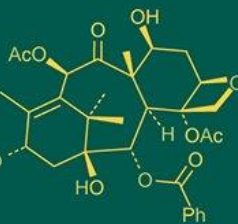
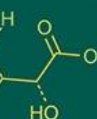
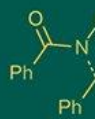


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## Seasonal impact on biological and commercial traits of PM × CSR2, FC1 and FC2 silkworm hybrids

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### Abstract

Seasonal variation significantly influences the performance of silkworm hybrids, affecting both biological and commercial traits critical for sericulture. This study evaluated the impact of different seasons (Summer, rainy, and winter) on the performance of three silkworm hybrids: PM × CSR2, FC1 and FC2. The experiment was conducted under field conditions, and key biological parameters such as larval duration, larval weight, pupation rate, and survival rate were recorded. Commercial traits including cocoon weight, cocoon yield, shell ratio, and filament length were also assessed. Results revealed significant seasonal variation in both biological and commercial traits ( $p < 0.05$ ). The winter season exhibited the best performance across all hybrids, with higher larval weight, improved survival rate (above 90%), and superior cocoon traits. The summer season negatively affected performance, leading to increased larval mortality and reduced cocoon yield. Among the hybrids, PM × CSR2 showed superior adaptability across seasons, maintaining relatively stable performance even under adverse conditions. FC1 and FC2 exhibited moderate sensitivity to seasonal fluctuations, particularly during summer. The study highlights the strong influence of environmental factors such as temperature and humidity on silkworm growth and productivity. Seasonal variations affect feeding efficiency, metabolism, and disease susceptibility, thereby influencing economic traits. The findings emphasize the importance of selecting season-specific hybrids and adopting appropriate management practices to enhance silk production. This study provides valuable insights for optimizing sericulture practices under varying climatic conditions.

**Keywords:** Silkworm hybrids, seasonal variation, cocoon yield, sericulture, PM × CSR2, climate impact

### 1. Introduction

Sericulture is a climate-sensitive agro-based industry where environmental factors play a crucial role in determining productivity and quality. The mulberry silkworm (*Bombyx mori*) is highly sensitive to fluctuations in temperature, humidity, and seasonal variations. These environmental factors directly influence biological processes such as feeding, growth, and metabolism, ultimately affecting cocoon production and silk quality.

Seasonal variation is one of the most critical abiotic factors influencing silkworm performance. In tropical and subtropical regions, silkworm rearing is carried out in different seasons, including summer, rainy, and winter. Each season presents unique environmental challenges. High temperatures during summer can lead to physiological stress, reduced feeding efficiency, and increased disease incidence. Conversely, optimal conditions during winter promote better growth, higher survival rates, and improved cocoon characteristics. Previous studies have demonstrated that silkworm hybrids show significant variation in performance across seasons due to genotype × environment interactions. Seasonal changes in temperature and humidity affect food consumption, digestion, and conversion efficiency in silkworms. Additionally, climatic factors have been shown to influence disease incidence, further impacting productivity. Silkworm hybrids such as PM × CSR2, FC1, and FC2 are widely used in sericulture due to their improved productivity and adaptability. However, their performance varies depending on environmental conditions. PM × CSR2 is known for its high yield and better adaptability, while FC1 and FC2 are valued for their cocoon quality and filament characteristics. Biological traits such as larval duration, larval weight, and survival rate are important indicators of silkworm health and growth.

Commercial traits including cocoon weight, shell ratio, and filament length determine the economic value of silk production. Understanding the seasonal influence on these traits is essential for optimizing hybrid selection and improving sericulture efficiency. This study aims to evaluate the seasonal impact on biological and commercial traits of PM × CSR2, FC1 and FC2 silkworm hybrids. The findings will help in identifying the most suitable hybrids for different seasons and contribute to sustainable sericulture practices.

## 2. Materials and Methods

### 2.1 study area and experimental design

The present study was conducted in a major sericulture region under natural environmental conditions covering three distinct rearing seasons, namely summer (April-June), rainy (July-September), and winter (October-February). The experimental site was selected based on its active involvement in mulberry sericulture and availability of standard rearing infrastructure. Seasonal climatic variations in terms of temperature and relative humidity were recorded throughout the study period using digital thermohygrometers.

The experiment was designed using a Completely Randomized Design (CRD) with three replications for each treatment. Each replication consisted of a fixed number of disease-free layings (DFLs), ensuring uniformity across treatments. The study aimed to evaluate the effect of seasonal variation on the biological and commercial performance of selected silkworm hybrids.

### 2.2 Silkworm hybrids and rearing material

Three commercially important bivoltine silkworm hybrids, namely PM × CSR2, FC1, and FC2, were selected for the study based on their widespread adoption and economic importance in sericulture. Disease-free layings (DFLs) of each hybrid were procured from a certified government grainage center to ensure genetic purity and disease-free stock.

Mulberry leaves used for feeding were harvested from well-maintained mulberry gardens grown under recommended agronomic practices. Leaves were selected based on maturity and quality, ensuring uniform feeding conditions across all treatments. Fresh leaves were supplied four times daily during the rearing period to maintain optimal nutrition.

### 2.3 Rearing procedure

Silkworm rearing was carried out following standard sericulture practices recommended by national research institutes. The rearing process was conducted separately for each season to evaluate seasonal effects.

The brushing of larvae was performed uniformly for all hybrids, and the larvae were reared in disinfected rearing trays. Proper hygiene and sanitation were maintained throughout the rearing period to minimize the risk of disease incidence. Bed cleaning was carried out regularly, and leftover leaves and excreta were removed to maintain a healthy rearing environment.

Environmental conditions such as temperature and relative humidity were maintained as close as possible to optimal levels; however, natural seasonal fluctuations were allowed to influence the rearing conditions. During summer, temperatures ranged between 32-38 °C with lower humidity levels, while winter conditions were characterized by moderate temperatures (20-25 °C) and higher humidity.

## 2.4 Parameters studied

### 2.4.1 Biological parameters

The following biological parameters were recorded to assess silkworm growth and development:

- **Larval duration (Days):** The total number of days from hatching to cocoon formation.
- **Larval weight (g):** Average weight of fifth instar larvae measured using a digital balance.
- **Survival rate (%):** Percentage of larvae surviving from brushing to cocoon formation.
- **Pupation rate (%):** Percentage of larvae successfully forming cocoons.

### 2.4.2 Commercial parameters

Commercial traits were recorded to evaluate the economic performance of each hybrid:

- **Cocoon weight (g):** Average weight of individual cocoons measured after harvest.
- **Cocoon yield (kg/100 DFLs):** Total cocoon production per 100 DFLs.
- **Shell ratio (%):** Ratio of shell weight to total cocoon weight, indicating silk content.
- **Filament length (m):** Length of silk filament reeled from individual cocoons.

All measurements were taken using standardized methods and calibrated instruments to ensure accuracy and reproducibility.

### 2.5 Data Collection and recording

Data were collected systematically for each replication and season. Observations were recorded at specific growth stages to capture variations in biological performance. Cocoon-related parameters were recorded after harvesting and drying of cocoons. All data were expressed as mean values along with standard deviation (Mean ± SD).

### 2.6 Economic analysis

An economic evaluation was conducted to assess the profitability of each hybrid under different seasonal conditions. Parameters such as cost of rearing, market price of cocoons, and net returns were considered. Economic loss due to seasonal stress was calculated by comparing cocoon yield and income across seasons.

### 2.7 Statistical analysis

The collected data were subjected to statistical analysis using software such as SPSS and Microsoft Excel. Analysis of Variance (ANOVA) was performed to determine the significance of differences among seasons and hybrids. Mean comparisons were carried out using Tukey's Honestly Significant Difference (HSD) test at a significance level of  $p < 0.05$ .

Correlation analysis was also conducted to evaluate relationships between biological and commercial traits. This helped in identifying key parameters influencing cocoon yield and overall productivity.

### 2.8 Experimental reliability

To ensure reliability and reproducibility, the experiment was conducted with multiple replications, and standard rearing protocols were strictly followed. All instruments were calibrated prior to use, and data validation procedures were implemented to minimize experimental error.

### 3. Results

The performance of silkworm hybrids PM × CSR2, FC1 and FC2 varied significantly across different seasons (summer, rainy, and winter). Seasonal fluctuations in temperature and humidity had a pronounced effect on both biological and commercial traits. Statistical analysis (ANOVA) revealed significant differences among seasons, hybrids, and their interactions ( $p < 0.05$ ).

#### 3.1 Biological traits

##### 3.1.1 Larval duration (Days)

Larval duration was significantly influenced by seasonal variation (Table 1). The shortest larval duration was recorded during winter (22-24 days), while the longest duration was observed in summer (26-29 days). Among the hybrids, PM × CSR2 showed relatively stable larval duration across seasons, whereas FC1 and FC2 exhibited greater variation.

##### 3.1.2 Larval weight (g)

Larval weight was highest during the winter season, ranging from 3.5 to 3.8 g, while the lowest values were recorded in summer (2.5-2.8 g). PM × CSR2 showed superior larval weight in all seasons, indicating better growth performance. FC1 and FC2 showed moderate reduction under stress conditions.

##### 3.1.3 Survival rate (%)

Survival rate was significantly affected by seasonal conditions. Winter recorded the highest survival rate (>90%), followed by the rainy season (80-85%), while summer showed the lowest survival (70-75%). PM × CSR2 maintained relatively higher survival across all seasons compared to other hybrids.

##### 3.1.4 Pupation rate (%)

Pupation rate followed a similar trend as survival rate, with the highest values recorded in winter (>92%) and lowest in summer (~72-78%). Significant differences ( $p < 0.05$ ) were observed among hybrids.

**Table 1:** Biological Traits of Silkworm Hybrids under Different Seasons

| Hybrid    | Season | Larval Duration (days) | Larval Weight (g) | Survival Rate (%) | Pupation Rate (%) |
|-----------|--------|------------------------|-------------------|-------------------|-------------------|
| PM × CSR2 | Summer | 26±1.2                 | 2.8±0.2           | 75±3              | 78±3              |
| PM × CSR2 | Rainy  | 24±1.0                 | 3.2±0.3           | 85±2              | 88±2              |
| PM × CSR2 | Winter | 22±0.8                 | 3.8±0.3           | 92±2              | 94±2              |
| FC1       | Summer | 28±1.3                 | 2.6±0.2           | 72±4              | 75±3              |
| FC1       | Rainy  | 25±1.1                 | 3.0±0.2           | 82±3              | 85±3              |
| FC1       | Winter | 23±0.9                 | 3.6±0.3           | 90±2              | 92±2              |
| FC2       | Summer | 29±1.5                 | 2.5±0.2           | 70±4              | 72±3              |
| FC2       | Rainy  | 26±1.2                 | 2.9±0.2           | 80±3              | 83±3              |
| FC2       | Winter | 24±1.0                 | 3.5±0.3           | 88±2              | 90±2              |

#### 3.2 Commercial traits

##### 3.2.1 Cocoon weight (g)

Cocoon weight varied significantly across seasons (Table 2). The highest cocoon weight was observed during winter (1.8-2.0 g), while the lowest was recorded in summer (1.3-1.5 g). PM × CSR2 consistently produced heavier cocoons across all seasons.

##### 3.2.2 Cocoon yield (kg/100 DFLs)

Cocoon yield was highest in winter (65-75 kg/100 DFLs), followed by rainy season (55-65 kg), and lowest in summer (40-50 kg). PM × CSR2 recorded the highest yield across all seasons, while FC2 showed the lowest yield under stress conditions.

##### 3.2.3 Shell ratio (%)

Shell ratio, an important indicator of silk content, was highest during winter (20-22%) and lowest during summer (16-18%). Seasonal variation significantly influenced silk quality.

##### 3.2.4 Filament length (m)

Filament length was significantly affected by seasonal conditions. The longest filament length was recorded in winter (900-1100 m), while summer resulted in reduced filament length (700-850 m).

**Table 2:** Commercial Traits of Silkworm Hybrids under Different Seasons

| Hybrid    | Season | Cocoon Weight (g) | Cocoon Yield (kg/100 DFLs) | Shell Ratio (%) | Filament Length (m) |
|-----------|--------|-------------------|----------------------------|-----------------|---------------------|
| PM × CSR2 | Summer | 1.5±0.1           | 50±3                       | 18±1            | 850±50              |
| PM × CSR2 | Rainy  | 1.7±0.1           | 65±4                       | 20±1            | 950±60              |
| PM × CSR2 | Winter | 2.0±0.2           | 75±5                       | 22±1            | 1100±70             |
| FC1       | Summer | 1.4±0.1           | 45±3                       | 17±1            | 800±50              |
| FC1       | Rainy  | 1.6±0.1           | 60±4                       | 19±1            | 900±60              |
| FC1       | Winter | 1.9±0.2           | 70±4                       | 21±1            | 1050±70             |
| FC2       | Summer | 1.3±0.1           | 40±3                       | 16±1            | 750±50              |
| FC2       | Rainy  | 1.5±0.1           | 55±3                       | 18±1            | 850±60              |
| FC2       | Winter | 1.8±0.2           | 65±4                       | 20±1            | 1000±60             |

#### 3.3 Seasonal Performance Comparison

Overall, winter season provided the most favorable conditions for silkworm growth and cocoon production, followed by the rainy season. Summer conditions negatively impacted all measured parameters due to high temperature

stress and reduced feeding efficiency.

PM × CSR2 demonstrated superior adaptability, maintaining relatively stable performance across seasons. FC1 showed moderate performance, while FC2 was the most affected by seasonal stress.

### 3.4 Statistical Interpretation

ANOVA results confirmed that seasonal variation had a highly significant effect ( $p < 0.05$ ) on all biological and commercial traits. Interaction effects between hybrids and seasons were also significant, indicating that hybrid performance is strongly dependent on environmental conditions. Post hoc analysis revealed that winter values were significantly higher than summer values across all parameters. PM  $\times$  CSR2 was statistically superior to FC2 under stress conditions.

### 4. Discussion

The present study clearly demonstrates that seasonal variation exerts a profound influence on both biological and commercial traits of silkworm hybrids, highlighting the sensitivity of sericulture systems to environmental fluctuations. Temperature and humidity, which vary considerably across seasons, are key determinants of silkworm growth, metabolism, and productivity. The superior performance observed during the winter season indicates that moderate environmental conditions are optimal for silkworm rearing, while extreme conditions, particularly high temperatures during summer, adversely affect physiological processes and economic traits.

The reduction in larval weight and prolongation of larval duration during summer can be attributed to thermal stress, which disrupts metabolic efficiency and reduces feeding activity. Elevated temperatures are known to impair digestive enzyme activity and nutrient assimilation, leading to slower growth and lower biomass accumulation. In contrast, winter conditions provide a stable thermal environment that supports efficient food conversion and rapid larval development. This explains the significantly higher larval weight and shorter larval duration observed during the winter season. The rainy season, although relatively favorable, exhibited intermediate performance, possibly due to fluctuations in humidity and increased susceptibility to microbial infections. Survival and pupation rates were also strongly influenced by seasonal conditions, with the lowest values recorded during summer. High temperatures combined with low humidity create stressful conditions that increase larval mortality and reduce cocoon formation efficiency. Additionally, such conditions favor the proliferation of pathogens, further compromising silkworm health. The higher survival rates observed during winter reflect a more conducive environment with reduced stress and lower disease incidence. These findings emphasize the importance of maintaining optimal environmental conditions to ensure high survival and productivity in silkworm rearing.

The significant variation in commercial traits such as cocoon weight, shell ratio, and filament length further underscores the impact of seasonal factors on silk production. Cocoon weight and yield were highest during winter, which can be linked to improved larval growth and efficient nutrient utilization. The decline in cocoon weight during summer suggests that stress conditions limit the accumulation of silk proteins, resulting in lighter cocoons. Similarly, shell ratio, which is a critical indicator of silk quality, was adversely affected under stress conditions, reflecting reduced silk deposition. Filament length, an important commercial parameter determining silk quality and market value, also showed significant seasonal variation. The longer filament length observed during winter

indicates better silk gland development and efficient protein synthesis under favorable conditions. In contrast, shorter filament length during summer suggests impaired silk production due to environmental stress. These findings are consistent with previous studies that have reported the negative impact of high temperature on silk gland physiology and fibroin synthesis.

Among the hybrids evaluated, PM  $\times$  CSR2 exhibited superior performance across all seasons, indicating its adaptability to varying environmental conditions. This hybrid maintained relatively higher survival rates, larval weight, and cocoon yield even under summer stress, suggesting the presence of inherent genetic traits that confer resilience. The ability of PM  $\times$  CSR2 to maintain stable performance may be attributed to efficient metabolic regulation, better stress tolerance mechanisms, and improved utilization of mulberry leaves. In contrast, FC2 showed the highest sensitivity to seasonal stress, with significant reductions in both biological and commercial traits. FC1 exhibited intermediate performance, indicating moderate adaptability. The observed genotype  $\times$  environment interaction highlights the importance of selecting appropriate hybrids for specific seasonal conditions. Hybrids that perform well under optimal conditions may not necessarily maintain their performance under stress, emphasizing the need for evaluating their stability across environments. The consistent performance of PM  $\times$  CSR2 suggests that it is a suitable candidate for year-round cultivation, particularly in regions experiencing climatic variability.

The results also indicate that seasonal stress not only affects biological efficiency but also has direct economic implications. Reduced cocoon yield and quality during unfavorable seasons can significantly impact farmers' income and the overall profitability of sericulture. Therefore, understanding the seasonal performance of different hybrids is essential for optimizing production strategies and minimizing economic losses. Adoption of season-specific rearing practices, such as temperature regulation, humidity control, and improved feeding management, can help mitigate the adverse effects of environmental stress. Furthermore, the findings of this study emphasize the need for developing climate-resilient silkworm hybrids through selective breeding and genetic improvement programs. Incorporating traits such as heat tolerance, disease resistance, and efficient nutrient utilization can enhance the adaptability of silkworms to changing environmental conditions. Advances in molecular biology and genomics offer promising tools for identifying stress-responsive genes and developing improved hybrids. In addition to genetic approaches, improved management practices play a crucial role in enhancing silkworm performance under seasonal stress. The use of environmental control systems, such as temperature and humidity regulators, can help create optimal rearing conditions even during adverse seasons. Proper sanitation, disease management, and quality feeding are also essential components of successful sericulture. Overall, the study provides comprehensive insights into the seasonal dynamics of silkworm performance and highlights the critical role of environmental factors in determining productivity and quality. The findings underscore the importance of integrating genetic and management strategies to improve resilience and sustainability in sericulture systems. As

climate change continues to alter environmental conditions, adaptive approaches will be essential to ensure the long-term viability of the silk industry. The results contribute to a better understanding of how seasonal variation influences silkworm biology and commercial traits, providing a scientific basis for optimizing hybrid selection and rearing practices. By identifying hybrids with superior adaptability and understanding their response to environmental stress, it is possible to enhance productivity, improve silk quality, and ensure economic stability for sericulture farmers.

## 5. Conclusion

The study concludes that seasonal variation has a significant impact on biological and commercial traits of silkworm hybrids. Winter season provides the most favorable conditions for silkworm rearing, while summer poses significant challenges. Among the hybrids, PM × CSR2 demonstrated superior adaptability and consistent performance across seasons, making it suitable for year-round cultivation. FC1 and FC2 performed well under favorable conditions but were more sensitive to environmental stress. The findings emphasize the need for season-specific hybrid selection and improved management practices to enhance silk production. Adoption of climate-resilient hybrids and optimized rearing strategies can ensure sustainable sericulture under changing climatic conditions.

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