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Innovative Rearing and Management Practices for Improving the Health, Survival, and Commercial Performance of the Mulberry Silkworm (Bombyx mori L.)

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Abstract : Sericulture benefits the local economy by creating jobs and producing high-quality natural silk. Mulberry sericulture's productivity and profitability are heavily dependent on the mulberry silkworm's health, survival, and performance. Innovative raising and management strategies, such as improved rearing house sanitation, environmental control, balanced nutrition with high-quality mulberry leaves, illness prevention, and scientific handling procedures, have considerably increased silkworm development and cocoon production. Recent developments in raising efficiency, including as automated monitoring systems, eco-friendly disinfectants, precision feeding, and integrated pest and disease management, have reduced output losses. Sustainable management strategies also help to conserve the environment and ensure economic viability by reducing chemical use and maximizing resource utilization. This data emphasizes the importance of implementing modern rearing technologies and evidence-based management strategies to improve larval health, survival rate, cocoon quality, and overall commercial performance, thereby ensuring the sericulture industry's long-term sustainability and competitiveness.

Keywords: Sericulture; Bombyx mori L.; Mulberry silkworm; Rearing management; Cocoon quality; Disease management; Sustainable sericulture; Precision farming; Silkworm health; Commercial silk production.

I. INTRODUCTION

Sericulture, or the scientific rearing of silkworms for silk manufacturing, is one of the world's oldest and most commercially significant agriculture-based enterprises [1]. It contributes significantly to rural development by creating job possibilities, notably for small and marginal farmers, women, and landless labourers. Sericulture, as a labor-intensive sector, significantly contributes to rural livelihoods while promoting sustainable agricultural practices by combining mulberry production and silkworm rearing [2]. Bombyx mori L., sometimes known as the mulberry silkworm, is the most domesticated and cultured silkworm species due to its outstanding silk quality, high productivity, and adaptation to regulated rearing conditions.Bombyx mori cultivation success is dependent on scientific upbringing and good management procedures throughout the species' life cycle. Mulberry cultivation is essential for sericulture because the larvae rely solely on fresh, nutritious mulberry (Morus spp.) leaves [3]. During the final larval instar, the silkworm's specialized silk glands secrete a continuous proteinaceous strand. This filament, mostly made of fibroin and covered in sericin, creates a protective cocoon around the pupa [4]. The cocoons are plucked and degummed, which eliminates sericin and allows fine silk strands to be extracted for textile manufacture. The health of the larvae, the environmental circumstances during rearing, and the use of proper management strategies all has a significant impact on silk quality [5].

Innovative raising and management approaches have emerged as critical tactics for enhancing the health, survival, cocoon quality, and commercial performance of mulberry silkworms. Traditional methods have been steadily complemented with modern technologies like as enhanced disinfectants, environmentally controlled raising rooms, precise temperature and humidity management, robotic feeding systems, disease surveillance and integrated pest

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management [6]. These innovations have considerably reduced larval mortality, reduced disease outbreaks, increased cocoon yield, and improved silk quality while supporting sustainable and environmentally friendly production methods. Mulberry cultivation, or moriculture, is the foundation of effective sericulture. High-quality mulberry leaves contain important nutrients for silkworm growth and development [7]. Scientific farming approaches such as enhanced mulberry types, balanced fertilizer management, effective irrigation, and integrated crop protection all have a direct impact on leaf quality and as a result, silkworm productivity [8,9]. As a result, combining modern moriculture with innovative silkworm rearing techniques is critical for increasing economic returns and ensuring long-term silk production. Sericulture is practiced in various nations worldwide, including China, India, Japan, Brazil, the Republic of Korea, Thailand, Uzbekistan, and Vietnam. India is the only country that commercially produces all four primary types of natural silk—mulberry, tasar, eri, and muga—with mulberry silk accounting for roughly 70-75% of total silk output. The major mulberry silk-producing states are Karnataka, Andhra Pradesh, Telangana, Tamil Nadu, West Bengal, and Jammu and Kashmir. The sector continues to make major contributions to the rural economy by creating jobs throughout the value chain, from mulberry production to silk weaving and sale.

In recent years, rising demand for high-quality silk, changing climatic circumstances, developing illnesses, and the need for sustainable production have all underlined the significance of implementing innovative rearing and management approaches [10,11]. Biotechnology, environmental monitoring, precision farming, digital technologies and eco-friendly disease management are all helping to make traditional sericulture more efficient and robust [12,13]. These advances not only improve the health and survival of Bombyx mori, but they also increase cocoon yield, silk quality, and economic profitability.

Climate and Soil Requirements for Successful Mulberry Cultivation

Mulberry (Morus spp.), the mulberry silkworm's (Bombyx mori L.),major host plant, is well adapted to the Indian subcontinent's different agroclimatic areas, which range from tropical to temperate. It thrives in warm, humid circumstances with temperatures ranging from 24 to 28°C, relative humidity of 65 to 80%, annual rainfall of 600 to 2,500 mm, and evenly distributed sunlight, all of which support rapid vegetative development and high-quality leaf output. Major mulberry-growing regions include Karnataka, Andhra Pradesh, Telangana, Tamil Nadu, West Bengal, Jammu and Kashmir, Himachal Pradesh, and sections of the northeastern states with ideal climatic conditions for year-round or seasonal sericulture. Deep, fertile, well-drained loamy soils with a pH ranging from slightly acidic to neutral (6.2-6.8) increase mulberry productivity and leaf nutritional quality, consequently enhancing silkworm growth, cocoon yield, and silk quality [14].

Table 1. Favorable Agro-Climatic Conditions for Mulberry Cultivation in the Indian Subcontinent [15]

Parameter	Optimum Range/Condition	Importance
Temperature	24–28°C	Promotes vigorous vegetative growth and leaf yield
Relative Humidity	65–80%	Maintains leaf moisture and supports healthy plant growth
Annual Rainfall	600–2,500 mm	Ensures adequate water availability for continuous leaf production
Soil Type	Deep, fertile, well-drained loam	Encourages healthy root development and nutrient uptake
Soil pH	6.2–6.8	Enhances nutrient availability and plant growth
Major Cultivation Regions	Karnataka, Andhra Pradesh, Telangana, Tamil Nadu, West Bengal, Jammu & Kashmir	Major mulberry-producing regions supporting commercial sericulture

Leaf Chemical Composition

The chemical composition of mulberry leaves has a significant impact on the mulberry silkworm's growth, health, and commercial performance. High-quality leaves are high in proteins, carbs, amino acids, vitamins, minerals, and moisture, all of which are required for larval growth, cocoon development and silk production [16]. Nitrogen levels and food mix are optimal for feed utilization, larval survival, and silk yield. Young, fragile leaves have a higher nutritional value than older leaves, making them more ideal for the early instars. As a result, ensuring optimal leaf quality through correct cultivation and nutrition management is an essential component of modern silkworm rearing procedures [17].

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Climatic Requirements

Mulberry silkworms (Bombyx mori L.) require good climatic conditions to thrive, resist disease, and increase economic productivity. During various larval stages, an optimal temperature of 24-28°C and relative humidity of 70-85% are regarded ideal, with adequate ventilation to prevent the buildup of hazardous gasses. Stable environmental conditions enable better feeding, consistent larval development, successful moulting, and higher cocoon quality. Temperature and humidity changes can cause physiological stress, illness incidence, and larvae mortality, lowering silk output. As a result, maintaining a regulated rearing environment through novel management strategies is critical for increasing survival rates and improving economic returns in sericulture.

Table 2. Chemical Composition of Mulberry Leaves and Optimum Climatic Requirements for Bombyx mori L.

Parameter	Recommended/Typical Value	Remarks
Leaf Moisture	**72–75% (fresh weight)**	Maintains leaf freshness and larval hydration
Crude Protein	**22–28% (dry weight)**	Essential for growth and silk protein synthesis
Total Carbohydrates	**35–40% (dry weight)**	Major source of energy for larvae
Crude Fiber	**8–10% (dry weight)**	Improves digestion; excess reduces leaf quality
Total Minerals (Ash)	**8–10% (dry weight)**	Supplies essential macro- and micronutrients
Temperature	**24–28°C**	Ideal for optimum larval growth and cocoon quality
Relative Humidity	**75–85% (1st–3rd instars); 65–75% (4th–5th instars)**	Supports moulting, feeding, and healthy larval development
Light	**12–16 h diffused light/day**	Avoid direct sunlight during rearing
Ventilation	**Air velocity 0.2–0.5 m s^{-1}**	Prevents accumulation of CO_2 and excess moisture
Photoperiod	**12L:12D (Light:Dark)**	Promotes normal physiological activity and feeding

Soil Requirements for Mulberry Cultivation

Healthy mulberry farming begins with proper soil conditions, as soil quality has a direct impact on leaf yield and nutritional composition, both of which are required for successful silkworm rearing. Mulberry thrives in deep, fertile, well-drained loamy to clay loam soils with high moisture holding capacity and appropriate aeration [18]. The ideal soil pH varies from 6.2 to 6.8, with 6.5-6.8 considered optimal for nutrient availability and root development. The addition of organic manures, green manures, and soil amendments increases soil fertility, microbial activity, and water retention. Maintaining optimal soil health through integrated nutrient management helps to produce high-quality mulberry leaves, which improves Bombyx mori L. larval health, survival, cocoon quality, and overall commercial performance [19].

Propagation of Mulberry

Mulberry plantation quality is greatly determined by the propagation strategy used. Although mulberry can be spread by seeds (sexual propagation), commercial farming relies mostly on vegetative propagation to preserve desired genetic features and ensure consistent plant growth [19]. Vegetative multiplication via stem cuttings is the most popular and cost-effective method, however grafting and budding are occasionally used to generate superior cultivars. The use of healthy, disease-free planting material promotes vigorous plant development, increased leaf productivity and consistent quality. Modern propagation strategies, like as nursery management and clonal multiplication, have enhanced the establishment and sustainability of sericulture plantations [20].

Land Preparation and Planting

Setting up productive mulberry gardens requires proper land preparation. To allow for proper drainage and root development, the soil should be carefully ploughed and leveled. Contour planting, terracing, or bund development in sloping locations help to reduce soil erosion and conserve moisture [11]. Before planting, pits are often prepared based on soil type and treated with well-decomposed farmyard manure or compost. Healthy seedlings or rooted cuttings should be planted at the start of the monsoon or under irrigated conditions to ensure speedy establishment. Adequate staking during the initial growth stage encourages straight stem development and increases plantation uniformity [12].

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Nutrient Management

Nutrient management must be balanced in order to maintain vigorous mulberry growth and produce nutritionally superior leaves for silkworm feeding. Nitrogen, phosphorus, and potassium (NPK) are the most important nutrients for optimal leaf formation, with nitrogen having a critical role in boosting leaf protein content. The suggested fertilizer schedule varies depending on soil fertility, irrigation availability and local agro-climatic conditions, with organic manures being used to promote soil structure and microbial activity. Integrated nutrient management that includes both organic and inorganic fertilizers has been found to improve leaf quality, increase biomass production, and promote healthy silkworm growth and silk productivity [15].

Spacing and Plantation Management

Appropriate plant spacing optimizes the use of sunshine, water, and nutrients while also promoting air circulation within the plantation. Spacing recommendations vary according to cultivation practices, soil fertility, and topography, with closer spacing preferred in intensively irrigated systems and broader spacing preferred in rainfed or sloping locations. Proper spacing makes intercultural operations easier, minimizes disease incidence, and increases leaf harvesting efficiency [16]. Well-managed plantations generate consistent, high-quality foliage, which promotes larval development and increases cocoon yield.

Maintenance of Mulberry Plantation

Mulberry plantations require regular upkeep to be fruitful throughout the year. Weeding, watering, nutrient treatment, shoot removal and protection from grazing animals all help to promote healthy plant growth. Routine plant health monitoring helps to prevent pest and disease outbreaks that might impair leaf quality [17]. Integrated crop management measures, such as mulching and moisture conservation, increase plant vigor and maintain a consistent supply of nutritious leaves for subsequent silkworm rearing cycles.

Intercultural Operations

Intercultural techniques like as hoeing, soil loosening, and weed control help to improve soil aeration and moisture conservation around mulberry plants. These activities limit the competition for nutrients and water while encouraging healthy root growth. Periodic intercultivation also enhances fertilizer consumption efficiency and reduces insect and disease prevalence. The implementation of mechanized intercultural procedures in modern sericulture has lowered manpower requirements while increasing crop output.

Pruning Practices

Pruning is an important cultural operation that promotes the formation of sensitive, nutrient-dense leaves that silkworm larvae love. Regular pruning encourages branching, maintains good plant architecture, synchronizes leaf production with silkworm rearing timetables, and boosts yearly leaf yield. Proper pruning practices prevent plant damage and the danger of disease invasion through cut surfaces. Scientific pruning schedules have become an essential component of novel mulberry management methods aiming at increasing leaf quality and plantation output.

Leaf Harvesting and Quality Management

Efficient leaf harvesting is critical to maximizing caterpillar health and commercial silk production. Individual leaf picking and shoot harvesting are used based on the rearing strategy and larval stage. Young instars are typically given tender leaves, whereas later instars are fed older leaves to suit their nutritional needs. Timely harvesting retains leaf moisture, protein content, and digestibility, but delayed harvesting degrades nutritional quality and has a negative impact on larval growth and cocoon properties. Mulberry leaves must be handled, transported, and stored properly after harvest to retain freshness and improve feeding effectiveness in Bombyx mori L.

Role of Improved Mulberry Cultivation in Innovative Silkworm Rearing

Successful silkworm rearing methods are built on innovative mulberry farming and management practices. The combination of enhanced cultivars, precise fertilizer management, precision irrigation, efficient pruning, and quality leaf harvesting guarantees that silkworms have a consistent supply of nutritious foliage. These techniques promote larval health, decrease illness incidence, raise survival rates, and boost cocoon output and silk quality. As a result, sustainable mulberry cultivation remains an important feature in increasing the commercial performance and profitability of modern sericulture.

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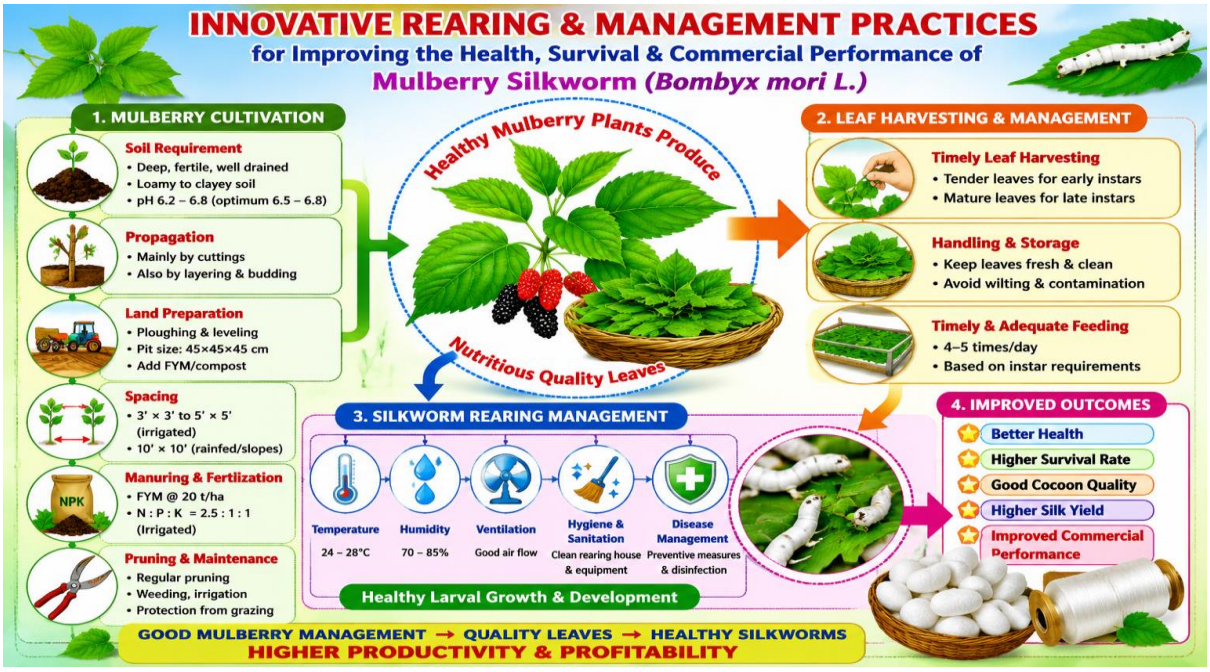
Fig 1. Sericulture Management Practices



Types Of Silkworm Rearing In India

Chawki Rearing

Chawki raising is the process of rearing juvenile silkworm larvae from the first to the third instar under regulated environmental circumstances. Tender mulberry leaves, careful hygiene, and exact temperature and humidity regulation are required for good larval growth

Late-Age Rearing

Late age rearing occurs between the fourth and fifth instars, during which larvae ingest enormous amounts of mulberry leaves and rapidly grow in size. Proper feeding, ventilation, spacing, and disease care are all necessary for producing high-quality cocoons.

Shoot Rearing

Shoot rearing is a recent method in which silkworms are fed complete mulberry shoots rather than individual leaves. This strategy saves time, keeps leaves fresh, increases feeding efficiency, and improves cocoon quality.

Shelf (Tray) Rearing

Traditional silkworm raising involves placing bamboo or plastic trays on multi-tier racks. It enables effective management of feeding, cleaning, and environmental conditions while making the best use of rearing area.Floor Rearing During the late larval stage, silkworms are spread over sterilized floors that have been covered with rearing nets or paper sheets. This method is appropriate for large-scale commercial rearing because it gives adequate area for larval growth and cocoon spinning.

Mulberry silkworm (Bombyx mori L.).

The mulberry silkworm is the most significant domesticated silkworm species in India, and it is raised solely on mulberry leaves. It produces excellent, glossy silk, accounting for around 70-75% of the country's total silk production.

Tasar silkworm (Antheraea mylitta Drury).

The tropical tasar silkworm is a wild species that feeds on forest trees like Terminalia arjuna and Terminalia tomentosa. It produces coarse, copper-brown silk that is prized for its strength and natural texture.

The Oak Tasar Silkworm (Antheraea proylei Jolly)

The oak tasar silkworm is mostly raised on oak leaves (Quercus spp.) in temperate Himalayan regions. It produces high-quality silk with outstanding strength and is ideal for cool climates.

Eri Silkworm (Samia Ricini Donovan)

The eri silkworm is primarily raised on castor (Ricinus communis) leaves, but it may also consume cassava and kesseru. It creates silky, warm, and long-lasting silk, sometimes known as "peace silk" because the moth exits before the cocoon is harvested.

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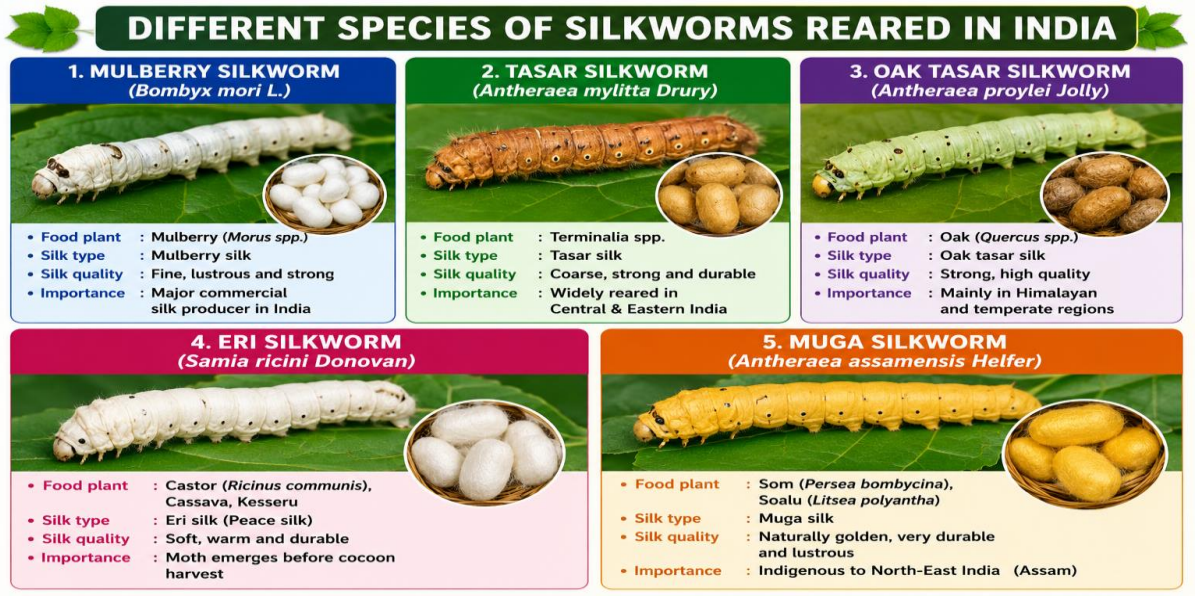
Muga Silkworm (Antheraea assamensis Helfer).

The muga silkworm is native to northeastern India, particularly Assam, and feeds mostly on som (Persea bombycina) and soalu (Litsea polyantha) plants. It yields naturally golden-yellow silk, which is known for its distinctive brilliance, strength, and longevity.

Fig 2. Types of Silk worm Species



Processes of Silkworm Management (Bombyx mori L.)

1. Select Disease-Free Layings (DFLs)

The silkworm raising method begins with selecting verified disease-free layings from permitted grainages. Healthy DFLs result in increased hatching percentages, homogeneous larval growth, lower illness incidence, and higher cocoon yield.

2. Incubation of eggs

Silkworm eggs are incubated under regulated circumstances at 25 ± 1°C and 80-85% relative humidity until they hatch. Uniform incubation promotes synchronous larval emergence and efficient rearing management.

3. Chawki (Young Age) Rearing

Newly born larvae (1st-3rd instars) are raised in a clean, disinfected environment and fed on tender, nutrient-dense mulberry leaves. Proper temperature, humidity, hygiene, and frequent feeding are required for proper larval development.

4. Late Age Rearing

Fourth and fifth instar larvae consume large quantities of mature mulberry leaves and exhibit rapid growth. Adequate feeding, sufficient spacing, proper ventilation, and regular bed cleaning improve larval health and cocoon quality.

5. Bed Cleaning

Bed cleaning entails removing remaining leaves, excreta, and unhealthy larvae from the raising bed at set intervals. This approach lowers microbial contamination, increases ventilation, and prevents illness outbreaks.

6. Bed spacing

As the larvae grow in size, adequate rearing space is supplied to prevent overcrowding. Proper spacing lowers competition for food, increases aeration, and promotes even larval growth.

7. Environmental Management.

The rearing room should be kept at an optimal temperature of 24-28°C and relative humidity of 70-85%, with adequate ventilation and diffused light. Stable environmental conditions reduce stress and promote healthy larvae growth.

8. Disease and pest management.

Strict sanitation, regular disinfection of rearing equipment, and routine monitoring all help to prevent infections such as grasserie, flacherie, muscardine, and pebrine. Effective pest control, such as ants, rats, and uzi flies, enhances larval survival rates.

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9. Mounting for cocoon spinning.

When mature fifth instar larvae have stopped feeding and become translucent, they are put to appropriate mountages such as bamboo chandrikas or plastic mountages. Proper installation promotes uniform cocoon spinning and reduces cocoon flaws.

10. Cocoon Harvest

Fully developed cocoons are taken 5-7 days after spinning, before the adult moth emerges. Harvesting silk filaments on time preserves their quality and minimizes damage from emerging moths.

11. Cocoon Sorting and Grading

Cocoons harvested are classified according to size, shape, shell ratio, compactness, and defect-free status. Grading ensures increased market value and provides high-quality cocoons for silk reeling.

12. Stifling and Silk Reeling

Selected cocoons are stifled using hot air or steam to kill the pupae and preserve the silk filament. The cocoons are then reeled to produce continuous silk threads, which are processed into high-quality raw silk for the textile industry.

Various Activities on Silk worm management

Cocoons boiling area

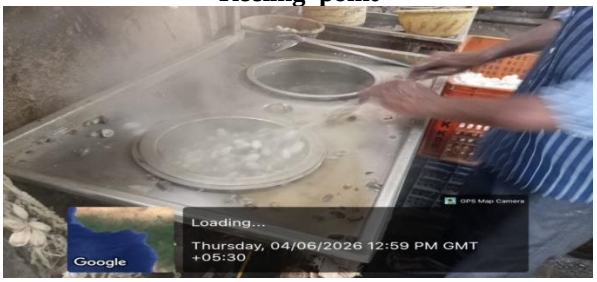
Thread collecting area

Observation of Reeling area

Separation of quality cocoons

Reeling point

Recovering of cocoons after boiling



Cocoon Boiling area

Close observation of cocoons

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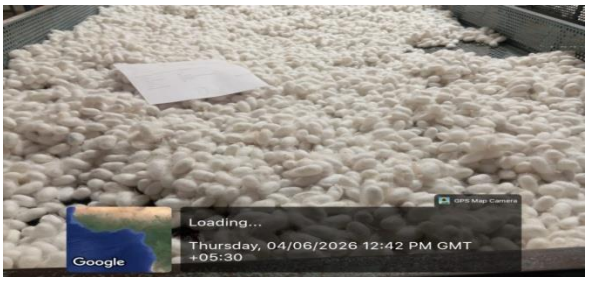

Observation of Cocoons tray

Mulbery form visit

Economic Importance of Silkworm Rearing (Bombyx mori L.)

1. Employment Creation

Sericulture is a labor-intensive agricultural enterprise that employs rural households year-round, primarily women and small-scale farmers. It generates cash from mulberry planting, silkworm breeding, cocoon production, silk reeling, weaving, and marketing.

2. Income generating

Silkworm farming provides consistent and steady income with a cheap initial investment compared to many other agricultural enterprises. Farmers can produce numerous silkworm crops each year, assuring consistent revenue flow and improved livelihoods.

3. Raw materials for the silk industry

Mulberry silkworms create high-quality cocoons, which are the principal raw material in the silk weaving industry. The silk obtained is used to make high-quality fabrics, clothes, furniture, handicrafts, and luxury items.

4. Export Revenues

Silk and silk products make a significant contribution to India's exports. High-quality silk fabrics, yarn, garments, and handicrafts are exported to international markets, generating significant foreign currency.

5. Rural Development

Sericulture encourages integrated rural development by creating jobs in villages, reducing migration to cities, and promoting self-employment through cottage and small-scale industries.

6. Women's empowerment

Women perform many sericulture activities, such as leaf harvesting, feeding, cocoon sorting, and silk reeling. This increases women's participation in income-generating activities and boosts household economic stability.

7. Eco-friendly and sustainable business

Silkworm rearing is a low-pollution enterprise. Organic wastes, such as silkworm litter and pupal residues, are converted into organic manure, livestock feed, and compost to promote sustainable agriculture.

8. Use of By-products

Sericulture produces several important byproducts, including silk waste, sericin, silkworm pupae, and silkworm frass. These products are used in the textile, pharmaceutical, cosmetic, culinary, poultry feed, aquaculture, and organic fertilizer sectors.

9. Support for Allied Industries

Sericulture supports various linked industries, including silk reeling, spinning, dyeing, weaving, textile manufacturing, handicrafts, machinery production, and transportation, all of which contribute to industrial progress.

10. National Economic Contribution

India is one of the world's leading silk producers, and sericulture makes a significant contribution to agricultural diversification, rural employment, export revenue, and national economic progress.

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Fig.3 Economic Importance of Sericulture

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CONCLUSION

Sericulture is a sustainable and economically significant agricultural enterprise that combines mulberry farming, scientific silkworm rearing, and silk production to produce high-quality natural silk. The use of new rearing and management approaches, including as enhanced nutrition, environmental control, illness prevention, and hygienic rearing, improves Bombyx mori L.'s health, survival, cocoon yield, and commercial performance. In addition to giving work and income to millions of rural families, sericulture benefits the textile sector, promotes environmental sustainability, and contributes significantly to national economic development. Continued research, technical breakthroughs, and farmer-oriented extension initiatives will boost sericulture's productivity, profitability, and worldwide competitiveness.

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