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Review Article

Impact of climate change on silkworm rearing and mitigation strategies

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Climate change significantly influences silkworm growth and development, including larval duration, mortality, hatching, moulting, and post-cocoon parameters such as cocoon weight, pupation, shell weight (g), and shell ratio (%). Day-to-day and seasonal changes in temperature, aeration, light, and relative humidity are important for effective environmental condition management to ensure sustainable silkworm rearing. This paper highlights the impact of climate change on the growth and development of silkworms. It also outlines practical mitigation strategies that farmers can adopt to protect rearing houses from climate change. Additionally, it proposes future safeguarding measures, including low-cost methods and advanced IoT, AI, and climate-resilient techniques for managing climatic conditions in rearing houses to achieve successful silkworm rearing.

Keywords: *silkworm rearing, cocoon weight, pupation, shell weight, environmental condition*

Introduction

Sericulture is the rearing of silkworms to produce silk in various aspects. Silk, often referred to as the “queen of textiles,” is valued for its radiant lustre, elegance, durability, softness, and tensile strength. Silk is produced from silkworm larvae and is a natural protein obtained from the cocoons they spin. Owing to its exceptional qualities, silk possesses water absorbency, dyeing efficiency, heat resistance, and sheen, making it superior to most other fibres. Among the various environmental factors influencing insect physiology, temperature and humidity play dominant roles. Despite fluctuations in external conditions, many insects exhibit remarkable adaptability, maintaining temperature and water balance within their bodies within certain tolerable limits (Nath, 2025). This adaptive capacity varies widely among species and involves complex mechanisms, including dispersal, developmental rates, habitat selection, water regulation, diapause, cold resistance, sensitivity to environmental cues, and the production of cryoprotective substances (Kumar et al., 2024). The mulberry silkworm is a domesticated species that has been reared for over 5000 years, rendering it extremely sensitive to different environmental conditions. Unlike non-mulberry silkworms, the mulberry silkworm cannot withstand extreme fluctuations in temperature or humidity. Environmental factors such as humidity, air, temperature, light, and gas composition interact intricately and influence the physiology, development, growth, productivity, and silk quality produced by silkworms (Sarkhel et al., 2017). It is the most economically significant domesticated silkworm, producing luxurious silk in the form of cocoons through the rearing of silkworms. Its growth and development are highly influenced by environmental factors such as temperature, seasons, humidity, quality of leaves, and the genetic makeup of the breeds. Seasonal variations significantly affect the performance of the mulberry silkworm through the expression of genetic traits and phenotypic characteristics such as cocoon weight, shell weight, and shell ratio. The environmental changes observed in recent years highlight the importance of managing temperature and relative humidity in the rearing house to ensure sustainable silkworm rearing (Kumar et al., 2001). Sericulture in India is traditionally practiced in tropical regions such as Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, and the eastern regions, and to a smaller extent in the temperate climate of Jammu and Kashmir (Taufique & Hoque, 2021). The tropical conditions favour the commercial rearing of Multivoltine × Bivoltine hybrids, which are hardy and capable of thriving under fluctuating climatic conditions. Unlike multivoltine races, bivoltines are more susceptible to environmental stress, poor leaf quality, and suboptimal rearing practices, especially during summer, making them difficult to rear for small-scale farmers with limited resources (Rahmathulla, 2012). Climatic stress (heat, humidity, or cold) severely impacts silkworm physiology. It disrupts cellular homeostasis by inducing oxidative damage, altering hormonal signaling (Juvenile Hormone/20-hydroxyecdysone), and triggering molecular defense pathways such as the expression of Heat Shock Proteins to ensure survival and maintain silk production (Kaushik et al., 2025). Climate-resilient sericulture blends biotechnology and digital automation to protect silk production from climate change. By utilizing heat-tolerant breeds, IoT environmental sensors, and AI predictive models, farmers can mitigate crop loss, enhance leaf quality, and maintain optimal rearing conditions for mulberry silkworms (Dhanapriya, 2025).

With rising global temperatures, uneven rainfall patterns, droughts, and changing weather conditions, traditional sericulture practices are being affected by climatic challenges. This paper explores the climate-related challenges in sericulture and the strategies for safeguarding rearing houses from these adverse conditions.

Effect of temperature on rearing of silkworms

Temperature plays a major role in the growth and development of silkworms throughout their life cycle. Being cold-blooded organisms, silkworms are highly sensitive to temperature variations, which directly influence their internal growth activities. Generally, early instar larvae tolerate higher temperatures better, which contributes to improved survival rates and enhanced cocoon quality (Hazarika et al., 2023). There is a direct correlation between temperature and silkworm growth; however, wide variations are detrimental to their development. As temperature rises, metabolic and physiological processes accelerate; conversely, a drop in temperature slows these activities. Elevated temperatures during the later instars speed up larval growth and shorten the rearing period, while cool temperatures slow growth and prolong larval duration (Hussain et al., 2011).

Table 1. Optimum environmental conditions for silkworm (*Bombyx mori* L.) rearing

Environmental factors	Temperature (° C)	Relative Humidity (%)
Incubation	25	75-80
1st instar	28	85-90
2nd instar	27	85
3rd instar	26	80
4th instar	25	70-75
5th instar	24	65-70
Spinning	25	70
Cocoon preservation	25	80

The optimum temperature for silkworm growth ranges from 20°C to 28°C, with maximum productivity observed between 23°C and 28°C. when temperatures increase by 30°C, its adversely affect silkworm health and below 20°C retard physiological processes, particularly in early instars, making the larvae weak and more prone to diseases. Early instar larvae require relatively higher temperatures for active feeding and vigorous growth, which enhances their ability to tolerate stress during later developmental stages. The specific temperature requirements for different instars are presented in Table 1. During winter and rainy season, room temperatures often drop and must be regulated to maintain optimal conditions for silkworm rearing. This can be done by using electric room heaters or charcoal fires, and thermoregulator-fitted electric room heaters are ideal for maintaining consistent temperatures without emitting harmful gases. However, in rural areas where electricity is either expensive or unavailable, well-dried charcoal may be used as an alternative source. But as charcoal combustion releases carbon dioxide and other gases that can harm silkworms, adequate ventilation, especially during the daytime, is essential to ensure proper air circulation (Kaushik et al., 2025).

At night, windows and doors need to be kept closed to retain warmth. As outdoor temperatures rise later in the day, they need to be opened to allow warm air to enter the rearing room. During the summer, when daytime temperatures are high, windows should remain open to facilitate airflow, and covering windows and doors with gunny cloth along with spraying water during hot days helps to reduce room temperature and increase humidity. Alternatively, air coolers may be used to maintain favorable environmental conditions in the rearing house for silkworm rearing (Sekarappa &

Gururaj, 2009). The success of the silkworm rearing is influenced by several factors, particularly environmental conditions with both abiotic and biotic factors playing important role. Among the abiotic factors, temperature is significant determinants of silkworm growth and productivity (Manisankar et al., 2008). Several studies have reported that quality cocoons are produced within a temperature from 22 to 27°C, while quality declines beyond this range. Polyvoltine breeds, traditionally reared in tropical regions, can tolerate small increasing temperatures and have adapted to such climatic situations (Rahmathulla,1999). High temperatures negatively impact the most biological activities by altering biochemical and physiological reactions, which in turn affects cocoon yield and silk quality. Research findings documented that silkworms are highly sensitive to elevated temperatures during the 4th and 5th instars (Zhuo et al., 2025). But, most economically important genetic characters of silkworms are qualitative, their phenotypic traits are highly impacted by environmental conditions such as temperature, humidity, air, light, and nutrition (Vijaya Kumari et al., 2001).

Influence of humidity on rearing of silkworms

Humidity plays a major role in rearing of silkworms, influencing the process both directly and indirectly. Along with temperature, it significantly affects the overall development and growth of silkworms and quality of cocoons produced. Humidity directly impacts the physiological functions of silkworms. Chawki larvae tolerate high relative humidity better than late instar larvae, and this conditions, their growth tends to be more vigorous (Gupta & Dubey, 2021). The suitable humidity levels for different larval stages are presented in Table 1. Indirectly, relative humidity also affects drying of mulberry leaves in beds of rearing. During summer seasons, leaves lose moisture quickly, reducing larval consumption and leading to slower growth, increased leaf wastage, and greater susceptibility of young larvae to diseases. When humidity is maintained at 90% or higher and temperature between 26°C and 28°C, silkworms can grow without major stress. However, humidity fluctuates considerably, between the seasons or within a single day, proper regulation is essential for successful rearing (Pandey & Tripathi, 2008).

To maintain adequate humidity during chawki rearing, rearing beds may be covered with paraffin coated paper to prevent leaf drying. Alternatively, wet foam pads or water-soaked paper pads may be used to raise humidity. Progressive farmers often used humidifiers equipped with humidistats for more precise control in rearing house (Harsha et al., 2024). It is observed, that humidity is reduced to 70% or below during each instar stage to ensure uniform and healthy moulting. Water constitutes a major proportion of an insect's body, and survival depends on maintaining internal water balance (Lakshminarayana et al., 2002). Although there is no fixed optimal humidity range, most insects can thrive at various humidity levels if they can regulate their water balance effectively. Studies have examined that high humidity affects larval weight in silkworms, revealing that the water content can range from below 50% to over 90% of total body weight, even within the same species reared under same conditions (Sisodia & Gaherwal, 2017). Environmental factors especially humidity, temperature, and the moisture content of mulberry leaves strongly affect the silkworm growth (Bhat et al., 2024).

Effect of air and light on silkworm rearing

Silkworms require a constant supply of fresh air for respiration and during respiration, silkworms release carbon dioxide (CO_2) into the rearing environment, and the freshness of air can be gauged by its CO_2 concentration. Under normal conditions, the atmospheric CO_2 level in the rearing room is around 0.03–0.04%. However, when farmers use charcoal fires to increase room temperature, gases such as carbon monoxide, ammonia, and sulfur dioxide are also produced, which are harmful to silkworms. Hence, maintaining proper ventilation is essential to dilute these toxic gases and ensure a healthy atmosphere (Manzoor & Qayoom, 2024). If CO_2 levels rise above 2%, silkworm growth becomes stunted. Insecticides and strong disinfectants need to be avoided in the rearing room, as chawki larvae are highly sensitive to poisonous fumes. Artificial air circulation is highly effective in reducing contamination, and studies have shown that maintaining an air current of about 1.0 m/sec during the fifth instar lowers larval mortality while improving ingestion, digestion, larval weight, pupation rate and cocoon weight, compared to damp air conditions (Ashrith et al., 2025). Silkworms are photosensitive creatures with a natural tendency to move toward dim light. They avoid both intense light and complete darkness. Continuous exposure to light slows down their growth, causes pentamoulting, and reduces both larval and cocoon weights. The ideal lighting condition for silkworm rearing is dim light ranging from 15 to 20 lux. Late-age larvae perform better under a 16 hours light and 8 hours dark cycle, whereas chawki larvae thrive with 16 hours of darkness and 8 hours of light. Although silkworms do not adopt strong light and total darkness, the presence of light generally stimulates larval activity compared to dark phases (Sujatha et al., 2024). Silkworms exhibit positive phototaxis, meaning they are naturally attracted to light. When larvae are reared in complete darkness throughout their lifecycle, they exhibit longer larval durations and produce cocoons of inferior quality (Iqbal et al., 2008). Similarly, rearing under constant light or darkness disrupts normal growth and moulting patterns. Generally, the light phase prolongs larval duration compared to the dark phase. The combined effects of temperature and light on silkworm growth and development have been extensively studied (Ram et al., 2016).

Physiological and molecular adaptations

Silkworms are poikilothermic (ectothermic) insects, meaning their body temperature fluctuates directly with ambient conditions. Mild to moderate thermal stress initially increases oxygen consumption and metabolic rates. However, extreme heat causes a mismatch between oxygen demand and tissue delivery, ultimately forcing metabolic depression (Jena et al., 2013). Silkworms adapt by altering cuticular lipid composition to minimize transpiratory water loss. The energy usually dedicated to the silk gland and larval growth is rapidly reallocated toward baseline survival and cellular repair, resulting in decreased cocoon weight and filament length (Zhuo, et al., 2025). Thermal and climatic extremes disrupt the electron transport chain, causing a toxic accumulation of intracellular Reactive Oxygen Species. They prevent oxidative damage to lipids, DNA, and proteins, silkworms activate a coordinated cascade of antioxidant enzymes such as Superoxide Dismutase and Catalase, Glutathione S-transferase. Oxidative stress triggers the activation of the transcription factor *Nrf2*, which in turn upregulates the expression of cytoprotective proteins to clear ROS and repair damaged macromolecules (Jianfang et al., 2025). The genomic level, silkworms mount rapid plastic and genetic responses to survive extreme climates. When cellular proteins begin to unfold and denature under thermal stress, HSPs act as molecular chaperones to refold proteins and prevent aggregation. As a major blood sugar, trehalose acts as an osmoprotectant and cryoprotectant, stabilizing cellular membranes and preventing cold or heat-induced denaturation. Recent research indicates that heat and humidity stress can trigger DNA methylation and autophagy, which act to protect the genome and alter stress-responsive gene expression (Talukdar et al., 2025).

Climate-resilient sericulture

Climate-resilient sericulture blends biotechnology and digital automation to protect silk production from climate change. By utilizing heat-tolerant breeds, IoT environmental sensors, and AI predictive models, farmers mitigate crop loss and maintain optimal rearing conditions for mulberry silkworms. Research and development focus on crossbreeding silkworm strains with improved heat shock protein expression, allowing them to withstand extreme temperatures without mortality spikes. New breeds and hybrids are genetically engineered to resist climate-induced pathogens like grasserie and flacherie, which thrive in humid conditions. Regions such as West Bengal and Karnataka are focusing on robust multivoltine x bivoltine hybrids that adapt well to fluctuating seasonal temperatures (Dhanapriya, 2025). IoT sensor networks monitor rearing rooms in real-time for temperature, humidity, light, and CO_2 levels. Connected actuators and automated systems trigger heaters, coolers, and humidifiers to maintain optimal microclimates. Artificial Intelligence models analyze historical and real-time environmental data to forecast silkworm growth rates and pre-emptively identify conditions ripe for disease outbreaks.

Conclusion

Climate changes influence multifaceted and depth challenges to sericulture, in facts of both mulberry cultivation and rearing of silkworm. Changes in temperatures, uneven rainfall, and high disease incidence directly affect the silkworm rearing, yield and quality of the cocoons. To mitigate the effects, adaptive strategies such as modified rearing rooms, humidifiers, air coolers, room heaters and few low-cost available methods are essential to safeguarding the rearing houses from the climate change. Innovations in rearing of silkworms including heat resistant breeds, IoT, AI predictive models, climate resilient techniques, for maintain the environmental conditions also hold promise.

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Author contributions

The authors were equally contributed to writing this manuscript.

Competing interest

The authors declare that, no competing interest.

Ethics approval

Not applicable.

AI Tool Usage Declaration

We declare that, we did not used any AI tool for writing manuscript. The authors were only utilized the AI tool Grammarly for improving the readability and spell check.

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