Review Article

Advancing Sustainable Sericulture: A Review on Biological Control Agents in Managing Pests and Diseases of Mulberry and Silkworms

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ABSTRACT

Sericulture, the culture of rearing of silkworms (*Bombyx mori* L.) for silk production, is significantly impacted by pests and pathogens that affect silkworms and mulberry plants which is primary food source for these insects. Traditional chemical pesticides, though effective, pose risks including environmental pollution and harm to non-target organisms. To address these issues, the sericulture industry is increasingly adopting biological control methods, which utilize natural enemies such as parasitoids, predators and pathogens to manage pest populations in an eco-friendly manner. This approach offers several advantages: it minimizes environmental pollution, protects beneficial organisms and promotes sustainability by leveraging natural pest regulation mechanisms. Key biological control agents in sericulture include parasitoids like *Acerophaguspapayae* and *Trichogrammachilonis*, predators such as ladybird beetles, and pathogens including fungal and bacterial species. Despite its benefits, biological control faces challenges such as slower action and environmental dependencies. Effective implementation requires careful planning, integration with other pest management strategies and ongoing monitoring. Overall, biological control represents a significant advancement towards more sustainable and resilient sericulture practices.

Keywords: [Sericulture, Biological Control, Parasitoids, Predators, Pathogens, Sustainable Agriculture]

1. INTRODUCTION

Sericulture, relies heavily on the health and productivity of mulberry plants, the sole food source for these insects. However, both mulberry plants and silkworms are vulnerable to a variety of pests and diseases, which can significantly reduce leaf quality and yield. Infestations from pests and diseases can result in an estimated 25% reduction in mulberry foliage, adversely impacting the nutritional value of the leaves and, consequently, the growth and silk production of silkworms (Rajadurai and Thiagarajan, 2003). Historically, chemical pesticides have been the conventional method for controlling these pest and disease threats. While effective in the short period, the use of chemicals has led to significant unintended consequences, including environmental pollution, health risks to humans and the disruption of beneficial insect populations (Nordlund, 1984). These negative impacts highlight the limitations of chemical control and underscore the need for more sustainable pest management solutions. In response to these challenges, the sericulture industry has increasingly explored biological control methods. This approach employs natural enemies such as parasitoids, predators and pathogens to manage pest populations in an environmentally friendly and sustainable manner (Van Lenteren, 1986)). Biological control offers a viable alternative by leveraging natural mechanisms to regulate pest populations, thereby reducing depending on harmful chemical pesticides, (Singh *et al*., 1994). By integrating these methods, sericulture can enhance both the health of mulberry plants and also productivity of silkworms while minimizing adverse environmental and health effects.

The adoption of biological control represents a significant step towards achieving more sustainable and resilient sericulture practices, (Doutt, 1964).

Biological Control Agents in Sericulture

Biological control involves the use of natural enemies, such as parasitoids, predators and pathogens to control pest populations. This approach offers a promising solution by targeting specific pests in a manner that minimizes environmental impact and promotes long-term pest management sustainability (Singh *et al*., 1995; 1999 and Hagen *et al*., 1976).

Parasitoids

Parasitoids are organisms that spend a significant period of their life cycle attached to or within a host organism, eventually killing it. They offer high specificity and effectiveness in pest control due to their targeted nature. In sericulture, several parasitoids have demonstrated efficacy against pests affecting mulberry and silkworms.

- ***Acerophagus papaya***

Acerophaguspapayae is a parasitoid effective against the papaya mealybug (*Paracoccusmarginatus*), a significant pest of mulberry. This parasitoid targets the early nymphal stages of the mealybug, making it highly specific to its host. Recommended release practices involve inoculating 100 adults per acre as soon as the pest is detected. The use of *Acerophaguspapayae* has been shown to significantly reduce mealybug populations, thereby protecting mulberry plants and ensuring better leaf quality, (Narendra Kumar *et al*., 2011).

- ***Trichogramma*Species**

Trichogrammachilonis is a well-documented egg parasitoid used extensively to control a range of lepidopteran pests. This tiny parasitoid targets the eggs of various moths and butterflies that infest mulberry plants. The recommended release rate is 100,000 adults per acre in split doses. *Trichogrammachilonis* has been particularly effective in managing pests such as leaf webbers and wasp moths, leading to improved crop health and yield (Singh et al., 1994). Similarly, *Trichogrammaembryophagum* has shown promise in controlling other pest species through egg parasitism, (Narendra Kumar *et al.,* 2003).

- ***Nesolynx thymus***

The uzi fly (*Exoristabombycis*) is a significant parasitoid of silkworms, causing substantial damage. *Nesolynx thymus*, a hymenopteran parasitoid, targets this fly and has proven effective in managing its populations. To optimize its impact, *Nesolynx thymus* should be released in coordination with the silkworm rearing stages. This timing ensures that the parasitoid effectively controls the uzi fly, reducing its detrimental effects on silk production (Singh *et al*., 1995 and Devaiah *et al*., 1992).

Predators

Predators are organisms that consume multiple prey items throughout their lifetime for survival, playing a crucial role in managing pest populations. In sericulture, several key predators have been utilized effectively, (Hassell, 1978).

Ladybird Beetles

Ladybird beetles, such as *Cryptolaemusmontrouzieri* and *Scymnuscoccivora*, are effective predators of the pink mealybug *Pseudococcuslongispinus.* Both species consume various life stages of mealybugs, including eggs, nymphs and adults. For optimal control, it is recommended to release 250 beetles per acre per year, split into two doses (Singh *et al*., 1994; 1995). Careful timing and monitoring of beetle releases are essential to maximizing their impact (Singh *et al*., 1994; 1995 and Mani *et al*., 2013). Regular assessments of mealybug populations and beetle activity can enhance the effectiveness of this biocontrol strategy.Their voracious feeding habits help maintain pest populations at manageable levels (Sakthivel *et al*., 2012).

Other Predatory Insects

In addition to ladybird beetles, other predatory insects have shown potential in sericulture. For instance, the predatory bug *Oriusinsidiosus* has been reported to effectively manage pest populations of thrips and other small pests in mulberry and silkworm habitats. Lacewing larvae are commonly known as “aphid lions” as they feed on aphids, whiteflies and other small insects. Their presence in mulberry orchards can significantly reduce pest numbers (Singh *et al*., 2004). The integration of these predators into pest management strategies can enhance overall effectiveness. (Rajadurai *et al*., 2003 and Bhattacharjee *et al*., 1994).

Case Studies and Recommendations

Several case studies illustrate the successful application of biological control agents in sericulture.

Ladybird Beetles Against Pink Mealybug

The use of ladybird beetles, such as *Cryptolaemusmontrouzieri* and *Scymnuscoccivora*, has proven highly effective in controlling pink mealybug populations. Careful timing and monitoring of beetle releases are essential to maximizing their impact (Singh *et al*., 1995; 1999 and Mani *et al*., 2013). Regular assessments of mealybug populations and beetle activity can enhance the effectiveness of this biocontrol strategy.

***Trichogrammachilonis* Against Lepidopteran Pests**

Trichogrammachilonis, a tiny parasitoid targeting the eggs of various moths and butterflies, has been successful in reducing pest populations in infested crop fields. For optimal results, *Trichogrammachilonis* should be used in conjunction with other pest management strategies to achieve comprehensive control (Singh *et al*., 1994 and Jalali *et al*., 2003).

***Nesolynx thymus* Against Uzi Fly**

Nesolynx thymus, a hymenopteran parasitoid, has effectively managed uzi fly populations affecting silkworms, (Datta *et al*., 1978). The timing of its release, aligned with the silkworm rearing stages, is crucial for maximizing its impact on the uzi fly (Singh *et al*., 1995). Regular monitoring and adjustment of release strategies can improve outcomes, (Ram Kishore and Kumar, 1990).

Pathogens

Pathogens used in biological control include bacteria, fungi and viruses that specifically target pests. Although their application is less widespread compared to parasitoids and predators, they can be effective under certain conditions.

- **Fungal Pathogens**

Fungal pathogens such as *Beauveria bassiana* and *Metarhiziumanisopliae* have been utilized to control various pests affecting mulberry plants. These fungi infect and kill pests through direct contact and are particularly effective against insect pests, (De Leij *et al*., 1991). *Beauveria bassiana*, for example, has been shown to control whiteflies, aphids and spider mites that infest mulberry(Singh *et al.,*2017). Beneficial fungus, *M. anisopliae* targets soil-dwelling pests and can be effective against beetles and other ground-dwelling insects that affect mulberry plants (Singh *et al.,* 2024).

- **Bacterial Pathogens**

Bacterial pathogens, such as *Bacillus thuringiensis* (Bt), are well-known for their efficacy against certain pests. Bt produces toxins that specifically target the larvae of insects like leaf rollers and caterpillars. The application of Bt in sericulture can help manage these pests while minimizing harm to beneficial organisms.This bacterium produces toxins that specifically target caterpillars and other insect larvae. Bt formulations are commonly used in organic mulberry cultivation to control pests like borers (Lui *et al.,* 2014).

Antagonistic Microorganisms

***Trichoderma* Species**

Trichoderma harzianum and *Trichoderma viride* are antagonistic microorganisms effective against various fungal pathogens affecting mulberry, (Latha *et al*., 1993 and Banerjee *et al*., 2016). These fungi work by outcompeting pathogens for resources and producing antagonistic compounds that inhibit pathogen growth (DhahiraBeevi and Qadri, 2010). Their application can significantly reduce disease incidence and support healthier mulberry plants, (Nordlund, 1984 and Shivapratp*et al*., 1996).

Plant Extracts

Natural plant extracts, such as garlic, neem and tulsi, have demonstrated efficacy against fungal diseases like *Aspergillosis* and *muscardine*. Extracts of garlic and datura have been particularly effective, reducing disease incidence without negatively impacting commercial silk production. Incorporating these natural remedies, (Krishna Prasad *et al*., 1979).

Effective implementation of bio-control agents

Effective implementation of bio-control agents requires careful planning and integration into a comprehensive pest management strategy. Key approaches include:

1. **Selecting the Right Bio-Control Agents**:

Success depends on matching the appropriate bio-control agent to the specific pest and environmental conditions. For instance:*Trichogramma* species are useful for controlling lepidopterans pests by parasitizing their eggs**.**Lady beetles (Coccinellidae) are efficient

predators of aphids and scale insects.*Beauveria bassiana,* a type of entomopathogenic fungus, is effective against a wide range of insect pests, while *Bacillus thuringiensis* (Bt) targets caterpillar pests (Nadaf *et al.,* 2022). Understanding the life cycle and behavior of both the pest and bio-control agent is critical.

2. **Proper Timing and Application**:

Timing the release of bio-control agents is crucial for maximizing their impact. This involves synchronizing the introduction of agents with the vulnerable stages of pest populations. For example, Trichogramma wasps should be released when moths are laying eggs to ensure they parasitize before hatching (Bhat *et al.,* 2018 and Singh *et al.,* 2002). Additionally, appropriate application techniques should be used to distribute the agents effectively across affected areas.

3. **Monitoring and Evaluation**:

Continuous monitoring is essential to track the performance of bio-control agents. Regular assessments of pest populations and bio-control agent activity help determine whether adjustments are needed. Monitoring also allows for tactical decisions, such as increasing release frequency or modifying application methods if initial efforts are insufficient. This ongoing evaluation helps improve bio-control strategies over time (Cappellozza*et al.,* 2022).

Advantages and Limitations of Biological Control

Biological control offers several promising advantages over traditional chemical methods:

Pollution-Free

Biological control agents do not harm to air, soil or water pollution, making them an environmentally friendly alternative to chemical pesticides (Sabbahi*et al.,* 2022). This advantage aligns with the growing emphasis on sustainable agricultural practices (Pritam Singh *et al*., 1980).

Safe for Non-Target Organisms

Biological control agents typically target specific to pests, leaving other organisms unharmed (Sharma *et al.,* 2020). This specificity helps maintain ecological balance and supports biodiversity within the sericulture environment (Van Lenteren, 1983).

Cost-Effectiveness

When it has been set up, bio-control agents for pest management are long-term. Because they may have setup costs in their introduction and the costs involved in pest management if reduced through the use of these organisms may prove cheaper in the long run mainly because of little or no use of chemicals (Wani *et al.,* 2017).

Sustainable

Biological control agents can perpetuate themselves as long as the pest populations persist, offering a form of long-term pest management (Singh *et al.,* 2002). This sustainability is beneficial for maintaining healthy sericulture ecosystems over time (Rajadurai, 2005).

Despite these advantages, biological control also has some limitations:

Slower Process

Biological control methods often take longer to achieve observable results compared to chemical treatments. The gradual nature of biological control can be a drawback in cases requiring immediate pest suppression, (Sathyaprasad *et al*., 2005).

Limited Scope

Some biological control agents may not be effective against all types of pests or in all environmental conditions. This limitation necessitates careful selection and application based on the specific pest and environmental context.

Dependency on Environmental Conditions

The effectiveness of biological control agents can be depended by various environmental factors, such as the presence of alternate hosts or hyper-parasites. These factors can impact the success of biological control strategies and require ongoing monitoring. (Van Lenteren*et al*., 2006).The effectiveness of bio-control agents can be influenced by environmental conditions such as temperature, humidity, and habitat structure. For example, certain biocontrol agents may not perform well in extreme weather conditions or poorly managed environments (Leger *et al.,* 2010)

Conclusion

Biological control represents a highly promising and environmentally friendly alternative to traditional chemical pest management in sericulture. By harnessing natural enemies such as parasitoids, predators and pathogens, the sericulture industry can effectively manage pests and diseases while reducing reliance on harmful chemicals. This approach not only mitigates environmental and health risks but also promotes more sustainable practices within the industry. Despite its potential, biological control does come with challenges, including slower action times and limitations in its effectiveness across all pest types and environmental conditions. However, its significant benefits-such as minimizing pollution, protecting non-target organisms, and offering long-term pest management solutions-make it an invaluable component of integrated pest management strategies. To maximize the effectiveness of biological control, careful planning and ongoing research are essential. This includes optimizing the release rates and timing of biocontrol agents, integrating biological control with other pest management practices, and continually monitoring and evaluating their impact. As the sericulture industry continues to evolve towards more sustainable practices, biological control will undoubtedly play a crucial role in ensuring its future resilience and success.

CONSENT (WHERE EVER APPLICABLE)

Authors may use the following wordings for this section: "All authors declare that 'written informed consent was obtained from the patient (or other approved parties) for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editorial office/Chief Editor/Editorial Board members of this journal."

ETHICAL APPROVAL

This article does not contain any studies with human participants or animals performed by any of the authors

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