttarakhand, Assam, J&K, Meghalaya

3. SILK

Silk is known as 'queen of textiles' because it is the most elegant and soft among all the textile fibres. Moreover, it is well known for its natural glittering lustre, light weight and high tensile properties. It is a nature- grown protein fibre available in the form of silk cocoons spun by silkworms. Silk fibre is the product of a pair of silk glands which are nothing but the modified labial glands of the larva (Fig. 1). The silk (fibre) is composed of two proteins, fibroin (secreted as fibrinogen and converted to fibroin on exposure) and sericin. A small gland, Lyonnet's or Filippi's gland is also present whose duct meets with the duct of silk glands. It helps in lubricating the tube through which secretions of the silk gland passes. The weight in grams of 900 m long silk filament is called a 'denier' and the size of a normal cocoon is 1.8 to 3 deniers.

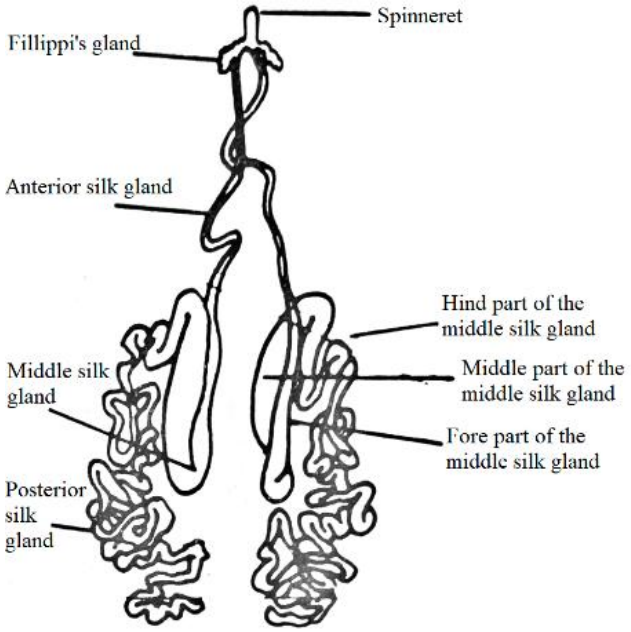

Fig. 1: The silk gland

4. MULBERRY SERICULTURE

4.1. MORICULTURE: CULTIVATION OF FOOD PLANTS

4.1.1. CHOICE OF FOOD MULBERRY VARIETY

Cultivation of mulberry plants is called moriculture. There are over 20 species of mulberry (family Moracea) and of which 4 are more common. They are: *Morus alba* L., *M. indica* L., *M. serrata* Royb, *M. laevigata* Wall. These plants grow both in tropical and temperate climates. An annual rainfall of 600-2500 mm, 24^{o}C to 28^{o}C temperature, and 60-80 % Relative Humidity (RH) are optimum conditions needed for its growth. Both quality and quantity of silk produced by silkworms depend on the quality of mulberry leaves fed to them. A choice in the species of mulberry to be grown is, therefore, important. While the local *M. indica* offers certain good features (quick growing, hardiness, remaining flush throughout the year), its yield is rather low. Therefore, research institutions of the Central Silk Board have developed high yielding varieties such as Kanva-2, Victory-1, MR-2 from south India, Ber S-1, S-623, S-162 and Tr-23 from East and north India and Kosen, Bota-tul KNG and Stari- tul from hilly areas of eastern and north India. The selection of varieties is based on their quality, quantity of leaf yield and easy propagation ability. The recommended strains or varieties give 30-70 per cent more leaves per hectare than the local strain.

4.1.2. PLANTING METHODS OF MULBERRY

Laterite soils are more suitable than alluvial, black and red soil for mulberry growth. Mulberry is propagated by **seeds**, **root-grafts** or **stem cutting** methods and the stem cutting method is most commonly adopted. Pencil thick stem cuttings, 22-23 cm long, 10-15 mm diameter and 6-8 months old with 3-4 buds obtained from mature stems are either planted directly in the field or first in the

nurseries then to be transplanted later. This ensures greater survival percentage. Two systems of cutting-planting are in vogue: pit and row systems. In **the pit system**, pits 45 cm wide and 45 cm deep with 90 cm and 45 cm distance between rows and plants, respectively are dug prior to monsoon and are filled with compost. After first rainfall the cuttings are planted in these pits. In **the row system**, cuttings are planted on the margins of 60 x 30 cm ridges (raised platforms). Distances here between the rows and plants are 45 cm and 10 cm, respectively. Mulching (covering the soil between the mulberry rows with paddy straw, stubbles, dry leaves or sunnhemp grown in between the rows and later pulled) and pruning is also done for proper growth of mulberry plants. Harvesting of leaves for feeding larvae is done in three ways: leaf picking, branch cutting and top shoot harvesting.

4.1.3. DISEASES AND PESTS OF MULBERRY PLANT:

The success of sericulture depends on the quantity and quality of mulberry leaves. Therefore, the cultivation of mulberry plants is challenging due to the occurrence of plant diseases and pests as enlisted in table 2.

Table 2: Diseases and pests of mulberry plants					
S. No.	Name of Disease/ Pest	Causal agent/ Pest	Symptoms	Occurence	Control measures
1	Leaf spot	*Cercospora moricola*, (fungus)	Leaf surface with brown necrotic, irregular or circular spots Affected leaves fall off	Rainy season followed by winter	Weeding, burning of affected leaves, wider spacing, Use of Bavistin (0.2%) and Difolatan
2	Powdery Mildew	*Phyllactinia corylea* (fungus)	White powdery patches on the ventral side of leaves and chlorotic lesions on the dorsal surface. Later the patches become brownish black. Affected leaves – yellow and fall off	Winter and rainy season	Wider spacing Picking and burning Weeding and proper pruning Use of Dinocap 30% EC (Karathane, 0.2%) Morestan, Dithane M-45
3	Black leaf rust	*Cerotelium fici* (=*Perdiospora mori*) (fungus)	Brown pinhead sized eruptive lesions on leaves Leaves fall off	Winter and rainy season	Wider spacing Use of Chlorothaionil 75% WP (Kavach, 0.2%)
4	Red leaf rust	*Aecidium mori* (fungus)	Golden yellow powdery spots on leaves, buds, petioles and stems	Rainy and winter season	Wider spacing No delay in harvesting Use of Bavistin (0.2%) and sulphur dust
5	Fungal leaf blight	*Alternaria alternate*/ *Fusarium pallidoroseum*	Brown and black leaves Leaves fall off	Summer and rainy season	Wider spacing Use of streptomycin (0.2%) or Dithane M
6	Bacterial leaf blight	*Pseudomonas syringae* pv. *mori* (=*Bacterium mori*/ *Pseudomoas mori*) or *Xanthomonas compestris* pv. *mori*	Black brown patches on leaves	Rainy and winter season	Wider spacing Use of streptomycin (0.2%) or Dithane M

7	Wilt disease	*Sclerotium rolfsii* (fungus)	Black patches on cuttings and sprouted shoots become wilt	Rainy season	Use of Bavistin (0.2%) Trichoderma (biofungicide)
8	White root rot	*Rosellinia necatrix* (fungus)	Rotting roots with white patches Plants become weak; defoliation	Throughout the year	Uprooting and burning of infected plants Use of Dithane M-45 and biofungicide (Trchoderma harzianum)
9	Violet root rot	*Helicobasidium mompa* (fungus)	Rotting roots with violet patches		
10	Fusarium root rot	*Fusarioum oxysporum* (fungus)	The root surface beneath the bark sticky appearance		
11	Stem rot	*Polyporus hispidus* and *Ganoderma applantum* (fungi)	Hear wood affected Drying and rotting of twig and branches	Throughout the year	Burning the affected plants
12	Collar rot	*Phoma mororum*	Bark brown to black at ground level and appear as collar by encircling the shoot Leaves withered	Throughout the year	Pruning at level close to ground
13	Cutting rot	*Fusarium solani* (fungus)	Cuttings rotten and death of sprouted shoots	Throughout the year	Use of Dithane M-45
14	Stem canker	*Botryodiplodia theobromae*	Greenish black eruptions on stem cuttings Cuttings do not sprout		Use of Bavistin (0.2%) and carbendazim (0.1%)
15	Leaf Mosaic	Mulberry mosaic virus	Mosaic dark green patches on leaves		Burning of affected plants Sanitization using disinfectants Use of plant resistant varieties
16	Yellow Net Vein	Mulberry yellow net vein virus	Yellow leaves with net vein appearance		Burning of affected plants Sanitization using disinfectants Use of plant resistant varieties

17	Dwarf disease	*Mycoplasma*	Short and fragile branches and leaves		Burning of affected plants Sanitization using disinfectants Use of plant resistant varieties
18	Nematode disease	*Meloidogyne incognita* *M. javanica*	Leaves yellow Growth arrested Reduced leaf lamina	Throughout the irrigation	Deep ploughing Mulching Neem oil cakes @ 2 MT/ha/yr
19	Pink mealy bug	*Maconellicoccus hirsutus*	Leaves become wrinkled roseate, bunchy top appearance of internodes, Sooty mould develops on leaves and stem	Summer months	Destruction of eggs after clipping off infested leaves Spraying of Dimethyl Dichloro Vinge Phosphate (0.2%), Azadirachtin (0.03%)
20	Mulberry leaf roller	*Diaphania pulverulentalis*	Larvae are leaf feeder and remain entangle in silky secretions	September to November	Clipping off infested part for destruction Spraying of 0.076% DDVP and Azadirachtin Biological control by egg parasitoid, *Trichogramma chilonis* and pupal parasitoid *Tetrastichus howardii*
21	Leaf hopper-Jassid	*Empoasca flavesceus, Eusarcocoris ventrlis*	Sap suckers causing withering of leaves	Summer months	Collection by light traps and destruction Spraying of DDVP (0.05%)
22	Bihar hairy caterpillar	*Spilosoma obliqua* (=*Diacrisia obliqua*)	Voracious feeder, defoliate the plants	August to February	Collection and destruction Deep ploughing Spraying of DDVP (0.2%) Biological control by larval parasite *Apanteles obliqua*

23	Scale insect	*Saissatia nigra*	Sap suckers, shoots start dying and leaf yellowish or mottled	Summer months	Scrapping off or swabbing with diesel and soap emulsion (1:3) or Lime-Sulphur mixture to dislodge the scale insects Spraying of Malathion (0.05%)
24	Thrips	*Pseudodendrothrips mori*	Sap suckers	Throughout the year	Dispersion of thrips through sprinkler irrigation Spraying of DDVP
25	Stem girdler beetle	*Sthenias grisator*	Beetles form a girdled branch by ringing the stems and cause wiltings	Throughout the year	Cutting and burning of infested branches and stems Spraying of Benzene Hexachloride (0.1%) or malathion (0.1%)
26	Short horned grasshopper	*Neorthacris acuticeps nilgriensis, Letana inflata, Ailopus sinulatrix*	Nymphs and adults are voracious feeder causing defoliation	July- August	Deep ploughing to expose egg masses for destruction Spraying BHC (0.5%)
27	Spiraling white fly	*Aleurodiscus disperses Dialeuroplora decempuncta*	Feed on nutrients of plant resulting stunted growth and sooty mould due to accumulation of honeydew secreted by nymphs	Throughout the year	Scrapping off to dislodge the nymphs Spraying of DDVP Installation of yellow sticky trap during June – November @ 60 Nos/acre Spray 0.015% Thiamethoxam (25 WG) @ 5g/10 Litre water Safe period: 15 days Release a native predator, Brumoides suturalis (Bio-Control) @ 500 pairs/acre

4.2. MULBERRY SILK WORM

The insect: *Bombyx mori* L.

Distribution: Being fully domesticated, this species does not occur in the wild but can be reared at any place which has the optimum climatic conditions such as 20-28°C temperature, 70-85 per cent relative humidity, 16 hours photo phase and unpolluted air. These or near about conditions are available in the states of Jammu & Kashmir, W. Bengal, Karnataka, A.P. and T.N. and accordingly mulberry sericulture can be carried out there. The wild ancestor *Bombyx mandarina* Moore native of China, from which *B. mori* is supposed to have evolved can be found in mulberry fields.

Life-cycle (Fig. 2): Adult's life-span is of 1-2 weeks after emergence. Mating occurs soon after emergence for 2-3 hrs. Egg laying which would normally occur on the upper surface of the mulberry leaves is made to take place on sheets of paper or cards by sericulturists for the purpose of preservation and transport. The eggs are laid in clusters around 400-500 eggs by univoltine and bivoltine races whereas 300-350 eggs are laid by multivoltine races. Eggs undergo diapause in temperate region however, in subtropical regions (India) non diapause eggs are laid by the moths. In about 10 days, eggs hatch into larva called as ants, kego or chawki, which undergoes 4 moults thus, have 5 instars. The larval period lasts for 25 days. The growth and feeding attain the peak in the last two instars thus the weight of the last instar increases several thousand times. The last instar stopped feeding and start spinning cocoon which is completed in 48-72 hours the larvae transforms into pupa within the cocoon which lasts for 10-14 days.

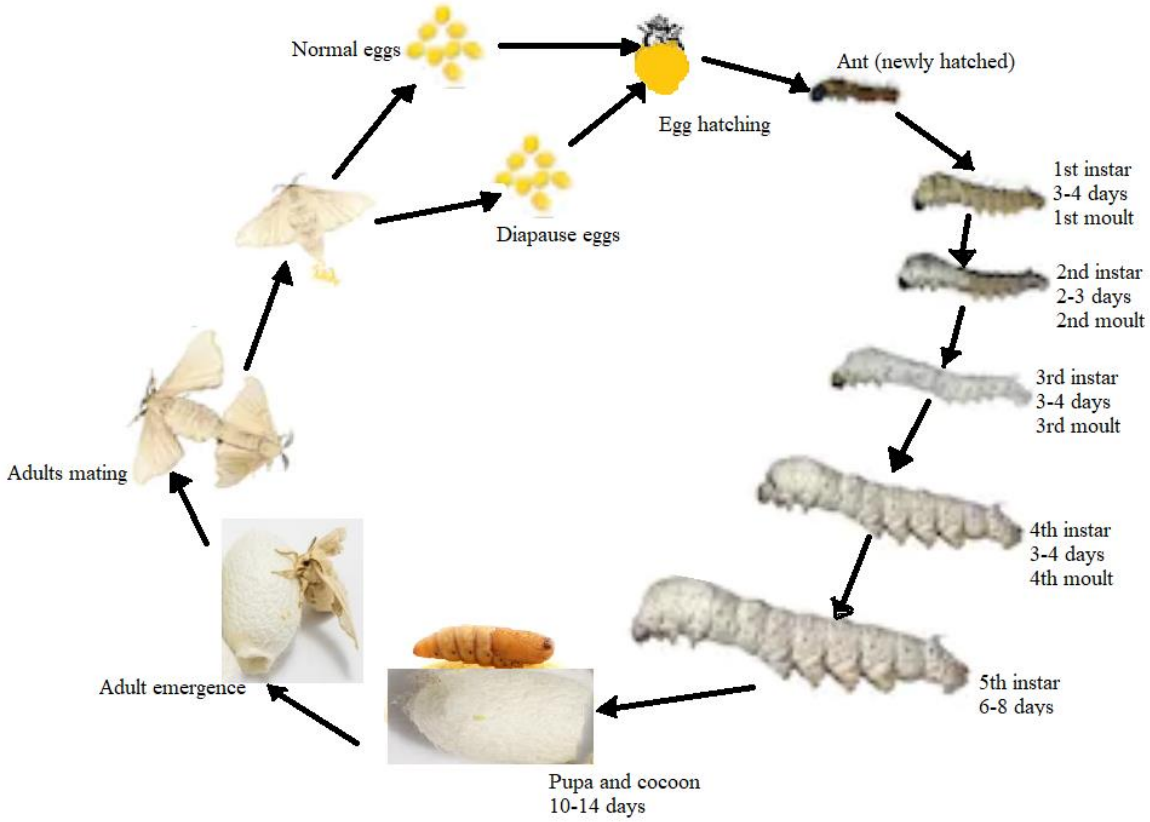

Fig. 2: Life cycle of *Bombyx mori*

4.3. REARING OF *Bombyx mori*

4.3.1. SELECTION OF RACES OF *B. mori*

The number of generations called "crops" in the language of sericulturists, varies according to the race or strain of the moth. Thus, **Votinism** is the number of crops or broods or generations produced by moth annually. A moth is **univoltine**, if it produces only one crop a year and only hibernating eggs which undergo diapause and hatch during the spring. **Bivoltine** moths produce two generations annually laying non-hibernating eggs during first generation and hibernating eggs in the next generation which hatch in the following spring. **Multivoltine** moths produce more than 2 (4 or more) generations annually laying only non-hibernating eggs which develop without diapause. Multivoltines are usually the locally occurring races at some places e.g., "Mysore" race (producing greenish-yellow cocoons) in Karnataka and "Nistari" race (producing deep yellow cocoons) in W. Bengal. A bivoltine race, "Nandi" in Karnataka and univoltine race, 'Kashmir race' (extinct) in Kashmir is also known to be used. The cocoon yield of multivoltine races is poor when compared to uni- and bivoltine races, the latter in particular. Culturing bivoltine races is, therefore, more profitable and generally done by the sericulturists.

4.3.2. REARING HOUSE

Silkworms are very sensitive to weather conditions humidity and temperature, therefore, the room/building in which they are to be reared should meet certain specification. The place selected for construction of the building should be sunny, airy, dry and as far as possible, elevated. Level land is preferred. Damp or water-logged area should have drainage deep enough to drain the moisture, or the building should be built on a high basement. The best orientation of a rearing room would be north or north-west face and south-east back. The length of rearing room varies according to the brushing capacity.

4.3.3. REARING EQUIPMENTS

Following are the equipment needed for proper rearing of silkworms:

4.3.3.1. REARING STANDS

These are stands of frame on which are placed rearing trays containing silkworms. They could be made of wood or bamboo.

4.3.3.2. ANTWELLS

Ants are serious menace to silkworms. To protect them, the legs of the rearing stand are kept in rectangular/circular enamel or concrete bowls containing water mixed with ant repellents.

4.3.3.3. REARING TRAYS

These are trays, generally circular made up of locally available cheap material like bamboo. Sometimes, box type wooden trays are employed to rear early (I and II) instars.

4.3.3.4. PARAFFIN PAPER

Thick craft paper sheets coated with paraffin wax (M.P. 55°C) are required to cover the rearing trays to maintain humidity and prevent

withering of leaves. Polythene sheets and dried banana leaves are also alternative to paraffin paper.

4.3.3.5. FOAM RUBBER STRIPS

Pieces (2.5 x 2.5 cm) of foam rubber soaked in water are kept all around silkworm rearing beds to maintain humidity. Newspaper or blotting paper folded strips moistened with water could also be an alternative.

4.3.3.6. CHOP STICKS

Chop sticks are tapering bamboo rods meant to pick up younger stages of larvae to ensure their hygienic handling and preventing from injuries.

4.3.3.7. FEATHERS (Fig. 3)

Feathers, preferably white, are important items of silkworm rearing room. They are used for brushing off newly hatched worms from egg card to rearing trays or spreading larvae for proper spacing to prevent injuries.

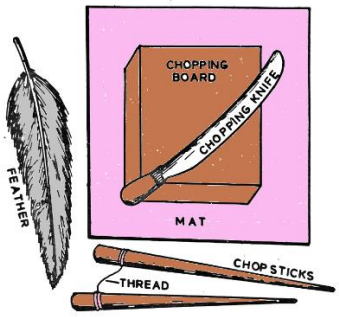

Fig. 3: Feather, chopsticks for handling delicate younger larvae and knife, chopping board and mat for chopping mulberry leaves.

4.3.3.8. LEAF BASKET

It is made of bamboo to keep collected leaves and for transportation from field to rearing house. Wet gunny bags or multi-layered gunny bags could also be used for the same purpose.

4.3.3.9. LEAF CHAMBER

Mulberry leaves meant for feed are stored in chambers made up of 7.5 cm wide wooden strips fixed some distance apart or of some porous board. The chamber with leaves is covered all over with wet gunny bag cloth during the summer months and dry days.

4.3.3.10. CHOPPING BOARDS, KNIVES AND MATS (Fig. 3)

As mulberry leaves are offered to the worms in a chopped condition, chopping board, knives and mats are required. Soft-wood-chopping-board while chopping is placed on mat. Two sized knives, small and large for chopping (small pieces for younger instars and large pieces for older instars) are needed. Chopped leaves falling on the mat are also collected in an enamelled receptacle.

4.3.3.11. CLEANING NETS

Nets made up of cotton or nylon mesh of different size for different instars are used. As manual separation of larvae from the litter has the risk of injuring and killing many of them, it is used for changing the rearing beds so that the left-over leaf-pieces and litter are filtered out without the larvae being touched by hand. Mesh sizes suitable for I, II, III and IV and V suitable for instars are 2 mm, 10 mm and 20 mm, respectively.

4.3.3.12. MOUNTAGES/ COCOONAGES

Mountages (cocoonages) are made up of rectangular bamboo, wood, cardboard, plastic, grass, dry leaves or twigs used to support the penultimate larvae for spinning cocoon. Ripe worms about to spin from cocoons are transferred on to them. The larvae suspend themselves to the mountages and spin cocoons. There are various types of mountages used all over India with the requisite characters like- they can easily be made, easily stored/stacked, excreta of spinning worms dry up soon to free passages and thus prevent cocoons getting stained, easily be shifted from place to place, the space between the frames be sufficient for uniform and proper sized cocoon spinning and disinfection can easily be done.

Types of mountages are as follows:

- Bamboo chandrike (Fig. 4)

Fig. 4: Mountage (Bamboo Chandrike)

- Plastic mountages
- Plastic collapsible mountages
- Screen type mountages
- Bottle brush mountages
- Plastic bottle brush mountages
- Rotary mountages
- Vertical fixed mountages
- Shoot rearing rack

4.3.3.13. MISCELLANEOUS APPLIANCES

Hygrometer, wet and dry thermometer, charcoal stove, disinfection pads of gunny kept at the entry of rearing house, wooden stands to place trays during feeding and bed cleaning, plastic basin, stand for wash-basin, disinfection mask and protective gum shoes, sprayer for disinfection, room heater, water air cooler, kerosene blow lamp, 6" forceps, egg transportation box, egg incubation chamber, loose egg incubation frame, black box, buckets, mug, plastic box, foot rugs, formalin, bleaching powder, lime powder, bed disinfectants, slides and cover slips, gunny cloth and cora cloth.

4.3.4. PRODUCTION OF QUALITY SEEDS

Use of quality silkworm eggs is the vital step to successful sericulture. Silkworm eggs are called as seeds which are of two types **reproductive seed** and **commercial or industrial seed**. Reproductive seeds are used for the production of parents of different commercial seeds and are pure breeds whereas commercial seeds are hybrids produced in mass for supply to sericulturists.

Seed production centres are **Breeding stations**, **Breeding centres** and **Grainages**, where disease-free seeds of pure and hybrid races are produced in large quantities. In grainages, first purchase cocoons from the government certified seed producers and subject them to selection. Pupae randomly obtained from the seed cocoons are crushed in mortar with a pestle and examined under a microscope for pebrine or any other disease. After ensuring that the stock or crop purchased is free from any disease, good quality cocoons with specified characteristics are selected and others that are deformed, flimsy, stained or dead, are rejected. Floss (loose downy materials) from the selected cocoons is removed to facilitate adult emergence. The cocoons of the univoltine and bivoltine being hard are cut for the same purpose. Sometimes even naked (uncocooned) pupae are employed. These cocoons or pupae are allowed to develop in well ventilated rooms with proper temperature (23- 25°C) and humidity (70-80 per cent). Moths usually emerge during early morning hours. To bring about a near simultaneous emergence, grainage rooms are kept in dark and on the expected day of emergence, lights are put on suddenly. Males are kept in the trays of the females and as soon as copulation occurs. Three hours of mating secures maximum fertilized eggs. Male moths are then stored at 5°C to be used for a second mating while the female moths are kept for egg laying:

Within 12 hours, 400-600 eggs are laid. Each layer is then crushed and examined for pebrine. If infected, its eggs are discarded and destroyed. The surface of paper sheets or cards used for egg laying is generally coated with a gummy substance. The egg sheets/cards are washed with 2% formaline for hour to disinfect the eggs and again with water to remove traces of formaline. The sheets are dried in shade and transferred to incubators for hatching.

In commercial production, 50-100 moths are allowed to lay eggs on paper sheets. The egg-sheets are soaked in water to loosen the eggs. The loose eggs are washed in salt solution to remove unfertilized eggs which float on the surface. The fertilized eggs thus separated are disinfected with 2% formaline,

shade dried and packed (loose) in egg boxes to be despatched to buyers (seed producers).

4.3.5. DISINFECTION

Before the commencement of rearing process, the rearing house, equipments etc. are disinfected by physical (sunlight, steam, hot air) or chemical method. Chemicals used as disinfectant should be animal and human safe, readily soluble in water and cost effective. Chemicals like chlorine, iodine, phenol, formaldehyde and bleaching powder are used as sprays or fumigants.

4.3.6. BRUSHING

The silk worm eggs will be either attached onto egg sheets or loose eggs in egg cases. The larvae which hatch from the eggs be gently separated from the empty egg shells. Separation of larvae from the empty shells and their transfer onto a rearing tray is called brushing. This helps in proper handling of the larvae.

Use of feather for brushing is simple but sometimes it hurts the larvae. Brushing with mulberry leaves or husk and mulberry leaf (which are similar) is easier in making the silkworm seat flat.

4.3.7. SELECTION OF LEAVES

Growth of silkworms and quality of cocoon formed depends on the right kind of mulberry leaves obtained from the high yielding mulberry varieties fed to the larvae. Younger (I and II) instar larvae are given tender succulent leaves with a high moisture content and the older instars are fed with mature but soft leaves with lesser moisture content.

Mulberry leaves fed to the larvae should be in a chopped condition. Chopped leaves are preferred over the entire leaves as chopped leaves can be spread evenly, the quantity of feed can be regulated, they do not curl when the weather is dry and prevent from getting damp in wet weather.

4.3.8. PREPARATION OF FEED BED

Feed bed or simply bed is a layer of chopped leaves spread on a tray or over a larger area. In the case of younger (I and II instar) larvae, first a good quality paraffin paper sheet (or newspaper) is spread in a rearing tray. Finely chopped mulberry leaves are evenly scattered on the paper and the larvae carefully brushed off on the leaves. A second sheet of paraffin paper is placed loosely over the bed and in between the two sheets on all the sides, water-soaked foam-rubber-strips (or wet newspaper folds) are placed to maintain the humidity. To prevent muscardine (a fungus) disease, in humid places, a thin layer of ceresan lime (slaked lime + ceresan) or dithan M-45 is spread over the bed. In place of trays, wooden boxes (10-15 cm deep) with or without lids can be used. The boxes could be stacked one above the other but separated by thin wooden strips for ventilation. The older (IlI-V) instars can be reared by 3 methods: shelf-rearing, floor-rearing and shoot-rearing. In shelf rearing, silkworms are reared in round bamboo trays arranged one over the other in tiers on a rearing stand. A stand can accommodate 10-11 trays and, therefore, this method provides economy of space but requires more labour for handling so many individual trays. Larvae are fed on chopped leaves in this method. In floor-rearing, fixed

rearing seats or benches, 5-7 X 1-1.5 m size, constructed in 2-3 tiers out of wooden or bamboo strips, are used for rearing the silkworms. In this method chopped leaves are also given. This method is more economical than the first one because it does not involve labour in handling innumerable trays. In shoot rearing, the rearing seat, 1 m wide and any length long, is in single tier and the larvae are fed with big shoots. To change the bed in this method, ropes parallel to each other are stretched on the old bed and new shoots are placed on these ropes. When all the larvae climb on to the new branches, the ropes are rolled into loose bundles. The ropes and the branches are spread after cleaning the old bed and litter making a new bed. This method is suitable for IV and V instars and saves both labour (50-60%) and leaves (10-25%) and, therefore, most economical among three methods. Four feeds a day are sufficient for each instar. The feeds are normally given at 9 A.M., 3, 5 and 9 P.M. A gap of two hours before and after the moulting for feeding is also considered.

4.3.9. BED CLEANING

Periodical removal of leaf leftovers and worm excreta is referred as bed cleaning. It is necessary to maintain hygienic conditions and for proper growth of the larvae. Bed cleaning is done by four methods viz., conventional method, husk method, net method and the combined husk and net method. Conventional method is the largely practiced method in which I-III instar larvae are simply swept together with a feather and transferred to the new bed from the old one whereas, IV and V instar larvae are transferred manually. In the husk method, a thin and even layer of paddy husk is sprinkled over the bed to be changed and the chopped leaves are scattered on the husk. The worms quickly crawl through the husk to get at the feed from where they are transferred to the new tray. For I and II instars, broken (not powdered) husk by pounding, for III instar, whole husk and for IV and V instars evenly chopped straw are used. For the first two instars, husk can be substituted with mosquito net cloth which have the advantage of easy visibility of minute larvae against white background. In the net method, a cotton or nylon net of suitable mesh size is spread over the old bed and leaves are scattered on it. The larvae as usual migrate to the net in search of fresh leaves which can be collected and transferred to a new bed. In the combined husk and net method, a thin layer of paddy husk is first sprinkled over the old bed and a net of suitable mesh is superimposed on it. This combination of both methods has an advantage of cleanliness due to husk method as well as ease of transference due to the net method. It also requires less skill and care in manipulation though it is slightly more expensive than others. The information from feeding to bed cleaning are summarised in the following Table 8.

4.3.10. SPACING

Spacing means avoiding overcrowding of caterpillars by increasing the size of the feeding trays (areas) with the growth of the insects as crowding leads to under-nourishment and so uneven development resulting in a substandard harvest. Besides, crowding increases accumulation of gases, heat, and

fermentation of faecal matter, particularly during the early stages when the temperature and humidity in the rearing beds are high. Such unhygienic conditions may lead to infection, death and loss of crop. For optimum results, rearing space is increased twice or thrice for I-IlI instars, for IV instar 2-3 times more than that for I-III instars and for V instar 2 times more than that for the IV instar. It would save time and labour if the spacing is combined with bed cleaning. Spacing could be achieved by marking out the extended feed area and distributing both the leaves and worms evenly over the entire area. If some crowded spots are still left, worms from those spots are picked up and transferred to sparser areas.

4.3.11. MOULTING

Moulting is a very critical event in the life of caterpillars. When about to moult, the larvae attain their maximum size for that particular instar. At this stage bed cleaning should be carried out and leaves should be chopped to small size for pre-moult feeding. Larvae stop feeding, when they settle down for moulting so at that time it is advisable to sprinkle some lime powder to prevent larvae of early moulting from commencing feeding and thus maintaining uniform growth in all. During moulting, the worms are most susceptible to muscardine infection which could be prevented by dusting them with ceresan+lime.

4.3.12. MOUNTING

Transferring mature V instar larvae to mountages (cocoonages or chandrikes) is called mounting. When the larvae are fully fed and ripe, they become translucent, their body shrinks, they wander away from food (i.e. stop feeding) and start searching for a suitable place to attach themselves for cocoon spinning and pupation. They generally move to the periphery of the rearing tray for this purpose. This is the right time to pick them up and put them on mountages. The worms attach themselves to the spirals of the mountages and start spinning cocoon. If unripe worms are put on the mountages, they will move and defecate spoiling the cocoons of the nip worms or will fall off resulting in loss to the rearer. Therefore, it is necessary that only right age larvae are put on the mountages and a correct density is maintained to avoid crowding. Mounting can be done by hand picking, branch method and net method. In the branch method, branches of mulberry with green leaves are kept over the rearing bed and when the worms crawl on to them, they are shaken off on a net and transferred to the mountages. In the net method, a net is spread over the bed after feeding. The non-feeding (mature) worms come up and crawl on to the net which is then shaken on mat and the larvae are transferred to the mountages.

4.3.13. HARVESTING OF COCOONS

When the caterpillar has spun its silken cage or cocoon around itself, it casts off its skin to pupate. In early days, pupal skin is tender and ruptures easily. Therefore, early harvest of the cocoons could injure the pupae and result in their blood not only soaking in and staining the cocoon but also inducing

fermentation and infection and making the stained portion unreelable. Late harvest, on the other hand, leaves less time for transporting the cocoons to the market and for their stifling and results in the risk of being cut by the emerging moths and thus being rendered unfit for reeling. It is, therefore, very crucial for the sericulturists to harvest the cocoons at the correct time. In tropical climate (as in Karnataka, A.P., W. Bengal), the proper time to harvest cocoons is 5th day after their formation whereas, it is 7th to 8th day in temperate climate (as in Kashmir). Harvesting is normally done by hand (Fig. 5) or cocoon harvester and it is the best time for sorting out cocoons into good cocoons, stained cocoons, pierced cocoons and double cocoons.

Fig. 5: Cocoon Harvesting

4.3.14. POST HARVEST PROCESSING OF COCOONS

After harvesting of cocoons, the industrial part of the silk industry begins. The post-harvest processing of cocoons includes following events:

4.3.14.1. STIFLING

The purpose of stifling or cocoon drying is to kill the pupae before they metamorphose into moths and emerge, cutting the cocoons and rendering them unreelable. This is achieved by any of the three methods i.e., drying cocoons under the sun, hot air stifling or steam stifling.

4.3.14.2. COCOON BOILING/COOKING

This is done to make the cocoon thread reelable (loose) by dissolving the gum-like protecting sericin that binds the winding segments of the thread.

4.3.14.3. DEFLOSSING

Deflossing is important to remove floss (loose layer of silk filament) and is done before reeling. Deflossing is done by brushing manually or power operated machines to reduce the labour expenditure.

4.3.14.4. REELING

Silk reeling is the process of finding the right end of the cocoon filament and jointly taking several ends together to reel raw silk. In other words, unwinding of the silk filament from the cocoon with the help of a reeling

machine is called silk reeling. The reeling methods used are country charka, cottage basin and filature.

4.3.14.5. RE-REELING

The raw silk is first reeled on small reels, allowed to properly dry up on them and then re-reeled on large reels. Direct reeling on large reels leads to insufficient drying which in turn leads to production of hard gum spots on the thread. This is overcome by reeling the raw silk first on small reels which permits better drying.

4.3.14.6. RAW SILK TESTING

There are Indian and International standards to judge the quality of the raw silk and facilitate its marketing. To maintain these standards, raw silk is put to a number of tests viz., visual examination, winding test, denier size and deviation test, seriplane test to assess its size variations, winding quality, neatness, evenness, cohesion and tenacity.

4.3.14.7. SPINNING (SPUN-SILK YARN PRODUCTION)

The following by-products are obtained in the process of silk reeling:

- Pierced cocoons
- Silk Waste

These by-products are utilized for producing silk yarn by the process of spinning, since these cannot be reeled by the method used for normal silkworm cocoons. The yarn is, therefore, taken out by the process of spinning.

The process of spinning involves drawing the loose lump of waste containing fibres of small staple length into slender slivers where the fibres can lie in a more or less parallel manner, and are then simultaneously twisted in spun yarn and wound on a wooden spindle.

5. PROBLEMS RELATED TO SERICULTURE

Mulberry silkworms, the most important of all the silkworms, are susceptible to many diseases and enemies which are summarised in table 2.

Table 2: Diseases and Enemies of *Bombyx mori*

Diseases/ Enemies		Causative agent (pathogens) / Insects	Stage infected	Symptoms/ damage	Control measures
Bacterial disease	Gastro entric disease	*Brevundimonas, Stenotrophomonas, Enterobacter, Staphylococcus, Aeromonas, Brevibacterium, Citrobacter, Escherichia, Klebsiella, Pseudomonas Agrobacterium*	Larvae	Diarrhoea, vomiting, shrinkage after moulting, loss of appetite	Maintenance of hygienic conditions Proper disposal of litter Use of bed disinfectants like formalin, bleaching powder or paraformaldehy

	Septicaemia	*Bacillus sp*, S*taphylococcus aureus, Streptococcus bombycis, Serratia marcenscens*	Larvae	Lack of appetite, loss of clasping capacity of prolegs, brown, red, green colouration	de
	Sotto disease	*B. thuringiensis var. Sotto*	larvae	Gut paralysis, vomiting, twitching of the body, black or dark brown colouration	
	Rangi or court disease	*Serratia marcescene* Bizio (*Bacillus oridigiosus* Fluigge)	larvae	Crimson-red colour, foul smell after death	
	Gattine Disease or clear head disease	*Streptococcus bombycis*	larvae	Body swollen, loss of appetite	
Protozoan disease	Pebrine	*Nosema bombycis* Naegeli	All stages	Deformed wings, distorted antennae in Adults Poor egg laying, poor hatching, loss of appetite in larvae, hanging down, sluggishness, flabby pupae, dark patches on the abdomen near wing pads	Use of disease free females and eggs Sterilisation of eggs, equipments room and workers with 2% formaline Destruction of infected seeds and laying females
Viral disease	Flacherie	Cytoplasmic Polyhedrosis Virus (CPV)	larvae	Head disproportionately large, Loss of appetite	Proper incubation and rearing Disinfectant use for sterilisation Avoidance of injury Proper incubation and rearing Disinfectant use for sterilisation
	Grasserie	Nuclear Polyhedrosis Virus (NPV)	larvae	Intersegmental membrane glossy, swollen body, loss of appetite	

					Avoidance of injury
Fungal disease	White muscardine	*Beauveria bassiana*	Larvae	Loss of appetite, Diarrhoea, vomiting, infected fifth instar larvae die in the cocoon	Use of bed disinfectants like formalin chaff (0.4 0.8%), dithane M45 and captan 1-2% in combination with kaolin (levigated china clay)
	Green muscardine	*Spicaria prasina*	Larvae	Black specks, vomiting, diarrhoea, loss of appetite	
	Yellow muscardine	*Isaria farinose*	Larvae	Black specks around spiracles, larvae harden after death, loss of appetite	
	Black muscardine	*Metarhizium anisopliae*	Final larval instar, pupa, adult	Loss of appetite, body rigid, brownish yellow	
	Aspergillosis	*Aspergillus flavus*, *A. oryzae*, *A. ochraceous*, *Sterigmatocystis japonica* *S. fulva*	Younger larvae	Body tensed and lustrous	Disinfection with 0.1- 0.4% pentachlorophenol is recommended for the control of the disease. Sprinkling 0.2% of Chlorkalk after moults is also found to be effective.
Diptera fly	Uzi fly	*Tricholyga bombycis*	larvae	Cocoons are built in the V instar Black scar on the larvae due to penetration of maggots	Using Uzi trap Biological control by *Nesolynx thymus* (a pupal parasitoid) Wire mesh for doors and windows
Coleoptera	Beetles	*Dermestes cadeverinus*, *Anthrenus verbasi*	Cocoons, sometimes eggs	Larvae greyish	Maintenance of hygienic conditions

			and larvae		wire mesh for door and windows use of 0.2% malathion solution Collection of the grubs and adults destroying by burning or dipping in soap water. Use of Deltamethrin treated bags

6. SERICULTURE IN INDIA

India occupies 5th position in the world in its silk production, the first four in order of production being Japan, China, South Korea and USSR. Brazil, Bulgaria and Italy come behind India. Nonetheless, sericulture Industry in India employs about 60 lakhs people, mostly tribals, and is thus rated as the second largest employer next only to handloom industry. It is also an export-oriented industry exporting silk to over 50 countries of the world, the major ones being the west European countries and the USA and bringing in foreign exchange worth about Rs. 250 crores. Incidentally, North-Eastern part of India is the only region in the world where all four varieties of silk viz., mulberry, tasar, muga and eri, are produced. Their output is 5% of the global output of mulberry silk, 10% of tasar silk and 100% of muga silk (eri silk output figure is not known). The actual seed production of the four silk varieties by India is given in Table 3. Thus, India has the monopoly on muga silk production.

The export earnings during 2019-20 were Rs. 1498.39 crores.

Table 3: The total quantity of seed production (Unit: Lakh dfls) during the year 2018-19 and 2019-20 (CSB)

Silk	2018-19	2019-20
Mulberry	483.04	399.87
Tasar	51.08	55.53
Oak Tasar	0.78	0.44
Muga	5.33	5.71
Eri	7.22	6.64
TOTAL	547.45	468.19

7. SERICULTURE RESEARCH CENTRES IN INDIA

There are following major research centres for sericulture working under the common Central Silk Board (under the Ministry of Trade and Commerce). They are-

1. Central Sericulture Research Station, Behrampur, Orissa (mulberry).
2. Central Sericulture Research and Training Institute, Mysore (mulberry).
3. Central Muga Eri Research and Training Institute, Lahdoigarh, Jorhat, Assam.

4. Central Tasar Research Station, Ranchi, Jharkhand.
5. Central Sericulture Research Station, Behrampur, West-Bengal (Mulberry).
6. Sericulture Research Institute Channapatna, Mysore (Mulberry).

These stations have substations and extension centres in different parts of the country trying to reach to almost every silk producing region for advice and guidance (Table 4).

Table 4: Silk centres in India

S. No.	State	Silk Centre
1	Andhra Pradesh	Dharmavaram, Pochampalli, Venkatagiri, Narainpet
2	Assam	Sualkuchi
3	Bihar	Bhagalpur
4	Gujarat	Surat, Cambay
5	Jammu & Kashmir	Srinagar
6	Karnataka	Bangalore, Anekal, Ilkal, Molakalmuru, Melkote, Kollegal
7	Chhattisgarh	Champa, Chanderi, Raigarh
8	Maharashtra	Paithan
9	Tamil Nadu	Kanchipuram, Arni, Salem, Kumbhakonam, Tanjavur
10	Uttar Pradesh	Varanasi
11	West Bengal	Bishnupur, Murshidabaad, Birbhum