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17. Sericulture: Research and Development

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Abstract:

Sericulture, the art and science of silk production, has been intertwined with human civilization for millennia, originating in ancient China and spreading across the globe. Silk, a natural protein fiber, is primarily produced by silkworms during their larval stage. China leads in raw silk production, followed by India. The industry primarily involves insects from the order Lepidoptera, families Bombycidae and Saturniidae. Major types of silkworms include mulberry, tasar, eri and muga. Silk production varies based on voltinism, with silkworms categorized as univoltine, bivoltine, or multivoltine. Mulberry silk, mainly from Bombyx mori silkworms, dominates the market. Challenges such as diseases and climate change persist, but genetic engineering holds promise for enhancing silk quality. Modern sericulture research encompasses a wide array of disciplines, ranging from genetics and molecular biology to entomology, agronomy and engineering. This interdisciplinary approach aims to optimize silk production by enhancing silk yield, quality and disease resistance while minimizing environmental impact. Technological innovations in sericulture equipment and infrastructure have also revolutionized silk production processes, optimizing cocoon harvesting, silk reeling and post-harvest processing. Automation and digitalization streamline production workflows, improve efficiency and reduce labor costs, enhancing the competitiveness of sericulture industries worldwide. Sustainable practices aim to reduce chemical fertilizer use and utilize waste effectively.

Keywords:

Sericulture, Silk production, Mulberry, Tasar, Eri, Muga, Modern sericulture, Silk farming.

17.1 Introduction:

Sericulture is derived from the Latin word “Sericos” meaning “Silk” and the English word “Culture” meaning “Rearing”. So, sericulture means the art of cultivation of silkworms to produce silk.

It is also known as silk farming. Agricultural-based sericulture involves growing mulberries for their leaves, raising silkworms from leaves to cocoons, reeling the cocoon to produce silk yarn, and weaving the yarn to create textiles.

Silk: It is a natural protein fibre produced by silkworms, during their larval stage. It is known for its smooth texture, lustrous appearance and strength. Silk is known as *Kaushika* or *Kausheya* in Sanskrit, *Resham* in Hindi, *Soie* in French, *Seide* in German, Tsi in Chinese.

Silk holds a place of greatest significance in the social and cultural fabric of India. Revered for its unmatched qualities such as durability, unparalleled lustre and feather-light weight, it rightfully claims the title of "Queen of Textiles" on the global stage. This prestigious status is not merely a matter of acclaim but a testament to silk's enduring legacy as a symbol of luxury and refinement, woven deeply into the tapestry of Indian tradition and heritage.

According to Chinese records, silk production from *Bombyx mori* was discovered around 2700 B.C. Legend has it that Prince Hoang-ti instructed his wife, Si-ling-chi, to investigate the silkworm and explore the feasibility of using its thread. Si-ling-chi not only discovered how to raise silkworms but also developed techniques for reeling the silk and making garments from it. As a result of her contributions, Si-ling-chi was later revered for her work and bestowed with the title Seine-Than, meaning "The Goddess of Silkworms."

In 139 B.C., the Silk Road opened, spanning from Eastern China to the Mediterranean. It facilitated the exchange of goods like gold and jade, as well as the transmission of new ideas and religions. Named after its key commodity, silk, it became renowned as the world's longest highway.

The history of sericulture begins in ancient China. According to a fascinating tale, a Chinese princess who was married to the King of Khoten secretly smuggled mulberry and silkworm seeds in her hat, which is how the secrets of the practice made their way to Tibet. Sanskrit literature describes the ancient craft's voyage from Tibet to the Indian subcontinent in 140 BC. Domestication of silkworms started in the foothills of the Himalayas.

During the colonial period, the British East India Company profited from India's silk industry, especially in West Bengal, exporting large quantities to England. Despite this exploitation, the British resisted privatizing the silk industry, while sericulture thrived in regions like Mysore and Jammu and Kashmir.

India's diverse sericultural states each hold a traditional reputation for producing unique silk goods. The distinctive qualities of silk from Banaras, Kashmir, Bengal, Mysore, and Kanchipuram are highly prized, since they are a reflection of centuries of experience in sericulture and cultural legacy.

India, with 36.58 thousand metric tonnes in 2023, is the world's second-largest producer of raw silk, behind China (Anon., 2024).

17.2 Types of Silkworms:

Around 400-500 species are known to produce silk but only very few are commercially exploited. Silk is divided into two categories: **insect silk** and **non-insect silk**, depending on the creature that produces it. Commercially, insect silk is more significant. The order Lepidoptera, Superfamily, **Bombycoidea**, and families **Bombycidae** and **Saturniidae** comprise the majority of insects that produce silk.Roughly ninety-five percent of commercial insect silk is made from mulberry, which is mostly obtained from the *Bombyx mori* silkworm. The term "non-mulberry silk" (also known as "Vanya silk") refers to the remaining sources of commercial silk. The only nation in the world that produces all four varieties of natural textile silk is India.

Table 17.1: Major Four Types of Silkworms

Sr.No.	Common name	Scientific name	Host plant
1.	Mulberry Silkworm	*Bombyx mori*	Mulberry leaves
2.	Tasar silkworms		
	a. Tropical Tasar silkworms	*Antheraea mylitta*	Arjun, Asan, Sal, ber
	b. Temperate Tasar silkworms	*Antheraea proylei*	
	c. Chinese Tasar	*Antheraea pernyi*	
	d. Japanese Tasar	*Antheraea yamamai*	
3.	Eri Silkworm	*Samia cynthia ricini*	Castor leaves
4.	Muga silkworm	*Antheraea assamensis*	Som, Champa and Moyankuri

A. Mulberry Silkworm (*Bombyx mori*): The mulberry silkworm (*Bombyx mori*), which only consumes mulberry leaves, produces most of the commercial silk produced worldwide. All of these silkworms are raised indoors and are completely domesticated. Major mulberry silk-producing states in India are Andhra Pradesh, West Bengal, Tamil Nadu, Karnataka, and Assam & Kashmir. These states together account for 92% of the nation's total production of mulberry raw silk.

B. Tasar Silkworm: Tasar silk is produced from silkworms belonging to the genus Antheraea and is obtained from trees such as Asan and Arjun. Rearing occurs naturally on trees, particularly in Bengal and Andhra Pradesh. Tasar silk has a copperish color and is coarser compared to mulberry silk, but it has its own unique appeal. The main types of tasar silkworms are tropical tasar (*Antheraea mylitta*), temperate tasar (*A. proylei*), Chinese tasar (*A. pernyi*) and Japanese tasar (*A. yamamai*).

C. Eri Silkworm (*Samia cynthia ricini*): Also known as Endi or Errandi, the domesticated silkworm *Philosamia ricini*, which mostly feeds on castor leaves, spins eri silk from open-ended cocoons. Eri culture is commonly practiced in northeastern states like Assam, as well as in Bihar, Orissa, and West Bengal. The silk is mainly used for making wraps called chaddars and eri culture is significant for providing protein-rich pupae, a delicacy for tribal communities.

D. Muga Silkworm (*Antheraea assamensis*): Muga silk, characterized by its golden-yellow color, is unique to India and is particularly associated with the state of Assam. It comes from the multivoltine, semi-domesticated silkworm *A assamensis*, which consumes the fragrant leaves of Som and Soalu plants. Unique to Assam, Muga culture is integral to the state's customs and culture. Muga silk is extremely valuable and utilized in many different items, including chaddars, mekhalas, and sarees.

17.3 Classification of Silkworms Based on Voltinism:

There are three primary classifications based on the number of generations: Univoltines, bivoltines and multivoltines.

A. Univoltines: These species have only one generation per year and undergo diapause during the egg stage. They are unsuitable for rearing in summer and autumn due to their long larval period. However, they produce cocoons of superior quality. Examples include European races.

B. Bivoltines: With two generations in a year, bivoltines produce robust larvae with white cocoonale gelatinous protein. They are tolerant to various environmental conditions and their diapause can be artificially broken. Examples include Japanese and Chinese races.

C. Multivoltines: More than three generations per year, Golden yellow-coloured cocoons, Larvae can withstand high temperature and humidity, well adapted to tropical conditions, comparatively the cocoons are of poor quality E.g. Indian and Chinese races.

17.3.1 Silkworm Biology:

Egg: Approximately 1.0 g of white, spherical eggs are laid for every 2,000 eggs. Its dimensions are 0.9–1.2 mm in width and 1-1.3 mm in length. In time, the eggs become darker.

Eggs are pale yellow when produced by white cocoon-bearing races and darker yellow when produced by yellow cocoon-bearing races. The color of hibernating eggs from bivoltine and univoltine races darkens to a dark brown or purple color as a result of the serosal pigment color deepening. There are two sorts of eggs: diapause and non-diapause. Silkworms that live in temperate zones lay diapause eggs, which are eggs that stop all important activity during diapause.

Larva: After approximately 10 days of incubation, the eggs hatch into larvae, known as caterpillars. The freshly hatched caterpillars are pale yellowish-white and measure around 0.3 cm in length.

The larval body has five instars and evolves from a dense covering of bristles to a smoother, lighter-colored body. The larval growth is marked by four moltings. Full-grown caterpillars develop silk glands, which are modified labial glands secreting silk composed of fibroin and sericin.

Pupa: The silkworm's pupa, or inactive resting stage, is housed in a thick, oval, white or yellow silken shell known as a cocoon. The adult moth emerges by slicing through the pupal epidermis and puncturing the cocoon shell with alkaline salivary secretions. The pupal stage can last anywhere from 8 to 14 days.

Adult: The adult Bombyx mori is creamy white in color and measures around 2.5 cm in length. Because of its hefty body and weak wings, it cannot fly. For the seven days or so of its brief adult life, the moth does not feed. The female lays 400-500 eggs in clusters covered with a gelatinous secretion.

Total life cycle: Egg: 7-8 days, Larval period: 20-22 days, Pupal period: 10 days, adult period: 7 days.

Sericulture can be divided into three divisions as follows:

- Cultivation of Mulberry
- Rearing of silkworms
- Reeling of cocoons

Moriculture: Cultivation of mulberry plants for rearing the silkworm called as **Moriculture.**

17.3.2 Mulberry:

Mulberry, thought to have originated from the lower Himalayan slopes in India or China, has a rich history dating back to around 2800 BC when Chin-Nong, a successor of Emperor Fo-Hi, introduced its cultivation in China.

Today, mulberry cultivation spans 29 countries globally. Belonging to the Moraceae family and genus *Morus*, mulberry plants, with about 20 species in India, including *M. alba, M. indica, M. serrata, and M. latifolia*, continue to be widely cultivated, reflecting their enduring significance in agriculture and sericulture.

The Importance of Mulberry Leaves as The Primary Food Source for Silkworms:

A. **Nutrient-Rich Diet**: Mulberry leaves are **abundant in nutrients**, including proteins, soluble sugars and fats. These components are **essential** for the **growth and development** of silkworms (Zhang *et al.,* 2022)
B. **Palatability and Digestibility**: Silkworms find mulberry leaves **highly palatable and easily digestible**. This characteristic makes them an ideal food choice for these silk-producing insects.

C. **Cocoon Production**: Silkworms exclusively consume mulberry leaves to create their **cocoons**, from which silk is produced. Interestingly, there exists a **strong correlation** between the **leaf protein content** and the **efficiency of cocoon production** (Sharma *et al.,* 2020.)
D. **Jasmine-Scented Attraction**: A jasmine-scented chemical emitted by mulberry leaves acts as a potent attractant for silkworms. These chemical triggers a specific olfactory receptor in the silkworms' antennae, guiding them toward their primary food source (Nishid, 2014). This attractant, called **cis-jasmone**, is present only in small amounts in mulberry leaves.

A. Climatic Conditions for Cultivation of Mulberry:

Mulberry flourishes in climates from temperate to tropical, between 28° N and 55° N latitude, thriving best at 24-28°C with rainfall of 600-2,500 mm annually. It needs 340 m3/ha of water every 10-15 days, prefers 65-80% humidity, and 9-13 hours of sunlight daily. It grows from sea level to 1,000 m elevation. Ideal soil is flat, deep, fertile, well-drained, loamy to clayey, with pH 6.2-6.8. Cotton soil can also be used for moriculture after improvement with organic matter and gypsum (Choudhury, 1972; Datta, 2000).

Mulberry Varieties for Different Areas:

- Irrigated area: Kanva 2 (M5), MR 2, S30, S36, S54, DD (Viswa), V1
- Semi irrigated: Kanva 2 (M5), MR 2.
- Rainfed area: S13, S34, RFS135, RFS175, S1635

Newly Released Varieties (CSB, 2023):

- C-2038, C-2028 and C776 (E and NE India).
- PD-1, PD-8, PP-8 and PP-10 (Irrigated and rainfed conditions of E & NE India).

Propagation Methods:

Mulberries can be propagated through various methods

- **Sexual propagation /Seed Propagation**: Collect seeds from ripe mulberry fruits and plant them directly in the ground. This method is straightforward but may result in genetic variability due to seed variation (Ozturk *et al.,* 2023).
- **Root Cuttings**: Take root cuttings from a healthy mulberry tree. These cuttings are sections of the root system that can be planted to grow new trees. Root cuttings help maintain genetic similarity and are useful for obtaining clonal plants with consistent leaf yield.
- **Air Layering**: Air layering is a more advanced method involving bending a low branch of a mulberry tree to the ground, wounding it, and covering it with soil until it forms roots. Once rooted, the branch can be separated and planted as a new tree.
- **Grafting:** Grafting merges two plant parts, the scion (desired variety) and the stock (local hardy variety), to grow as one plant. It's less popular due to its laborious, costly,

and skill-demanding process. Also, it's not efficient for obtaining large quantities of planting materials quickly.

Micropropagation: It is a valuable technique for rapidly multiplying plants in a controlled environment.

- **Single-Node Culture (SNC):** This technique involves culturing a single node, typically a small stem section with a bud, in vitro (Anis *et al*., 2003). The culture medium used lacks cytokinins but is supplemented with vitamins and sucrose. Generally, SNC cultures yield a single well-rooted, notably longer axillary shoot with larger leaves. The shoots obtained from SNC cultures can be rooted in vivo and develop into similar plantlets (Litwińczuk and Jacek, 2020; Sarkar *et al*., 2018).
- **Axillary-Branching (A x B):** A more widely practiced method, axillary-branching involves promoting shoot branching, particularly from axillary buds. Shoots are cultured on a modified MS medium supplemented with cytokinins (such as BA), vitamins and sucrose. A x B cultures typically generate more shoots and callus formation at the base of the explant (Attia *et al.*, 2014).
- Using stem cuttings and root grafting techniques, mulberry plantations are most effective in the early spring and late autumn seasons. We only utilize fully established, robust main stem cut-pieces that are roughly 22–23 cm long and have three to four buds. Hard wood cuttings give good results. They should be cut at an angle of 45 from one year old bushes (Tembhare, 1997)

Planting Methods:

- **Row system**
- **Paried row system**
- **Pit system**
- **Kolar system**

In Karnataka, mulberry cultivation is practiced using the 'pit system' with plant spacing of 0.45 to 0.9 m and row spacing of 0.75 to 0.9 m, requiring 27,225 cuttings per hectare Dandin *et al*., 2003). Under irrigated conditions, the 'row system' is common with plant spacing of 0.30 to 0.60 m and row spacing of 0.10 to 0.25 m, needing 48,400 cuttings per hectare. The Kolar planting technique, popular in Kolar, Karnataka, involves spacing rows 20 cm apart and cuttings 8 cm apart. Holes are made in the soil for planting cuttings, which are placed in a slant position and firmly pressed into the soil. Mulching with dried mulberry twigs or thatch is provided, and irrigation occurs weekly during dry periods (Anon., 2018).

The Kanva-2 strain of *M. indica* is favored for its high leaf yield of 9,000 to 30,000 kg per hectare annually. Mulberry plants remain productive for 15-20 years and are pruned once a year during July-August (bottom pruning) and December-January (middle pruning) to promote leaf production. Pruning is essential for multiple harvests, done at intervals of 10-12 weeks using methods like individual leaf picking, branch cutting, or whole shoot harvesting (Saini *et al.*, 2023).

There are three methods for leaf harvesting: (a) Individual leaf piking (b) branch cutting and (c) whole shoot harvesting at intervals of 10-12 weeks to obtain 4-5 harvests in a year.

17.3.3 Rearing of Silkworms:

A. Environmental Conditions Required for Successful Silkworm Rearing

- **Temperature**: The ideal temperature range for silkworm growth is 20°C to 30°C, with the most desirable range for cocoon production being 23-28°C.
- **Humidity**: Along with temperature, humidity plays a crucial role in the physiology of silkworms. It affects their growth, development, and the quality of silk produced (Gupta and Dubey, 2021).
- **Air Circulation**: Proper air circulation is necessary to maintain the desired temperature and humidity levels (Gupta and Dubey, 2021).
- **Light:** Light also influences the development of silkworms, although the specific requirements can vary depending on the stage of development (Gupta and Dubey, 2021).

These factors interact significantly and can affect the silkworm's physiology depending on the combination of factors and developmental stages. Managing these environmental conditions is essential for sustainable cocoon production and higher silk quality (Gupta and Dubey, 2021).

B. Selection of Silkworm Race:

Multivoltine silkworms are economically vital, cycling 5-6 times annually from non-hibernating eggs. In India's tropics, 'Mysore' is raised in Karnataka, Tamil Nadu and Andhra Pradesh, while 'Nistari' is preferred in West Bengal. Though sturdy, multivoltine cocoons yield less silk than bivoltine ones. Other important multivoltine races are Nichi (Originally Japanese bivoltine race), Pure Mysore, Sarupat, Tamilnadu white. Kolar gold, Moria, OS-616 etc (Ashok Kumar *et al.*, 2009).

Bivoltine silkworms undergo two alternating life cycles, with four involving hibernating eggs. By manipulating light and temperature, their hibernation can be controlled to mimic multivoltine behaviour. In India, commonly reared bivoltine races include Kalimpong, A NB7, NB4D2 and NB18 (Thangavelu, 1997). In the year of 1999, Datta identified seven highly productive bivoltine hybrids viz., CSR-2 × CSR-5, CSR-2 × CSR-4, CSR-3 × CSR-6, CSR-12 × CSR-6, CSR-13 × CSR-5, CSR-16 × CSR-17 and CSR-20 × CSR-29.

Univoltine silkworms in temperate region complete only a single life cycle in a year as the eggs after some development enter diapause for a long period, till spring. Hibernation is hereditary and these breeds are of little use for silk industry. Nowadays, hybrids of multivoltine and bivoltine breeds are popular in India and other silk producing countries. Females of Mysore race and males of bivoltine KA, NB_4D_2 are crossed. The combination of multivoltine yellow females (PA_1) with bivoltine males (PB_1, PB_2, PB_3) to create hybrids (Ibrahim *et al.*, 2017).

C. Silkworm Seed Production:

Hybrid races are reared for commercial silk production due to their superior quality and abundant egg production. Reproductive seeds (pure breed cocoons) are obtained, and from these cocoons, hybrid seeds (industrial seeds) are produced. These hybrids result from mating between two or more races.

Grainages: These facilities produce silkworm seeds on a large scale. Healthy, disease-free cocoons are selected, and poor-quality cocoons are removed. The floss is removed from the cocoons to allow moths to emerge. Moths typically emerge early in the morning. Virgin females are transferred to plastic trays, and male moths of the desired race are placed in the same trays. After copulation, females lay eggs within 12 hours, usually on egg sheets or cards at the bottom of cellules. Disease-free layings (DFLs) are used for worm culture (Omura, 1973; Rajan and Himantharaj 2005; Tazima, 1972).

D. Worm Culture:

Brushing: Around 10 a.m., newly hatched first-instar larvae (silkworms) are gently brushed from the egg cards. They are then placed in tissue paper in a refrigerator at 10°C. These tiny, black, and hairy silkworms are often referred to as "ants." Other brushing methods include using husk, cloth, paper, or net materials.

Feeding: Fresh mulberry leaves, chopped into square pieces, are provided to the silkworms at different instars. Rearing beds for young silkworms are covered with paraffin paper to maintain hygiene.

Clean unconsumed leaves regularly during each developmental stage using husk, net, or combined methods. Silkworms grow rapidly, increasing in weight by 10,000-fold and size by 7000-fold in just 20-30 days. Protect delicate young larvae with paraffin paper-covered rearing trays. Provide fresh air by removing the cover sheet at least 30 minutes before each feed. Alternatively, use boxes with lids or wooden cellars measuring 2 x 2.5 x 1 meters for rearing.

Silkworms in late stages (3rd to 5th instars) are often raised in bamboo trays, stacked on tiers of a rearing stand. Alternatively, floor or shoot rearing methods may be employed.

E. Cocoon Formation:

Mounting: Mature silkworms stop feeding and are transferred to montages, like 'Chandrike' in India, to prevent double cocoon formation. Each Chandrike holds about 1000 silkworms in a space of 1.8 x 1.2 m. Ideal conditions for cocoon spinning are 24°C temperature, 60-70% humidity and good ventilation.

Spinning: Silkworms excrete semi-solid excreta and spin cocoons by drawing out silk fluid, forming long continuous filaments. In multivoltine races, cocoon spinning lasts 1-2 days, while in uni/bivoltine races, it lasts 2-7 days. The cocoon's floss, about 2% of its weight, forms a tangled network.

Harvesting: Cocoons are removed from mountages for sale or transportation to the reeling industry. Typically done by hand on the 5th day in tropics and 6-7th day in subtropics. For seed use, harvesting occurs slightly later, on the 6th day in tropics and 7th-8th day in temperate zones. Sorting is done based on quality - good, double, pierced, stained cocoons, etc.

F. Reeling:

About 58 per cent of silk in each cocoon is usable; the rest is silk waste. Raw silk is processed through boiling, drying and brushing stages.

Cocoon Drying: Cocoons are steam-stifled or sun-dried to kill pupae.

Cocoon Boiling: Boiling removes sericin or gum and softens the cocoon.

Brushing: This identifies the free end of the silk filament for reeling.

The resulting thread is very fine, about 0.05 to 0.08 mm in diameter and 900 meters long, obtained from cocoons weighing around 2 gm with pupa and 0.45 gm without.

Reeling Methods: Three methods of reeling (i) country charkha, (ii) cottage basin or (iii) filature method. The loose ends of five to ten cocoons' worth of silk filaments are gathered, secured on a reeling device, and then twisted into one thick thread before being wound onto a reel. Silk thread is unwound from cocoons using manual methods like the country charkha or automated processes in large-scale filature industries. The resulting silk is known as ‘spun silk’.

17.3.4 Applications of Silk:

Raw Silk: Used for clothing items like shirts, suits, ties, blouses, lingerie, pajamas, and jackets.

Hand-Spun Mulberry Silk: Utilized for making comforters and sleeping bags.

Spun Silk Fabrics from Reeling Waste and Bad Cocoons: These fabrics are hand-spun into matka, katan, feshua (jatan or Jhut), and noil yarns. Articles made from waste silk also find a good export market.

Tasar Silk: Produced in exotic designs by handlooms. Varieties include Gicha-noil, tasar plain, cotton-tasar blend, tasar-mulberry blend, and peduncle fabric.

Muga Silk: Widely used by Assamese women for mekhela, riha-sador sarees.

Eri Spun Silk: Used for dress materials, while the coarse variety is employed for making scarves, chaddar, shawls, and quilts.

Industrial Uses: In France, 22-24 denier silk is used in tire manufacturing for longer-lasting bicycle tires and artillery gunpowder bags. Parachutes were also made from 13-15 denier silk fibers during World War II.

Biomedicine Uses: Natural silk, composed of fibroin and sericin, finds applications in various human tissues, including skin, bone, and nerves. Additionally, silk exhibits a range of beneficial properties, such as being anti-cancer, anti-tyrosinase, anti-coagulant, anti-oxidant, anti-bacterial and anti-diabetic. Its versatility makes it a valuable material in both medical and functional contexts (Khosropanah *et al.,* 2022).

Silk is a versatile material used in both soft and hard tissue engineering for cardiac, vascular, skin, and cartilage regeneration. It offers biocompatibility, biodegradability and resorbability (Farahani *et al.*, 2023). Silk-based systems also serve as effective drug carriers for wound healing, skin applications and medical implants, providing controlled release and targeted delivery for enhanced therapeutic outcomes (Bernardes *et al.*, 2024).

Used in electronics and environmental remediation: In electronics, they offer biodegradable substrates, biocompatible sensors and potential for optoelectronic devices. In environmental remediation, they can be utilized for water and soil purification as well as air filtration due to their adsorption properties. Continued research is likely to lead to innovative applications in these fields.

A. Challenges Facing the Sericulture Industry:

a. Silkworm Health Challenges:

Silkworms are vulnerable to various diseases like pebrine, flacherie, grasserie and muscardine, which can significantly impact silk production by reducing yields and quality (Harsha *et al.,* 2024). Disease management remains a pressing issue for sericulture farmers as it directly affects the sustainability of silk production.

b. Environmental Factors:

- **Climate Change Impact:** Sericulture faces substantial challenges from climate change, including rising temperatures, altered weather patterns, and fluctuating humidity levels. These changes affect silkworm behavior, growth, and survival, leading to potential crop losses.
- **Global Warming Effects:** The increasing global temperature due to greenhouse gas emissions also threatens sericulture. Extreme natural variations further endanger silkworm populations, directly impacting silk output.
- **Cocoon and Silk Production:** Environmental elements such as rainfall, temperature, humidity, and soil quality play pivotal roles in determining the quality and quantity of cocoons and silk. Maintaining optimal conditions is crucial for economic growth in the industry (Bora and Saikia, 2022).

- **Synthetic Fabric Competition:** The sericulture sector faces competition from synthetic fabrics as consumer preferences evolve, potentially affecting the demand for silk.

c. Innovations in Sericulture:

- In 2023, Vasta *et al.* introduced an automated prototype for sorting *Bombyx mori* cocoons, aiming to enhance silk quality by categorizing them based on size, shape, and stains. Using imaging algorithms, light sensors and AI, the prototype achieves an impressive efficiency of around 80 cocoons per minute.
- Employing CRISPR/Cas9 technology, incorporating spider silk proteins into silkworms has the potential to notably enhance the mechanical characteristics of silk fibers, leading to significant improvements in their properties (Zhang *et al.,* 2019; Mi *et al.*, 2023).
- Yu *et al.* (2024), developed effective transformation methods for silkworms, including TALEN-based fusion and replacement systems for silk protein genes (BmFibL-F and BmFibH-R) and a piggyBac-mediated transgenic system (BmFibH-T). They found that incorporating the 160 kDa MaSp2 protein notably improved the stretchiness of silk fibers in the genetically modified silkworm lines.

d. Sustainable Practices in Sericulture:

Organic Farming Methods:

- Avoid synthetic pesticides and fertilizers.
- Use natural alternatives like neem oil and biopesticides.
- Implement mulching and composting for soil health.

Waste Reduction Strategies:

- Properly manage silkworm excreta (frass) as organic fertilizer.
- Optimize cocoon processing to minimize waste.
- Explore value-added products from waste silk.

17.4 Conclusion:

Sericulture stands as a crucial agro-based industry, cantered around cultivating mulberry, tasar, muga, and eri silkworms, with Karnataka spearheading mulberry silk production in India. Silk serves both traditional and modern needs, yet encounters hurdles from diseases and climate change.

Genetic engineering offers hope for silk quality improvement. Sustainable practices reduce reliance on chemical fertilizers, utilizing waste efficiently. By focusing on research and development, the sericulture sector can overcome challenges and move towards a sustainable and prosperous future.

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