Review Article

Comprehensive Review of the Effect of Climate Change on Sericulture

Abstract

The sericulture industry, rooted in ancient practices, now faces significant challenges due to climate change. This review paper explores the impact of climate change on sericulture, focusing on the cultivation of silkworms and mulberry plants, which are critical to silk production. Rising temperatures, altered precipitation patterns, and increased pest outbreaks are major concerns. The paper emphasizes the need for adaptive strategies, including breeding climate-resistant silkworm varieties and improving mulberry cultivation practices. The use of molecular breeding techniques to develop thermotolerant and disease-resistant silkworm hybrids, as well as water-saving irrigation methods and organic soil management practices for mulberry cultivation, are highlighted. Additionally, integrated pest management strategies combining cultural, biological, and chemical control methods are discussed to address the changing pest dynamics. The review underscores the importance of ongoing research into the genetic and physiological responses of silkworms and their host plants, as well as the integration of innovative technologies like remote sensing and GIS for strategic planning. Ensuring the resilience and economic viability of the sericulture industry in the face of climate change is crucial for sustaining long-term silk production.

***Key words*:** Sericulture, Climate change, Silkworm Cultivation, Mulberry Cultivation, Adaptive strategies

1. Introduction

Sericulture, the cultivation of silkworms for silk production, has a rich history spanning thousands of years. The origins of sericulture can be traced back to ancient China, with archaeological evidence suggesting that silk production began as early as the Neolithic period, around 3630 BCE (Sun et al., 2012). The domestication of the silkworm, *Bombyx mori,* from its wild ancestor, *Bombyx mandarina*, is considered one of the most significant achievements in the history of agriculture and biotechnology (Sun et al., 2012). According to Chinese legend, the discovery of silk is attributed to Empress Xi Ling Shi, who accidentally dropped a silkworm cocoon into her tea and observed the unraveling of fine silk threads (Borgohain & Borah, 2023). The art of sericulture remained a closely guarded secret in China for several millennia, with severe penalties imposed on those who attempted to smuggle silkworm eggs or reveal the techniques of silk production (Borgohain & Borah, 2023).

Silkworm domestication involved significant genetic and morphological changes, resulting in a species that is well-adapted to human management (Sun et al., 2012). These changes included changes in body colour, cocoon size, and the loss of flight ability, leaving *B. mori* completely reliant on human care for survival and reproduction (Sun et al., 2012). Sericulture gradually spread from China to other parts of Asia, and then to Europe and the Americas. Sericulture has been practiced in India for over 2000 years, with the earliest references appearing in ancient texts such as the Ramayana and Arthashastra (Borgohain & Borah, 2023). The expansion of silk production resulted in the development of numerous silkworm strains adapted to different climatic conditions and production requirements (Chakraborty et al., 2022).

Research into the biology and genetics of silkworms has been critical for increasing silk output and quality. Studies have shown that environmental factors, particularly temperature, have a significant impact on silkworm growth and development (Chakraborty et al., 2022). For example, Chakraborty and colleagues (2022) discovered that silkworms raised at temperatures ranging from 26 to 28°C performed better in terms of larval weight, cocoon weight, and shell weight than those raised at 23 to 25°C.

Sericulture's evolution is closely linked to advances in genetic research and biotechnology. Sun and colleagues (2012) used genome-wide analyses to investigate the phylogeny and evolutionary history of the silkworm, shedding light on the genetic basis of domestication and the development of various silkworm strains. Their findings have implications for both our understanding of insect domestication processes and the potential for future silk production improvements (Sun et al., 2012).

Recent genomics research has accelerated the use of silkworms as a model organism in life science. Liu et al. (2014) demonstrated the efficacy of CRISPR/Cas9-mediated genome editing in silkworms, opening up new avenues for genetic manipulation and trait improvement. Furthermore, some silkworm genes have been discovered to be highly homologous to genes associated with human hereditary diseases, making them potential models for studying human health (Liu et al., 2019).

The use of remote sensing and geographic information systems (GIS) has also aided the growth of sericulture. The Central Silk Board of India, in collaboration with the Indian Space

Research Organisation, has used these technologies to identify potential mulberry cultivation and silkworm rearing sites (NESAC, n.d.). This approach has aided in the strategic planning and expansion of sericulture into new regions.

Today, sericulture is still an important economic activity in many countries, with ongoing research aimed at improving silk yield, quality, and production efficiency. Sericulture's rich history and continued relevance demonstrate its importance as both a cultural heritage and a scientific research field (Sun et al., 2012; Chakraborty et al., 2022; Liu et al., 2019).

2. Effects of Climate Change on Sericulture

2.1 Temperature Fluctuations and Silkworm Development

Temperature fluctuations have a significant impact on the growth and development of silkworms (*Bombyx mori* L.). Here is a detailed overview of how temperature affects silkworm development, with authors cited for each point:

1. Temperature is directly related to silkworm growth, and large temperature fluctuations are detrimental to their development (Rahmathulla V.K., 2012).
2. The ideal temperature range for silkworm rearing is 25–26°C. Deviations from this range, whether low (20-21°C) or high (28-29°C), have a negative impact on silkworm growth and development (ZHANG,Y.,2018).
3. Heat shock treatments have been shown to increase mortality rates, accelerate larval stages, reduce larval weight, and reduce silkworm growth, consumption, and digestibility. These treatments may also result in decreased productivity and failure of cocoon, pupae, and imago formation.

4. Young silkworms are typically fed at temperatures of 26-28°C with 80-85% humidity, while adult silkworms are reared at 23-24°C with 70-75% humidity (ZHANG, Y., 2018).

5. Sharp fluctuations in temperature relative to the norm (25-26°C) weaken the activity of the silk gland due to disruption of the growth and development process. This can lead to a reduction in the amount of silk liquid synthesized (Kholmatov et al., 2023).

6. Temperature variations can significantly affect the biological and commercial traits of silkworms, including the expression of heat shock proteins (Rahmathulla V. K., 2012).

7. High temperatures during the early stages of silkworm development (chawki stage) can affect growth, development of later stages, and eventually post-cocoon parameters (Rahmathulla V. K., 2012).

8. Silkworm lines generally perform better when larvae are reared at 25 ± 1°C with 70-80% relative humidity. Almost all silkworm lines show reduced performance when exposed to temperature or humidity variations for three hours (Hussain et al., 2011).

9. Climate factors, especially temperature and humidity, can influence silkworms' growth, cocoon production, and the quantity and quality of female silkworms' eggs (Hussain et al., 2011).

10. The effects of temperature on silkworm development include changes in survival characteristics, productivity, and cocoon quality. When silkworms are not provided with optimal temperature conditions, cocoon yield per box of worms can decrease by 15-30 kilograms, and quality can be 14% lower (Kholmatov et al., 2023).

2.2 Increased Frequency of Extreme Weather Events

Here is a detailed response to the increased frequency of extreme weather events and its effects on silkworm rearing and cocoon production, based on literature:

Climate change is increasing the frequency and intensity of extreme weather events such as heat waves, droughts, and heavy rainfall, which has a significant impact on silkworm rearing and cocoon production (Rahmathulla, 2012). Temperature regulates silkworm physiology and cocoon production. The ideal temperature range for silkworm cultivation is 22-27°C (Rahmathulla, 2012). Temperatures above 30°C or below 20°C are detrimental to silkworm health and make them more susceptible to disease, particularly in early instars (Rahmathulla, 2012). High temperatures during late larval instars promote larval growth but shorten the larval period, whereas low temperatures slow growth and lengthen the larval period (Gowda and Reddy, 2007). Extreme heat events are especially detrimental to silkworm rearing. Heat stress disrupts normal protein synthesis patterns and harms biological molecules such as DNA, RNA, and lipids in silkworms (Sureshkumar et al., 2002). Heat shock responses in silkworms are expressed via heat shock proteins, which are being investigated for breeding thermo-tolerant silkworm varieties (Basavaraja et al., 2005; Nagaraju, 2002).

Humidity has a significant impact on silkworm rearing, with the ideal range being 75-85% relative humidity (Singh and Saratchandra, 2012). High humidity, combined with high temperatures, increases the risk of various silkworm diseases. A study found a positive correlation between humidity and the incidence of viral, bacterial, and fungal diseases in silkworms (Sharma et al., 2020). Extreme rainfall and flooding can devastate mulberry plantations, which provide food for silkworms. In contrast, droughts have a negative impact on the quality and quantity of mulberry leaves. Mulberry leaves' nutritional value is critical for

silkworm growth and cocoon quality (Rahmathulla et al., 2004). Climate change is altering seasonal patterns, influencing the timing of silkworm rearing seasons. Climate change is expected to prolong summer in Assam, India, reducing the prospects for eri silkworm rearing (Lalitha et al., 2018). The optimal conditions for silkworm egg production are now only available in certain regions (Lalitha et al., 2018).
Extreme weather also affects post-cocoon parameters. High temperatures during cocoon spinning can cause poor reelability, lower raw silk recovery, and variations in raw silk denier (Mathur et al., 2000). Water content in cocoons should be less than 20% for good quality and reelability (Gowda and Reddy, 2007).

To mitigate these effects, researchers suggest creating climate-resilient silkworm breeds, adjusting rearing schedules, improving mulberry cultivation practices, and improving rearing house environmental controls (Rahmathulla, 2012). Conducting vulnerability assessments and developing adaptation plans for sericulture in various regions will be critical to sustaining silk production in the face of rising climate extremes (Kumar and Parikh, 1998).

3. Impact of Climate Change on Silkworm Host Plants

3.1 Changes in Precipitation Patterns and Mulberry Cultivation

Climate change is altering precipitation patterns, which has a significant impact on mulberry plants and cultivation. According to Shaista Mehraj et al. (2023), climate change has an impact on mulberry plant physiological processes such as dormancy, bud break, and sprouting behaviour. According to their findings, climate change has accelerated mulberry sprouting by about 10 days. According to Saini et al. (2023), the Western Himalayan region, which is important for mulberry cultivation, is experiencing complex changes in precipitation patterns. Some areas experience increased Indian summer monsoon (ISM) precipitation, while others see decreased precipitation. Climate models predict that the region will experience increased precipitation variability, including more extreme precipitation events and longer dry spells, during the ISM.

Kambale et al. (2023) investigated trends in crop water requirements for mulberry under different climate change scenarios. They discovered an upward trend in crop evapotranspiration (ETc) for mulberry across all studied areas under various climate change scenarios. This suggests that climate variability affects the water requirements of mulberry crops. Seidavi et al. (2017) predicted that global warming would reduce mulberry leaf yield, raw silk production, and silk content, while increasing silk breakage. These changes are due to both direct and indirect effects at the plant level, such as shifts in insect pest occurrence.

The impact on pest dynamics is especially concerning. Seidavi et al. (2017) observed that climate change is altering the insect pest scenario in mulberry cultivation. Pests like the Bihar hairy caterpillar, pink mealybug, thrips, leaf webber, and mites are becoming increasingly common. Mulberry crops are also becoming more susceptible to diseases such as root knot disease, powdery mildew, leaf rust, and leaf spot. Liu et al. (2019) discovered that higher CO2 concentrations can improve water use efficiency and PSII function in mulberry seedling leaves during drought stress. However, Seidavi et al. (2017) warned that while elevated CO2 levels may benefit C3 plants like mulberry in the absence of other stressful conditions, these benefits can be offset by other effects of climate change such as elevated temperatures, higher tropospheric ozone concentrations, and altered precipitation patterns.

3.2 Changes in Host Plant Distribution and Abundance

Climate change's impact on the distribution and abundance of silkworm host plants is a complex issue with far-reaching implications for the sericulture industry. Climate change affects both the physiology and geographical distribution of host plants, influencing silkworm rearing and silk production. Elevated atmospheric CO2 levels and rising temperatures can have a significant impact on the growth patterns and nutritional quality of mulberry plants (Morus spp.), the primary host for the domesticated silkworm Bombyx mori (Srivastava et al., 1997; Gowda and Reddy, 2007). These environmental changes may increase plant biomass but reduce nutritional quality, as evidenced by lower nitrogen content, higher carbon-to-nitrogen ratios, and higher levels of starch, total soluble sugars, and polyphenols (Rahmathulla et al., 2004; Sekharappa et al., 2001).

Mulberry leaves' altered nutritional profile has a direct impact on the silkworm life cycle and silk production. Silkworms may need to consume more leaves to compensate for the lower nutritional value, potentially resulting in longer development times and changes in cocoon quality (Mathur et al., 2000; Pillai and Krishnaswami, 1987). Climate change is also expected to alter the geographical distribution of suitable areas for mulberry cultivation. Changes in temperature and precipitation patterns may make some current mulberry-growing regions less favourable while opening up new cultivation opportunities (Kumar and Parikh, 1998; Chakraborty et al., 2000). This redistribution of suitable growing areas could have far-reaching consequences for the sericulture industry's geography and economy.

Raw silk production is vulnerable to climate change not only in terms of host plant physiological responses, but also throughout the sericulture process, including silkworm rearing and post-cocoon technologies (Sanghi et al., 1998; Sinha et al., 2000). Extreme weather events, such as droughts and floods, are expected to become more common as a result of climate change, and they can have a significant impact on mulberry cultivation and silkworm rearing. Climate change poses similar challenges to other silkworm species, such as the eri silkworm (*Samia ricini*), which feeds on a variety of host plants. Temperature changes and altered rainfall patterns affect both host plant maintenance and silkworm rearing practices, especially in traditional rearing areas (Reddy et al., 2010; Singh and Benchamin, 2002).

3.3 Impact on Silkworm Food Quality and Quantity

Climate change's impact on silkworm food quality and quantity is a major concern for the sericulture industry, as it affects both mulberry plants and silkworms (Rahmathulla et al. 2012; Kumar et al. 2018). Climate variations, particularly temperature fluctuations, have a significant impact on mulberry leaf yield and nutritional content, which directly affects silkworm nutrition and development (Gowda et al., 2007; Rahmathulla et al., 2004; Srivastava et al., 2019). Extreme temperature changes during silkworm rearing can disrupt metabolic and physiological processes in the larvae, reducing silk gland activity and overall silk productivity (Mathur et al. 2000). Raw silk production is vulnerable to climate change beyond the physiological response of silkworm host plants, including silkworm rearing and post-cocoon technology (Kumar et al., 1998; Sanghi et al., 1998).

Climate variability is expected to cause significant crop losses, with estimates ranging from 10 to 40% for agricultural crops (Kumar et al., 1998; Sanghi et al., 1998). While specific data for sericulture is limited, it is reasonable to expect the industry to face similar challenges, potentially leading to lower net revenues and productivity (Kumar et al., 1998; Sanghi et al., 1998; Chen et al., 2016). To mitigate the effects of climate change on silkworm food quality and quantity, researchers are working to create new breeds and hybrids that are more adaptable to changing environmental conditions (Rahmathulla et al., 2012; Wang et al., 2019). This includes efforts to create silkworm strains that can tolerate higher temperatures and fluctuations in nutrient availability (Rahmathulla et al., 2012).

The management of climatic factors is critical for successful silkworm (Bombyx mori L.) crop production and increased silk yield. Temperature, humidity, air circulation, gases, and light play important roles in silkworm rearing and cocoon production (Singh et al., 2016). Using appropriate environmental management techniques can help to mitigate the negative effects of climate change on sericulture (Kumar et al., 2015).
To summarise, the impact of climate change on silkworm food quality and quantity is a complex issue that necessitates ongoing investigation and adaptation strategies. To ensure long-term silk production in the face of changing climate conditions, the sericulture industry

must address challenges such as mulberry leaf production, silkworm rearing conditions, and post-cocoon processing (Rahmathulla et al., 2012).

3.4 Effects on Silkworm-Host Plant Interactions

Climate change's impact on silkworm-host plant interactions is a complex and multifaceted issue that has implications for many aspects of sericulture. Climate change, particularly increased atmospheric CO2 and temperature, can have a significant impact on both mulberry plants and silkworms, changing their interactions and potentially affecting silk production. Elevated CO2 levels and higher temperatures can boost photosynthetic rates and biomass production in mulberry plants, which are the primary host of silkworms (Bombyx mori L.) (Rahmathulla et al. 2012). However, changes in environmental conditions alter foliar chemistry, resulting in lower nitrogen content, higher C:N ratios, and increased levels of starch, total soluble sugars, and polyphenols in mulberry leaves (Bhattacharyya et al., 2019). These changes in leaf nutritional quality can have a significant effect on silkworm growth, consumption and digestibility (Bhattacharyya et al., 2019).

The deterioration of nutritional quality in mulberry leaves under elevated CO2 and temperature conditions may force silkworms to consume more leaves to compensate for the lower nutrient content (Bhattacharyya et al., 2019; Ghosh et al., 2019; Mandal et al., 2019). This increased feeding behaviour, like that of other Lepidoptera species, may result in longer developmental times in silkworms (Bhattacharyya et al., 2019; Ghosh et al., 2019; Mandal et al., 2019).

Climate change may also affect the timing of silkworm emergence and mulberry leaf availability, which is critical for successful sericulture (Gowda and Reddy, 2007; Rahmathulla et al., 2004). Temperature and precipitation patterns can alter the timing of mulberry leaf growth and maturation, potentially leading to mismatches with silkworm developmental stages. (Gowda and Reddy, 2007; Rahmathulla et al., 2004).

The vulnerability of raw silk production to climate change is determined not only by mulberry plant physiological responses, but also by silkworm rearing and post-cocoon technologies (Kumar and Parikh, 1998; Sanghi et al., 1998). Environmental factors such as temperature, humidity, and air circulation have a significant impact on silkworm physiology and cocoon quality. Extreme weather events, such as droughts or floods, can have a negative impact on both mulberry cultivation and silkworm rearing, reducing overall sericulture productivity (Kumar and Parikh, 1998; Sanghi et al., 1998). According to research, climate variability can result in significant losses in agricultural production, including sericulture (Kumar and Parikh, 1998; Sanghi et al., 1998). A 2°C increase in average global temperature is expected to result in crop losses ranging from 10 to 40%, as well as significant revenue losses in agriculture. While specific data for sericulture is limited, the industry is expected to face similar challenges (Kumar and Parikh, 1998; Sanghi et al., 1998).

4. Adaptation and Mitigation Strategies for Sericulture

4.1 Breeding Climate-Resistant Silkworm Varieties

Breeding climate-resistant silkworm varieties has grown in importance in the sericulture industry, particularly in tropical and subtropical regions where silkworm rearing conditions can be challenging. The primary goal of developing these varieties is to identify and cultivate silkworm breeds that can withstand high temperatures and humidity while producing good quality and quantity of silk (Ramesha et al., 2009; Kumar et al., 2002). One of the primary goals in breeding climate-resistant silkworms is thermotolerance. Many important qualitative characters, such as viability and cocoon traits, decline sharply when temperatures rise above 28°C (Ueda and Lizuka, 1962; Pillai and Krishnaswami, 1980, 1987; Kato et al., 1989). To address this issue, researchers have been screening and selecting silkworm breeds that can withstand higher temperatures (Shirota, 1992; Tazima and Ohnuma, 1995; Kumar et al., 2001). Researchers evaluated 24 bivoltine silkworm germplasm resources for tolerance to thermal stress at 36 ± 1°C and relative humidity (RH) 50 ± 5% over three generations (Kumar et al., 2002; Koundinya et al., 2003). The study found significant variability among germplasm resources in terms of nine genetic traits related to survival and pupation rate under high-temperature conditions (Kumar et al., 2002).

For bivoltine silkworms, a pupation rate of more than 70% was used to select thermotolerant varieties (Kumar et al., 2002). During this screening process, seven bivoltine germplasm were identified as temperature tolerant with a pupation rate greater than 70% (Kumar et al., 2002; Koundinya et al., 2003). Breeding efforts have also centred on creating silkworm varieties suitable for spring and autumn rearing. Researchers have identified key technologies, principles, and methods for selecting and breeding silkworm varieties that are seasonally adaptable (He and Oshiki, 1984; He et al., 1991). These efforts seek to develop robust silkworm races that can thrive in a variety of environmental conditions throughout the year. In addition to temperature tolerance, researchers are working to create silkworm hybrids that are disease resistant while remaining thermotolerant. This approach seeks to develop more resilient varieties capable of withstanding both environmental stresses and pathogenic challenges (Suresh Kumar et al., 2005; Basavaraja et al., 2005).

Recent advances in molecular breeding techniques have provided new opportunities for developing climate-resistant silkworm varieties. Molecular marker-assisted breeding has been used to create silkworm hybrids that are both thermotolerant and resistant to specific pathogens such as Bidensovirus (BmDNV2) (Rao et al., 2006; Sudhakara Rao et al., 2002). To summarise, breeding climate-resistant silkworm varieties requires a multifaceted approach that combines traditional breeding methods with modern molecular techniques. The goal is to create silkworm breeds that can maintain high productivity and silk quality in harsh environmental conditions, ensuring long-term silk production in a variety of climate zones (Suresh Kumar et al., 2004; Basavaraja et al., 2005).

4.2 Improving Mulberry Cultivation Practices

Climate change has had a significant impact on mulberry cultivation, with early sprouting being a key phenological change (Zhang et al., 2021). This shift necessitates adaptations to traditional cultivation methods in order to maintain optimal growth and yield in the face of changing environmental conditions. Water-saving irrigation techniques have emerged as critical approaches to improving mulberry cultivation in the face of climate change. Drip irrigation and micro-sprinkler systems have been shown to be effective at conserving water while maintaining or improving mulberry leaf yield and quality (Ghosh et al., 2022; Wang et al., 2023; Patel et al., 2022). These methods not only help to conserve water but also promote overall sustainability in mulberry cultivation (Singh et al., 2022; Rao et al., 2023).

Soil management practices are critical for increasing mulberry resilience to climate change. Organic amendments, such as vermicompost and farmyard manure, have been shown to improve soil health, water retention capacity, and nutrient availability for mulberry plants (Singh et al., 2023; Rao et al., 2022; Li et al., 2022; Gupta et al., 2021). These practices not only promote plant growth but also help to sequester carbon in the soil, thereby mitigating the effects of climate change (Zhang et al., 2022; Kumar et al., 2023). Mulberry trees have demonstrated significant potential for carbon sequestration, making them valuable assets in the fight against climate change. Mulberry plantations have been shown in studies to sequester significant amounts of carbon in both above- and below-ground biomass (Chen et al., 2023; Sharma et al., 2022). Improving cultivation practices to increase natural carbon sequestration can help mitigate climate change (Kumar et al., 2022). Mulberry genetic improvement is another important strategy for adapting to changing climate conditions. Breeding programmes are currently underway to develop drought-tolerant, heat-resistant, and disease-resistant mulberry cultivars (Sharma et al., 2022).

Climate change is changing pest and pathogen dynamics, making integrated pest and disease management approaches more important. Implementing biological control methods, such as pheromone traps and promoting beneficial insects, can help keep pest populations below economic thresholds while reducing reliance on chemical pesticides (Zhang et al., 2021). These approaches help to create more resilient and environmentally friendly mulberry cultivation systems (Kumar et al., 2021). Mulberry-based agroforestry systems have shown promise in improving farm resilience to climate change. These systems not only generate additional income for farmers, but they also help to improve soil health, biodiversity, and carbon sequestration (Singh et al., 2021). Mulberry integration in diverse agricultural landscapes can result in more sustainable and climate-resilient farming practices (Rao et al., 2021). Mulberry farmers can better adapt to climate change challenges by implementing these improved cultivation practices, as well as contribute to mitigation efforts through increased carbon sequestration and sustainable land management practices (Reddy et al., 2020).

4.3 Integrated Pest Management Strategies

Integrated Pest Management (IPM) strategies in sericulture are becoming increasingly crucial in the face of climate change, aiming to control pests and diseases while minimizing environmental impact (Rahmathulla et al., 2012). Climate change has been observed to significantly affect the population dynamics and distribution of insect pests in various agricultural systems, including sericulture (Bale et al., 2002). Rising temperatures and altered precipitation patterns can lead to increased pest outbreaks and the emergence of new pest species in sericulture-producing regions (Srinivasa et al., 2019). To address these challenges, IPM strategies in sericulture focus on a combination of cultural, biological, and chemical control methods (Srinivasa et al., 2019; Rahmathulla et al., 2012).

Cultural practices include maintaining proper hygiene in rearing houses, using disease-free silkworm eggs, and adopting appropriate rearing techniques (Srinivasa et al., 2019; Bhat and Nataraju, 2006). These measures help reduce the incidence of pests and diseases, thereby improving the overall health of silkworms (Sakthivel et al., 2012). Biological control methods play a crucial role in IPM strategies for sericulture, including the use of natural predators, parasitoids, and microbial agents to control pest populations (Srinivasa et al., 2019; Bhat and Nataraju, 2005). For instance, the application of Bacillus thuringiensis (Bt) has shown promising results in controlling lepidopteran pests in mulberry cultivation, which is essential for silkworm rearing (Srinivasa et al., 2019; Sakthivel et al., 2012).

Chemical control methods, when necessary, should be used judiciously and in combination with other IPM strategies (Sharma et al., 2015). Researchers emphasize the importance of using eco-friendly and biodegradable pesticides to reduce the ecological footprint of sericulture practices (Bhat and Nataraju, 2005). Monitoring and early warning systems are essential components of IPM strategies in sericulture (Srinivasa et al., 2019; Bale et al., 2002). Climate-based pest forecasting models are being developed to predict pest outbreaks and guide management decisions in the context of changing climatic conditions (Rahmathulla et al., 2012).

Breeding silkworm varieties and mulberry cultivars that are resistant to pests and diseases is another important aspect of IPM strategies in sericulture (Srinivasa et al., 2019; Sakthivel et al., 2012). This approach can help reduce the reliance on chemical pesticides and improve the resilience of sericulture systems to climate change impacts. In conclusion, integrated pest management strategies in sericulture against climate change require a holistic approach that combines various control methods, emphasizes sustainability, and adapts to changing environmental conditions (Srinivasa et al., 2019; Sharma et al., 2015). Continued research and collaboration among scientists, policymakers, and sericulture practitioners are essential to develop and implement effective IPM strategies in the face of climate change (Srinivasa et al., 2019).

5. Conclusion

The evolving field of sericulture, deeply rooted in ancient practices and modern scientific advancements, faces significant challenges from climate change. As temperature fluctuations, extreme weather events, and altered precipitation patterns impact silkworm development and mulberry cultivation, adaptive strategies such as breeding climate-resistant silkworm varieties and improving cultivation practices become essential. Ongoing research into the genetic and physiological responses of silkworms and their host plants is crucial for sustaining silk production. Integrating innovative technologies like remote sensing and GIS for strategic planning, alongside traditional knowledge, will be vital in ensuring the resilience and economic viability of the sericulture industry amidst changing climate conditions.

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