NETAJI SUBHAS OPEN UNIVERSITY

Choice Based Credit System (CBCS)

UG

SELF LEARNING MATERIAL

Skill Enhancement Course (SEC)

Zoology (HZO)

Sericulture

SE - ZO - 11

PREFACE

In a bid to standardize higher education in the country, the University Grants Commission (UGC) has introduced Choice Based Credit System (CBCS) based on five types of courses *viz. core, discipline specific, generic elective, ability and skill enhancement* for graduate students of all programmes at Honours level. This brings in the semester pattern, which finds efficacy in sync with credit system, credit transfer, comprehensive continuous assessments and a graded pattern of evaluation. The objective is to offer learners ample flexibility to choose from a wide gamut of courses, as also to provide them lateral mobility between various educational institutions in the country where they can carry their acquired credits. I am happy to note that the university has been recently accredited by National Assessment and Accreditation Council of India (NAAC) with grade ''A''.

UGC (Open and Distance Learning Programmes and Online Programmes) Regulations, 2020 have mandated compliance with CBCS for UG programmes for all the HEIs in this mode. Welcoming this paradigm shift in higher education, Netaji Subhas Open University (NSOU) has resolved to adopt CBCS from the academic session 2021-22 at the Under Graduate Degree Programme level. The present syllabus, framed in the spirit of syllabi recommended by UGC, lays due stress on all aspects envisaged in the curricular framework of the apex body on higher education. It will be imparted to learners over the six semesters of the Programme.

Self Learning Materials (SLMs) are the mainstay of Student Support Services (SSS) of an Open University. From a logistic point of view, NSOU has embarked upon CBCS presently with SLMs in English / Bengali. Eventually, the English version SLMs will be translated into Bengali too, for the benefit of learners. As always, all of our teaching faculties contributed in this process. In addition to this we have also requisitioned the services of best academics in each domain in preparation of the new SLMs. I am sure they will be of commendable academic support. We look forward to proactive feedback from all stakeholders who will participate in the teaching-learning based on these study materials. It has been a very challenging task well executed, and I congratulate all concerned in the preparation of these SLMs.

I wish the venture a grand success.

Professor (Dr.) Subha Sankar Sarkar
Vice-Chancellor

Netaji Subhas Open University
Under Graduate Degree Programme
Choice Based Credit System (CBCS)
Subject: Honours in Zoology (HZO)
Course : Sericulture
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Netaji Subhas Open University

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Netaji Subhas Open University

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Unit - I ❑ Economic zoology deals with the development of economy by rearing economically important animals. Sericulture is a part.

Structure

1.0 Objectives

By studying this unit learners would be able to know about the following :

- Different types of silk worm;
- Sericulture in India;
- Classification of mulberry silk worm;
- Mulberry and non mulberry Sericulture.

1.1 Introduction

Economic Zoology deals with the development of economy by reaming economically important animals Sericulture is a part of economic zoology i.e. by the use of silk producing insect, we can develop our economy as well as the empowerment of the unemployed of the country. It is actually a combination of rearing of the insect concern as well as their host plant. The superiority of silk as a textile fiber has been recognized from the immemorial. The luxurious look, sleek feel and luster of the silk fiber is unquestionable. The natural silk are broadly classified as *mulberry* and *wild or non mulberry*. Non mulberry sericulture is universally known

as wild sericulture. Tropical and temperate *Tasar, Eri, Muga* and *Anaphe* are the primary non mulberry silk. The annual world output of the raw silk, including both mulberry and non mulberry is estimated about 48000 metric tons (mulberry) and 4000 metric tons of non mulberry. Not only that non mulberry sericulture holds great promise for the world forestry as a supplementary activity. On one hand it can help arrest forest destruction and on the other hand it permits gainful utilization of this vast natural wealth.

Figure 1 : Tasar silk moth

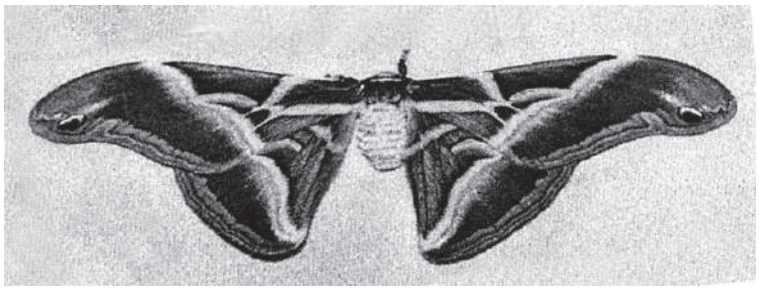
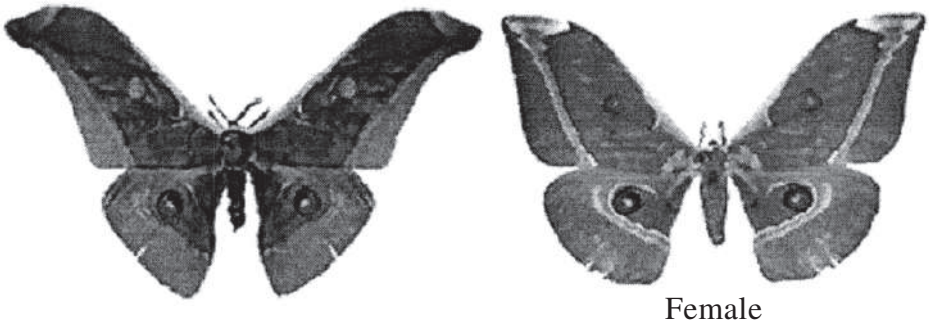


Figure 2 : Eri silk moth



Male Female

Figure 3 : Muga silk moth

Figure 4 : Anaphe silk moth

Definition

Sericulture, also called silk farming, is the process of making silk fibers. It starts by raising silkworms and then processing the fibers they produce.

- **History of sericulture**

Sericulture, or silk production, from the moth, ***Bombyx mori*** (L.), has a long and colorful history unknown to most people. The history of silk is as long as that of civilization itself. Although there are several commercial species of silkworms, *B. mori* is the most widely used and intensively studied and techniques for its rearing are the most improved. This insect is the sole living species in its family, Bombycidae, and has been domesticated for so long that it probably no longer survives in the wild. According to Chinese records, the discovery of silk production from *B. mori* occurred about 2,700 B.C. Chinese legend states that the great prince, Hoang-ti, directed his wife, Si-ling-chi, to examine the silkworm and test the practicability of using the thread. Thereafter, Si-ling-chi discovered not only the means of raising silkworms, but also the manner of reeling the silk, and of employing it to make garments. Is-lingo-chi was later deified for her work and honored with the name Seine-Than or "The Goddess of Silk Worms". By the middle of the first century A.D., writers in Rome were complaining about the sumptuous silk garments that rendered women naked in the streets. But the Chinese had guarded the secrets of sericulture so closely the early Romans never learned it and Virgil thought the thread was derived from combing the fuzz off leaves. In spite of their secrecy, however, the Chinese were destined to Jose their monopoly on silk production. Sericulture reached Japan through

Korea, but not before the early part of the third century A.D. Shortly after 300 A.D., sericulture traveled Westward and the cultivation of the silkworm was established in India. According to tradition, the egg of the insect and the seed of the mulberry tree were carried to India concealed in the headdress of a Chinese princess. The emperor Justinian gained the secrets of sericulture for the Roman Empire in 522 A.D., with the smuggling of the silk worm eggs from China by Persian monks. With China's monopoly on sericulture broken, silk importations from China became smaller and smaller. In 877 A.D., the rebel chief Biachu captured Canfu, the center of foreign silk trade, put to death all its inhabitants, destroyed all of the mulberry trees and silkworms of the region, and levied heavy and cruel taxes on all foreign trade. These actions stopped foreign commerce in China for more than 60 years. However, by this time, silk production was so well established in western Asia and eastern Europe that this wholesale destruction hardly effected the price of silk in the rest of the world. During the 18th and 19th centuries, Europeans also produced several major advancements in silk production. England by the 18th century led Europe in silk manufacturing because of English innovations in the textile industry. These innovations included improved silk-weaving looms, power looms and roller printing. In 1801, A Frenchman named Joseph Jacquard exhibited his new machine foe figured silk weaving and gradually spread through the industry. The great French scientist, rs asteur, rescued the silk industry in 1870 by showing that the then epidemic pebrine disease of silk-worms could be controlled by prevention through simple microscopic examination of adult moths. These advances set the trend for a more mechanized and scientific approach to silk production than existed previously.

Silk production today is a blend of ancient techniques and modern innovations. The first stage of silk production is hatching the silkworm eggs, which have been previously examined and shown to be free from disease. Larvae are then fed cut-up mulberry leaves and after the fourth molt climb a twig placed near them and spin their silken cocoons. The silk is a continuous-filament fiber consisting of fibroin protein secreted from two salivary glands in the body of each larvae, and a gum called sericin, which cements the two filaments together. Pupae within cocoons are killed by steam or fumigation to prevent adult emergence, which would cut and tangle the silk filaments. Cocoons are latter softened in hot water to remove the sericin, thus freeing silk filaments for reeling. Single filaments are drawn from cocoons in water bowls and combined to form yarn. This yarn is drawn under

tension through several guides and eventually wound onto reels. The yarn is dried, packed according to quality, and is now raw silk ready for marketing. World silk production has approximately doubled during the last 30 years in spite of man-made fibers replacing silk for some uses. China and Japan during this period have been the two main producers, together manufacturing more than 50% of the world production each year. China during the late 1970's drastically increased its silk production and became the world's leading producer of silk. The 1970's were a period of tumultuous political and social upheaval in China, resulting in various economic reforms. Undoubtedly, these reforms are partially responsible for China's increased silk production.Thus the country that first developed sericulture approximately 4,700 years ago has again become the world's main producer of silk.

- **A brief note on sericulture in India :**

Use of silk and its marketing has been practiced in India since ancient times as it has been regarded as a prestigious matter not only in the social life but in commercial aspects of the country also.

(1) **In the Pre-British period** — It has been recorded in ancient literature that raw silk was exported to Rome from India via Silk Road during the period of Kanishka in 58 B.C. and some historians also acknowledged the same. India has a traditional reputation for a particular type of silk goods from ancient times in the form of Benaras Silk, Mysore Silk, Bengal Silk, Kashmir Silk, etc. with own traditional method of sericulture of local worms of each state.

(2) During British period — In true sense, modern Sericulture was set up in British period by importing mulberry plant and silk moth strains. Pioneer was Lefroy in 1905-06 of Pusa Institute and James Anderson at Madras tried to spread the silk industry. Gradually, in India, Mysore Silk Association (1925), Mysore Silk Weaving Factory (1932), silk conditioning and Testing House at Mysore (1932) like silk producing organizations have developed.

(3) After Independence — Control Silk Board was introduced in 1947 but was established in 1949 through legislation in the constituent Assembly of India. Since then, the Board aims to improve sericulture in India in consideration with its quality, quantity by increasing culturable area, marketing, research on Silk, etc. Sericulture is now practised by the people of many parts of India and India occupies 5th position in this status of the world.

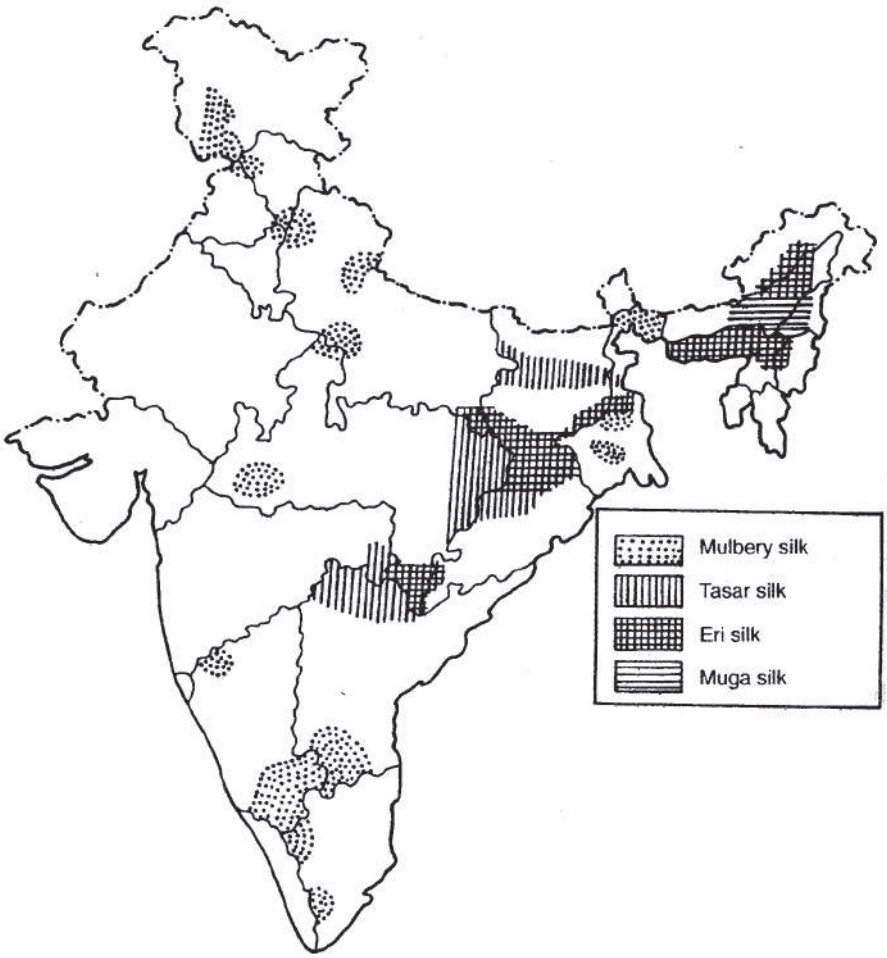


Figure 5 : Rearing of different silk in different regions of India.

1.1.1 Silk route or silk road

Sericulture during the following centuries spread through China and silk became a precious commodity highly sought by other countries. In 139 B.C., the world's longest highway was opened, and stretched from Eastern China to the Mediterranean sea. In addition to tangible commodities such as gold and jade, new ideas and religions also passed along this road. This road was the historically famous "Silk Road," named after its most important commodity.

1.1.2 Types of silk worm

Apart from insects, there are several other non insect animals are also able to produce silk which are good qualities and have different uses. Normally silk worm means the silk producing insects.

Silk producing insects can be classified into two primary types- mulberry silk worm and non mulberry silk worm.

1.1.3 Mulberry silk worm

This silk producing insects belongs to the Genus -Bombyx under the Family-Bombycidae, Order -Lepidoptera, Class-Insecta. This mulberry silk worm may again be classified in different ways. For example the classification may be based on the native regions, the number of hatching in a year i.e. voltinism , or even the number of larval moults. Besides this classification silk worms are also classified according to the rearing period, body markings or pattern, body colour of the freshly hatched larva, body colour of the mature larva, colour of the cocoon, colour of the eggs and so on. Following are the some example of mulberry silk worm classification :-

1. Classification based on the native regions :-

On the basis of this classification the mulberry silk worms are classified into Japanese, Chinese and European race.

2. Classification based on voltinism :-

In this way silk worm can be classified into univoltine, bivoltine and multivoltine silk worm.

3. Classification based on moulting :-

According to the number of larval moults the silk worms are classified into three larval moult, four larval moult and five larval moult silk worm. The silk worm with more larval moults have shorter life span.

4. Classification based on cocoon colour :-

In this way silk worm can be classified into white coloured cocoon and coloured cocoon silk worm. White colour may again be classified into inferior white and superior white. Similarly coloured may again be classified into yellow, buff, straw, green etc.

5. Classification based on rearing period :-

According to this classification silk worm are broadly classified into spring and summer-autumn silk worm. Summer-autumn silk worm may again be classified as summer, early autumn, late autumn and very late autumn silk worm.

6. Classification based on larval markings :-

In this way silk worms are classified into striped, dark coloured, zebra bands, brown spotted, quail marked and multi star silk worm.

1.1.4 Non mulberry silk worm

A large number insect species , about 500 , are used in the production of non mulberry silk. Although about only 80 species have been commercially exploited in Asia and Africa. Following are the classification of non mulberry worms:-

1. Tasar silk worm :-

There are four species belongs to the genus *Antheraea* are used for this tasar silk production . The species are *A. mylitta, A. proylei, A. pernyi,* and *A. yamamai.* All belongs to the Family-Saturniidae.

2. Muga silk worm :-

Muga silk is golden yellow in colour and is one of the costliest silk and the insect belongs to *Antheraea assamensis.*

3. Eri silk worm :-

This silk worm is known as *Philosamia ricini* and a domesticated multi voltine silk worm. This silk worm also produces costliest silk.

4. Anaphe silk worm :-

This is a southern and central African silk worm and belongs to the genus *Anaphe* which have four species. These are *Anaphe moloneyi, A. panda, A. reticulata,* and *A. ambrizia.*

5. Fagara silk worm :-

This is one of the giant silk moth and is known as *Attacus atlas* and are primarily found in Indo-Australian bio-geographical regions.

6. Coan silk worm or Italian silk worm :-

This silk worm is known as *Pachypasa otus* and are found in Southern Italy. This silk is also a costly silk due to its lusture.

• N.B. Non insect silk producing animals

Apart from the above mentioned insects, there are two other groups of animals are also able to produce silk which are **:-**

1. Mussel silk :-

This silk is obtained from a bivalve *Pinna squamosa* (Mollusca) and are primarily found in shallow water in Italian and Dalmatian shores. This silk is popularly known as" Fish Wool".

2. Spider silk :-

This is another non insect silk primarily produced by the Madagascan species of spider which is known as *Nephila madagascarensis*. This is very costly silk and normally not used in textile industry. This is generally used in optical instruments.

1.2 Distributions and races of silk worm

The wild mulberry silk worms are distributed primarily in three countries like Japan, China and European countries. The ancestor of *Bombyx mori* (domesticated silkworm) is considered to be *Bombyx mandarina* which is wild and distributed in above three countries. The *Bombyx mori* has 2n chromosome number is 56 while the 2n chromosome number of *Bombyx mandarina* is 54. Therefore according to the distribution pattern there are three races of *Bombyx* which are Japanese race, Chinese race and European race. The Japanese race have two sub-races which are univoltine and bivoltine. The Chinese races have three sub-races which are univoltine, bivoltine and polyvoltine. European race has no sub-race and all are univoltine.

1.3 Exotic and indigenous race

All the three races and their sub-races like Japanese, Chinese and European are considered to be the exotic races while the *Bombyx mori* bivoltine and polyvoltine are considered to be indigenous race. Now a days all the exotic and indigenous races are mixed up through selected breeding process. This breeding is done due to selection of certain specific characters found in both exotic and indigenous races.

1.4 Mulberry and non mulberry sericulture

Non-mulberry sericulture is universally known as forest or wild sericulture. Tropical and temperature tasar, eri, muga and anaphe are the principle non-mulberry silks. Other varieties i.e. fagara, coan, mussel and spider silks are of limited interest, Nearly 95% of the global production of non-mulberry silks is tasar. All branches of sericulture require food plants and manpower. In mulberry sericulture over 60% of the cost of production goes into raising and maintaining the food plants, besides a heavy initial investment is necessary for rearing houses, rearing appliances and other essentials. Likewise, among the non-mulberry varieties, eri has the disadvantage of higher production costs. Tasar is endowed by nature with vast potential. But continuous deforestation resulted in depletion of non-mulberry food plants. One should not

forget that non-mulberry sericulture holds great promise for the world forestry as a supplementary activity. Non-mulberry sericulture is a forest-based industry uniquely suited to the economy and social structure of developing countries because of its minimum investment requirement, high employment, and foreign exchange earning potential. Mulberry silk are produced in many countries of the world while the non-mulberry sericulture is commercially cultivated only in two countries China (almost 80% of the total production) and India (almost 20% of the total non-mulberry silk production).

1.5 Summary

From this unit we learn that as a part of Economic Zoology. Sericulture plays important role for the benefit of mankind. The natural silk are classified as mulberry and non-mulberry. Non mulberry sericulture is broadly known as wild sriculture. There are many silkworm strains and vearing have been engaged in several countries, because of their economic importance. India is the only country which is engaged in rearing both mulberry and non-mulberry silkworms viz., tasar, eri and muga. We also learned about the brief history of sericulture and the dominance by the countries like China and India in this regard. The flourish of the sericulture industry in India from the British era to the post-Independence era can be assumed. The mulberry silk worms can be classified on the basis of different parameters like native vegion, voltinicm, moulting, cocoon colour, rearing period etc.

1.6 Questions

1. Write any ten countries where mulberry is cultivated?
2. What is 'Silk.Road'?
3. State ideal weather conditions in sericulture.
4. Write the scientific name of Tasar moth.
5. Define Vanya silks or non-mulberry silks.
6. Which place is monopolized for muga silks?
7. Name the scientific names of Tasar, Eri and Muga silkworms.
8. Discuss the distribution of the non-mulberry silk.worms.
9. Describe the salient features of non-mulberry silkworms.
10. What is the soil pH required in sericulture?
11. What is sexual propagation?

12. Define weed.
13. What is field capacity?
14. What is vermicompost?
15. Name the different host plants of different silkworms.
16. What are the items made of Muga silks?
17. Mention the food plants of all the non-mulberry silkworms.

Multiple choice questions

1. The rearing of silkworms for obtaining silk is called-

(a) cocoon (b) silk

(c) sericulture (d) silviculture

2. Which of the following is not a type of silk?

(a) Mulberry silk (b) Tassar silk

(c) Muga silk (d) Moth silk

3. Ankita wanted to buy a gift made of animal fiber obtained without killing the animal. Which of the following would be the right gift for her to buy?

(a) Woolen shaw (b) Silk scarf

(c) Animal fur cap (d) Leather jacket

4. The term sericulture is used for-

(a) culture of bacteria. (b) rearing of silkworm.

(c) making silk fabric from silk yarn. (d) production of sarees.

5. Wool fiber cannot be obtalned from which of the following?

(a) Goat (b) Llama

(c) Alpaca (d) Moth

6. Selective breeding is a process of-

(a) selecting the off springs with desired properties.

(b) selecting the parents with desired properties.

(c) selecting an area for breeding.

(d) selecting fine hair for good quality wool.

7. The general process that takes place at a sheep shearing shed is-

(a) removal of fleece.

(b) separating hair of different textures.

(c) washing of sheep fiber to remove grease.

(d) rolling of sheep fiber into yam.

1.7 Suggested readings

1. **Hisao Aruga (1986)- Principles of Sericulture.,** Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, pp 375.
2. **Jaiswal Kamal, Trivedi, S.P.** & **Pandey, B.N. (2009)- Mulberry Sericulture-Problems and Prospects.,** APH Publishing Corporation, New Delhi, pp 380.
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Unit - 2 ❑ Biology of Silkworm

Structure

2.0 Objectives

By studying this unit learners will be able to know about the following :

- Different stages of Life cycle of *Bombyx mori*.
- Structure and importance of different parts of silk gland.
- Secretion of Silk.

2.1 Introduction

Silkworm actually means the larval stages of the silk moth. There are different kinds of silk moth like *Bombyx mori, Antheraea mylita ,Antheraea asamensis* etc and therefore there are different kinds of silkworm. All the silk moths belongs to the same order Lepidoptera and that's why most of them have more or less same type of life cycle and biology. The only difference is that the duration of life cycle, number moults per life cycle and number of generation completed per year by a particular type of silk moth. The most common silk worm is the *Bombyx mori* and that's why here life cycle of *Bombyx mori* is described. Adult moth *(Bombyx mori)* is cream in colour. It lives for

two or three days only and it never feeds and fly. Mating takes place immediately after emergence. Mating period is very long and lasts for 24 hours. The primary food plant of this silk worm is the mulberry plant *(Marus alba)* and that's why the name of the insect is given.

2.2 Life cycle of *Bombyx mori*

The silkworm is actually the larvae, or caterpillar stage, in the life cycle of the silkworm moth. If allowed to develop from pupa, and not destroyed at this stage in the cycle so that silk can be created, the caterpillar will develop into a creamy white moth patterned in brown—scientifically named *Bombyx mori.* **The domestic silkworm can no longer be found in the wild,** but the wild silkworm and other silk-spinning relatives remain untamed. As a domesticated insect, the adult moth has lost many of the abilities it once had, including the ability to find food and defend itself against predators. In addition, the silkworm moth can barely fly. Copulation between silkworm moth lasts for several hours. After mating, the female silkworm moth lays her tiny eggs on mulberry leaves. Silkworm moths do not eat or drink in the final stage of their life cycle, they mate; the female lays her eggs and the adult moths die. In areas where the seasons change, silkworm moths reproduce only once each year. In areas where the climate is always warm, the moth's life cycle is ongoing. The silkworm life cycle goes through several stages, from egg to adult moth. These stages are explained in detail in the following paragraphs.

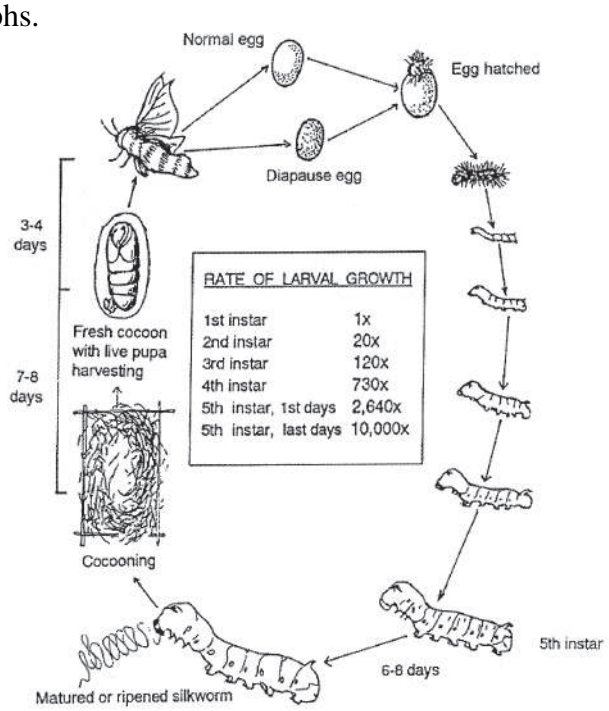

Figure 6 : Life cycle of *Bombyx mori*

2.2.1 Egg :-

Egg is the first stage of a silkworm's life cycle. The female moth lays an egg about the size of an ink dot during summer or the early fall and it is just after mating which continues for 12-24 hrs. The egg remains in dormant stage until spring arrives. The warmth of the spring stimulates the egg to hatch. Most females laid 150-300 eggs over a period of 1-2 days. In some exceptional cases one female can lay more than 1000 eggs. *Bombyx mori* can lay two types of egg and it depends upon the race of the *Bombyx sp.* These two types eggs are hibernating or diapausing eggs and non hibernating or non diapausing eggs. The morphological appearance of the eggs are ovoid, spherical or ellipsoid. The eggs are centrolecithal and eggs are covered by two layers — which are exochorion and endochorion. All eggs has an opening which is known as micropyle and is present at the anterior end of the egg. The hatching time of the fertilized egg varies with the environmental conditions and as well as voltinism of the insects concern. Non diapausing eggs normally take 9-12 days to hatch.

2.2.2 Larvae :-

The silkworm, upon hatching, is about 118^{th} of an inch and are extremely hairy. Young silkworms can only feed on tender mulberry leaves. However, during the growth phase they can eat tougher mulberry leaves as well. The larval stage lasts for about 27-30 days and the silkworm goes through five growth stages called instars, during this time. The number of instars or growth stages varies with the moultinism of the silk insects. For example, if the insect is tri-moultine then the larval stages will be three and if the insect is penta-moultine then the growth stages will be five. During the first molting, the silkworm sheds all its hair and gains a smooth skin. Of the total larval stages, the last larval stage is the longest one and this stage will eat more food. If the insect is penta-moultine then the last larval instars is fifth larva. The fully grown fifth larva is about 7.5-10 cm in length. Its body is divided into three parts : head, thorax and abdomen. Thorax is 3 segmented and the abdomen is 11 segmented. Each thoracic segment bears one pair of true clawed leg. These legs are not for walking but for holding or anchoring purposes. Of the 11 abdominal segments the last, 3 segments are fused together. The 3rd, 4th, 5th and 6th abdominal segments bears a pair of fleshy, unjointed muscular protuberances which are commonly known as **pseudo leg** or **pro legs**. Similarly the 8^{th} abdominal segment bears a projection on the dorsal side and known as **caudal horn.** Apart from these important characters the full grown larva of silk worm has a number of projections or nodules

present all over the body which are very race specific. The larval stages of *Bombyx mori* have **sexual dimorphism**. In female larva there is a pair of milky white spots present on each side of the 8th and 9th abdominal segments which are known as **Ishiwata gland.** Similarly in case of male larva there are pair of white protruberances on the ventral side of 8th and 9th abdominal segments which are known **Herold gland.** The fully grown final instar larva stopped feeding and ready to spin the cocoon. Normally 7-9 days are required for maturing the final instar larva.

2.2.3. Cocooning and pupa formation

After maturation of the final instar larva its gut discards all of the contents and emptying the gut and starts secreting the silk from the silk gland and cocooning begins. During the time spinning the larva moves its head in a typical manner so that the filament of silk is spun in the fixed shape. During the time of spinning silks are secreted from the silk glands through the spinneret for formation of fibre which is known as brins. The secreted silk of both the silk glands adhered together forming a single thread which is known as bave. After the cocooning is over the larva moult inside and transform into pupa. This pupa formation is known as pupation. Pupal stage is very inactive stage in the Iife cycle of silk worm. Morphologically it is the inactive stage but there are huge transformation is going on which is under the control of two important hormones- the **ecdysone** and **juvenile hormone** secreted from the prothoracic gland and corpora allata respectively. Both histolysis and histogenesis are going on in the body of the pupa for the metamorphosis purpose. The old cuticle of the pupa is disintegrated and a new cuticle is formed. The newly formed cuticle is very soft and yellow in colour. Gradually the newly formed cuticle will became darker and this phenomenon is known as **tanning of the cuticle**. Both male and female larvae are transformed into the pupa. The female pupa is much larger than that of male pupa. The pupal stage persists for about 10-12 days, although it depends upon the environmental conditions.

2.2.4 Metamorphosis and adult formation

After completion of cocooning the pupal stage inside the cocoon persists for 10-12 days and during this time the complete adult is formed through metamorphosis. After complete development of adult inside the cocoon the adult secretes an enzyme known as protease from its salivary gland. This enzyme actually dissolves the cocoon membrane forming a hole in the cocoon through which the adult comes out

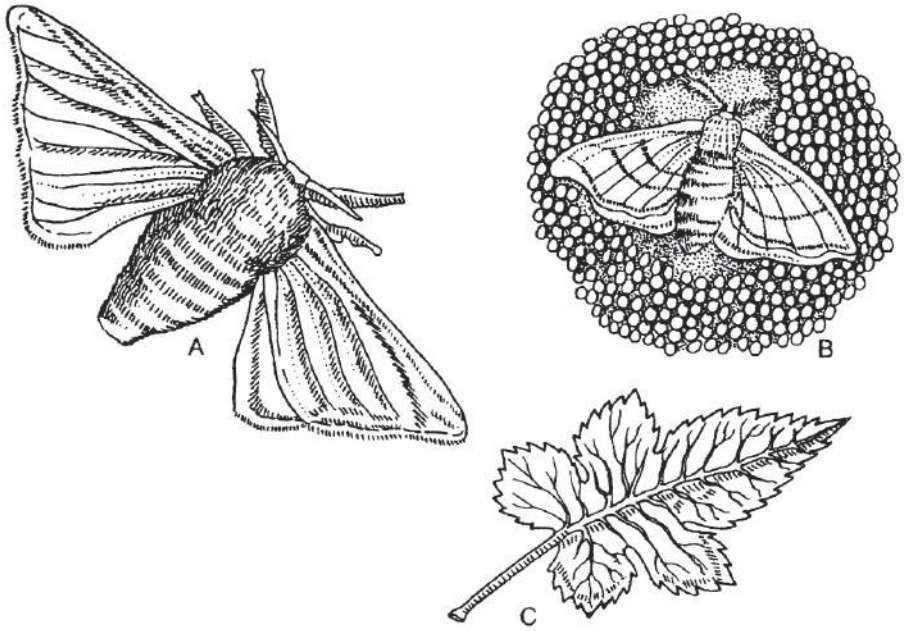

Figure 7 : (A) Mulberry silk moth, (B) Female moth in egg laying posture, and (C) Mulberry leaf

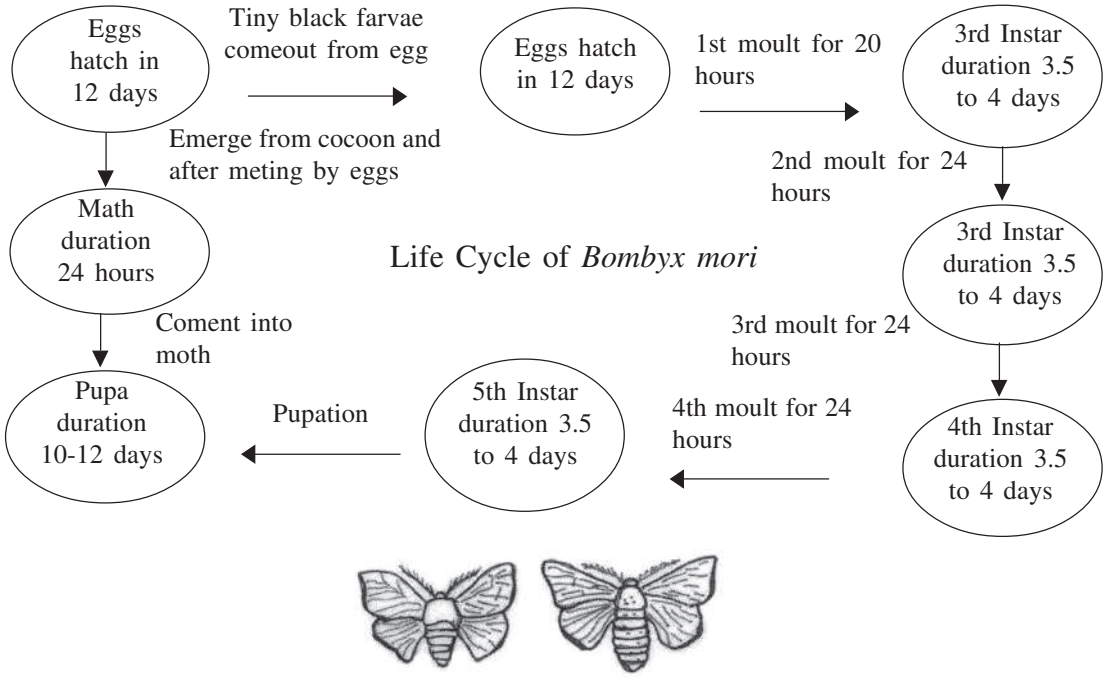

Figure 8 : Adult *Bombyx mori*

2.3 Structure of silk gland and secretion of silk

The silk of silkworms is secreted by a pair of labial gland, which is known as silk glands. The silk glands situated ventral to the alimentary canal. In full grown larvae, silk gland occupy most of the body cavity. The silk glands are tubular in shape with different diameters in different regions, Each gland has 3 distinct regions. Silk gland is a exocrine gland. Each gland is basically a tube like structure made up of glandular epithelium tissues. The cells of the silk gland constitute with extremely ramified nucleus containing numerous nucleoli. Nuclear ramification develops gradually as the larva grows and reaches prominent size in the late instars (IV and V).

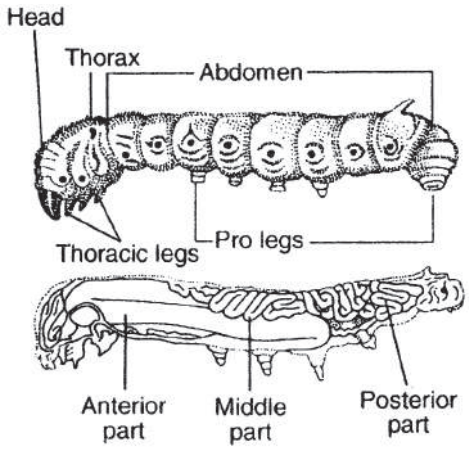

Figure 9 : (a) Structure of a typical larva of silk moth and Lateral view of larva and silk gland.

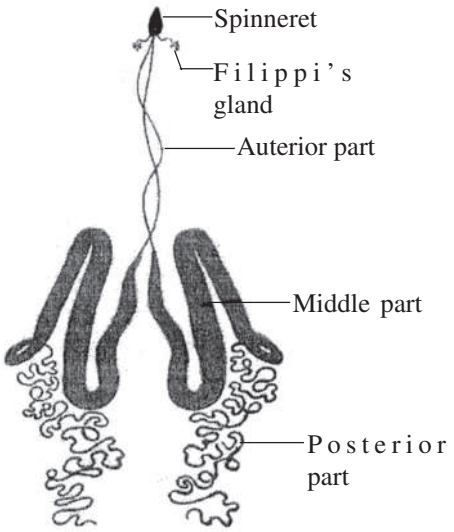

Figure 9 : (b) Structure of Silk gland (Schematic)

2.3.1 Posterior region:

Blunt, highly folded tubular posterior regions of both glands remain attached to tracheal bushes of silkworm. This part secretes fibroin as fibrinogen which converted to fibroin upon extrusion. The posterior division of the silk gland of the silk worm, *Bombyx mori,* conventionally called posterior silk gland as used here, is known to synthesize exclusively a single exportable protein, **fibroin,** which is the most important silk protein with a simple amino acid composition; it is rich in **glycine, alanine, serine,** and **tyrosine** . During the fifth instar, fibroin is synthesized very rapidly in the posterior silk gland, the maximum rate of synthesis having been reported to be much larger than that of the synthesis of albumin in liver . Another interesting characteristic of the gland is that the extensive biosynthesis and secretion of fibroin are observed only in a very short period of the larval life, that is, only during the fifth instar. The posterior silk gland of the young larvae is quite rudimentary, and even in the fourth instar larvae it is very small. At the beginning of the fifth instar, however, the growth of the gland is triggered suddenly and the weight of it increases very rapidly.

2.3.2 Middle region:

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

This sericin again gets surrounded by sericin- III secreted from the anterior limb. The middle region of silk gland also acts as the reservoir of fibroin where the later gets mature during the storage period.

2.3.3 Anterior region:

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

2.3.4 Spinneret:

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

2.4 Filippi's gland or Lyonnet's gland:

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

2.5 Secretion of silk

The *B. mori* silk gland consists of three regions:

- the posterior silk gland (PSG),
- the middle silk gland (MSG), and
- the anterior silk gland (ASG).

Microscopic studies show that PSG secretes fibroin and MSG secretes gelatinous sericin. The fibroin inner core and the outer coating of sericin layers are observed in a cross section of *B. mori* cocoon filament. The sericin functions as adhesive material, which glues a pair of fibroin layers and the cocoon to its pupation site.

The *B. mori* sericin is divided into inner, middle, and outer sencm layers based on the histological staining properties of the liquid silk in MSG. The histochemical study and transmission electron microscope observations suggest that the sericins in the inner, middle, and outer layers are secreted in the posterior, middle, and anterior parts, respectively, of MSG. The middle part of MSG is further divided into the posterior and anterior sections, of which the former secretes exclusively middle-layer sericin and the latter secretes both middle- and outer-layer sericin. SDS-PAGE analysis has shown that the principal components of sericin are sericin P (150 kDa), sericin M (400 kDa), and sericin A (250 kDa), located largely in the posterior, middle, and anterior part of MSG, respectively.

Therefore the silk gland could be divided into four divisions on the basis of the types of silk secretion and the histological features: **the posterior silk gland, the middle silk gland, the bulbous region,** and **the anterior silk gland.**

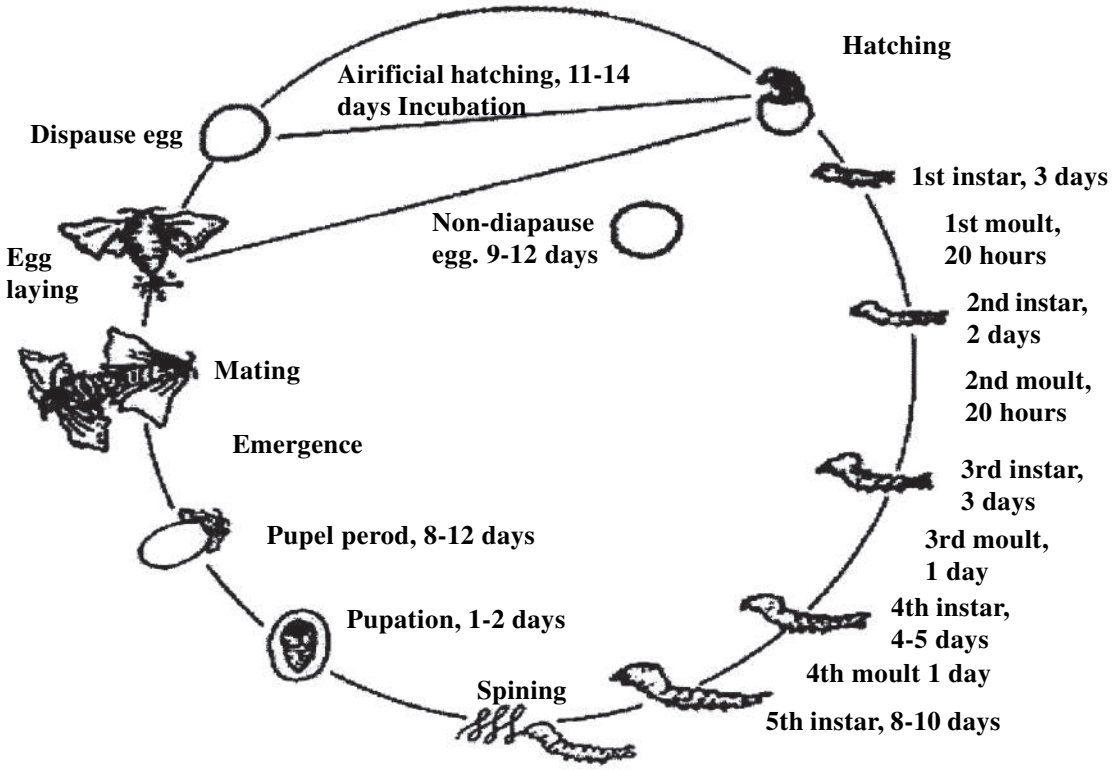

Figure 10 : Life cycle of *Bombyx mori*

2.6 Summary

From this unit we learn that *Bombyx mori,* is a lepidopteran sercigenous insect. Other than *Bombyx mori,* there are different other silk moths live *Antheraca asamensis, Antheraca mylita* etc. are available in nature, For *Bombyx mori,* mulberry is sole food plant. Like any other holometabolous insect, it passes through four distinct life stages such as egg, Larva, Pupa and adult stages. In silkworm, though voltairism and moultinism are inherited characters, but these characters are manifested at some extant by the environmental conditions like temperature and relative humidity. besides quality of mulbary leaf provided. The silk of silkworms is secreted by silk gland. The silk gland contains different regions like the posterior, region, middle region, anterior vegion, spinneret etc. The silkworm utilizes mulberry nutrients and convert the same into silk proteins such as fibroin and sericin in the form of cocoons.

2.7 Questions

1. What is instar?
2. What is moulting?
3. Why mulberry silkworms are known as domesticated variety?
4. Which gland is modified into silk glands?
5. Write the characters ofTasar, Eri and Muga silkworms.
6. Explain the life cycle ofTasar silkworm.
7. Write about the life cycle of Muga silkworm.

Multiple choice questions

1. Silk fiber is obtained from-

(a) fleece of sheep (b) cotton ball

(c) cocoon (d) shiny jute stalk

2. Silk worms secrete fiber which is made up of-

(a) fat (b) cellulose

(c) protein (d) nylon

2.8 Suggested readings

1. **Hisao Aruga (1986)- Principles of Sericulture.,** Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, pp 375.
2. **Jaiswal Kamal, Trivedi, S.P. & Pandey, B.N. (2009)- Mulberry Sericulture-Problems and Prospects.,** APH Publishing Corporation, New Delhi, pp 380.
3. **Sehgal, P.K. (2017)- Text Book of Sericulture, Apiculture and Entomology.,** Kalyani Publisher, New Delhi, pp 421.
4. **Sathe, T.V.** & **Yadav, A.D. (2012)- Sericulture and Pest Management.,** Daya Publishing House., New Delhi., pp 654.
5. **Patnaik, R.K. (2013)- Sericulture Manual.,** Biotech Books., Jodhpur., pp 640.

Unit- 3 ❑ Rearing of Silkworm *(Bombyx mori)*

Structure

3.0 Objectives

By studying this unit learners will be able to know about the following :

- The techniques of incubation and brushing of silkworm eggs.
- Methods of silkworm rearing.
- Things to consider during selection and establishment of mulberry garden.
- Importance of disinfectants in silkworm rearing.
- Spinning, harvesting and storage methods of cocoons.

3.1 Introduction

Rearing is a part of sericulture in which worms are raised for the production of raw silk. The first step of silk worm rearing is the incubation and brushing of the eggs until hatched. After hatching the larva can be reared.

3.2 Incubation and Brushing of the silk worm eggs

1. Spread the eggs in one layer on a paraffin paper kept on a bamboo tray.
2. Cover the eggs with another paraffin paper.
3. Except rainy season, keep wet foam pads around the eggs covered by paraffin papers.
4. Maintain the room temperature at 25-26^{0}C and relative humidity at 80%.
5. When blue pinhead appears wrap the eggs (25-50 dfls each) in a tissue paper and keep the eggs inside a black painted box or cover with black cloths or papers for 1-2 days.

   [dfls / DFLs means Discase Free layings, i.e. eggs]
6. On the next day, expose the eggs under diffused sunlight or under shade. There are two types of silk worm larval rearing which are as follows :

3.3 Young age silk worm rearing

The Young age silkworm rearing houses are often called as **Chawki Rearing Centre** (CRC). Adequate care in terms of temperature, relative humidity and hygienic conditions should be provided to young silkworms for their good and healthy growth. A CRC for brushing 5000-6000 dfls per batch consists of a rearing hall of 30' x 30', leaf storage roohi of 10' x 20' and ante-room of 10' x 10' size. Adequate ventilation in the rearing hall is recommended. A continuous water channel inside the rearing hall along the walls helps in keeping the ants away from silkworms and also maintaining the humidity. The windows should be fitted with wire mesh to avoid entry of Uzi fly. The ceiling should be kept at 9'-10' from floor. In case of more roof height a false ceiling at 8' to 9' from floor helps in reducing the volume of air in the rearing hall so that required temperature and humidity can be maintained conveniently.

3.4 Late age silk worm rearing

1. The silkworm rearing house should be located on an elevated place to avoid moisture migration from floor to rearing house, provide good cross ventilation, facilitate drainage of the water at the time of cleaning and disinfection.
2. The rearing house should be north facing i.e., the windows face north and south. This will avoid direct entry of the sunlight into the rearing house.
3. Ventilators should be provided above and below the windows for air circulation inside the rearing house.
4. The rearing house should have cement flooring for maintaining hygiene.

5. A 10-15 cm deep channel inside all around the rearing hall should be provided to prevent entry of ants in the rearing area and also to drain out water at the time of cleaning and disinfection.
6. During summer, the water in channel helps in increasing the humidity and cooling the air entering in through the lower ventilators.

3.5 Selection of mulberry variety

Mulberry plantation and harvesting is commonly known as **Moriculture** which is correlated with the Sericulture because the *Bombyx mori* is a mono phagous insect and it totally depends upon the mulberry plants. The success of mulberry leaf production depends on three factors namely variety, cultivation practices (agronomical inputs) and plant protection methods. The variety selected for cultivation must respond well to optimum agronomic inputs and plant protection measures. Cultivating improved or high yielding mulberry varieties forms the most important aspect in improving the leaf yields.

There are several species of *Morus* (mulberry) and from these species one should be chosen for cultivation and it is totally dependent upon the soil condition, irrigation facility as well as the environmental conditions. The most important species are *Morus alba* (White Mulberry), *Morus rubra* (Red Mulberry), *Morus nigra* (Black Mulberry), and *Morus macroura* (Himalayan Mulberry). Most of the Indian farmers choose *Morus alba* as their choice of cultivation. The Several varieties of *Marus alba* are available. The farmers should choose one of these varieties as per their need and soil conditions. The most important varieties are Kanva-2 (K-2) or Mysore-5 (M-5), MR2 or Mildew Resistant variety-2. The most important high yielding varieties are S30, S36, S54 and Vishwa. The most important varieties for Rain dependant conditions are the RFS 135 and RFS 175, S33 and S34. At present there are more than 1000 varieties of mulberry which are being cultivated.

3.6 Establishment of mulberry garden

A major factor determining productivity and hence the profitability in Sericulture is the yield of mulberry crop. Mulberry belongs to the Family Moraceae and Genus **Morus** which allied to the Genus **Brousonetia** and Genus **Ficus**. Maximization of mulberry leaf yield per unit area will lead to the realization of two most important objectives namely increased cocoon production per hectare and reduced cost of production. Therefore, it should be the primary aim of every sericulturist to ensure that he gets maximum leaf yield from his mulberry crop. It should also be realized that all measures taken to maximize leaf yield, simultaneously help to improve the quality of leaves which automatically secures an insurance against cocoon crop losses at the later stage of silkworm rearing.

Mulberry is a hardy plant capable of thriving under a variety of agro-climatic conditions. At the same time, it is also sensitive responding extremely well to optimum agricultural inputs but showing practically no growth when plant nutrients and moisture begin to operate as limiting factors. Mulberry can grow practically on any type of land except on very steep lands. Good growths, however, are obtained when it is raised on either flat land or gently sloping or undulating lands. Mulberry grows in a wide range of soils, but **best growth is obtained in loamy to clayey loam soils.** The mulberry plant can tolerate slightly acidic conditions in the soil. Since mulberry is a deep rooted plant, the soil should be sufficiently deep up to about two feet in depth . Mulberry falls under the category of perennial crops and once it is properly raised during the first year, it can come to full yielding capacity during the second year and last for over 15 years in the field without any significant deterioration in the yield of leaf. It is, therefore, very important that the initial planting and establishment of the crop is carried out according to scientific methods for obtaining best yield results in the subsequent years. Land should be prepared by deeply ploughing with heavy mould board plough up to a depth of 12"-15" (30-35 cm.) in order to loosen the soil before planting, taking advantage of the pre-monsoon showers during April-May.

Generally, pit system of planting with wider spacing should be adopted for rain fed mulberry while row system with closer spacing can be adopted for irrigated mulberry. The pits should be of the size 1.25' x 1.25' (95cm. x 35 cm.) and at least 1.25 ' (35 cm.) deep. These pits are filled with soil, preferably mixed with some cattle manure and in the pits, the cuttings or rooted saplings are planted. At the time of planting, it is important to see that the cuttings are placed deep and the soil around well compacted, leaving just one inch alone of the cutting exposed. This ensures the cuttings being planted sufficiently deep in the soil resulting in the formation of roots below the ground level. Further, this will prevent the cuttings from drying up. While planting, the cuttings should be planted either upright or with only a very slight tilt. In the case of rain fed mulberry gardens, the aim should be to raise mulberry plant with a sturdier frame so that it is able to withstand prevailing drought conditions better. Therefore, the spacing should be at least 3’x3' (0’9 m. x 0’9 m.) as is being currently practiced. When cuttings are planted in the pits prepared for the purpose, they should be planted in “threes” at a spacing of 6" (15.cm.) from each other, forming an equilateral triangle. When nursery raised rooted plants are transplanted, they may be planted as single plants. In the case of irrigated mulberry, the overall

advantage in raising mulberry for both quantitative and qualitative harvest is in favour of planting mulberry with a spacing of 2' (0.6 m.) between the rows and 9-10" (23-25 cm.) within the row.

Application of a basal dose of organic manure like compost or cattle manure, is necessary for successful establishment of the garden. Thereafter, the young growing plants should be assisted to put forth vigorous and maximum growth through periodical fertilizer applications.

During the initial stages of plant establishment in the field, weed growth should be kept to the minimum, so that the growing young plants are not smothered by the weeds. At least two weeding should be carried out during the first six months after planting of cuttings. Once after two months of planting and again after an interval of 2 to 3 months. The weeding operation should be thorough and the soil should be dug deep to remove the weeds with roots. For maintaining mulberry in a state of vigorous growth and also for obtaining good quality leaves, periodic pruning is necessary. Pruning should also take into consideration the growth attained by the plants; normally the growth should be more than 6' (2 m.) in height and stem or branch girth not less than the 0.75" (23 mm) at the bottom.

Organic manure should be applied at the rate of ten tones per hectare, immediately after pruning, inter-cultivation and thoroughly incorporated in the soil. This should be carried out systematically once in a year so that the organic content in the soil is improved and as a result, the fertilizer application is more effectively utilized. Leaf harvest commences after about ten weeks from the time of pruning in June and up to six harvests can be taken during the year at an interval of roughly 7-8 weeks in between harvests.

3.7 Rearing house and rearing appliances

The rearing of the mulberry silkworms is fully domesticated. A silkworm-rearing house is the place where the silkworms are reared to produce cocoons. The cocoon quality and yield are adversely affected if the optimal environmental conditions i.e. temperature, relative humidity, ventilation, illumination, hygiene, etc. are not provided to the silkworms. The rearing house should be rationally designed in order to keep the micro-climatic and environmental conditions for rapid and healthy growth of the silkworms. It should, therefore, have facilities for creation and maintenance of the optimal environmental conditions inside the silkworm-rearing house. The rearing

house should also provide sufficient space and healthy environment for the workers attending the silkworm rearing. The roof of the house should be of either asbestos sheets or RCC to avoid entry of the Uzi-fly. In hot regions, coconut fronds or straw should be placed over the roof to avoid heat radiations during day time. A false ceiling of plywood or thermocol sheet is also effective in reducing the solar radiation from roof. The minimum width of a rearing house for late age rearing should be 5.5 m (18'). The length of the rearing house can be calculated as follows:-

1. The wall height in a rearing house should be minimum 10' on the sides and 14' at the center.
2. An ante-room should be provided for washing hands and disinfecting legs before entering into the rearing area.
3. Doors and windows should be fitted with wire mesh to avoid entry of uzi-fly into the rearing house.
4. Water facility should be provided in a rearing house for cleaning/washing and disinfection and also for humidification purpose.
5. The rearing house should have adequate lighting arrangements for working during night.
6. Electrical points in the rearing house should be provided for using heaters, humidifiers, coolers and lighting the building for workers during night hours.
7. Provisions must be made for exhaust fans for evacuating humidity from rearing house during rainy days.
8. Arrangements should be made to ward off rats, lizards etc. and avoid entry into the rearing house.
9. Shade trees around the rearing house should be planted to protect the walls and the roof from afternoon sun.
10. The optimum rearing temperature and relative humidity are 25-26°C and 70% respectively.
11. When the temperature and relative humidity inside the rearing house are below optimum conditions, they are artificially raised through charcoal or electric heaters and running humidifiers.

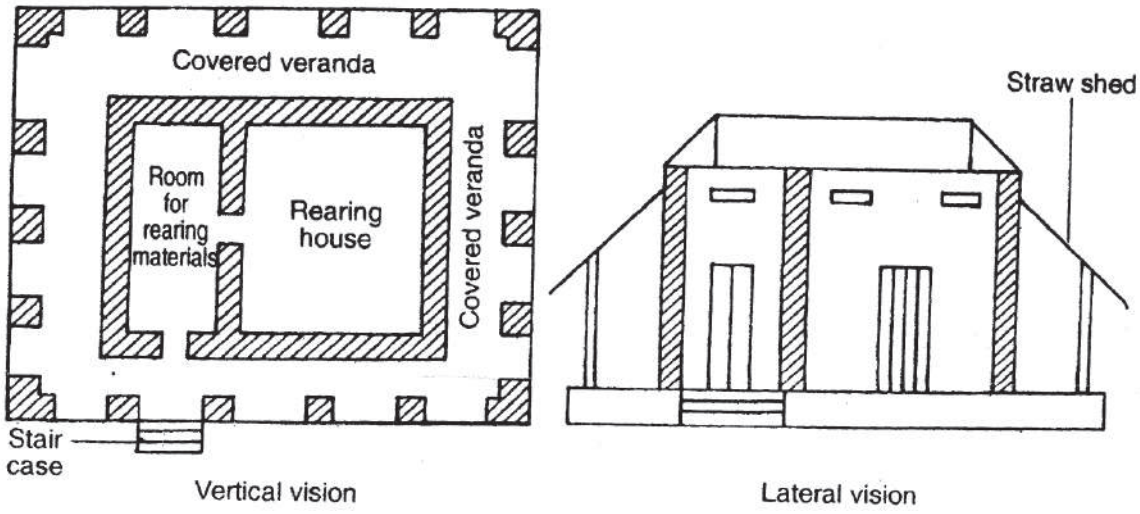

Figure 11 : **Rearing house of silk moth larvae**.

12. A silkworm rearing house should be well ventilated. Poor ventilation leads to humidity built up and accumulation of gases like carbon monoxide, carbon dioxide, ammonia etc., which adversely affect the growth of silkworms and make them susceptible to diseases.

Rearing appliances :-

Following appliances are necessary to rear the young age or late age rearing of silk worm.

1. Power sprayer,
2. Rearing stands,
3. Rearing trays,
4. Foam pads,
5. Wax coated paraffin papers,
6. Nylon nets,
7. Basket for keeping leaves,
8. Gunny bags,
9. Rotary or Bamboo mountages
10. Drier.

11. Leaf chopping board
12. Leaf chopping knife

3.8 Disinfectants

It is one of the most important items and disinfection process to be carried out prior to the commencement of silk worm rearing. Disinfection is an integral part of healthy and successful silkworm rearing. It aims at the total destruction of disease causing pathogens. Several diseases caused by bacteria, viruses, fungi and protozoa affect the silkworms. These pathogens released by diseased silkworms easily accumulate and spread in the rearing environment through different routes. They are not easily destroyed and can persist / survive for long periods under congenial conditions. The spores of the pathogens, especially those of fungi are light and can easily be drifted by air current resulting in easy spread of diseases. There are no curative methods for any of the silkworm diseases and they are best prevented than cured. This is achieved by adoption of proper and effective methods of disinfection and stepwise maintenance of hygiene during rearing.

3.8.1 Formalin

It is commercially available as 36% formaldehyde in solution form. A mixture of 2 % formalin + 0.05 % detergent is an effective solution that can be used for disinfection purpose as spray. Formalin is effective only in rearing houses, which can be made airtight and it is faster and more pronounced at temperature above 25°C and humidity more than 70 %.

3.8.2 Bleaching powder

It is white amorphous powder, with a pungent smell of chlorine. For effective disinfection, a high-grade bleaching powder with an active chlorine content of 30 % must be used. It should be stored in sealed bags, away from moisture, failing which it will be rendered ineffective. The action of bleaching powder is optimal under wet and contact conditions and therefore the surfaces of equipment and walls should be drenched with this solution. A 2% bleaching powder in 0.3 % slaked lime solution is used for disinfection as spray.

3.8.3 RKO or Resham Keet Ousadh (in Hindi)

RKO was the first silkworm body and rearing bed disinfectant developed in

1986. It protects silkworm from diseases during young and late age silkworms. It became very popular among farmers during nineties. The important RKO product normally used in sericulture process are **1. Vijetha, 2. Vijetha Supplement, 3. Ankush and 4. Amrut.**

The most important device that helps or supports the **silkworms** (larvae) for comfortable spinning their cocoon is called cocoonage or **mountage.** It determines both the quality and quantity of the cocoons. In India following types of mountage are normally used:-

1. Chandraki

It is rectangular shaped mountage made up of bamboo. This mountage is very easy to handle and very popular in West Bengal.

2. Screen type mountage

It is normally made up of either bamboo or wood and most durable mountage.

3. Polythene sheet or plastic mountage

It is quite similar with chandrika but it is made from polythene sheet. The most important positive side of this mountage is that it is very easy to clean and not prone to the rodent pest.

4. Japanese low cost mountage

It is made up of wood and iron rod and very durable and cheap.

5. Bamboo strip mountage

This mountage is also very cheap and durable and very easy to handle

6. Bottle brush mountage

It is very recent I developed mountage and made up of jute fiber and rope. Coconut leaves are also used.

7. Plastic bottle brush mountage

This is developed by Central Sericulture Board and are actually a modified bottle brush.

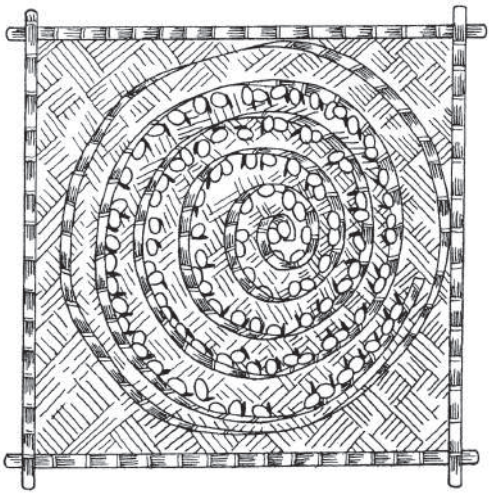

Figure 12 : Cocoon formation in Chandraki

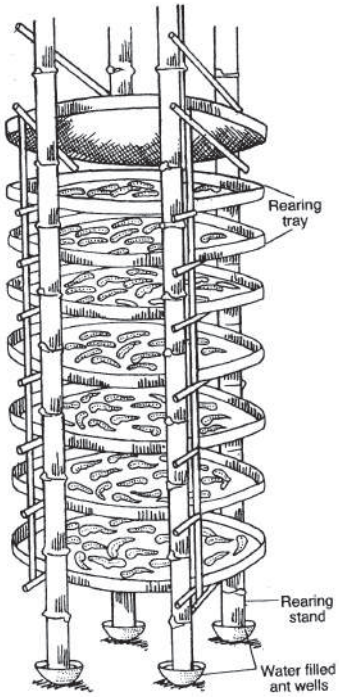

Figure 13 : Arrangements of rearing trays

3.9 Spinning, harvesting and storage of cocoons

3.9.1 Spinning

After the mature worms are mounted on the mountages they pass out the last excreta in semi-solid condition. During rains when the humidity is high, excess body moisture is also eliminated as liquid urine at the time of mounting. After defecation, the worm starts spinning the cocoon. It anchors itself first to the mountage by oozing a tiny droplet of the silk fluid which immediately hardens and sticks to the mountage. Then by swinging the anterior part of the body continuously in the form of lateral eight (8), the silkworm draws out the silk fluid from the two silk glands which lie on either side of the body of it. Silk fluid is excreted in minute quantities and hardens to form the long continuous silk filament. At first, however, the worm spins a loose hammock which provides it with necessary foothold to start spinning of the cocoon proper. The cocoon may be of various in shape — oval, spherical, conical etc. The filament is spun accordingly and in this way layers after layers of filament are laid to form the compact shell of the Cocoon. The larva spins from exterior to interior and the larva rotates its head 60,000 to 3,00,000 times to form a cocoon. The

hammock though formed of a continuous filament will remain of highly tangled network and this constitutes the floss of the cocoons which is not reelable.

Quantity of floss is comparatively less in uni-and bivoltine varieties of silkworms and is about two per cent of the weight of cocoons. In the case of multivoltine races, it is high and may amount to as much as ten per cent or even more. After the compact shell of the cocoon is formed, the shrinking larva finally wraps itself in a gossamer layer and detaches itself from the shell to transform into the pupa or chrysalis. This last layer is only a body sheath of the worm and does not form part of the main shell and as such is not reel able just like the floss layer. The process of spinning the cocoon by the worms takes about 1 to 2 days in the case of multivoltines and 2 to 3 days in the case of uni/bivoltine worms. It is necessary to keep the silkworm larvae undisturbed during this period. The worms require attention during spinning of cocoons as the quality of cocoons is to a great extent determined by the environmental conditions that obtain when the worms are on the mountages. It may, in general, be stated that dry weather is good for spinning. Generally, worms during spinning require a slightly higher temperature than during rearing; but too high a temperature is to be avoided as it will compel the worms to spin in haste and thus waste a lot of silk.

3.9.2 Harvesting

After completion of spinning of cocoon, the larval skin is cast off and pupation takes place. This generally occurs on the 3rd or 4th day of spinning in the case of multivoltines and 4th or 5th day of spinning in bivoltines and univoltines in the temperate regions. The pupa when formed has a thin cuticular skin which is soft to touch and may get ruptured easily, if disturbed. The stained cocoons, one frequently sees in Karnataka and West Bengal are due to very early harvest of cocoons from the mountages and the consequent damage to the pupa leading to the blood soaking through the cocoon shell. This stain sometimes soaks through the whole of the cocoon shell rendering the stained portions un-reelable. Besides, at the stage when pupation has just commenced, the vital functions are very vigorous and even the slightest damage to the pupae during harvest or subsequent transportation leads to fermentation with disastrous effects on the reeling quality of the cocoons. Too much delay in harvest is also not desirable, as it reduces the time available for transportation of cocoons to the market, subsequent stifling of cocoons etc., with a possible danger of moths emerging. Additionally there is the loss in weight of cocoons due to driage and the consequent erosion of monetary returns to the cocoon grower. It is, therefore, desirable that the cocoons are harvested on 5^{th} day in Karnataka and West Bengal type of climates and on 6^{th} or 7^{th} day in Jammu & Kashmir region. By this time, the

pupa begins to turn brown and becomes firm and less liable to injury during harvest, transport etc. If the cocoons are intended for seed, it would be preferable to wait till the pupae assume a darker colour and begin to be active. This means that the harvest should be on 6^{th} day in tropical regions and 7^{th} or 8^{th} day in temperate zones. Harvesting of cocoons is normally done by hand. Only in the case of revolving mountages simple devices are used to separate the cocoons from the cubicles. The frames containing the cocoons are pressed against a wooden board which carries pegs corresponding to the cubicles in the revolving cocoonage. The harvesting process is the best time for sorting cocoons according to the quality.

3.9.3 Storage of cocoons

The cocoons dried to the optimum level may be conditioned for a minimum period of 7 - 10 days before taking up for reeling in order to achieve better reeling performance. The cocoons should be stored in an appropriate storage room for long duration storage. The cocoon storage should have 20°C or below temperature in the center of the room and the air inside the room should have 55% or below relative humidity so that fungus will not attack the cocoons.

3.10 Summary

From this unit we learn that silk moths are reared and their cocoons are gathered to get silk threads. A female silk moth lays hundreds of eggs which are then stored carefully on strips of cloth or paper. The eggs are then kept and reared by silkworm farmers under hygienic conditions of temperature and humidity for the rearing of silkworm. Since the silkworm feed on mulberry leaves, approprite selection of mulberry variety and establishment of mulberry garden need careful attention. The catterpillers feed on the nulberry leaves day and night to grow enormody in size. Then preparation of silkworm rearing houses, equipped with necessary appliances is important. Disinfectants like formalin, bleaching powder, RKD etc. helps to protect the silkworms from infection. We also have learned that how on different days spinning, harvesting and storage of cocoons is done.

3.11 Questions

1. What is the best time for leaf harvest?
2. Define brushing.
3. Define mounting.
4. Write about hatching & brushing.

5. Describe various types of mountages.
6. Explain about rearing methods of late age silkworms.
7. Write short notes on: a) spinning b) mounting.
8. What do you mean by Moriculture?
9. Mention different types of rearing houses.
10. Which type ofrearing house is ideal for tropical conditions?
11. How Uzi entry is restricted in designing of rearing houses?
12. How the chawki rearing room should be designed?
13. Mention any four mountages used in rearing.
14. What are the chemicals used in disinfection?
15. Define disinfection.
16. Name any four disinfectants used in sericulture.
17. What is chalooni?

Multiple choice questions

1. Reeling of silk is-

(a) a process of making silk reels.

(b) spinning of silk fibers.

(c) weaving of silk cloth.

(d) the process of taking silk threads from cocoon.

3.12 Suggested readings

1. **Hisao Aruga (1986)- Principles of Sericulture.,** Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, pp 375.
2. **Jaiswal Kamal, Trivedi, S.P. & Pandey, B.N. (2009)- Mulberry Sericulture-Problems and Prospects.,** APH Publishing Corporation, New Delhi, pp 380.
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Unit - 4 ❑ Pest and Diseases

Structure

4.0 Objectives

By studying this unit learners would be able to know about the following :

- Different pests of mulberry silkworm and their control measures, and also diseases of these silkworms.
- Various diseases and pests of Non mulberry silk worms.

4.1 Introduction

As previously discussed that the sericulture are of two types, mulberry sericulture and non mulberry sericulture and the causal insects for these purposes are different therefore the pest and diseases will also be different. We will discuss this topics under two headings which are as.

4.2 Pest and diseases of mulberry silk wor*m (Bombyx mori)*

Pests are any organisms that are considered, from the perspective of humans, to be undesirable in some ecological context i.e. a pest is an organism whose population often increases above a certain level of economic injury and its existence conflicts with man's welfare, convenience and profits. For example, pests could be insects that compete with humans for some common resource, such as agricultural production or timber. Or in other words pest is a destructive insect or other animal that attacks crops, food, livestock, etc. While the **disease** is a disordered or incorrectly functioning organ, part, structure, or system of the body resulting from the effect of genetic or developmental errors, infection, poisons, nutritional deficiency or imbalance, toxicity, or unfavorable

environmental factors; illness; sickness; ailment. Or in other words we can say the **disease** is a disorder of structure or function in a human, animal, or plant, especially one that produces specific symptoms or that affects a specific location and is not simply a direct result of physical injury. There are primarily two important pests and seven important diseases normally found in mulberry silk worm *Bombyx mori.*

Pests

Two insects, Uzi fly and Dermestid Beetle and one mite, *Pediculoides ventiricosus*, known as **straw itch mite** are the known pests of mulberry silkworm.

A. Uzi fly

The Uzi fly, *Exorista bombycis or Tricholyga bombycis* is a serious endo-larval parasitoid of the silkworm, *Bombyx mori*, inflicting 10-15% damage to the silkworm cocoon crop in the premier silk producing states of Karnataka, Andhra Pradesh and Tamil Nadu. Uzi fly occurs throughout the year, but severe during rainy season. Presences of eggs or black scar on the silkworm body and maggot emergence hole at the tip of the cocoon are the typical symptoms of Uzi fly attack. As soon as the Uzi fly enters into rearing house, it lays one or two eggs on each silkworm larva. After 2-3 days, egg hatches, enters inside the larva and feed on internal contents for 5- 7 days, after which it comes out by rupturing the larva. The maggot pupates in a dark corner or cracks & crevices in about 18-24 hours. The pupal stage lasts for 10-12 days. If the Uzi fly infests at last instar, the uzi maggots come out after cocoon formation by making a circular hole.

Control measures :

There are five ways by which the Uzi fly can be controlled which are :--

a. Exclusion method

1. Provide wire mesh/nylon net on all windows/doors.
2. Provide doors with automatic closing mechanism.
3. Provide anteroom at the entrance of the rearing house.
4. Keep the leaf in the verandah of the rearing house and observe for the uzi fly before shifting leaf into the rearing house.

b. Physical (using Uzi trap)

Dissolve one table in 1 litre of water and keep the solution in white trays both inside and out side the rearing house at window base from 3rd instar onwards up to spinning.

Place Uzi traps inside the rearing house/mounting hall after spinning up to 20 days under close-door condition to trap Uzi flies emerging inside.

c. Chemical

An effective result can be obtained by spraying 3% phenol or 1% Benzoic acid over the worms. Application of Uzicide power over the worms may also be effective.

d. Biological

1. Release *Nesolynx thymus* (a pupal parasitoid of the uzi fly) inside rearing house on 2^{nd} day of 5^{th} instar.
2. Besides *N. thynus*, there are other hymenopteran parasites like *Brachymirea lugubris, Dirhinus himalayanus* etc. reproduce on Uzi fly maggots and pupae. So release of these parasites would be the effective biological control against Uzi fly attack.

e. Proper disposal of silkworm litter after cocoon harvest or sanitations

1. Separate the silkworm litter from mulberry twigs.
2. Do not throw silkworm litter in open space/litter pit, as it contains hundreds of Uzi fly pupae.
3. Instead, pack it in plastic bags and keep for 15 to 20 days to prevent the emergence o uzi fly from litter. Alternatively, it can be buried in soil or burnt immediately.

B. Dermestid beetles

Dermestid beetles, *Dermestis ater, D. valpinus, D. Coar* known to attack pierced cocoons in cocoon storage rooms. The female beetles lay about 150-250 eggs in the floss of cocoons. The beetles migrate from cocoon storage room to grainage and attack green cocoons as well as moths also. Generally they attack the abdominal region of the moth. The damage is estimated to be 16.62% on cocoons and 3.57% on moths.

Control measures

There are three ways by which the dermestid beetle can be controlled which are:-

a. Preventive measures

1. Storage of rejected cocoons and perished eggs for long period should be avoided.
2. Rearing house & cocoon storage rooms should be cleaned periodically.
3. Grainage (means where silk worm eggs are produced in large quantities under hygenic condition) remises should be cleaned before & after moth emergence.
4. Provide wire mesh to door & windows in pierced cocoon (PC) storage rooms.

5. Wooden articles of storage room & grainage should be dipped in 0.2% malathion solution for 2-3 minutes. Trays etc., shouldbe thoroughly washed & sun dried for 2-3 days before reusing.

b. Mechanical control:

Collect the grubs and adults by sweeping or by using a vacuum cleaner, destroy by burning or dipping in soap water.

c. Chemical control:

1. Store pierced cocoons in Deltamethrin treated bags i.e., soak the bags in 0.028% Deltamethrin solution (1 ltr : 100 ltr water) and dry in shade.
2. Spray 0.028% Deltamethrin solution on walls and floor of PC room once in 3 months.
3. Sprinkle bleaching powder (200 gm/sq.mt.) all around inner wall of PC room to prevent crawling of grubs from PC room.
4. Fumigation of cocoon with methyl bromide @ 0.5 kg/m^2 for a day.

C. Straw Itch Mite

Silkworm, infected with straw itch mite like *Pedicolus Ventricosus,* lose their appetite and gradually become sluggish. Infected larvae are unable to excrete regularly and often a long string of globular faecal matter is excreted. The body of the infected larvae may develop a black spot. The mite mostly infect the young larvae and female sex are more susceptible than male sex.

Control measures

Special precautionary measure should be taken if paddy, wheat husk and bamboo are used in the rearing room of silk worm because these are the primary source of infection. Before use these should be fumigated by proper fumigants such as carbon disulphide, chloropicrin and sulphur dioxide etc. The cocoon frame should be well dried in the scorching sun and the rearing bed should be sprayed with acetic acid.

Diseases

The seven common diseases of *Bombyx mori* are :-

A. Flacherie

It is the most commonest disease of *Bombyx mori* and it causes most damage to the sericulture industry. The symptom of this disease are not always same. This is also known as **Sotto disease** and **Clear bead disease** (due to loss of appetite). Previously it was regarded as bacterial disease but recent studies established the fact

that viruses are also responsible for the disease. The causative agent is *Bombyx mori* infectious flacherie virus BmIFV / *Bombyx mori* densonucleosis virus BmDNV or different pathogenic bacteria viz., *Streptococcus* sp. / *Staphylococcus* sp. / *Bacillus thuringiensis* / *Serratia marcescens* individually or in combination of bacteria and viruses. This disease is most common in summer and rainy seasons. Fluctuation in temperature and high humidity are the two important factors for prevalence of this disease.

1. Symptoms of this disease

a. The larvae become soft and flaccid.

b. The growth of infected larvae retarded, becomes inactive and vomit gut juice. The faeces become soft with high moisture content. Sometimes chain type excreta and rectal protrusion also observed.

c. Larval head and thorax become translucent.

d. When infected with *Bacillus thuringiensis* symptoms of toxicity such as paralysis and sudden death are observed.

e. After death, larvae turn black in color and gives foul smell.

Some times, the dead larvae turn red when infected with *Serratia* sp.

2. Control measure

a. Disinfect the rearing house, its surroundings and equipments with recommended disinfectant or with 2% formation.

b. Pick up diseased larvae and dispose them by burning.

c. Provide good quality leaf grown under good sunlight and recommended inputs. Do not provide over matured/over stored /dirty leaf to the silkworms.

d. A void starvation, overcrowding and accumulation of faeces in the rearing bed.

e. Rear silkworms under optimum temperature and humidity.

f. A void injury to the larvae.

g. Apply recommended bed disinfectant as per schedule and quantity.

h. Feed Amruth as per schedule to control flacherie disease.

B. Cytoplasmic polyhedrosis

It is a viral disease (polyhedrosis virus) and is considered to be one of the major disease of silkworm. The symptoms of this disease is quite similar with that of flacherie. Cytoplasmic polyhedrosis is mainly infected orally with the mulberry leaves.

1. Symptoms of this disease

a. The skin of infected larvae becomes shining before moult and fails to moult.

b. Inter segmental swelling appears and the colour of the body becomes yellowish.

c. The infected larvae move restlessly in the rearing bed along the rim of the trays.

d. Infected larval body ruptures easily and turbid white haemolymph oozes out.

2. Control measure

a. Practice thorough disinfection of rearing house, its surroundings and appliances with any recommended disinfectant like 2% formation.

b. Conduct an optional disinfection with 0.3% slaked lime solution when high incidence of disease noticed in the previous crop.

c. Practice personal and rearing hygiene.

d. Collect the diseased larvae and ensure its proper disposal.

e. Maintain optimum temperature and humidity in the rearing house.

f. Feed quality mulberry leaf and avoid overcrowding.

g. Apply recommended bed disinfectant as per schedule and quantity.

h. Feed Amruth as per schedule to control the disease.

C. Nuclear Polyhedrosis or Grasserie

This disease is variously known as silk worm jaundice or grasserie etc. This disease is also caused by a virus known as grasserie virus.

1. Symptoms of this disease

The infected larvae do not show any sign of moulting and their skin become stretched and shiny white. All the body segments become protuberant. The skin gets easily ruptured. Other symptoms are more or less similar with that of the cytoplasmic polyhedrosis disease.

2. Control measure

a. Should avoid exposure of silkworm to extreme thermal fluctuation.

b. Contaminated mulberry leaves should be avoided for feeding the silkworm larva.

c. Those larvae are detected to be wandering on the rearing bed, they should be removed immediately.

d. Effective disinfection of the rearing room can be done with 2% formalin and the rearing implements can be sterilized in boiling water.

D. Muscardine or Fungal disease

Muscardine is a disease of silkworms caused by the infection of fungi. There are more than 10 types of fungi which are causing muscardine. There are several types muscardine diseases occurs in silkworm which are:-

1. White muscardine : This is caused by a fungus *Botrytis bassiana* . The primary symptoms are the loss of appetite, dullish morphology, body becomes stretched and covered with white powdery material.

2. Green muscardine: This disease is caused by the infection of *Nomuraea pracina* but this. disease rarely occurs in springs and summer rearing of silkworms. This disease is prevalent in early and late autumn rearing. It is mild disease in comparison to white muscardine and it is prevalent in young larvae only.

3. Yellow muscardine : This disease is caused by the infection of *Isaria farinosa* fungus. This disease usually occurs from spring to late autumn. This disease is prevalent in both young and mature larva and the symptoms are more less same with that of white muscardine.

4. Black muscardine : This fungal disease is caused by the infection of *Oospora destructor* and this disease is prevalent in hot summer and autumn.

❑ **Control measure for muscardine disease**

a. Disinfect the rearing house, its surroundings and equipments with recommended disinfectant 2% formalin)

b. Control mulberry pests in the mulberry garden.

c. Pick up diseased larvae before mummification and dispose them by burning

d. A void low temperature and high humidity in the rearing house. If required use heater/stove to raise the temperature.

e. Regulate bed humidity during rainy season by dusting slaked lime powder during moult.

f. Apply bed disinfectant, Vijetha and Vijetha supplement/Ankush/any recommended bed disinfectant as per schedule and quantity.

E. Pebrine or Protozoan disease

This disease is caused by microsporidian protozoa known as *Nosema bombysis.* Silkworm gets infected through eggs (Transovarian / Transovum transmission) or by eating contaminated mulberry leaf. Infected silkworms, faecal matter, contaminated rearing house, apppliances and alternate hosts (mulberry pest) are the sources of infection. This is not a seasonal disease but it is nonseasonal.

1. Symptoms of this disease

a. Irregular hatching of silkworm eggs. Infected eggs lacking adhesive Ium and are easily detached from the reariong board.

b. Irregular size of the larval body and moulting.

c. The infected larva looses its appetite and becomes inactive with wrinkled skin.

d. Black pepper-like spots appear on the body of the infected worms.

e. White postules appear on the silk gland when examined under microscope with presence of shining oval spores.

2. Control measure

a. Disinfect the rearing house, surroundings and with recommended disinfectant (2% formalin)

b. Conduct strict mother moth examination and surface disinfection of silkworm eggs to produce and rear disease free laying.

c. Follow strict hygiene maintenance during rearing.

d. Control mulberry pests in and around the mulberry garden.

e. Apply recommended bed disinfectant, Vijetha/Ankush as per schedule and quantity.

f. Monitor seed crops constantly to eliminate the microspodian infection.

F. Aspergillosis

This is also a fungal disease but it is due to the infection of any fungus belongs to the genus *Aspergillus*. There are several species which can cause aspergillosis

disease to the silkworm. The most common species are ***Aspergillus jlavus, Aspergillus oryzae*** , ***Aspergillus ochraceus*** , etc. Susceptibility of silk worm to aspergillosis varies with differences in the environmental conditions during rearing. Usually the susceptibility increases with an increase in humidity. When the humidity is 70% the disease is rare but as the humidity increases and reaches saturation point the incidence of infection reaches maximum. Similarly the infection is also related with temperature, higher the temperature more the infection. One of the interesting feature is that this fungus is resistant to formalin.

G. Red Muscardine disease

This disease is caused by fungus *Isaria fumosorosea.* One of the important point of this disease is that it has very pathogenicity to the silk worm but it has high pathogenicity to Uzi fly. Therefore this pathogen can be used to control the Uzi fly biologically which is serious pest of silkworms. The red muscardine fungus readily penetrates the body of the Uzi fly. This fungus has no sensitivity to the late age larva of silk worm.

4.3 Pest and diseases of non mulberry silk worm *(Tasar, Muga, Eri, Anaphe* and *Fagara)*

As most of the non mulberry silk worms are wild and non domesticated, therefore most of them have common diseases and pest. Here some of the important pest and diseases of non mulberry silk worms are described :-

A. Diseases

There are four important diseases are found in non mulberry silk worms which are :-

1. Virosis or Polyhedrosis

This disease is caused by the polyhedral virus. High humidity and temperature causes higher infection and mortality. The primary symptoms of infected larva are that the larva becomes soft and sluggish. The skin becomes fragile and blackish.

2. Bacteriosis

The causative agent of this disease are gram negative micrococcus and gram positive bacilli. Late larval stages are more prone to this disease than the early larval stages. The primary symptoms are:-

a. Sealing of anal lips

b. Larva produce chain type excreta

c. Larva stops feeding

d. Claspers of the larva lose hold of the twig of the host plant

This disease is primarily transmitted through mouth during feeding. Late age larva are more prone to the infection than the early stage larva.

3. Mycosis

The causative agent of this disease are two types of fungus which are *Paecilomyces varioti and Penicillium citrinum*. Infection occurs primarily through the integument injuries and also through the spiracles. This disease is highly prevalent from late August to early September.

4. Microsporidiosis

This disease is caused by a monosporoblastic microsporidian of the Family nosematidae under the genus *Nosema*. Infection is generally occurs through mouth or through transovum or through transovarial. Of these transovarial transmission is the most important mode of dissemination.

B. Pests

Two parasites and four predators are the most notorious pest of non mulberry silk worm. These are:-

1. Parasites

Two insects are the important parasites of non mulberry silk worm, which are :-

a. Tachinid fly *(Blepharipa zebina)*

It is the parasite of the larval stages and pupal stage of non mulberry silk worm. A female tachinid fly lays 250-300 eggs on a single larval host and after hatching of the eggs the maggots of the parasite bore into the body of the host (either larva or pupa).

b. Ichneumon fly (***Xanthopimpla pedator***)

It is an endoparasite of non mulberry silk worm larvae. This parasitic insects are yellowish in colour with a black spot dorsolateraly on each sternum well as four black spots on the prothoracic shield.

2. Predators

There are four predators which normally inhibits the non mulberry sericulture which are :

a. Canthecona bug *(Canthecona furcellata)*

It is most harmful enemy of non mulberry silk worm particularly the tasar silk worm. A single bug can kill 130-220 tasar silk larva from first instar to third instar larva in its life span. This insect belongs to the order hemiptera.

b. Red ant *(Oecophylla smaragdina)*

This is a social insect lives in primary or secondary nests which are made up of leaves. The colony primarily consists of workers and sexuals. These ants generally attacks in groups and carry young silk worm larvae to their nests. They normally prefer to attack the mature larva.

c. Praying mantis *(Hierodula bipapilla)*

This is a carnivorous insect and found all over the tropical regions. These insects can only inflict injury on fourth and fifth instar larvae and the injury is so severe that the larvae will ultimately die.

d. Reduvid bug *(Sycanus collaris)*

This is a common reduvid bug belongs to the order hemiptera. Early instar larvae are more likely to be attacked by the predator.

4.4 Summary

From this we learn that silkworms (both the mulberry and non mulberry silkworms) suffer from several diseases and the silk cocoon crop failure or low harvest is due to the diseases in silkworm. These diseases are caused by germs and are highly infections. The development of diseases in silkworm is influenced by environmental and nutritional factors. The common diseases in silkworms are Grasserie, Flacherie and Muscardine. There is also an uncommon but dangerous disease i.e. pebrine. Apart from these diseases there are several pests like Uzi fly insects, by laying eggs on the inter segmental region of silkworm body, these eggs hatch and scoop into the body of the larvae, becoming an internal parasite. Normally Uzi fly infection can cause upto 30% crop loss. Apart from these diseases and pests cocoons are damaged in different stages by ants, bug, mantis, etc. Therefore approprite control measures need to be adopted during silkworm rearings.

4.5 Questions

1. What is causal agent of pebrine.
2. What are the symptoms of grasserie disease?
3. What is the causal agent of muscardine?
4. What is the scientific name of Uzi fly?
5. Name any four minor pests of mulberry silk worms.
6. Write symptom, and control measures of pebrine disease.
7. Symptoms and control measures of Uzi — Discuss.
8. Write about different types of minor pests in sericulture.
9. Write short note on the symptoms of Flacberie.
10. What is Aspergillosis?
11. What is the causative agent of Pebrine disease?
12. Define pest and parasites.
13. What is polyphagous?

4.6 Suggested readings

1. **Hisao Aruga (1986)- *Principles* of Serlculture.,** Oxford & IBH *Publishing* Co. Pvt. *Ltd.,* New *Delhi, pp* 375.
2. **Jaiswal Kamal, Trivedi, S.P.** & **Pandey, *B.N.* (2009)- Mulberry Sericulture-Problems and Prospect,.,** APH *Publishing* Corporation, *New* Delhi, *pp* 380.
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Unit - 5 ❑ Entrepreneurship in Sericulture

Structure

5.0 Objectives

By studying this unit learners would be able to know about the following :

- The opportunity and possibilites of sericulture industry in India.
- Important silk manufacturing and product centers of the country.
- Employment possibilities

5.1 Introduction

Sericulture is agro-based industry, practiced in India for many centuries. Sericulture involves the cultivation of silkworm food plants, rearing of silkworms for the production of cocoons, reeling the cocoons for unwinding the silk filament and other post-cocoon processes such as twisting, dyeing, weaving, printing and finishing etc. Commercially traded varieties of natural silks are Mulberry, Tropical Tasar, Oak Tasar, Eri and Muga. Silks other than mulberry are all grouped together and called as **Vanya Silks** or **Wild Silk.** Mulberry silk production involves a series of activities and the success of mulberry cocoon crop depends on the productivity levels of breed, quality of the mulberry leaves, supply of disease free laying, adoption of scientific rearing technologies and climatic conditions. Rearing of silkworms which is done domestically under controlled conditions is an important component of sericulture and throughout the rearing period, silkworms have to be taken care of properly and nourished with good quality mulberry leaves. Silkworm larvae pass through five instars (stages) beginning from hatching of the larvae from eggs to their maturation and change their skin called as moulting for four times. Silkworms are very delicate

and susceptible to a various diseases. They need to be reared scientifically under the close supervision of the experienced technicians. Every year, 5-6 cocoon crops can be taken in the irrigated conditions as the mulberry leaves will be available throughout the year. Sericulture is considered as an effective tool for poverty eradication in the rural areas. This enterprise provides employment opportunities to all the family members of the farmers. This sector has the unique feature of converting family labour into useful income for the family of the farmers. This vocation can bring significant revenue to the households, thereby helping several poverty stricken families in the rural areas, especially the marginalized section of the population. Sericulture is one of the most potential agricultural vocations with low capital investment and high returns. Silk is produced by the farmers belonging to economically weaker section and is purchased by the rich people. It is an excellent tool for transfer of wealth from affluent section of the society to the poor.

Sericulture is multidisplinary activity consists of food plant cultivation (mulberry leaf production), silkworm rearing (cocoon production), silkworm egg production, silk reeling (yarn production), twisting, Warp and weft making, printing and dyeing, weaving, (fabric production), finishing, garment designing, marketing etc. The industry encompasses different on-farm and non-farm activities, with diversified nature of skills, involving heterogeneous group of people, bringing people of various walks of life together work for the production of silk. Sericulture is continuous activity and employment is available throughout the year. Sericulture involves low investment with frequent income with 5-6 crops per annum. Once the mulberry plantation is established it will continue to yield consistently for 15-20 years with minimum expenditure for maintenance. Division of mulberry garden into plots with alternate harvesting timings could enable the sericulturists to carryout silkworm rearing throughout the year continuously with 10- 12 crops/year. Basic sericulture activities are village-based; hence migration of people from rural to urban areas in search of jobs can be minimized. There is a high export possibility creating trade surplus and a good source for earning foreign exchange. Presently India is earning more than Rs 3,000 crore rupees from export of silk fabrics, waste and garments. In addition to high export opportunities, silk is having very good domestic market and strong handloom base blended with artisan skill, which is the real strength of the Indian sericulture industry. Silk industry is a labour intensive in nature, which is mainly a cottage industry in India providing livelihood to more than 9.42 lakh families.

The present global scenario clearly indicates that there is enormous opportunities for the Indian Silk Industry. Sericulture is one of the most labor intensive sectors, combining activities of both agriculture (sericulture) and industry.

Comparative Production of Raw Silk in the World :-

Country	Production (mt)	%
1. China	1,26,000	82.42
2. India	23,670	15.48
3. Uzbekistan	940	0.62
4. Thiland	655	0.43
5. Brazil	616	0.41
6. Vietnum	450	0.29
7. Others	537	0.35

Source : Central Silk Board (2013)

India has a prolific wealth of food plants and abundant man power and also ideal climatic conditions, both mulberry and non mulberry silk culture offers India a unique opportunity to boost her silk production and the economic status of the tribal population which are the most retarded section of the Indian society. In India the total tribal population is about 38 million and of this total population approximately about 12.89 million lives in tropical forest belt and 2.89 million lives in the temperate forest belt. At present about 1.04 million are engaged in tropical tasar cultivation. There is a vast wealth of non mulberry silkworm food plants in the tropical and temperate belt of lndia which is about 11.16 million hectors and of this only about 5% of this non mulberry silkworm food plants. Therefore there is a huge scope to exploit these wealth to generate meaningful remunerative employment for another 2.75 million tribal families. Similarly there is a huge scope for the export of non mulberry silk and silk product in the developed countries.

5.2 Prospects of sericulture in India

It is important to look into the real situation in Indian sericulture. All the major commercial silks are produced in the country. However, different races and hybrids of the monophagous silkworm *Bombyx mori* produce the major portion of silk in India. The gene pool available in the country can be broadly divided into two groups, low yielding stocks characterized by high adaptability to tropical conditions and highest yielding stocks exhibiting regular diapause, suffer from the low adaptability to the

highly variable tropical agro climatic conditions. To increase productivity and quality of silk there is an urgent need to develop technology suitable for tropical sericulture. Transplanting the technology developed for by the temperate sericulture is neither practical nor economically viable. This is because we have to consider at the same time the agro climatic conditions where the technology is going to be applied as well as the economic status of the technology user. Sericulture R&D in India demanded the twin requirement of evolving of high yielding breeds and development of the sericulture technology suitable for it. Since the productivity through better conversion to silk is higher in bivoltine silkworm, the shift to bivoltine sericulture will add to reduction. Recent switching to the high yielding mulberry variety from conventional **K2** and **CSR2 x CSR4** from the **multivoltine x Pure Mysore x NB4D2** are typical examples, through which productivity increased dramatically. Indian silk yarn is of poor quality, which not only affects our competitiveness in the world market, but has also resulted in a preference for imported yarn in the domestic market. Though the Indian breeds have the potential to produce the good quality of bivoltine silk, the problem arises due to lack of following factors :-

1. **Sufficient thrust on the adoption of improved technologies;**
2. **Strict disease control measures;**
3. **Quality leaf due to insufficient inputs to mulberry garden;**
4. **Appropriate mountages;**
5. **Grading system for cocoons;**
6. **Quality-based pricing system as well as use of young age silkworms.**

Seize Fall in production: It can be done by initiating area-specific research to improve fertility of the soils. This will ultimately enhance soil productivity, increase mulberry and non-mulberry host plant leaf and silkworm cocoon production as well as arrest decline in area under silk food plants. Bivoltine yarn is sturdier and is used by the power loom industry. But only 5% of the silk produced in India is bivoltine because its production requires much more attention and resources. It also yields just two crops in a year, as against the yield of four to six crops by multi-voltine silk. Even the farmers do not have any incentive to switch to bivoltine silk yarn production because the difference between the selling price of bivoltine and multivoltine silk is not much.

The other factors responsible for inhibiting the prospect of sericulture in India are :

1. **Insufficient adoption and proliferation of technology packages developed through R&D efforts;**
2. **No effort to increase the area under mulberry;**
3. **Fragmented and ad hoc approach;**
4. **Non-involvement of private partners in a big way in seed production; farming and reeling;**
5. **Non-penetration of the schemes;**
6. **Improper forward and backward linkages; and**
7. **Dumping of cheap Chinese raw silk and fabric.**

It is necessary to encourage farmers to move from production of multivoltine silk to bivoltine silk through proper incentives. At the same time it must be ensured that adequate amount of multivoltine is available for the handloom sector to continue production. The sericulturists want imports of raw silk to be restricted and the anti-dumping duty on yarn to remain in place. Exporters and weavers, on the other hand, want the anti- dumping duty to be withdrawn so that they get an assured supply of yarn and are able to export more silk products at competitive rates. Also, there has been a decline in the cultivated area and the raw silk production during 2002-04 due to drought and dumping of Chinese silk at cheap prices. Non-mulberry silk production in the country continues to be unsteady and fluctuates from year to year. With its uniqueness, non-mulberry silk production in India has a great potential for value added exports. Given the fact that, the scope for enhancing the production of silk in the country by expanding the cultivable area is limited. Hence, vertical expansion through productivity increase by using advanced technology and skilled man-power is the only option and have a huge prospect of sericulture in India.

5.3 Sericulture industry in different states of India

India's Silk Industry is world's second largest after China. The total production of silk in India stood at around 23,000 tonnes in the year 2011-12. India has the

unique distinction of being the only country producing all the five known commercial silks, namely, mulberry, tropical tasar, oak tasar, eri and muga, of which muga with its golden yellow glitter is unique and prerogative of India.

Karnataka, Andhra Pradesh, Assam and Borroland, West Bengal, Jharkhand, Tamil Nadu, Maharashtra, Jammu and Kashmir are major silk producing sates in the country. North East has the unique distinction of being the only region producing four varieties of silk viz., **Mulberry, Oak, Tasar, Muga** and **Eri.** Overall North Eastern region contributes 18% of India's total silk production. Among the **four varieties of silk produced in 2015-16,** Mulberry accounts for **71.8%** (20,434 Metric Ton), Tasar **9.9%** (2,818 Metric Ton), Eri **17.8%** (5,054 Metric Ton) and Muga **0.6%** (166 Metric Ton) of the **total raw silk production of 28,472 Metric Ton** . The demand for superior quality bivoltine silk is increasing in India for domestic consumption as well as value added silk products for the export market. The Ministry of Textiles, Government of India and Departments of Sericulture in various states provide technical and financial assistance for enhancing the bivoltine silk production.

India's most Important Silk Manufacturing and Product Centers:

SI. No	States	Important Silk Centers
1	**Andhra Pradesh**	**Dharmavaram, Pochampalli, Venkatagiri, Narainpet**
2	**Assam**	**Sualkuchi**
3	**Bihar**	**Bhagalpur**
4	**Guirat**	**Surat, Cambay**
5	**Jammu & Kashmir**	**Srinagar**
6	**Karnataka**	**Bangalore, Anekal, Ilkal, Molakalmuru, Melkote, Kollega**
7	**Chhattisgarh**	**Champa, Chanderi, Raigarh**
8	**Maharashtra**	**Paithan**
9	**Tamilnadu**	**Kanchipuram, Arni, Salem, Kumbhakonam, Tanjavur**
10	**Uttar Pradesh**	**Varanasi**
11	**West Bengal**	**Bishnupur, Murshidabad, Birbhum**

5.4 Employment Possibilities

Since agriculture is a basic need for humans, there is always a lot of scope in this field of study. With the advent of technology and developments that come with it, there has been a wide variety of job opportunities in both public and private enterprises. Labour is one of the most predominant resources on farms in the developing countries. The labour costs constitutes anywhere between one half and one fourth of the total costs on farms managed with traditional technology. No wonder it is mostly recognized as surplus or abundant resources with other scarce resources in such way as it could increase returns to the farmer. The efficient use of labour or the labour use efficiency is a prime issue with the farm management economists.

Sericulture, in recent times, has begun to offer a wide variety of employment and entrepreneurship options. Most importantly, every state in· India has a Sericulture Department to focus on rearing of silk worms, production of fibre and marketing. There are many laboratories that conduct experimentation on this natural fibre and these serve as excellent avenues for those inclined towards technology and scientific experimentation. There is demand for Indian silk items from America, Japan, Spain, Germany, Italy and Europe. Demand for Kashmiri silk carpets has been on the rise constantly. All these have created additional avenues for Sericulturists. Sericulture is quite popular in Southern India and is now available as a career option in Northern India too. With research institutions devising new technological processes, Sericulture is now being recognized as a mainstream profession. Sericulture offers career opportunity in Govt. research centers, silk boards, academic fields, sericulture units, agriculture sector banks etc. One can get jobs in Central Government agencies like Central Silk Board/ Silk Export Promotion Council/ FAO / Nabard, Krishi Vigyan Kendra etc. Candidates with M.Sc sericulture can apply for the post of lecturer, professor and lab assistant. Sericulturists can find employment as officers, managers in the agricultural loan sector of nationalized as well as private banks.

They can work as a manager in sericulture farm, grainage, silk reeling (filature), silk weaving mill, dyeing, printing and spinning mill etc. as well as in various central government sponsored schemes like SGSY, Welfare Dep't. Scheme Run By NGO's like **Pradan, Vikash Bharati** etc. Sericulturists can also set up their own enterprise or start up as entrepreneurs in silk retailing, weaving, exporting etc. Consultants with a thorough and updated knowledge of the field are also in demand, especially to provide guidance for the setting up of sericulture farms.

In the light of this, it is appropriate to study the potential of employment generation in sericulture ***vis-a -vis*** other cropping systems in a non-traditional area, where sericulture has been undertaken very recently.

5.5 Potential in mulberry and non-mulberry sericulture

India continues to be the second largest producer of silk in the world. India has the unique distinction of being the only country producing all the five kinds of silk- **Mulberry, Eri, Muga, Tropical Tasar and Temperate Tasar.** Sericulture is an important labour-intensive and agro-based cottage industry, providing gainful occupation to around 7.25 million persons in rural and semi-urban areas in India. Of these, a sizeable number of workers belong to the economically weaker sections of society. There is substantial involvement of women in this Industry. In India, Sericulture is mostly a village-based industry providing employment opportunities to a large section of the population. Although sericulture is considered as a subsidiary occupation, technological innovation has made it possible to take it up on an intensive scale capable of generating adequate income. It is also capable of providing continuous income to farmers. India is the second largest producer of silk in the world with an annual silk production of more than 21,000 M. Tons in 2010-11. Although, all the known varieties of silk, viz. mulberry, eri, muga and tasar are produced in India, Mulberry silk is the most popular variety. Mulberry silk alone contributes more than 80% of the country's silk production. Silk and silk goods are very good foreign exchange earners. Export potential of this sector is promising as silk production in Japan is declining and that of China, the largest silk producer the world, it is stagnant. The present global scenario clearly indicates the enormous opportunities for the Indian silk industry. The export silk goods from India comprise mainly items of natural silk, fabrics, made-ups, ready-made garments, silk carpets and silk waste. The category of silk fabrics viz., dress materials, sarees and scarves & stoles constitute the bulk of silk exports followed by ready-made garments with contribution around 60% and 30% respectively to the total silk export earnings of the country. The Indian silk goods have high export potential because of its distinctiveness and low production cost. India, being a traditional sericultural country, holds a unique position in the world, since it has the distinction of cultivating all the four commercially known varieties of Vanya silks (wild silks) viz., tasar, oak tasar, muga and eri, in addition to the mulberry silk. Indian silk exports, which reach more than 190 countries, have increased over the years. The demand for Indian silk is not only in the domestic market but in global markets too. USA, UK, Italy and UAE, Germany & Spain are the top five importers of Indian silk products. Indian silk are steadily gaining greater demand in the new markets like Latin America and Russia also.

5.6 Summary

From this unit we learn that sericulture is an ancient and important rural agro-based industry per excellence with agriculture base and industrial super structure. In India this industry is widely distributed in several distrincts. Sericulture industry with its rural based on-farm and off-farm activities and enoromous employment generation potential has been recognised as one of the most appropriate avenues for socio- economic development. Sericulture growth will certainly improves rural economy, by creating income generating entrepreneurial opportunities. Sericulture industry with a broad agricultural base is an excellent avenue for prividing employment with various entrepreneurial opportunities for rural development. The cultivation of mulberry plants and rearing of silkworm are agro based, while the post cocoon activies are industrial. The various entrepreneurial opportunities in sericulture industry are raising of mulberry nurseries, preperation and supply of silkworm eggs, chawki rearing units (young age silkworm rearing), cocoon production, silk reeling, silk twisting, silk yarn and fabric dyeing, printing, silk weaving, silk fabric finishing etc. This industry has great potential to create job opportunities for rural women as well.

5.7 Questions

1. How much silk is produced by India?
2. Name the places which are producing tasar silk in India.
3. Which place is monopolized for muga silks?

5.8 Suggested readings

1. **Hisao Aruga (1986)- Principles of Sericulture.,** Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, pp 375.
2. **Jaiswal Kamal, Trivedi, S.P.** & **Pandey, B.N. (2009)- Mulberry Sericulture-Problems and Prospects.,** APH Publishing Corporation, New Delhi, pp 380.
3. **Sehgal, P.K. (2017)- Text Book of Sericulture, Apiculture and Entomology.,** Kalyani Publisher, New Delhi, pp 421.
4. **Satbe, T.V.** & **Yadav, A.D. (2012)- Sericulture and Pest Management.,** Daya Publishing House., New Delhi., pp 654.
5. **Patnaik, R.K. (2013)- Sericulture Manual.,** Biotech Books., Jodhpur., pp 640

Unit - 6 ❑ Glossary

Antheraea mylitta, Antheraea pernyi and ***Bombyx croesi-*** Species of wild (undomesticated) moths that produce silk fiber. The silk filament is about three times heavier than that of the cultivated (domesticated) silkworm and is a coarser fiber. It is called tussah.

Artificial silk- Material that is similar in look to genuine silk, but is made from man-made fibers such as polyester, nylon or acetate.

Bombyx mori- The native (domesticated) variety of silkworm that produces Thai silk.

Brocade- Woven cloth with a raised pattern, often using silver or gold metallic threads, made by adding additional threads in the weft-ways direction, where required, usually from hand-held bobbins.

Chemical dye - A dye created from artificial chemicals, usually formulated in an industrial facility.

Cocoon - The small, egg-shaped enclosure that a silkworm spins around itself, by creating silk filaments, to allow it to metamorphose inside to emerge as a moth. The cocoons of the native *Bombyx mori* silkworm of Thailand are yellow in colour.

Crossbreed (C.B.) -Hybrid silk worm eggs between two silkworm races. In Karnataka hybrid of multivoltine female and bivoltine male is common.

De-gumming - The process of washing raw silk in warm soapy water to remove the sericin. This process can reduce the weight of the silk by as much as 25%. De-gummed silk is creamy white in colour and quite soft.

Denier - A unit of measurement of the fineness of silk and other fibres. One denier is equivalent to the weight of a single strand of silk thread of 9,000 meters in length, usually equal to one gram.

Dupion (or dupioni)- Yarn made from “double” cocoons that are spun by two silkworms simultaneously.

Fibroin - The protein that makes up the fibre of silk filaments.

Floss - Low-grade silk from the outer part of the cocoon. It can also refer to a soft silk yarn without any twist that is often used in embroidery.

Grainage -Place where silk worm eggs are produced.

Ikat - The Indonesian name for Mudmee.

Incubation - Keeping the eggs at controlled temperature and humidity for good growth of embryo. Eggs are incubated at 22° C to 26°C depending on silkworm variety and at a relative humidity of 80%.

Loom - A device for weaving threads together to make fabric. Hand-looms are usually made mostly of wood. Looms usually have a number of peddles to raise and lower alternate warp threads.

Momme - A traditional unit of weight used to measure the density of silk. It is the weight in avoirdupois pounds of a piece of material of size 45 inches by 100 yards. One momme is 4.34 grams per square meter.

Mudmee - Patterned silk made by tying off parts of the silk thread with a protective material and dyeing the rest of the thread. Repeated cycles allow multiple colours in different locations, creating the pattern.

Mulberry - The tree whose leaves are the staple diet of silkworms. Approximately 200 kilograms of mulberry leaves will be eaten to produce one kilogram of raw silk.

Mulberry silk - Another name for silk produced by *Bombyx mori* silkworms because they eat mulberry leaves.

Natural dye - A dye created from natural ingredients specifically grown for use or collected in the wild, usually processed on location where weaving occurs.

Ply - An indicator of the weight of yarn, usually derived from the number of threads thrown together to form the yarn used to weave the fabric. The more threads used (i.e. the greater the ply), the heavier the fabric.

Polyvoltine - The term used to describe silkworms that can be harvested several times a year. The native variety of silkworm in Thailand is polyvoltine.

Pruning - Cutting the plants to give proper shape for optimum production of

leaf. Generally plants are pruned to bottom once a year in pit system and 5 times a year in row system.

Pure-dye silk - Silk that is coloured with dye and which may sometimes be finished with water-soluble substances such as starch, glue, sugar, or gelatin. Pure-dye silk is considered superior to weighted silk.

Raw Silk - Silk thread that has been reeled from cocoons and is still in its natural state. It consists mainly offibroin (the filament) with about 10-25% sericin (a gluey secretion). Raw silk is golden yellow in colour and somewhat stiff.

Reeling - The process of unwinding raw silk filaments from cocoons to produce a raw silk thread.

Resist dyeing - A traditional process for dyeing textiles with patterns. Various methods, including wax, paste, tying, stitching and blocks, can be used to "resist" or prevent the dye from reaching all the fabric. This creates a pattern and ground. In Thailand, mudmee is created by tying off parts of the fabric with waterproof material to prevent the dye from entering the material.

Selvedge - The edge of the woven fabric that is parallel to the warp.

Sericin - A gluey protein secreted by silkworms that holds silk filaments together in a cocoon.

Sericulture - The process of rearing silkworms to the cocoon stage where they can then be reeled.

Shot - A type of fabric made from two single but different colours, one colour for the warp threads and a different colour for the weft threads. Shot fabric typically has a prominent iridescent sheen and changes colours depending on how light shines on it.

Shuttle - A small wooden object, shaped a bit like a small canoe, used to hold weft thread. The shuttle slides side-to-side across the warp threads, crossing between the threads to produce the weave.

Silkworm - The larval stage of the *Bombyx mori* moth that produces silk fibers.

Skein - A coil of silk thread.

Slub - Tiny irregularities in the silk thread created by hand-making the thread.

Throwing - The process of taking raw silk threads and twisting them together to form skeins of silk yarn that will eventually be used for weaving. Different throwing techniques are used to produce warp and weft threads.

Tussah - Silk produced by wild silkworms; for example, *Antheraea mylitta.* Its silk filament is about three times heavier than that of the cultivated silkworm, *Bombyx mori,* and is a coarser fibre.

Warp - The long threads that run the length of the loom, under tension. These warp threads are put in place as the first stage of loom readiness. When sitting at the loom, the weaver sees these threads running away to the far end of the loom, possibly up to 10 meters away.

Weaving - The process of using a loom to interlace weft and warp threads to produce lengths of finished fabric.

Weft - The threads that are woven between the warp threads, alternately above and below adjacent warp threads, to produce the final fabric. The weft thread sits in a shuttle that is thrown side-to-side by the weaver.

Weighted silk - Silk that is colored with dye and to which metallic substances have been added during the dying process. This adds back weight which is lost during de-gumming and also adds body to the fabric. If weighting is not done properly, it reduces the life of the fabric. Pure-dye silk is considered superior.

Wild Silk - Silk made by wild silkworms; for example, *Antheraea mylitta* and *Antheraea pernyi.* Also called tussah.

Yarn - Silk thread that is ready to use for weaving

Notes

Notes