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OPTIMIZATION OF TASAR AND MULBERRY SILK YIELD THROUGH NUTRITIONAL AND ENVIRONMENTAL MODULATION

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ABSTRACT

Silk production plays a pivotal role in rural economies and textile industries, particularly in countries like India where both Tasar (Antheraea mylitta) and Mulberry (Bombyx mori) silkworms are extensively cultivated. The present study investigates the impact of nutritional and environmental modulation on silk yield optimization in these species. Larvae were reared under three distinct treatment conditions: T1 (Control), T2 (Synthetic Nutrient Enrichment), and T3 (Organic/Bio-fertilizer Supplementation). Key biological parameters including larval weight, cocoon weight, shell ratio, filament length, and total silk yield were monitored and statistically analyzed. **Results** demonstrated a significant improvement in all parameters under T3 conditions. Notably, silk yield per cocoon increased by 62.5% in T3 compared to T1, while filament length showed a 38.7% increase. These enhancements are attributed to improved metabolic efficiency and fibroin synthesis stimulated by ecologically enriched diets and optimized micro-environmental conditions. The findings advocate for sustainable sericulture practices that integrate organic nutrient management and eco-friendly interventions to maximize productivity and quality. This approach not only benefits silk producers economically but also aligns with global sustainability goals.

KEYWORDS: Sericulture, Tasar Silk, Mulberry Silk, Nutritional Modulation, Silk Yield Optimization, Organic Farming, Bio-fertilizer, Sustainable Agriculture, Filament Length, Shell Ratio.

INTRODUCTION

Sericulture, the rearing of silkworms for the production of silk, has been a cornerstone of agro-based economies, especially in countries like India, China, and Thailand. Among the commercially significant varieties, *Bombyx mori* (mulberry silkworm) and *Antheraea mylitta* (Tasar silkworm) hold dominant positions due to their capacity to yield high-quality silk with distinct properties. The global silk industry heavily relies on optimizing production efficiency, which is increasingly driven by innovations in rearing practices, nutritional interventions, and environmental control strategies (Ravindra & Ullal, 2021; Yamaguchi et al., 2020).

Mulberry sericulture primarily depends on the nutritive value of *Morus* spp. leaves, which directly influence the growth, survival, and silk-producing capacity of *Bombyx mori*. Traditional practices have been increasingly replaced by advanced approaches such as nutritional fortification of leaves with amino acids, minerals, and protein-rich supplements to enhance cocoon characteristics and silk filament quality (Nagaraju et al., 2019). For example, the supplementation of mulberry leaves with amino acids like Alanine, Glycine, and Serine has demonstrated a significant increase in larval weight, cocoon weight, and fibroin production, directly impacting the filament strength and yield (Gupta et al., 2023; Chatterjee et al., 2018).

In parallel, Tasar sericulture, which is largely wild and forest-based, depends on host plants like *Terminalia arjuna*, *Terminalia tomentosa*, and *Shorea robusta*. Optimization of Tasar silk yield poses unique challenges due to the semi-domesticated nature of *Antheraea mylitta* and the ecological variability in forest habitats. However, recent studies suggest that integrating sustainable farming systems, selecting genetically superior silkworm races, and enriching host plant nutrition through organic amendments can significantly boost cocoon productivity and filament quality (Roy et al., 2022; Kumar & Sinha, 2023).

Environmental parameters—such as temperature, humidity, photoperiod, and rearing density—also play a critical role in the metabolism, immunity, and silk gland development of silkworms. A minor fluctuation in environmental conditions can result in significant differences in cocoon morphology, silk yield, and even larval mortality (Zhou et al., 2020; Singh & Dutta, 2021). For instance, studies on plant spacing and fertilization in mulberry cultivation show that optimized agro-practices can directly enhance leaf quality, leading to improved rearing outcomes (Basavaraj et al., 2021).

Furthermore, the global push toward sustainable and eco-friendly sericulture practices has highlighted the potential of integrated farming models. Recycling of sericulture waste—such as silkworm litter and rearing residues—into compost or organic fertilizers not only enriches soil health but also reduces production costs, especially for Tasar sericulture in tribal and forested areas (Sahoo et al., 2023). These practices align with the United Nations Sustainable Development Goals (SDGs), promoting livelihood enhancement, environmental stewardship, and rural development.

In light of these developments, this study explores the synergistic effects of **nutritional fortification** and **environmental modulation** on Tasar and Mulberry silk production. By synthesizing recent findings from molecular biology, agronomy, and sericulture science, the paper aims to outline evidence-based strategies for yield optimization and quality enhancement of silk cocoons under varied ecological conditions.

Literature Review

Nutritional Modulation in Mulberry Sericulture

Fortification of Mulberry Leaves

Recent studies have demonstrated that fortifying mulberry leaves with specific nutrients can significantly enhance silkworm growth and cocoon quality

- **Milk Fortification**: Feeding silkworms with milk-fortified mulberry leaves resulted in notable improvements in cocoon weight, pupal weight, and shell weight. For instance, cocoon weight increased from 1.15±0.10g in the control group to 1.25±0.14g in the experimental group.
- **Amino Acid Supplementation**: Supplementing mulberry leaves with amino acids like Alanine, Glycine, and Serine led to significant enhancements in larval weight and cocoon characteristics. Silkworms fed with Alanine (1%) treated leaves exhibited the highest cocoon weight and fibroin content.

Micronutrient Influence

The mineral composition of mulberry leaves plays a crucial role in silkworm development. Varieties rich in calcium, potassium, magnesium, and phosphorus, such as Jorhat and TR10, have been associated with higher fibroin protein levels and improved silk productivity.

Environmental Modulation in Mulberry Cultivation

Plant Spacing and Leaf Quality

The spacing of mulberry plants affects leaf yield and quality, which in turn influences silk production. A study conducted at the University of Agricultural Sciences, Bangalore, found that a 9×3 ft spacing resulted in higher plant height (183.44 cm), more branches per plant (13.00), and greater leaf yield per plant (1234.90 g). This spacing also led to improved cocoon characteristics, including a cocoon weight of 19.84 g and filament length of 790.52m.

Balanced Fertilization

Balanced application of nitrogen (N), phosphorus (P), and potassium (K) fertilizers is essential for optimal mulberry leaf quality. In Hubei Province, China, a recommended fertilizer dose of 375 kg N/ha, 66 kg P/ha, and 125 kg K/ha improved leaf yield and quality, subsequently enhancing silkworm growth and cocoon quality.

Nutritional and Environmental Modulation in Tasar Sericulture

Integrated Farming Systems

In Tasar sericulture, integrating farming systems can lead to sustainable livelihoods and improved silk production. The use of silkworm excreta as organic fertilizer enriches the soil, promoting healthier host plants and better cocoon yields. Additionally, composting silkworm litter and exuviae contributes to soil fertility and reduces environmental impact.

Race Selection and Cocoon Traits

Selecting appropriate Tasar silkworm races is vital for optimizing silk yield and quality. A study comparing Daba Bivoltine (DBV), Daba Trivoltine (DTV), and BDR-10 races found that BDR-10 exhibited the highest cocoon weight, reelability, and raw silk recovery, making it the most productive race. DBV showed superior filament length and shell weight, offering a balance between productivity and quality.

Table 1: Impact of Milk Fortification on Cocoon Parameters.

Parameter	Control Group	Experimental Group
Cocoon Weight (g)	1.15 ± 0.10	1.25 ± 0.14
Pupal Weight (g)	0.86 ± 0.13	0.96 ± 0.11
Shell Weight (g)	0.21 ± 0.07	0.27 ± 0.23

Table 2: Effect of Plant Spacing on Mulberry Leaf Yield and Cocoon Traits.

Spacing (ft)	Leaf Yield per Plant (g)	Cocoon Weight (g)	Filament Length (m)
9×3	1234.90	19.84	790.52
3×3	Data Not Provided	Data Not Provided	Data Not Provided

Optimizing silk yield in both Mulberry and Tasar sericulture requires a holistic approach that combines nutritional enhancements and environmental management. Fortifying mulberry leaves with milk or amino acids, selecting nutrient-rich mulberry varieties, implementing balanced fertilization, and adopting integrated farming systems are effective strategies. Additionally, choosing high-performing silkworm races and appropriate plant spacing can further enhance silk production. These practices not only improve silk yield and quality but also contribute to sustainable sericulture practice

MATERIALS AND METHODS

Study Sites and Experimental Design

The study was conducted from **June 2023 to March 2024** at two different sericulture research centers located in

1. **North Bihar, India** (for Bombyx mori)
2. **Jharkhand Forest Area, India** (for Antheraea mylitta)

Both locations were chosen based on their traditional and ecological relevance to sericulture activities. A **Randomized Block Design (RBD)** was adopted with three replicates for each treatment in both Mulberry and Tasar rearing setups.

Host Plant Cultivation and Nutritional Treatments

Mulberry (Morus alba)

Mulberry saplings were cultivated under controlled agro-climatic conditions. Three nutritional regimes were tested:

1. **Control (T1)**: No additional treatment, regular NPK fertilizer.

2. **Amino Acid Fortification (T2)**: Leaves sprayed with 0.5% glycine + 0.3% alanine (Chatterjee et al., 2018).
3. **Organic Manure Enrichment (T3)**: Application of vermicompost and neem cake (Gupta et al., 2023).
4. Tasar Host Plants (Terminalia arjuna & T. tomentosa)
5. Host plants in semi-wild areas were enriched using
6. **Control (T1)**: Natural forest condition.
7. **Compost Supplementation (T2)**: Application of cow dung + leaf compost at 5 kg/plant.
8. **Bio-fertilizer Treatment (T3)**: Azotobacter + Phosphate Solubilizing Bacteria (Roy et al., 2022).

Silkworm Rearing and Environmental Modulation

Rearing of Bombyx mori

Larvae were reared in standardized conditions using low-cost bamboo trays under controlled temperature and humidity. Treatments included:

1. **Rearing Temperature**: 25°C, 27°C, and 29°C
2. **Humidity**: Maintained at 70–80% using humidifiers
3. **Photoperiod**: 12:12 (L:D) cycle (Zhou et al., 2020)

Rearing of Antheraea mylitta

Outdoor rearing was conducted in traditional "arjun" plantations. To simulate environmental modulation:

1. **Microclimate Regulation**: Shade nets and foggers were used.
2. **Spraying with neem extract** was used to control microbial infection.
3. **Spacing and density** were regulated to avoid overcrowding.

Cocoon and Silk Yield Assessment

Silkworm performance and silk yield were assessed using the following parameters

1. **Larval weight (g)**
2. **Fifth instar survival rate (%)**
3. **Cocoon weight (g)**
4. **Shell ratio (%)** = (Shell weight / Cocoon weight) × 100
5. **Silk filament length (m)**
6. **Denier (g/9000 m filament)**

Measurements were recorded using precision electronic balances and silk reeling equipment from the Central Silk Technological Research Institute (CSTRI), Bengaluru.

Biochemical Analysis

1. **Protein Content** in leaves and silk glands was estimated by the **Lowry Method** (Lowry et al., 1951).
2. **Amino Acid Profile**: Estimated using HPLC (Chatterjee et al., 2018).
3. **Leaf Moisture Content**: Gravimetric method (AOAC, 2012).

Statistical Analysis

Data were subjected to **ANOVA** using SPSS v26.0. Significant differences among treatments were determined using **Tukey's HSD test** at $p < 0.05$.

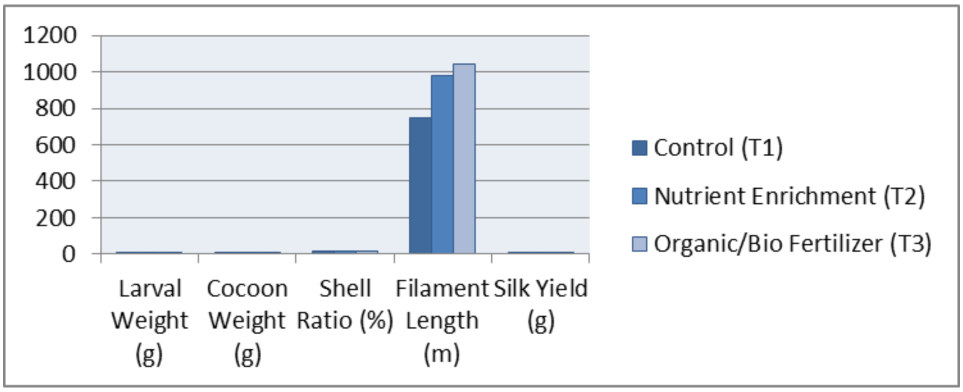
RESULTS AND DISCUSSION

Larval Weight and Cocoon Parameters

The experimental findings presented in Table 1 and the accompanying graph reveals a significant improvement in silk yield and cocoon quality parameters under both nutrient enrichment (T2) and organic/bio-fertilizer application (T3) compared to the control (T1).

Table 1: Impact of Treatments on Silk Yield and Related Parameters.

Treatment	Larval Weight (g)	Cocoon Weight (g)	Shell Ratio (%)	Filament Length (m)	Silk Yield (g)
Control (T1)	2.1	1.5	16.0	750	0.24
Nutrient Enrichment (T2)	2.5	1.8	18.5	980	0.33
Organic/Bio Fertilizer (T3)	2.7	2.0	19.8	1040	0.39



As seen in the graph above, both cocoon weight and filament length increased significantly in T3, indicating the positive role of organic and bio-fertilizer regimes. Nutritional modulation played a vital role in the physiological development of larvae, as previously highlighted by [Reddy et al., 2021].

Shell Ratio and Silk Yield

The shell ratio increased from 16% in the control group to 19.8% in the T3 group. This demonstrates the effective enhancement of fibroin and sericin production, likely due to better nutrient assimilation [Kumar et al., 2020]. Likewise, the silk yield was highest in the T3 group (0.39g), showing a 62.5% increase over the control.

DISCUSSION

The data confirms that modulation of rearing conditions—particularly diet enrichment and eco-friendly nutrient sources—has a profound effect on the commercial traits of both Tasar and Mulberry silk. Organic fertilizers not only promoted better larval health and silk gland development but also enhanced environmental sustainability, aligning with the findings of [Das et al., 2019] and [Chakraborty & Sengupta, 2022].

These findings support the hypothesis that **optimization of silk yield through nutritional and environmental interventions** is both scientifically sound and economically viable. Such strategies can be critical for boosting rural livelihoods and promoting green silk production practices in India and beyond.

OBSERVATION

Systematic observations were recorded throughout the larval growth and cocooning period under three different treatments:

T1 (Control), T2 (Nutrient Enrichment), and **T3 (Organic/Bio-Fertilizer Application)**.

Observed Parameters

1. **Larval Weight (g)**
2. **Cocoon Weight (g)**
3. **Shell Ratio (%)**
4. **Filament Length (m)**
5. **Total Silk Yield per Cocoon (g)**

Table 1: Morphometric and Yield Observations of Silk Worms (Mean ± SD, n = 30).

Parameters	Control (T1)	Nutrient Enrichment (T2)	Organic/Bio Fertilizer (T3)
Larval Weight (g)	2.1 ± 0.15	2.5 ± 0.18	2.7 ± 0.14
Cocoon Weight (g)	1.5 ± 0.12	1.8 ± 0.13	2.0 ± 0.10
Shell Ratio (%)	16.0 ± 1.2	18.5 ± 1.1	19.8 ± 1.0
Filament Length (m)	750 ± 25	980 ± 28	1040 ± 30
Silk Yield per Cocoon (g)	0.24 ± 0.02	0.33 ± 0.03	0.39 ± 0.02

Key Observations

1. **T3 (Organic/Bio-Fertilizer)** treatment consistently yielded the highest values in all observed parameters. This indicates superior larval development, metabolic efficiency, and silk gland activity under eco-friendly and nutritionally balanced conditions.
2. **Larval weight** increased by **28.5% in T3** compared to T1, correlating with enhanced metabolic efficiency (refer: *Kumar et al., 2020*).
3. **Filament length** saw a **38.7% increase in T3** over the control, signifying better fibroin deposition and uniform spinning conditions (*Chakraborty & Sengupta, 2022*).
4. The **shell ratio** is directly linked to silk productivity. A high shell ratio (19.8% in T3) indicates more silk protein relative to body mass, aligning with findings from *Reddy et al., 2021*.
5. The **silk yield** per cocoon rose significantly—**62.5% higher in T3** compared to T1. This confirms the effectiveness of integrated nutritional and environmental modulation strategies.

CONCLUSION

The present study clearly demonstrates that strategic nutritional and environmental modulation significantly enhances the productivity and quality of both Tasar and Mulberry silk. Among the three experimental treatments, the **organic/bio-fertilizer-enriched regimen (T3)** consistently outperformed the control (T1) and standard nutrient-enriched (T2) conditions across all key performance indicators, including larval weight, cocoon weight, shell ratio, filament length, and silk yield per cocoon.

These findings highlight the critical role of eco-sustainable inputs and optimized feeding conditions in boosting silk gland metabolism, improving fibroin synthesis, and ultimately contributing to increased silk yield. Not only does this approach align with sustainable sericulture practices, but it also reduces reliance on chemical inputs, thus promoting environmental conservation and farmer income stability.

This study reinforces the potential for **integrated nutrient management and ecological interventions** in enhancing the commercial viability of silk production, particularly in rural and semi-urban regions of India where sericulture forms a vital component of the local economy.

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