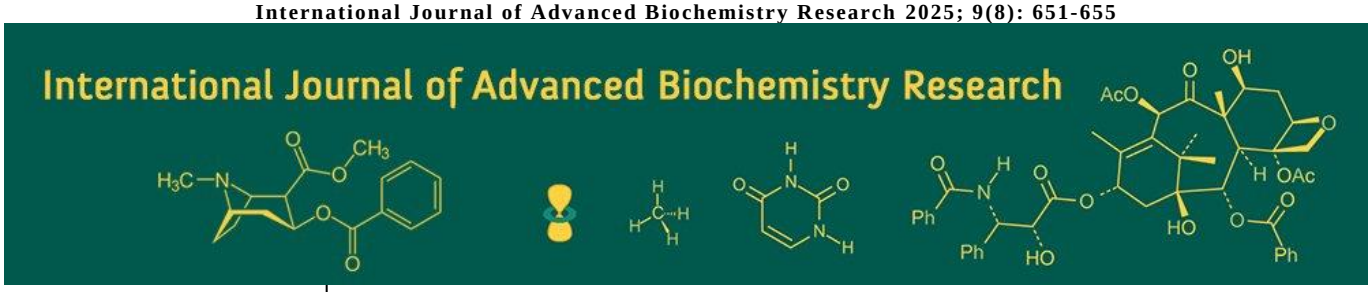

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Organic sericulture practices and potentials: A review on sustainable silk production

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Abstract
Organic sericulture represents a sustainable approach to silk production that emphasizes ecological balance, environmental safety and non-chemical practices in both mulberry cultivation and silkworm rearing. By integrating organic farming techniques, botanical extracts, and microbial probiotics, this method eliminates the use of synthetic fertilizers, pesticides, and antibiotics. These practices not only improve soil health and mulberry leaf quality but also enhance silkworm immunity and cocoon productivity. The growing global demand for eco-friendly textiles, along with increasing awareness of ethical production systems, supports the market potential of organic silk as a premium product. Furthermore, evolving national and international certification frameworks (e.g., India's NPOP and GOTS standards) and targeted branding strategies add commercial value to organic silk production. This review explores current organic sericulture practices, their ecological and economic benefits, the challenges involved in transitioning from conventional systems, and the potential for certification and market expansion. It provides a comprehensive roadmap for transforming sericulture into a resilient, green, and profitable enterprise.

Keywords: Biofertilizer, biocontrol, organic silk, pest, disease

Introduction
Sericulture plays a crucial role in the socio-economic development of rural populations, particularly in major silk-producing countries such as India, China, Thailand, and Vietnam. It provides employment, especially to women and small-scale farmers, through mulberry cultivation and silkworm rearing (Harshita Mala *et al.*, 2024) [6, 16]. Traditionally, sericulture has depended heavily on chemical fertilizers, pesticides and antibiotics to increase productivity and manage pests and diseases. However, these practices often degrade soil health, reduce biodiversity and leave harmful residues in silk products, raising environmental and health concerns (Sakthivel, 2014) [17].

Amidst increasing consumer awareness and global demand for environmentally responsible textiles, organic sericulture has emerged as a sustainable and eco-friendly alternative. This approach avoids synthetic chemicals and promotes the use of natural inputs, such as compost, green manure, botanical extracts and beneficial microbes to maintain ecological balance and ensure the well-being of both the host plant and silkworms (Bhattacharya *et al.*, 2018) [2]. Furthermore, organic sericulture supports soil fertility, reduces greenhouse gas emissions and ensures silk quality without chemical contamination. In response, certification schemes like India's National Programme for Organic Production (NPOP) and global standards such as GOTS (Global Organic Textile Standard) have been established to verify and promote organically produced silk Branding organic silk as a luxury and sustainable textile has opened new markets and export opportunities especially in Europe and North America (Gregory *et al.*, 2022) [5].

Concept and philosophy of organic sericulture
The foundation of organic sericulture lies in ecological balance, biodiversity conservation, and natural input use. It integrates traditional farming wisdom with scientific practices to ensure sustainable soil health, reduced environmental pollution, and toxin-free silk. The entire production chain from mulberry cultivation to silkworm rearing and silk processing is closely monitored to ensure compliance with organic norms and traceability (CSB, 2022; APEDA, 2023) [3, 1].

Core principles and practices

Non-chemical rearing practices in organic sericulture

In conventional sericulture, silkworm rearing practices commonly involve the use of antibiotics, chemical disinfectants, synthetic growth promoters and chemical bed sanitizers. While these methods may enhance productivity temporarily, they pose significant risks to silkworm health, cocoon quality and consumer safety due to chemical residues. In contrast, organic sericulture promotes non-chemical rearing protocols that focus on natural hygiene, bio-based disinfection and preventive care to reduce pathogen load without compromising silk quality (Hemavathi. *et al.*, 2024) [8]

One of the fundamental shifts in organic rearing is the replacement of synthetic disinfectants with natural alternatives. For instance, *neem leaf decoction*, *turmeric solution*, *cow dung ash*, and *soapnut extract* have been successfully used as eco-friendly disinfectants for cleaning rearing appliances and surfaces. These natural agents possess antifungal and antibacterial properties and are biodegradable, making them suitable for use in organic environments (Ma Ovais Ahmad Hajam *et al.*, 2024) [13]. Maintaining physical cleanliness and environmental hygiene is another cornerstone of organic rearing. Rearing trays, mountages and racks are physically scrubbed and sun-dried regularly, eliminating the need for chemical sterilants. Sun-drying serves as a simple yet effective method for controlling pathogens by exploiting ultraviolet radiation and desiccation (Gregory, *et al.*, 2022) [5].

In place of chemical bed disinfectants, organic systems utilize herbal-based powders such as dried and powdered neem leaves **(***Azadirachta indica***)**, holy basil **(***Ocimum sanctum***),** and turmeric**.** These substances are sprinkled on silkworm beds to absorb moisture, inhibit microbial growth and repel insect pests all without harming the silkworms (Naveen Chandra Reddy, *et al.*, 2024) [16]. Some studies also report the effectiveness of formulations containing wood ash, garlic powder and lime in suppressing secondary microbial infections in late instars (Kishore, *et al.*, 2024) [12]. Preventive measures such as quarantine and batch isolation are rigorously followed in organic rearing systems. Infected larvae or batches are immediately separated, and rearing appliances are disinfected using natural solutions to avoid horizontal transmission of pathogens. Additionally, maintaining optimal rearing conditions-adequate aeration, controlled temperature and humidity, and clean feeding practices-forms the basis of non-chemical disease prevention strategies (CSB, 2022) [3]. Overall, non-chemical rearing practices in organic sericulture not only reduce the incidence of silkworm diseases but also ensure the production of silk that is free from chemical residues, in line with the standards of the National Programme for Organic Production (NPOP) and Global Organic Textile Standard (GOTS). These eco-friendly practices contribute significantly to sustainable cocoon production and help meet the growing demand for certified organic silk.

Botanicals in pest and disease management

The use of botanicals in sericulture has gained increasing importance in recent years, especially in organic and sustainable farming systems. Botanicals are plant-derived substances used to control pests and diseases in mulberry and to ensure silkworm health without resorting to synthetic agrochemicals. Their eco-friendly, biodegradable, and non-toxic properties make them highly suitable for sericulture, where silkworms are extremely sensitive to chemical residues.

In mulberry cultivation, botanical pesticides have shown considerable promise in managing key pests such as *leaf rollers*, *mealybugs*, *thrips*, *whiteflies* and *tukra-causing mites*. Among these, neem-based formulations (derived from *Azadirachta indica*) are the most widely used botanicals due to their insecticidal, antifeedant and repellent properties. Spraying 3-5% neem seed kernel extract (NSKE) has been found effective against leaf webbers and jassids without harming leaf quality (Karthik Thangavel, *et al.*, 2017) [11]. Unlike synthetic pesticides neem extracts do not accumulate in the leaves and hence are safe for silkworm consumption.

Another important botanical used is pongamia oil (from *Pongamia pinnata*) which has shown efficacy in controlling soft-bodied insects like aphids and mealybugs through contact toxicity and growth regulation (Naveen Chandra Reddy, *et al.*, 2024) [16]. Pongamia oil also has systemic action, offering longer residual effects compared to some other botanicals. Similarly, garlic-chili extracts, when diluted and sprayed on mulberry, act as broad-spectrum repellents and are especially useful during pest outbreaks in organic farms (Gregory, *et al.*, 2022) [5].

In silkworm rearing, the use of botanicals is more cautious due to the sensitivity of larvae. However, cow urine-neem mixtures**,** tulsi (*Ocimum sanctum*) extracts and turmeric solutions have been successful ly used for disinfecting rearing houses and improving silkworm immunity. Turmeric (*Curcuma longa*) known for its antimicrobial and immunomodulatory properties has been applied as a bed disinfectant and mixed with silkworm feed to prevent bacterial flacherie and reduce larval mortality (Kalokhe *et al.*, 2024) [10].

Additionally, botanical fumigants such as dried neem leaves and camphor are used in rearing houses to repel flies and maintain air hygiene without the use of formalin or bleaching powder. These measures significantly reduce the risk of fungal and bacterial infections during late instars (Kishore, *et al.*, 2024) [12]. Use of such plant-based interventions also reduces the carbon footprint of sericulture and promotes residue-free silk production.

The effectiveness of botanicals in sericulture depends on multiple factors, including the plant species used, concentration, mode of application and pest or disease targeted. While they are generally safer than chemical counterparts, some botanicals may have phytotoxic or larvicidal effects at higher concentrations, emphasizing the need for standardization and farmer training. Nevertheless, with proper guidance botanicals offer a sustainable, farmer-friendly and silkworm-safe alternative for pest and disease management in both mulberry cultivation and silkworm rearing (Xiaoqiang Shen *et al.*, 2024) [19]

Probiotics and biocontrol agent

The integration of probiotics in silkworm rearing is gaining attention as a sustainable, residue-free strategy to enhance silkworm health, immunity and productivity. In organic sericulture systems, where the use of antibiotics and synthetic growth promoters is restricted, probiotics offer a natural alternative for disease management and nutritional support.

Probiotics are live microbial supplements that, when administered in adequate amounts, confer health benefits to

the host. In silkworm probiotics improve gut microbiota balance, facilitate digestion and strengthen immune responses, thereby enhancing resistance against common microbial diseases such as grasserie**,** flacherie and muscardine (Kalokhe *et al.*, 2024) [10]. These diseases, caused by viruses, bacteria, and fungi respectively, lead to heavy larval mortality and significant economic losses in sericulture. Probiotic interventions are thus critical to reducing disease incidence under chemical-free, organic farming systems.

Among the most effective probiotics used in silkworm rearing are lactic acid bacteria (LAB)**,** including species like *Lactobacillus acidophilus* and *Lactobacillus plantarum*, which help create an acidic gut environment that suppresses harmful pathogens (Gregory, *et al.*, 2022) [5]. These LAB strains have shown remarkable efficacy in reducing the severity of flacherie**,** a bacterial infection caused by *Streptococcus* and *Serratia* species. Another group of beneficial microbes, *Bacillus* spp.**,** especially *Bacillus subtilis*, contributes to enzymatic activity and acts as a bio-control agent by producing antimicrobial peptides that inhibit pathogenic microbes (Naveen Chandra Reddy, *et al.*, 2024) [16].

Recent studies have also demonstrated the role of yeast-based probiotics**,** such as *Saccharomyces cerevisiae*, in promoting growth and cocoon quality. These yeasts enhance the metabolic rate and enzyme production in silkworms, particularly amylase and protease activities, leading to better digestion and assimilation of nutrients (Habeanu *et al.*, 2025) [7]. Their supplementation has been associated with increased cocoon weight, shell ratio and overall silk yield, making them valuable in both conventional and organic rearing systems.

Incorporating probiotics in silkworm diets or spraying them on mulberry leaves is a common practice. This method helps in the colonization of beneficial microbes in the silkworm gut, especially during early instars when immunity is still developing (Kalokhe, *et al.*, 2024) [10]. Furthermore, probiotic usage aligns with organic certification protocols by reducing dependence on synthetic antibiotics**,** minimizing disease outbreaks and supporting the holistic health of the silkworm.

Despite the growing body of evidence supporting probiotic use, their application in field conditions requires standardization of strains, dosage and methods of administration. Future research should focus on developing multi-strain probiotic consortia and assessing their long-term effects on silkworm physiology and silk quality under various climatic and environmental conditions.

Certification of organic silk

For silk to be marketed as organic**,** it must adhere to strict standards and protocols prescribed by nationally and internationally recognized certification bodies. In India, the National Programme for Organic Production (NPOP)**,** implemented by the Agricultural and Processed Food Products Export Development Authority (APEDA) governs the organic certification process for mulberry cultivation and silkworm rearing (APEDA, 2023) [1]. Globally, guidelines from the International Federation of Organic Agriculture Movements (IFOAM) and the Global Organic Textile Standard (GOTS) govern both on-farm and post-cocoon processing of silk (GOTS, 2021) [4].

The certification process is multi-tiered and includes several critical stages. First, the certification of organic mulberry leaf production ensures that the soil, inputs, and pest management practices are free from synthetic agrochemicals and genetically modified organisms (GMOs). This is followed by the certification of silkworm rearing practices, which mandates non-use of antibiotics, synthetic disinfectants, and chemical growth stimulants (CSB, 2022) [3]. Silkworms must be reared on organically certified mulberry leaves throughout their lifecycle. Comprehensive documentation, including daily records**,** input registers and rearing logs is mandatory for traceability. Additionally, internal audits by producer groups and third-party inspections by accredited certification agencies ensure compliance. Residue analysis is often conducted to confirm the absence of chemical contaminants in the leaves and silk fibers (IFOAM, 2020) [9].

One of the crucial aspects of organic certification is that no genetically modified (GM) organisms or products derived from GMOs are allowed at any stage. This includes GM mulberry varieties, GM probiotics, or synthetic silkworm feed additives. The entire production process, including cocoon harvesting, reeling, dyeing, and finishing must also conform to GOTS standards to qualify as fully certified organic silk textiles (GOTS, 2021) [4].

Branding and market potential of organic silk

The demand for organic silk is rapidly increasing in domestic and global markets due to growing consumer awareness of environmental sustainability, animal welfare and ethical labor practices. Eco-labeling**,** traceability and certification have become key tools in enhancing consumer trust and establishing market differentiation (Gregory, *et al.*, 2022) [5]. With rising concerns about pollution and fast fashion, luxury and ethical brands are increasingly seeking fabrics that are both eco-friendly and socially responsible**.**

Organic silk is marketed using branding strategies such as “Eco-silk, ” “Green Silk, ” or “Peace Silk, ” depending on whether ethical rearing or non-violent harvesting is involved. These labels not only command premium pricing but also provide visibility in high-value textile segments like eco-fashion**,** natural dyes**,** and cruelty-free clothing. Studies have shown that farmers and weavers engaged in certified organic silk production earn 15-25% higher prices than their counterparts using conventional methods, due to the value addition and certification-backed trust (Philip. *et al.*, 2024) [18].

Moreover, geographical indication (GI) tags-such as those for Mysore Silk or Assam Muga-combined with organic branding, help create a unique identity and enhance export opportunities. The use of traceable QR codes on silk garments allows end consumers to track the silk’s journey from farm to fashion, thereby increasing transparency and appeal among environmentally conscious buyers (Madhu Rani, 2023) [15].

Countries like Japan**,** Germany**,** France and the USA have shown significant interest in importing certified organic silk from India, citing health safety, environmental ethics, and fabric quality (Karthik Thangavel *et al.*, 2017) [11]. Collaborations with ethical fashion brands, designers-including organic fashion lines, slow fashion movements-offer new channels for Indian silk to penetrate niche, high-end markets.

India, as the second-largest producer of silk globally and the largest producer of mulberry silk**,** is well-positioned to dominate the organic silk segment. However, this requires robust support in the form of policy incentives**,** infrastructure development**,** certification subsidies and market linkages (CSB, 2022) [3]. Government agencies, NGOs and private textile firms must collaborate to promote organic sericulture through awareness programs, cooperative branding and global trade facilitation.

Challenges and way forward in organic sericulture

While organic sericulture offers numerous ecological and economic advantages, its widespread adoption remains constrained by several practical challenges**.** One of the primary barriers is the lack of awareness and technical knowledge among farmers regarding organic protocols, certification norms and disease management through non-chemical means (Philip *et al.*, 2004: Madhu. *et al.*, 2025) [18, 15]. Most sericulture farmers continue to rely on conventional inputs due to familiarity and ease of access.

Another significant challenge is the unavailability of organized supply chains for certified organic inputs like biofertilizers, botanical pesticides and probiotics. Farmers often face difficulty in sourcing quality organic inputs that meet certification standards (Karthik Thangavel, *et al.*, 2017) [11]. Additionally, the initial transition to organic practices demands more labor, meticulous documentation and time, often leading to a temporary dip in yield and income during the conversion period. Infrastructure also plays a limiting role-certified rearing facilities**,** including disease-free seed zones and organically managed chawki rearing centers, are either scarce or unevenly distributed, particularly in remote and tribal regions (CSB, 2022) [3].

To overcome these hurdles, a multi-pronged approach is essential. First**,** government support in the form of incentives, input subsidies and certification cost reimbursements can encourage farmers to shift to organic sericulture (APEDA, 2023) [1]. Establishing farmer producer groups or clusters can facilitate collective certification, reduce costs, and strengthen marketing efforts. The development and distribution of low-cost botanical and probiotic kits**,** designed specifically for silkworm rearing and mulberry pest management, can offer practical alternatives to synthetic inputs. Furthermore, the integration of organic sericulture modules into training programs**,** Krishi Vigyan Kendras (KVKs), and sericulture extension services will equip farmers with the skills needed for sustainable transition (Qadri , 2004) [18].

Conclusion

Organic sericulture represents a holistic approach to silk production that harmonizes environmental sustainability, economic resilience, and ethical practices. By eliminating synthetic chemicals and embracing natural alternatives such as botanicals, probiotics, and organic inputs, this system not only ensures healthier mulberry and silkworm ecosystems but also produces high-quality, residue-free silk. With increasing global demand for eco-labeled and traceable textiles, organic silk is well-positioned to capture premium markets, particularly in Europe, Japan, and North America. However, realizing this potential requires strengthening of certification frameworks, widespread farmer training, and the development of organized supply chains for organic inputs. Investment in branding, traceability tools, and collaborations with ethical fashion brands can further enhance the visibility and value of organic silk. Ultimately, with coordinated policy support and community engagement, organic sericulture can evolve into a scalable, climate-resilient, and empowering livelihood for India's rural and tribal silk-farming communities.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Mode (Chat GPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

Competing interests

Authors have declared that no competing interests exist.

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