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## TRADITION TO INNOVATION: SUSTAINABLE DEVELOPEMENT IN SILK CULTURE

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**ABSTRACT :** Raising silkworms for producing silk has a long history that is intertwined with both cultural and economic value. The present work gave emphasis on historical evolution, contemporary significance, and most recent advancements, with a focus on technological innovation and sustainability. Some examples of traditional silk-making techniques that have been enhanced by modern techniques include the life cycle of various silkworms and the cultivation of host plants viz., Mulberry (*Morus alba*), Castor (*Ricinus communis*), Som (*Persea bombycina*), Arjun (*Terminalia arjuna*), Oak (*Lithocarpus dealbata*). Traditional methods often come with environmental challenges, such as deforestation, water pollution, and unsustainable farming practices. Recent technological developments that have significantly increased output and silk quality include silkworm genetic engineering, improved mulberry and non-mulberry growing methods, and automation in rearing systems. Integrating sustainability into sericulture involves the adoption of organic farming, eco-friendly pest control methods, soil and water conservation and efficient waste management. Organic farming improves leaf quality, eliminates the application of harmful synthetic chemicals and enhances market demand. Genetic engineering and molecular techniques are used to develop silkworm breeds with improved silk yield, disease resistance and faster growth cycle. DNA fingerprinting helps identify and preserve superior silkworm strains. Automation in reeling and spinning reduces labor costs and human error. Artificial intelligence and machine learning, data analytics etc. improve efficiency, productivity and profitability in the high production of silk. Present work highlights the need for policy frameworks, research advancements and stakeholder collaboration to promote sustainable sericulture practices, ensuring long-term environmental, economic and social benefits.

**Key words :** Sericulture, eri culture, organic farming, DNA fingerprinting, artificial intelligence, sustainable development, genetic engineering.

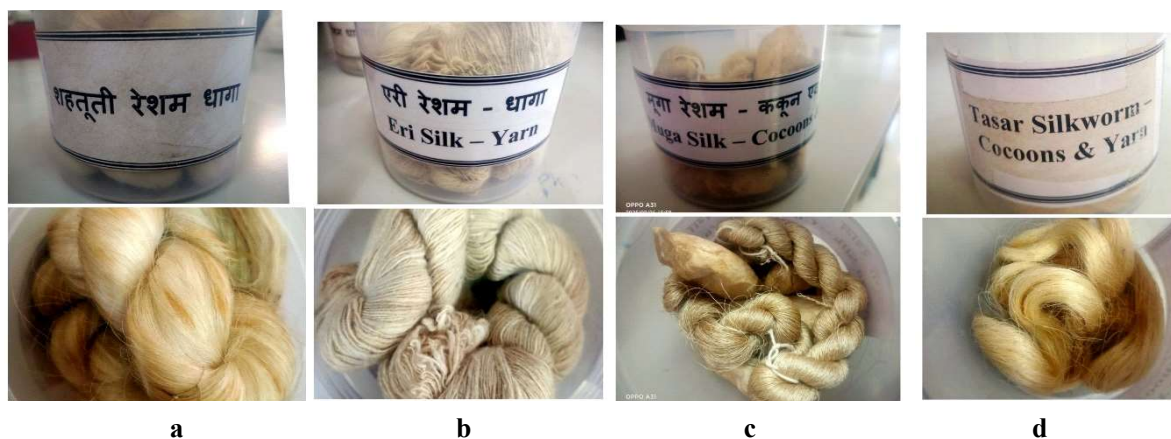
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### Introduction

Sericulture has a rich history dating back thousands of years. It is believed to have originated in China around 2700 BCE, with archaeological evidence suggesting silk production as early as the Neolithic period. The practice spread to India by 140 CE, becoming an integral part of the country's cultural and economic fabric (FAO, 2009). India holds a prominent position in the global silk industry, being the second-largest producer of silk. Major silk-producing states include Karnataka, Assam, West Bengal, Tamil Nadu and Andhra Pradesh. Sericulture provides employment to millions, especially in rural areas and contributes significantly to the nation's economy. There are 258 well-recognized tribal communities, notified as scheduled tribes in India. There are more than 58 countries practicing sericulture in the world.

Sericulture encompasses the entire process of silk production, starting from the cultivation of mulberry trees (the primary food source for silkworms) to the rearing of silkworms and the extraction of silk from their cocoons. It is an extremely labor-intensive industry and occupies a pivotal position from the point of providing employment and additional income to weaker sections (Best and Maier, 2007).

Sericulture also known as silk farming is the cultivation of silkworms to produce silk. Silkworm Rearing, Cocoon Formation, Reeling, twisting, dyeing, printing, finishing, knitting, and woven into textiles sector (Srivastav *et al*, 2005). These intricate process results in the production of various types of silk, including Mulberry (79%), Eri(13.32%), Tasar(6.8%), and Muga(0.54%), each with unique qualities and uses (Savithri *et al*, 2013).



Types of silk

By examining the transition from traditional to modern sericulture methods, we aim to highlight the advancements, challenges, and implications for sustainability and biodiversity preservation (Nagaraju and Goldsmith, 2002). Furthermore, we seek to emphasize the role of sericulture in promoting biodiversity conservation. As silk production relies on mulberry and non-mulberry cultivation and the preservation of silkworm habitats, sustainable sericulture practices can have positive impacts on global ecosystem health and biodiversity (Reddy *et al*, 2015).

### Traditional vs Modern Silk culture

Traditional sericulture involved a series of labor-intensive processes, from mulberry cultivation to silk harvesting. Traditional practices and methods are used in different stages of silk production, from the seed (silkworm eggs) to the silk production. Traditional methods often involve skilled artistry and knowledge passed down through generations, utilizing basic equipment and natural materials to produce high-quality silk. These practices highlight the rich cultural heritage and artisanship involved in sericulture and silk production. Farmers meticulously tended to mulberry orchards, ensuring optimal leaf quality for silkworms. Silkworm eggs were incubated and hatched. With larvae carefully nurtured through multiple instars until they spun cocoons. The cocoons were then harvested, boiled, and unwound to extract raw silk fibers, which were spun into threads and woven into fabric (Attri *et al*, 2024). Sericulture has deeply ingrained cultural significance in many societies, symbolizing prosperity,

beauty, and luxury. Silk production often formed the backbone of rural economies, providing livelihoods for countless families. Moreover, sericulture fostered a sense of community and tradition, with knowledge and skills passed down through generations. In regions like China and Japan, sericulture rituals and festivals celebrate the silkworm's life cycle, reinforcing cultural heritage (Goodle, 2016). Sericulture played a vital role in sustaining local economies, particularly in rural areas where alternative livelihoods were limited. Silk trade routes facilitated economic exchange and cultural diffusion, shaping regional economies and international relations. In modern times, traditional sericulture continues to support cottage industries and artisanal artisanship, contributing to sustainable development and poverty alleviation.

**Table 1 :** Comparasion of tradition vs modern methods.

| S. no. | Features                   | Traditional methods                                        | Modern methods                                              |
|--------|----------------------------|------------------------------------------------------------|-------------------------------------------------------------|
| 1.     | Cultivation of host plants | Local low yield varities                                   | Hybrid high yield varities                                  |
| 2.     | Rearing environment        | Natural, manual setups                                     | Controlled,tech-integrated environments through iot devices |
| 3.     | Rearing methods            | Bamboo trays and mats                                      | Platform and bunching methods                               |
| 4.     | Purpose of mounting        | Bamboo made chandrike                                      | Plastic mountage                                            |
| 5.     | Cocoon processing          | Sun drying, manual reeling                                 | Mechanized stifling and reeling processes                   |
| 6.     | Genetic practices          | Selective breeding                                         | Genetic engineering and molecular marker assisted selection |
| 7.     | Weaving and dyeing         | Handloom weaving, natural dyes                             | Mechanized weaving, synthetic or eco-friendly dyes          |
| 8.     | Sustainability             | Eco-friendly, aligns with the local regions and low-impact | Focus on global sustainability through innovation           |

Attri *et.al* (2024)

### Influential elements of sericulture

Sericulture, the cultivation of silkworms for silk production, its influenced by a variety of factors that affect its efficiency, productivity, and sustainability.

**Biotic and Abiotic Factors :** Climatic factors are one of the important factors that influence disease incidence in silkworms. The adaptability to environmental conditions in the silkworm is quite different from that of the wild silkworm and other insects. Temperature, humidity, air circulation, gases and light show a significant interaction in their effect on the physiology of the silkworm, depending upon the combination of factors and developmental stages affecting growth, development, productivity, and quality of silk. (Kant *et al*, 2022).

**Biological and Genetic Factors :** The economic trait of silkworm farming is cocoon production. Efficient feed conversion ratio and manure production depend on the genetics of silkworms. Different hybrids displayed different production performance and economic traits. Profitability, eco-compatibility and efficiency pointed to hybrids  $32 \times 31$ ,  $153 \times 154$  and  $104 \times 103$  as the best performing Iranian hybrids out of eight hybrid lines (Samami *et al*, 2019). In

silkworms, genetic engineering has been used to introduce genes that improve silk quality, enhance disease resistance, and increase silk yield. For instance, recombinant DNA technology has enabled the production of silkworms that secrete stronger and more durable silk fibers by integrating genes from other silk-producing organisms.

**Market Demand for Eco-Friendly Products :** India's sericulture industry, producing various types of silk such as Mulberry, Tasar, Eri and Muga, is witnessing a surge in demand for eco-friendly products. The Indian sericulture market was valued at INR 612.7 billion in 2024 and is projected to reach INR 2,217.5 billion by 2033, growing at a CAGR of 14.6%. This growth is attributed to factors like sustainable agrotech innovations, low investment costs for food plant cultivation, and increased focus on sustainable development. Eri Silk: Known as 'Peace Silk' due to its non-violent extraction process. The use of natural dyes from plants and plant parts makes Eri silk products environmentally friendly and culturally significant. Producers are exploring innovations like combining Tasar silk with other natural fibers and introducing value-added products such as dyed and printed Tasar silk to cater to the growing demand for eco-friendly luxury textiles.

**Beauty and Skincare:** Companies like Evolved by Nature are developing sustainable bioactive peptides from discarded silk cocoons, offering alternatives to synthetic ingredients in skincare products. This innovation aligns with consumer demand for ethical and environmentally friendly products. India's silk and silk products exports reached US\$ 220.58 million in FY23, with key markets including the USA, UAE, China, UK, and Australia (Prity, 2022).

### **Innovations in Silk Culture**

Modern technologies have revolutionized the sericulture industry, transforming traditional practices into highly efficient and productive processes. Mulberry, Castor, Arjun, Som and other food plants cultivation forms the backbone of sericulture, providing the food source for mulberry silkworms. Recent advancements in mulberry cultivation have significantly enhanced productivity and quality. Traditional mulberry varieties have been gradually replaced by high-yielding and disease-resistant cultivars through selective breeding and biotechnological interventions (Bai *et al*, 2019).

**Eco friendly, biocontrol and Intercropping :** Sericulture is an environment-friendly farm occupation. Since mulberry is a perennial crop, it does not require frequent opening of land, which exposes soil to natural vagaries such as wind and water erosion. Eco-friendly technologies such as bio-fertilizers, recycling of sericulture wastes into nutrient rich organic manure, biocontrol measures for pests and diseases of host plants and silkworm and use of safe chemicals for disinfection of rearing houses and appliances are encouraged in sericulture for preserving and promoting the natural ecosystem (Mahanta and Komal, 2022).

**Ethical Silkworm Rearing: The Ahimsa Approach :** Ahimsa silk, also known as peace silk, embodies a non-violent approach to sericulture by allowing silkworms to complete their natural life cycle. In regions like Assam, rearers meticulously care for Eri silkworms, ensuring they feed on castor leaves and live in hygienic conditions. The process includes careful collection of eggs, feeding with appropriate leaves based on growth stages and protecting the

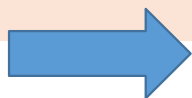
worms from parasites. Once moths emerge and vacate the cocoons, these are collected and processed into silk, termed ‘Ahimsa Cocoon’.

**Technological and Genetic Improvements :** The Internet of Things (IoT) revolutionizes sericulture by enabling real-time monitoring of environmental conditions, crop health, and production processes. IoT devices, such as sensors, cameras, and weather stations, collect data on temperature, humidity, light levels, and other variables, transmitting this data to cloud-based platforms for analysis and visualization. By accessing real-time insights into their operations, sericulturists can identify issues, optimize workflows, and make informed decisions to improve productivity and profitability (Arya, 2024).

Developed AI-based Pebrine detection Machine learning tools “PEBDETECT” classify pathogens with high accuracy, facilitating early disease detection and management of pests and diseases.

The genetic improvement of silkworms aims to develop strains with desirable traits, such as increased silk yield, improved cocoon quality and enhanced resistance to diseases and environmental stressors (Vidya *et al*, 2024; Pavithra *et al*, 2024).

Six strains of Eri-Silkworm: - GBP (Green Blue Plain), YP (Yellow Plain), YS (Yellow Spotted), YZ Yellow Zebra), GBS (Green Blue Spotted), GBZ (Green Blue Zebra)



The CRISPR/Cas9 gene-editing tool has revolutionized the field of genetic engineering by allowing precise modifications of genes. This technology allows for the creation of customized silkworm strains with enhanced traits tailored to specific industrial needs (Li *et al*, 2024 and Ma *et al*, 2014).

The development of vaccines for silkworms represents another promising approach to disease management. We are focusing on creating vaccines against the nuclear polyhedrosis virus (NPV), one of the most significant pathogens affecting silkworms. These vaccines can be administered during the early stages of silkworm development, providing long-lasting protection against viral infections (Kusakabe, 2023).

### **Sustainable Silk Production**

Sustainable silk production significantly contributes to enhancing livelihoods, preserving traditions, gaining Global recognition and offering Environmental benefits. By embracing these sustainable features, the silk industry moves towards a more eco-conscious future, aligning traditional practices with modern environmental and social standards.

**Enhancing Women and Rural Livelihoods :** A basic feature of this farm-based economic

enterprise is the involvement of women as it is an occupation by and for women and their contribution in the sericulture industry is to the tune of 60%, mostly in silkworm rearing and reeling (Mahanta and Komal, 2022). A large chunk of income goes back to the villages from the cities. Which 56.8% goes to the cocoon grower, 6.8% to the reeler, 9.1% to the twister, 10.7% to the weaver and 16.6% to the trade. Nearly 80 lakh persons are engaged in sericulture activities in India, and statistically, it generates an employment of 11-man man-days per kg of raw silk production (CSB, 2022). It involves various personnel at different levels of processing till it reaches the consumer, including the Silk rearers, farmers, reelers, twisters and weavers.

**Cultural Preservation and International Recognition :** Sericulture is deeply embedded in the cultural fabric of many societies, passed down through generations via hands-on apprenticeship and community traditions. In India, regions like Meghalaya maintain traditional sericulture practices, integrating them into sustainable livelihoods and cultural heritage. In 2022, the practices of sericulture and traditional production of silk for weaving was jointly inscribed for Afghanistan, Iran, Turkey, Tajikistan, and Uzbekistan. It highlights the role of silk in social cohesion and cultural identity across these nations. The evolution of sericulture is closely linked to the Silk roads, where the exchange of goods, ideas, and expertise facilitated the spread and diversification of silk production techniques. This cultural diffusion is evident in the distinctive artistic styles and artisanship that have emerged in various regions along these historic trade routes (UNESCO, 2022).

**Circular Economy approaches :** Circular economy approaches in the silk industry aim to transform traditional linear production models into sustainable, closed-loop systems. Silk production generates various forms of waste, including weaving remnants, defective fabrics, and cocoon by-products (Devi *et al*, 2025). Advancements in Biotechnology have led to the development of biodegradable silk alternatives. Companies like AMSilk produce synthetic silk biopolymers, such as Biosteel, through microbial fermentation. Implementing regenerative farming practices in sericulture enhances soil health and biodiversity. Brands are adopting digital IDs by 2025 to track product history, enabling consumers to participate in resale or recycling programs, thus extending the product's life and reducing waste.

Certification and Eco-labels like GOTS, Bluesign®system, EU Ecolabel and B Corp serve as valuable tools for silk producers and brands aiming to adopt sustainable practices. Global Organic Textile Standard/GOTS ensures that textile products at least 70% certified organic natural fibers. OEKO-TEX® STANDARD 100 indicates that the fabric has been tested for over 100 harmful substances. including pesticides and heavy metals, and found to be within safe limits. (Akepa, 2022)

**Policy shift and Government interventions :** To comprehensively address the Policy and Government Support within the context of integrative approaches in sericulture, it is essential to delve into various aspects such as government policies and programs, the role of NGOs and international organizations, subsidies, grants and global collaborations.

Sericulture has historically been a sector supported by government intervention due to its economic and ecological significance. National governments across sericulture-producing countries have formulated policies and implemented programs to promote and regulate the

silk industry. The Government of India has allocated Rs. 2161.68 cr. for three years i.e. 2017-2020 to its Central Sector Scheme “Silk Samagra” for the development of sericulture in the country. It focuses on improving the quality and productivity of domestic silk thereby reducing the country’s dependence on imported silk. The Central Silk Board (CSB) is implementing the scheme. It comprises the following four components:

- Research & Development, Training, Transfer of Technology and I.T. Initiatives
- Seed Organizations
- Coordination and Market Development, and
- Quality Certification Systems (QCS)/Export Brand Promotion and Technology Up-gradation.

The Food and Agriculture Organization (FAO, 2020) and the International Sericulture Commission (ISC, 2019) organizations facilitate collaboration among member countries, promote knowledge exchange, and advocate for policies that prioritize sustainable sericulture.

Governments often provide subsidies and grants to sericulturists to incentivize the adoption of sustainable practices and to mitigate economic risks associated with sericulture. These subsidies may cover costs related to mulberry cultivation, silkworm rearing, silk processing, and marketing.

Through capacity-building programs, market linkages, and advocacy campaigns, NGOs contribute to the empowerment of sericulture communities and the preservation of biodiversity (UNDP, 2019).



**Fig. 1 :** Establishment of SRC under DoS, Odisha supported with CMER&TI for regular Training. (Resources: Dr. Mahesh D S (Scientist -C) CSB - CMER&TI, Lahdoigarh, Jorhat, Assam 785700)

## Challenges and Limitations

While biotechnology has made significant strides in sericulture, there are still challenges to be addressed. Regulatory approval of genetically modified silkworms and recombinant silk products is one of the key barriers to large-scale commercialization. Public perception and acceptance of genetically modified organisms (GMOs) also remain a concern (Kankanawadi

*et al*, 2024).

**Biological and Environmental Challenges :** Silkworms are highly vulnerable to diseases such as Pebrine and flacherie, which can decimate entire crops. Fluctuations in temperature, humidity, and rainfall due to climate change adversely affect mulberry and Non-mulberry cultivation and silkworm rearing (Thrilekha *et al*, 2024).

**Socio-Economic and Operational constraints :** Market Instability: High price fluctuations in cocoon markets and lack of local market facilities hinder profitability for farmers (Choudhari *et al*, 2020). High labor wages and inadequate availability of skilled labor pose significant challenges (Dhane *et al*, 2004). Limited access to financial resources and credit facilities restricts farmers' ability to invest in better practices and technologies.

**Technological and Infrastructure limitations :** Reliance on outdated reeling equipment like the charka results in lower quality silk that does not meet international standards. Lack of proper storage, transportation, and electricity supply affects the overall efficiency of sericulture operations (Choudhari *et al*, 2020).

**Balancing Tradition with Modernization :** Sericulture, the practice of cultivating silkworms for the production of silk, has a rich history deeply intertwined with traditional practices across various cultures. However, in recent times, the integration of modern technologies into sericulture has become increasingly important. This integrative approach aims to combine the inherent wisdom of traditional knowledge with the advancements of modern technology, thus fostering sustainable sericulture practices while contributing to biodiversity conservation (Reddy, 2013).

The synergy between traditional knowledge and modern technology forms the cornerstone of integrative approaches in sericulture. Traditional practices, passed down through generations, offer valuable insights into the intricacies of silk production, including silkworm rearing, mulberry cultivation, and silk processing. These practices are often deeply rooted in local ecosystems and cultural contexts, making them highly adaptable to specific environmental conditions (Babu, 2019).

On the other hand, modern technologies bring innovations that enhance efficiency, productivity and sustainability in sericulture. Advances in biotechnology, genetics and agricultural practices have revolutionized various aspects of silk production, from the development of disease-resistant silkworm breeds to the optimization of mulberry cultivation techniques (Kumar *et al*, 2020).

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