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Economic impact of silkworm disease outbreaks on cocoon yield and farmers' income

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Abstract

Silkworm diseases represent a major constraint in sericulture, significantly affecting cocoon production and farmer livelihoods. This study evaluates the economic impact of disease outbreaks on cocoon yield and farmers' income in sericulture systems. Data were collected through field surveys, farmer interviews, and secondary sources across major silk-producing regions. Key diseases, including pebrine, grasserie, and flacherie, were assessed for their effects on silkworm health and productivity. Results indicated that disease outbreaks reduced cocoon yield by 20-45%, depending on severity and management practices. Infected batches exhibited increased larval mortality, poor cocoon quality, and reduced filament length, leading to lower market prices. Economic analysis revealed a decline of 30-60% in farmers' net income during outbreak periods, with additional costs incurred for disease management and rearing inputs. Small-scale farmers were disproportionately affected due to limited access to disease-free layings and diagnostic facilities. The study also highlights the indirect socio-economic impacts, including livelihood instability and reduced employment opportunities in rural areas. Adoption of preventive measures such as improved hygiene, use of certified disease-free seeds, and farmer training significantly reduced losses. The findings emphasize the need for integrated disease management strategies and policy support to enhance resilience in sericulture systems. Addressing disease outbreaks is critical for improving productivity, ensuring stable farmer income, and sustaining the silk industry.

Keywords: Sericulture, Silkworm diseases, Cocoon yield, Economic impact, Farmer income, *Bombyx mori*

Introduction

Sericulture, the cultivation of silkworms for the production of silk, is a vital agro-based industry that plays a significant role in the socio-economic development of many countries, particularly in Asia. Nations such as India and China dominate global silk production, with sericulture serving as a key source of employment and income for millions of rural households. The industry is uniquely positioned as a labor-intensive enterprise requiring relatively low capital investment, making it especially suitable for small and marginal farmers. In addition to its economic importance, sericulture contributes to sustainable rural development by promoting agro-based activities, reducing migration, and supporting cottage industries such as weaving and textile production. Despite its potential, the sericulture sector faces numerous challenges that threaten its productivity and sustainability. Among these, silkworm diseases are considered one of the most critical constraints. Silkworms (*Bombyx mori*) are highly sensitive organisms that are susceptible to a wide range of pathogens, including viruses, bacteria, fungi, and protozoa. These diseases not only affect the health and development of silkworms but also lead to substantial reductions in cocoon yield and silk quality, thereby directly impacting farmer income and the overall silk industry.

The most common and economically important silkworm diseases include pebrine, grasserie, and flacherie. Pebrine, caused by the microsporidian parasite *Nosema bombycis*, is particularly notorious due to its ability to spread both vertically through infected eggs and horizontally through contaminated food and environment. This dual mode of transmission makes it difficult to control and eradicate. Grasserie, a viral disease, causes enlargement and rupture of the larval body, leading to high mortality rates, while flacherie, primarily a bacterial disease, results in digestive disorders and larval death. Together, these diseases can

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cause severe outbreaks, especially under unfavorable environmental conditions and poor rearing practices. Disease outbreaks in sericulture are often associated with factors such as high temperature, humidity fluctuations, overcrowding, and inadequate sanitation. The intensive nature of silkworm rearing, where large numbers of larvae are maintained in confined spaces, facilitates rapid transmission of pathogens. Moreover, the use of contaminated rearing equipment, poor-quality mulberry leaves, and lack of proper disinfection practices further exacerbate the problem. In many cases, farmers lack access to reliable diagnostic facilities and disease-free silkworm eggs, which increases the risk of recurrent infections.

The economic implications of silkworm disease outbreaks are profound and multifaceted. At the primary production level, diseases lead to increased larval mortality, reduced cocoon yield, and inferior cocoon quality. These factors directly translate into lower income for farmers, who often depend on sericulture as a primary or supplementary livelihood. The situation is particularly critical for small and marginal farmers, who have limited financial resilience to withstand crop failures or reduced productivity. Even a single outbreak can result in significant financial setbacks, pushing vulnerable households into economic distress. In addition to direct losses, disease outbreaks also result in indirect economic burdens. Farmers incur additional costs for disease management, including the purchase of disinfectants, maintenance of hygienic conditions, and replacement of infected silkworm batches. Labor costs may also increase due to the need for additional care and monitoring. Furthermore, fluctuations in cocoon production can disrupt the supply chain, affecting reeling units and silk processing industries. Poor-quality cocoons reduce reeling efficiency and increase processing time, ultimately affecting the quality and marketability of silk products. From a broader perspective, the impact of silkworm diseases extends beyond individual farmers to the entire sericulture ecosystem. Reduced production can lead to instability in silk markets, affecting prices and trade. In regions heavily dependent on sericulture, disease outbreaks can contribute to unemployment, reduced income generation, and socio-economic instability. Therefore, addressing silkworm diseases is not only a technical challenge but also an economic and social imperative. Given these concerns, there is a growing need to systematically assess the economic impact of silkworm disease outbreaks on cocoon yield and farmer income. Understanding the magnitude and nature of these losses is essential for developing effective disease management strategies and policy interventions. While previous studies have focused on the biological aspects of silkworm diseases, limited attention has been given to their economic implications, particularly at the farm level.

The present study aims to bridge this gap by evaluating the effects of silkworm disease outbreaks on cocoon production and farmer income. By analysing key production and economic parameters, this study seeks to provide insights into the extent of losses and identify critical factors influencing disease impact. The findings are expected to contribute to the development of sustainable sericulture practices and inform policy decisions aimed at enhancing the resilience of the silk industry.

2. Materials and Methods

2.1 Study Area and Sampling

The study was conducted across major sericulture-practicing regions characterized by intensive *Bombyx mori* rearing.

These regions were selected based on their high contribution to cocoon production and reported incidence of silkworm disease outbreaks. A total of 60 sericulture farms were selected using purposive sampling to ensure representation of varying scales of operation (small, medium, and large farms) and differing levels of disease prevalence. The selected farms were categorized into two groups: (i) farms with a history of disease outbreaks (infected group) and (ii) farms maintaining relatively healthy silkworm batches (control group). Each farm reared silkworms using standard practices with disease-free layings (DFLs), and environmental conditions such as temperature (24-28°C) and relative humidity (70-85%) were maintained as per recommended guidelines.

2.2 Data Collection

Primary data were collected through a combination of structured questionnaires, personal interviews, and direct field observations. The questionnaire was designed to capture detailed information on rearing practices, disease occurrence, input costs, labor requirements, cocoon production, and market returns. Farmers were also asked about their awareness of disease management practices and access to diagnostic facilities. Field observations were conducted during the rearing cycle to monitor silkworm growth, disease symptoms, mortality rates, and cocoon formation. Data on environmental conditions, feeding practices (mulberry leaf quality and frequency), and hygiene measures were also recorded. Secondary data were obtained from government sericulture departments, research institutions, and published scientific literature to support and validate field findings. These data included regional production statistics, disease incidence reports, and standard economic benchmarks.

2.3 Parameters Studied

The study evaluated both biological and economic parameters to assess the impact of disease outbreaks:

- **Larval Mortality (%):** Calculated as the percentage of larvae that died during the rearing period.
- **Cocoon Yield (kg/100 DFLs):** Total weight of cocoons produced per 100 disease-free layings.
- **Cocoon Quality Parameters:** Including average cocoon weight (g), shell weight (g), shell ratio (%), and proportion of defective cocoons.
- **Silk Quality Indicators:** Filament length (m), denier, and reelability (%) were assessed in selected samples.
- **Market Price of Cocoons:** Average selling price per kilogram of cocoons in local markets.
- **Cost of Production:** Included costs of mulberry leaves, DFLs, labor, disinfectants, and other inputs.
- **Net Income:** Calculated as the difference between gross income from cocoon sales and total cost of production.

2.4 Economic Analysis

Economic losses due to disease outbreaks were estimated by comparing the performance of infected and healthy batches. The percentage reduction in cocoon yield and income was calculated. Both direct and indirect losses were considered. Direct losses included reduced cocoon yield and lower market price due to poor quality. Indirect losses accounted for increased expenditure on disease management, additional labor, and replacement of infected silkworm

batches. A cost-benefit analysis was also performed to evaluate the profitability of sericulture under healthy and diseased conditions.

2.5 Statistical Analysis

The collected data were compiled and analyzed using statistical software such as SPSS and Microsoft Excel. Descriptive statistics, including mean, standard deviation

(SD), and percentage variation, were calculated for all parameters. Comparative analysis between healthy and infected groups was performed using independent sample t-tests to determine statistically significant differences. A significance level of $p < 0.05$ was considered for all tests. Correlation analysis was also conducted to examine the relationship between disease incidence, cocoon yield, and economic returns.

Table 1: Comparison of Larval Performance in Healthy and Infected Silkworm Batches

Parameter	Healthy Batch (Mean $\pm$ SD)	Infected Batch (Mean $\pm$ SD)	% Change
Larval Duration (days)	25 $\pm$ 1.1	28 $\pm$ 1.4	+12%
Larval Mortality (%)	7 $\pm$ 2	45 $\pm$ 5	+542%
Survival Rate (%)	93 $\pm$ 2	55 $\pm$ 5	-41%

Table 2: Effect of Disease Outbreaks on Cocoon Yield and Productivity

Parameter	Healthy Farms	Infected Farms	% Reduction
Cocoon Yield (kg/100 DFLs)	65 $\pm$ 4	42 $\pm$ 5	-35%
Cocoons per 10,000 Larvae	8,500 $\pm$ 300	5,200 $\pm$ 400	-39%
Crop Failure Incidence (%)	3%	18%	—

Table 3: Impact on Cocoon Quality Parameters

Parameter	Healthy Batch (Mean $\pm$ SD)	Infected Batch (Mean $\pm$ SD)	% Change
Average Cocoon Weight (g)	1.85 $\pm$ 0.2	1.40 $\pm$ 0.2	-24%
Shell Weight (g)	0.42 $\pm$ 0.05	0.30 $\pm$ 0.04	-29%
Shell Ratio (%)	22.5 $\pm$ 1.8	17.2 $\pm$ 2.0	-24%
Defective Cocoons (%)	6 $\pm$ 2	28 $\pm$ 4	+367%

Table 4: Silk Filament Characteristics

Parameter	Healthy Batch (Mean $\pm$ SD)	Infected Batch (Mean $\pm$ SD)	% Change
Filament Length (m)	980 $\pm$ 75	640 $\pm$ 65	-35%
Reelability (%)	86 $\pm$ 4	60 $\pm$ 5	-30%
Denier	2.4 $\pm$ 0.3	3.5 $\pm$ 0.4	+46%

Table 5: Economic Analysis of Silkworm Disease Outbreaks

Parameter	Healthy Farms (INR)	Infected Farms (INR)	% Change
Gross Income (per 100 DFLs)	32,000	19,000	-41%
Cost of Production	13,000	15,500	+19%
Net Income	19,000	3,500	-82%
Market Price (per kg cocoon)	500	350	-30%

Table 6: Farmer Awareness and Management Practices

Parameter	Percentage (%)
Farmers aware of silkworm diseases	75%
Use of Disease-Free Layings (DFLs)	58%
Farms practicing proper hygiene	48%
Access to diagnostic facilities	35%
Farmers reporting disease as major constraint	72%

Table 7: Overall Economic Impact Summary

Impact Category	Observation
Biological Impact	High mortality, delayed larval growth
Production Impact	20-45% reduction in cocoon yield
Quality Impact	Reduced filament length and increased defects
Economic Impact	30-60% decline in farmer income
System-Level Impact	Supply chain disruption, reduced industry output

3. Results

The study revealed a substantial impact of silkworm disease outbreaks on biological performance, cocoon production, and farmers' economic returns. Comparative analysis between healthy and infected farms demonstrated statistically significant differences across all evaluated parameters ($p < 0.05$).

3.1 Larval Performance and Mortality

Silkworm batches affected by disease outbreaks exhibited pronounced physiological stress, reflected in reduced feeding activity, sluggish movement, and delayed growth. The average larval mortality rate in infected farms ranged between 25% and 60%, significantly higher than the 5-10% observed in healthy batches. Severe outbreaks, particularly

of pebrine and grasserie, resulted in rapid larval death during later instars, leading to incomplete development and failure to spin cocoons. The larval duration in infected batches was extended by 2-4 days compared to healthy groups, indicating metabolic disruption and inefficient nutrient utilization. Farms with poor hygiene and inadequate environmental control reported the highest mortality rates, suggesting a strong correlation between management practices and disease severity.

3.2 Cocoon Yield and Productivity

Cocoon yield was significantly reduced in farms experiencing disease outbreaks. Healthy farms recorded an average yield of 60-70 kg per 100 DFLs, whereas infected farms produced only 35-50 kg per 100 DFLs, representing a reduction of approximately 20-45%. In extreme cases, where disease incidence exceeded 50%, yield losses approached 60%, with some batches failing completely. The reduction in productivity was primarily attributed to high larval mortality and poor cocoon formation among surviving larvae. Statistical analysis confirmed a strong negative correlation ($r = -0.78$) between disease incidence and cocoon yield, indicating that increased infection levels directly resulted in lower production.

3.3 Cocoon Quality Parameters

In addition to reduced yield, cocoon quality was significantly compromised in infected batches. The average cocoon weight decreased by 15-25%, while shell weight and shell ratio declined by 10-20% compared to healthy controls. A higher proportion of defective cocoons, including malformed, double, and flimsy cocoons, was observed in diseased batches. Silk filament characteristics were also adversely affected. Filament length was reduced by 20-35%, and reelability decreased from an average of 85% in healthy cocoons to 55-65% in infected samples. The denier of silk fibers increased, indicating coarser and lower-quality silk. These changes negatively impacted reeling efficiency and overall silk output.

3.4 Market Value and Price Variation

The decline in cocoon quality directly influenced market prices. Healthy cocoons fetched an average price of INR 480-520 per kg, whereas infected cocoons were sold at significantly lower prices ranging from INR 320-380 per kg, reflecting a reduction of 20-30%. Farmers reported that buyers often rejected heavily infected or defective cocoons, further reducing their income. Price variability was also observed across regions, depending on disease severity and demand-supply dynamics. Farms maintaining better quality despite minor infections were able to secure relatively higher prices, emphasizing the importance of quality preservation.

3.5 Economic Impact on Farmers' Income

Economic analysis revealed that silkworm disease outbreaks resulted in substantial financial losses. Farmers with healthy batches earned an average net income of INR 15,000-20,000 per 100 DFLs, while those affected by disease outbreaks reported significantly lower returns ranging from INR 5,000 to 10,000. This represents a decline of approximately 30-60% in net income. In severe cases of complete crop failure, farmers incurred total losses, including the cost of DFLs, feed, labor, and other inputs. The increased cost of disease

management, including disinfectants and additional labor, further reduced profitability. On average, production costs increased by 10-20% in infected farms due to these additional expenditures.

3.6 Farmer Perception and Management Practices

Survey responses indicated that approximately 72% of farmers identified silkworm diseases as the primary constraint affecting their production. Among the diseases, pebrine and grasserie were reported as the most frequent and damaging. Only 58% of farmers consistently used certified disease-free layings (DFLs), while 42% relied on local or uncertified sources, increasing the risk of infection. Farmers practicing strict hygiene measures, including regular disinfection and proper waste disposal, reported lower disease incidence and better yields. However, limited access to diagnostic facilities and lack of awareness regarding early disease detection were identified as major challenges.

3.7 Overall System Impact

The cumulative effect of silkworm disease outbreaks was reflected in reduced productivity, declining income, and increased economic vulnerability among farmers. The study also indicated that disease outbreaks have broader implications for the silk production chain, including reduced raw material supply and compromised industrial efficiency. Overall, the results clearly demonstrate that silkworm disease outbreaks significantly affect both biological performance and economic outcomes, underscoring the urgent need for effective disease management strategies.

4. Discussion

The findings of this study clearly demonstrate that silkworm disease outbreaks exert a profound influence on both biological performance and economic outcomes in sericulture systems. The significantly higher larval mortality observed in infected batches reflects the susceptibility of *Bombyx mori* to pathogenic stress, particularly under suboptimal rearing conditions. Diseases such as pebrine, grasserie, and flacherie disrupt essential physiological processes, including digestion, metabolism, and silk gland development. The prolonged larval duration recorded in infected groups further indicates impaired growth and inefficient nutrient utilization, ultimately reducing the capacity of larvae to spin healthy cocoons.

A major outcome of the study is the substantial decline in cocoon yield associated with disease incidence. The observed reduction of 20-45% in cocoon production aligns with earlier reports highlighting the vulnerability of sericulture to disease outbreaks. High larval mortality, coupled with poor cocoon formation among surviving individuals, significantly lowers overall productivity. The strong negative correlation between disease incidence and cocoon yield reinforces the direct relationship between pathogen load and production loss. This decline is particularly critical in small-scale farming systems, where even minor reductions in yield can have disproportionate economic consequences. In addition to quantity, cocoon quality was severely affected by disease outbreaks. Reduced shell weight, lower shell ratio, and increased incidence of defective cocoons indicate that infections compromise silk gland function and protein synthesis. The deterioration in silk filament characteristics, including reduced filament length and reelability, has important implications for the silk

reeling industry. Poor-quality cocoons not only fetch lower market prices but also increase processing time and reduce reeling efficiency. The increase in denier observed in infected batches suggests the production of coarser fibers, which are less desirable for high-quality textile applications. Thus, the impact of silkworm diseases extends beyond farm-level production to influence downstream industrial performance.

The economic analysis highlights the severity of financial losses incurred by farmers during disease outbreaks. The reduction in net income by up to 60% underscores the vulnerability of sericulture-dependent households. These losses are driven by both decreased revenue and increased production costs. Farmers are required to invest additional resources in disease management practices, including disinfectants, labor, and replacement of infected batches. In cases of severe outbreaks, complete crop failure results in total economic loss, placing significant financial stress on already resource-constrained farmers. This situation is particularly concerning in rural regions where sericulture serves as a primary source of livelihood.

Farmer perception and management practices emerged as critical factors influencing disease outcomes. The study revealed that a considerable proportion of farmers do not consistently use certified disease-free layings (DFLs), thereby increasing the risk of infection. Limited awareness of disease transmission mechanisms and inadequate access to diagnostic facilities further exacerbate the problem. Conversely, farms adopting improved hygiene practices and environmental control measures reported lower disease incidence and better productivity. These findings emphasize the importance of capacity building and extension services in promoting best practices among sericulture farmers. From a broader perspective, the implications of silkworm disease outbreaks extend to the entire sericulture value chain. Reduced cocoon production affects the availability of raw material for silk reeling units, leading to fluctuations in supply and market instability. Lower quality cocoons also compromise the efficiency and profitability of downstream processing industries. Therefore, addressing disease-related challenges is essential not only for improving farm-level productivity but also for ensuring the stability and sustainability of the silk industry as a whole. Overall, the study underscores the need for an integrated approach to disease management in sericulture. Preventive strategies, including the use of certified DFLs, strict hygiene maintenance, and regular monitoring, are crucial for minimizing disease incidence. In addition, strengthening farmer awareness, improving access to diagnostic tools, and providing institutional support can significantly reduce economic losses. The adoption of such measures will enhance the resilience of sericulture systems and contribute to sustainable rural livelihoods.

5. Conclusion

Silkworm disease outbreaks represent a critical challenge to the sustainability and profitability of sericulture systems. The present study demonstrates that diseases such as pebrine, grasserie, and flacherie significantly reduce larval survival, cocoon yield, and silk quality, ultimately leading to substantial economic losses for farmers. The observed decline in cocoon production, coupled with inferior quality and reduced market prices, results in a marked decrease in farmer income, often exceeding 50% under severe outbreak

conditions. In addition to direct production losses, increased costs associated with disease management further exacerbate the economic burden on farmers, particularly smallholders with limited resources. The study also highlights the importance of management practices, as farms adopting improved hygiene measures and using certified disease-free layings exhibited comparatively lower disease incidence and better productivity. These findings emphasize the need for a comprehensive and integrated disease management approach, combining preventive strategies, farmer awareness, and institutional support. Enhancing access to diagnostic facilities, promoting best rearing practices, and implementing policy-level interventions can significantly reduce the impact of disease outbreaks. Overall, strengthening disease control measures is essential to improve productivity, stabilize farmer income, and ensure the long-term sustainability of the sericulture industry.

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