



The Silent Threat in Sericulture: Non-Spinning Silkworms and Their Impact on Silk Production

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Sericulture, often described as both a science and an art, involves the rearing of silkworms for silk production. For centuries, it has served as a cornerstone of agrarian economies, particularly in Asian nations such as India, China, Japan, and Thailand. Beyond being an agricultural activity, sericulture plays a vital role in rural employment, poverty alleviation, and cultural tradition. At the heart of this enterprise lies the domesticated silkworm (*Bombyx mori*), which has undergone long-term co-evolution with human intervention to emerge as a dependable source of one of nature's most exquisite natural fibers—silk. In the conventional sericulture process, silkworms pass through five larval stages while feeding solely on mulberry (*Morus* spp.) leaves. At the end of the fifth instar, the fully grown larva stops feeding and begins to spin a protective silk cocoon, within which it pupates and later transforms into an adult moth. The economic value of the industry depends almost entirely on this cocoon formation, as it provides the filament that is reeled into silk. The filament, made primarily of fibroin and sericin, determines the quality and usability of silk. In recent years, however, sericulture has been facing a serious challenge—the growing incidence of non-spinning silkworms. These larvae complete their developmental stages and appear externally normal, yet they fail to produce cocoons or spin only loose, irregular, and defective silk masses unsuitable for reeling. Once considered a rare occurrence, this phenomenon is now being reported with increasing frequency in several rearing regions, posing a significant threat to the sustainability of silk farming.

Introduction

Cocoon formation is a highly regulated physiological and behavioural process, not merely a mechanical act. It depends on precise coordination of hormonal, genetic, and environmental factors. During the final instars, the posterior and middle silk glands of the larva undergo intense growth, synthesizing and storing large quantities of fibroin and sericin in liquid form. Spinning begins under the regulation of key hormones, particularly ecdysone and juvenile hormone, which control moulting, metamorphosis, and activation of silk gland secretions. Any disruption in this delicate regulatory pathway may lead to impaired silk synthesis or failure to spin. Research indicates that non-spinning behaviour arises from multiple causes rather than a single factor. Possible contributors include genetic mutations in silk protein-related genes, endocrine imbalances, viral infections such as *Bombyx mori* nucleopolyhedrovirus (*BmNPV*), temperature & humidity stress, and nutritional deficiencies due to poor mulberry leaf quality. Additionally, environmental contaminants—such as irrigation with chemically polluted water or pesticide residues on mulberry—can impair silk gland function. Poor-quality or inbred silkworm seed further intensifies the issue in areas where strict quality control is absent. Thus, the increasing incidence of non-spinning silkworms is not just a biological anomaly but also an economic concern, as it directly reduces cocoon yield and threatens the long-term viability of sericulture.

Decline in cocoon yield due to non-spinning silkworms is a serious concern in sericulture. When a significant proportion of larvae fail to spin, cocoon production per 100 disease-free laying's (dfls) decreases noticeably. Alongside yield reduction, uniformity in cocoon size and shape is compromised, resulting in poor reeling performance. For marginal and small-scale farmers who depend on cocoon sales, these effects translate into substantial income loss. On a larger scale, reduced cocoon output directly impacts raw silk availability, thereby influencing national production levels and weakening the global competitiveness of the sericulture industry.

Biology of Cocoon Spinning

Cocoon spinning is an indispensable behavioural and physiological process in the life cycle of *Bombyx mori*, ensuring both protection of the pupa and successful completion of metamorphosis. While this process is tightly regulated in normal strains, certain mutant or abnormal strains exhibit failure in cocoon construction. Such individuals, commonly referred to as non-spinning silkworms, differ significantly from normal strains with respect to genetic composition, silk gland development, metabolic physiology, and expression of silk-related proteins.

1. Genetic and Molecular Basis

The non-spinning characteristic is frequently linked to mutations in silk protein-coding genes. In normal silkworms, fibroin and sericin are synthesized by the silk glands through the coordinated expression of major structural genes:

FibH – encodes the fibroin heavy chain

FibL – encodes the fibroin light chain

Ser1 – encodes sericin, which binds fibroin filaments together

Mutations, deletions, or regulatory defects in any of these genes can severely impair silk protein synthesis. For instance, alterations in FibH disrupt fibroin formation, resulting in the inability of larvae to spin cocoons.

2. Degeneration of Silk Glands

Another characteristic feature of non-spinning silkworms is the atrophy or degeneration of silk glands. Normally, the posterior silk glands (PSGs) undergo marked hypertrophy during the fifth instar, accumulating large amounts of fibroin protein. In non-spinners, however, these glands fail to enlarge due to reduced protein synthesis or early onset of programmed cell death (apoptosis) in glandular cells. Consequently, silk secretion is either minimal or completely absent.

3. Hormonal and Physiological Differences

The shift from feeding to spinning is under hormonal regulation, primarily controlled by juvenile hormone (JH) and ecdysteroids. In healthy larvae, a decline in JH levels accompanied by a rise in ecdysone initiates spinning behaviour. In non-spinning strains, hormonal imbalances occur—for example, an abnormally early drop in JH or a premature surge in ecdysone—which can trigger pupation before silk glands reach full maturity. As a result, larvae proceed to pupation without producing a cocoon.

4. Behavioural Abnormalities

In healthy silkworms, the pre-pupal stage is marked by a characteristic period of restlessness, during which the larvae actively search for a secure site and initiate rhythmic head movements to begin cocoon spinning. Non-spinning silkworms either fail to show this behaviour altogether or display it only partially. Even when provided with proper mountage facilities, they are unable to construct cocoons, secreting only minimal amounts of silk fluid that remain unorganized and fail to solidify. This suggests a neurophysiological impairment, possibly arising from defective silk gland function or disrupted neural signalling pathways that control the spinning motor pattern.

Non-Spinning Silkworms: Nature of the Problem Unlike normal larvae, non-spinning silkworms do not yield commercial-grade cocoons. They typically: Produce no silk at all
Secrete very small amounts of poor-quality silk
Construct fragile, loose, or malformed

cocoons. What was once considered an uncommon occurrence is now being reported more frequently by farmers, particularly under stressful or suboptimal rearing conditions. Identifying the root causes is therefore crucial for developing effective management strategies.

Causes of Non-Spinning in Silkworms

1. Genetic Factors and Mutations

Extended inbreeding or poorly managed hybridization programs often result in the accumulation of harmful mutations. These genetic changes can interfere with:

- Silk gland development
- Silk protein synthesis
- Hormonal regulation, especially involving ecdysteroids and juvenile hormones

Such mutations directly affect the physiological pathways required for cocoon formation.

2. Temperature and Humidity Stress

Silkworms are extremely sensitive to fluctuations in environmental conditions, particularly during the late fifth instar and pre-pupal stages. The optimal ranges for cocoon spinning are 23–28°C temperature and 70–85% relative humidity. Deviations can cause several physiological disruptions:

- Reduced silk gland enzyme activity
- Altered larval metabolism
- Imbalance in silk fluid moisture, affecting secretion quality

High temperatures (>30°C) accelerate larval development, leading to premature aging and inadequate time for spinning. Heat stress can also cause silk gland degeneration and lethargy, which suppresses spinning behaviour. Conversely, low humidity causes desiccation of silk fluid, resulting in incomplete or hardened cocoons.

3. Diseases and Pathogens

Non-spinning is frequently linked to pathogenic infections. Among these, viral diseases are the most destructive. The *Bombyx mori* nucleopolyhedrovirus (BmNPV) is particularly notorious, as it damages not only the silk glands but also other vital tissues such as the midgut epithelium. Infection weakens larval vitality, disrupts silk protein synthesis, and prevents proper cocoon formation.

4. Diseases and Pathogens (Bacterial and Fungal)

Apart from viral infections, bacterial and fungal diseases also contribute to non-spinning behaviour. Pathogens such as *Serratia*, *Streptococcus*, and *Aspergillus* primarily affect the gut, leading to toxemia, impaired digestion, and metabolic failure. Their impact extends to:

- Disruption of hormonal balance, which is essential for initiating spinning behaviour
- Poor nutrient absorption, limiting silk protein synthesis
- General decline in larval health and mobility

In some cases, subclinical infections remain unnoticed until the larva reaches the spinning stage, where spinning failure becomes apparent.

5. Nutritional Deficiency

Since silkworms are monophagous and feed exclusively on mulberry leaves, the quality of foliage directly influences cocoon formation. Leaves that are:

- Deficient in essential nutrients
- Cultivated on nutrient-poor or degraded soils

Affected by drought, salinity, or chemical contamination lead to undernourished larvae with poorly developed silk glands. The impact is especially critical during the fourth and fifth instars, when silk gland growth and protein accumulation are at their peak. Inadequate nutrition during these stages directly reduces spinning efficiency.

6. Chemical and Environmental Pollution

Environmental contaminants also play a significant role in the emergence of non-spinning silkworms. Major contributing factors include:

- Irrigation of mulberry fields with industrial effluents or wastewater from silk reeling units

- Pesticide drift or residual accumulation on mulberry foliage
- Presence of heavy metals (Zn, Pb, Cd)
- Soil pH imbalance and salinity stress

These pollutants bioaccumulate in silkworm tissues, causing structural and functional damage to vital organs such as silk glands and the gut epithelium. In addition, chronic exposure to toxins may induce epigenetic alterations, further impairing silk secretion and leading to defective or absent cocoon formation.

Impact of Non-Spinning Silkworms on Sericulture

The increasing incidence of non-spinning silkworms poses severe challenges for the sericulture industry, with cascading effects on both production and economics:

1. Reduced silk yield
2. Increased wastage
3. Loss of farmer income
4. High rearing costs
5. Breeding setbacks

Preventive Measures and Farm-Level Management

The occurrence of non-spinning silkworms can be minimized by adopting integrated management practices that focus on environmental regulation, nutritional quality, disease control, genetic stability, and hygienic rearing conditions.

a. Environmental Management

Silkworm growth and silk gland activity are strongly influenced by temperature and humidity. The optimal ranges are:

Temperature: 24–28 °C

Relative Humidity: 70–80%

Deviation from these conditions can delay larval development, disturb hormonal balance (particularly ecdysone secretion), and induce stress-related degeneration of silk glands.

Recommended practices:

- Use fans, heaters, humidifiers, or dehumidifiers to maintain stable microclimatic conditions.
- Ensure cross-ventilation to prevent CO₂ accumulation and suppress microbial growth.
- Avoid overcrowding, which increases heat stress, reduces oxygen availability, and facilitates pathogen spread.

b. Leaf Quality Assurance

As the sole food source for silkworms, mulberry leaves play a decisive role in cocoon formation. They supply proteins (notably serine and glycine), carbohydrates, and minerals that form the building blocks of fibroin and sericin. Poor-quality, nutrient-deficient, or chemically contaminated leaves impair digestion and silk protein synthesis, resulting in weak or absent cocoon formation.

Recommended practices:

- Provide clean, pesticide-free, and disease-free leaves at all times.
- Apply balanced fertilizers (NPK) along with farmyard manure (FYM) to improve leaf nutrient content, especially nitrogen, which enhances protein accumulation in silk glands.
- Avoid irrigating mulberry fields with untreated wastewater or industrial effluents, as these may contain heavy metals and harmful microbes that damage silk gland physiology.

c. Disease Prevention

Pathogens such as viruses (*Bombyx mori* nucleopolyhedrovirus, *BmNPV*), bacteria (*Serratia marcescens*), and fungi (*Aspergillus*, *Streptococcus*) directly compromise silk gland integrity, leading to reduced protein secretion and non-spinning behaviour. Their rapid transmission is often favoured by poor hygiene in rearing houses.

- Recommended practices:
- Maintain strict hygiene in rearing environments.

- Disinfect rearing rooms, appliances, and mountages regularly using 2–4% formalin, bleaching powder, or slaked lime to eliminate microbial spores.
- Dispose of diseased larvae properly to prevent secondary infection.
- Encourage regular monitoring for early detection of subclinical infections.

d. Breeding and Race Selection

Genetic predisposition plays a significant role in the occurrence of non-spinning behaviour. Certain mutant strains (e.g., “csr” (cocoonless silkworm races), “fl” (flaccid larvae), and “ns” (non-sericin)) are known to carry heritable defects that impair cocoon formation. If such traits persist within breeding lines, they reduce genetic fitness and lower cocoon productivity over successive generations.

Recommended practices:

- Avoid rearing low-performing strains with a documented history of high non-spinning incidence.
- Conduct systematic performance evaluation at seed supply centers to detect and eliminate races showing defective traits.
- Adopt selective breeding programs to gradually eliminate undesirable mutations and maintain race purity.

e. Proper Mountage Timing

Mountage management is critical during the transition from the larval to pupal stage. The hormonal surge of ecdysone at the end of the fifth instar induces spinning behaviour. If larvae are not mounted at the appropriate time, they may display prolonged wandering, sustain mechanical injuries, or experience silk gland degeneration, all of which can result in non-spinning.

Recommended practices:

- Install mountages at the correct stage, usually when larvae become translucent, glossy, and exhibit reduced feeding.
- Provide clean, soft, and spacious mountages that facilitate natural spinning and minimize larval stress.

f. Disease Monitoring and Health Enhancement

Non-spinning is often preceded by visible symptoms such as lethargy, regurgitation, or abnormal coloration. Early detection and intervention can significantly reduce losses.

Recommended practices:

- Regularly monitor larval behaviour and appearance to identify early disease symptoms.
- Use serivaccines (e.g., against grasserie) to boost immunity against viral pathogens.
- Incorporate probiotics (e.g., *Lactobacillus* spp.) into rearing practices to improve gut health and enhance disease resistance.

This now gives you a comprehensive preventive measures section:

1. Environmental management
2. Leaf quality assurance
3. Disease prevention
4. Breeding and race selection
5. Proper mountage timing

Conclusion

The increasing prevalence of non-spinning silkworms poses a serious challenge to the sustainability and profitability of sericulture. Larvae that fail to form cocoons—whether due to genetic mutations, environmental fluctuations, nutritional deficiencies, or pathogenic infections—directly reduce silk yield and disrupt the entire sericultural value chain. For farmers, this results in economic losses; for researchers, it highlights the need for targeted scientific investigation; and for policymakers, it signals the urgency of strengthening support systems for rural silk-based livelihoods. Understanding the etiology of non-spinning behaviour is essential for effective intervention. Factors such as extreme temperature and humidity variations, poor mulberry leaf quality, pathogen invasion, and inherited genetic

defects must be studied systematically to devise integrated solutions. At the farm level, improved rearing practices, environmental regulation, and disease surveillance are crucial for preventing outbreaks and minimizing production losses. Equally important is the role of capacity building, including farmer training, extension support, and timely government interventions. By combining traditional sericultural wisdom with advances in biotechnology, molecular breeding, and disease management, it is possible to mitigate the threat of non-spinning and ensure long-term stability in silk production. In conclusion, while non-spinning silkworms represent a critical obstacle to cocoon production today, they also provide an opportunity to rethink, reform, and future-proof sericulture. A coordinated, multidisciplinary approach—linking farmers, scientists, and policymakers—is imperative to sustain the golden legacy of silk as both an economic driver and a cultural heritage for generations to come.

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