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The attack of the teak defoliator (*Hyblaea puera*) on Shisham (*Dalbergia sissoo*) and its environmental impacts

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Abstract

In many areas, *Dalbergia sissoo*, sometimes called Shisham, is of great ecological and economic significance because of its sturdy wood and therapeutic qualities. However, a serious challenge to its sustainability is its vulnerability to infestation by the teak defoliator, *Hyblaea puera*. When *H. puera* larvae invade fake woods, they cause significant defoliation, which lowers photosynthetic activity and jeopardises tree health. The resulting loss of foliage impacts the natural balance of forest ecosystems in addition to reducing the grade of lumber. Promising remedies are provided by integrated pest management strategies, which include sustainable forestry practices and biological control techniques. Furthermore, prompt action depends on early *H. puera* epidemic detection and surveillance. To protect *Dalbergia sissoo* woods from the damaging impacts of *H. puera* infestation, this article highlights the urgent necessity for a thorough study and the application of sustainable management approaches. Resolving these issues would protect the resilience of related socioeconomic systems that rely on this priceless tree species, in addition to maintaining the ecological integrity of *Dalbergia sissoo* ecosystems.

1 Introduction

One of the most important timber species in South Asia, including Pakistan, is *Dalbergia sissoo*, sometimes referred to as Shisham or Indian Rosewood (Abdullah and Rafay, 2021). It is extensively grown for its premium wood, which is utilized in building, furniture manufacturing, and other industrial processes (Sharma *et al.*, 2018). Shisham is important for biodiversity, forestry, and soil protection in addition to its economic value (Khanum *et al.*, 2024). It supports the ecological stability of riverine and agroforestry systems by

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giving a variety of creatures a place to live and food sources (Jabbar *et al.*, 2016). However, Shisham is increasingly at risk from biotic and abiotic stressors, such as insect infestations, which have a major effect on the plant's survival, development, and productivity (Haq *et al.*, 2021). Shisham's health and commercial worth are jeopardized by its vulnerability to a variety of insect pests. Bark beetles (*Xylotrechus* spp.), stem borers (*Celosterna scabrator*), and leaf-eating caterpillars are some of the most prevalent pests that harm Shisham in Pakistan (Ali *et al.*, 2019). These pests undermine tree structure, defoliate leaves, and bore into stems, causing considerable damage. *Hyblaea puera*, sometimes referred to as the Teak Defoliator, has emerged as the most alarming pest in recent years (Remadevi, 2022). Despite being mainly a teak (*Tectona grandis*) pest, studies suggest that it is increasingly targeting Shisham plantations and broadening its host range (Singh and Gupta, 2020). In tropical and subtropical areas, *Hyblaea puera* significantly reduces the amount of leaves on teak wood (Karim and Zaman, 2017). Due to its ravenous feeding on immature leaves, this month's larvae cause significant defoliation and decreased photosynthetic activity (De Tillesse *et al.*, 2007). Trees in Shisham may become weaker, more susceptible to secondary pests and diseases, and their wood quality may deteriorate as a result of such infestations (Mansoor *et al.*, 2015). Furthermore, in regions where Shisham is widely grown, large outbreaks of this pest might result in deforestation and financial losses (Siddiqui *et al.*, 2021). *H. puera* infestation has alarming environmental effects on Shisham woods (Kumar *et al.*, 2017). Large-scale defoliation of Shisham, a crucial species in agroforestry and riparian ecosystems, has the potential to disturb ecological services such as carbon sequestration, soil stabilization, and animal habitat preservation (Raza *et al.*, 2018). This, in turn, can have a ripple effect on biodiversity, local livelihoods, and commercial forestry.

1.1 Objectives and scope of this review

Given the rising danger of *Hyblaea puera* on Shisham and its possible environmental and economic effects, this assessment seeks to:

- Evaluate the ecological and economic value of Shisham in Pakistan.
- Investigate the distribution, biology, and impact of *Hyblaea puera* on Shisham plantations.
- Emphasise the environmental and economic implications of extensive infestation.
- Investigate sustainable management options, such as biological control, integrated pest management (IPM), and cultural practices, to reduce infestation risk.

By addressing these issues, this study aims to help policymakers, academics, and forestry professionals establish effective methods for safeguarding Shisham forests against *Hyblaea puera* and maintaining their long-term viability.

2. Biology and behavior of *Hyblaea puera*

2.1 Taxonomic classification and morphological characteristics

The Teak Defoliator, or *Hyblaea puera*, is a member of the Hyblaeidae family in the order Lepidoptera (Sharma *et al.*, 2013). It has lately been observed attacking additional host plants, such as *Dalbergia sissoo*, and is a significant defoliator of teak (*Tectona grandis*) (Singh and Gupta, 2020). The adult moth has a wingspan of around 30 to 40 mm, making it modest to medium in size. The hindwings have a characteristic orange and black pattern that acts as a warning coloration when disturbed, while the forewings are brownish-gray and blend in well with tree bark (Sivakumar *et al.*, 2017). Before pupating, the light-green larvae go through five instars of development and have a black head capsule. Depending on the surroundings, pupation might take place in the soil or inside folded leaves (Becker *et al.*, 2002).

2.2 Life cycle and reproductive potential

The whole life cycle of *Hyblaea puera* includes four unique developmental stages: egg, larva, pupa, and adult. Environmental elements, including temperature, humidity, and food availability, affect how long a life cycle lasts.

On the underside of delicate leaves, the female deposits clusters of small, light green eggs. Depending on humidity and temperature, eggs hatch in two to four days (Nair, 2007). The freshly born larvae first scrape the leaf surface before developing into ravenous eaters that eat the whole leaf, excluding the midrib. The larvae go through five instars throughout the 8 -12 day larval stage. Severe defoliation results from the later instars' fast feeding habits (Sundararaj and Pushpavathi, 2018). Pupation lasts seven to ten days and might take place in curled leaves or leaf litter. Pupae may go into diapause under adverse circumstances, which would delay their growth. Under ideal circumstances, the adult moths complete a life cycle in around three to four weeks after emerging, mating, and laying eggs in a 24- to 48-hour period. The species can produce many generations per year, particularly in areas where host plants are consistently available (Nair, 1988).

2.3 Feeding habits and defoliation patterns

As highly specialized folivores, *Hyblaea puera* larvae mostly consume the leaves of hardwood species, such as *Dalbergia sissoo*, and teak (Mohanadas *et al.*, 2019). They have a distinctive pattern in their eating behavior:

2.3.1 Early Instars:

Larvae in their first and second instars skeletonize the leaf surface, eating just the epidermis and creating a translucent "window" appearance in the process (Kabade *et al.*, 2015).

2.3.2. Later Instars:

Larvae in their third to fifth instars exclusively eat the principal veins and midribs of leaves. As a result, there is a considerable decrease in photosynthetic capability and widespread canopy loss (Sharma *et al.*, 2013).

2.3.3 Peak Infestation:

When new foliage is available, *Hyblaea puera* outbreaks take place throughout the monsoon and post-monsoon seasons (Tewari & Campbell, 2018). In tropical locations, population maxima occur every 6–8 weeks, and defoliation is frequently cyclical.

2.3.4 Economic and Ecological Impact:

The host trees are weakened by severe defoliation, which increases their vulnerability to secondary infections, stunts their development, and results in low-quality lumber (Sharma *et al.*, 2020).

3 Infestation of *Hyblaea puera* on *Dalbergia sissoo*

3.1 Distribution of *Hyblaea puera* in Pakistan

Throughout South and Southeast Asia, teak (*Tectona grandis*) plantations have long been linked to *Hyblaea puera*, sometimes referred to as the Teak Defoliator (Bakewell-Stone, 2012). Nonetheless, reports of infestations on *Dalbergia sissoo* (Shisham) in several parts of Pakistan indicate that its range has increased recently (Latif *et al.*, 2025). Increasing host availability, shifting climatic circumstances, and adaptive feeding behaviour are probably the causes of this proliferation (Shah & Ali, 2020). In Punjab, Sindh, and Khyber Pakhtunkhwa, Pakistan, *H. puera* infestations have been documented, especially in riparian and agroforestry environments where Shisham is widely grown (Khan *et al.*, 2019). High humidity and constant foliage availability promote larvae growth and survival in infestation hotspots found around riverbanks and irrigated plantations (Secretariat *et al.*, 2021).

3.2 Seasonal infestation trends and severity

Temperature, precipitation, and leaf flush cycles all have an impact on the seasonal pattern of *Hyblaea puera* infestation on Shisham (Jha, 1999). In the monsoon (July–September) and post-monsoon (October–November) seasons, when new leaves appear and offer the best food supply for growing larvae, outbreaks usually take place (Naveed *et al.*, 2021).

Table 1 Seasonal Variation in Pest Infestation Levels

Season	Infestation Level	Factors
Early Season (March–June)	Low	Dry circumstances make it harder for larvae to survive
Peak Infestation (July–November)	High	Plenty of leaves, favorable moisture conditions, and extensive defoliation
Late Season (December–February)	Gradual decline	Chilly weather and less food available

Shisham trees have been known to experience 80–100% defoliation during severe outbreaks, which has a major effect on the vigor and production of the trees (Hussain *et al.*, 2020) as shown in figure 1. According to Ghelardini *et al.* (2016), these infestations frequently result in secondary fungal pathogen infections, which further damage the trees.

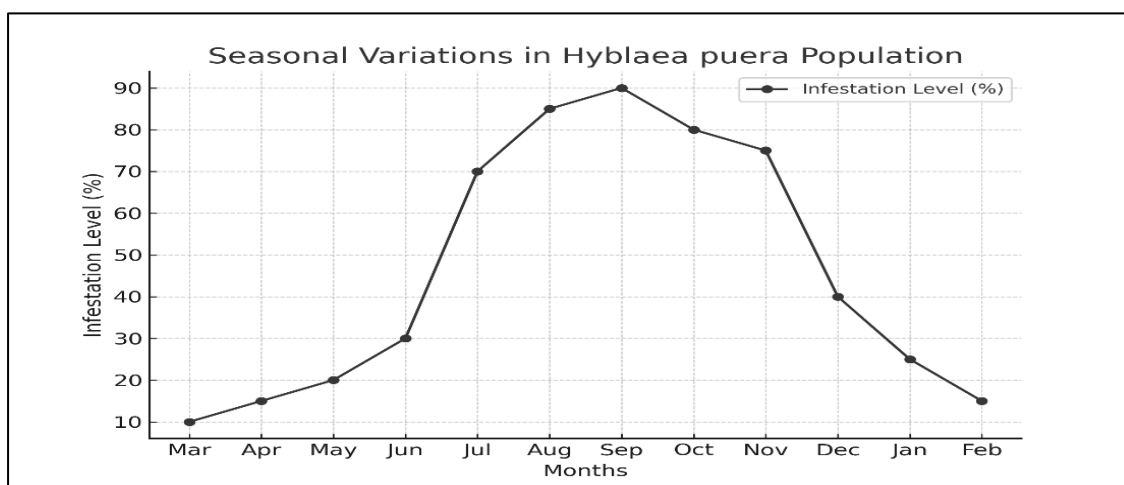


Figure 1: Seasonal fluctuations in *Hyblaea puera* population levels

3.3 Symptoms and visible damage to the Shisham tree

Hyblaea puera infestation is typified by certain eating habits and outward signs that worsen as the larvae become older. Tiny, pale green caterpillars start feeding by skeletonizing leaves in the early stages (first and second instars), devouring just the upper skin and producing the distinctive "windowing" look. The impacted leaves, therefore, seem transparent but stay attached to the tree (Rao, 2010). Larvae exclusively eat the midribs and major veins of leaves when they reach the advanced stages (third to fifth instars). Because of the thinned canopy caused by this severe defoliation, photosynthetic activity is greatly reduced. As a result of the significant leaf loss, afflicted trees appear browned and burned (James *et al.*, 2010). Pupation takes place under leaf litter or inside curled leaves during the pupal stage, where cocoons are created. Repeated defoliation weakens the tree and increases its susceptibility to fungal diseases like *Ganoderma lucidum*, which can cause dieback, and secondary pests such as stem borers (*Celosterna scabrator*) (Roychoudhury, 2015).

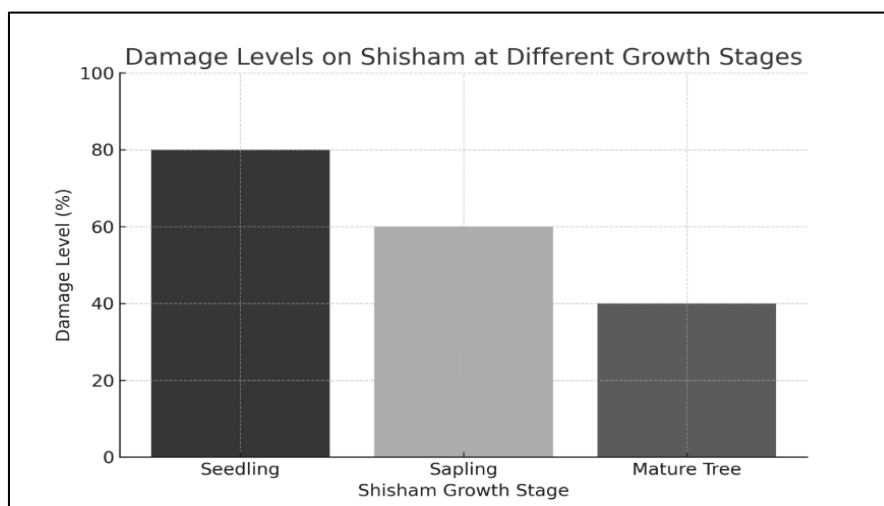


Figure 2: Severity of *Hyblaea puera* damage across different growth stages of Shisham

The comparative bar chart highlights the varying susceptibility of Shisham at different growth stages to *Hyblaea puera* infestation. Seedlings are the most vulnerable, often suffering complete defoliation, while saplings experience moderate damage that can hinder growth. Mature trees, though more resilient, face long-term weakening due to repeated infestations, leading to branch dieback and increased susceptibility to secondary pests. This analysis helps identify critical intervention points for effective pest management.

3.4 Long-term impacts on tree health and survival

Hyblaea puera infestations that are severe and ongoing can have disastrous long-term impacts on *Dalbergia sissoo* survival and health:

3.4.1 Reduced Growth and Timber Quality:

Defoliation reduces growth and timber quality by interfering with photosynthesis, which results in poor wood development and stunted growth, ultimately lowering timber value (Rashid *et al.*, 2018).

3.4.2 Increased Susceptibility to Pathogens:

Fusarium and *Ganoderma*, in particular, are more likely to infect weaker trees, causing root rot and stem cankers that ultimately result in death (Ahmed *et al.*, 2019).

3.4.3 Decline in Natural Regeneration:

Because of increased stress and decreased seed viability, infested Shisham crops exhibit poor seedling establishment (Javaid, 2016).

3.4.4 Economic Losses:

Lower wood yields and increased management costs result in major financial losses for farmers and the forestry industry (Wood, 2001).

3.4.5 Ecological Imbalance:

Since many bird, insect, and animal species depend on shisham trees for habitat and food, their loss has an impact on biodiversity. Deforestation in riparian zones can be exacerbated by extensive defoliation, which can further upset biological networks (Gangwar *et al.*, 2021).

4 Environmental and Economic Consequences

4.1 Effects on biodiversity and ecological balance

The ecological stability and biodiversity of *Dalbergia sissoo* are significantly impacted by the *Hyblaea puera* infestation. Because they offer food and shelter to a variety of bird species, pollinators, and small animals, shisham trees are essential to the maintenance of riparian ecosystems (Kumar *et al.*, 2021).

Severe defoliation, however, interferes with these ecological relationships, resulting in:

4.1.1 Wildlife Habitat Loss:

Shisham trees are essential for breeding and feeding insects, woodpeckers, parakeets, and other birds. Persistent defoliation lowers canopy cover, which disrupts food chains and renders trees unsuitable for nesting (Shah *et al.*, 2020).

4.1.2 Decrease in Pollinator Populations:

Pollinators like as bees and butterflies are impacted by the availability of floral supplies, which is impacted by the loss in Shisham health. The species' natural regeneration and seed production are also impacted by this reduction (Devi *et al.*, 2022).

4.1.3 Increase in Secondary Pests and Diseases:

Weakened Shisham trees are more susceptible to fungal diseases (*Ganoderma lucidum*) and stem borers (*Celosterna scabrator*), which might result in increased death rates (Khan & Baloch, 2019).

4.1.4 Soil Erosion:

Shisham trees reduce soil erosion and riverbank instability by stabilizing the soil near riverbanks. This function is compromised by defoliation and consequent tree decline, which increases soil loss and sedimentation in water bodies, hence affecting aquatic biodiversity (Abdullah *et al.*, 2021).

4.2 Consequences on timber production and the forestry industry

One of the most valuable wood species in South Asia, shisham is used extensively for building, furniture, and farming implements (Sunny, 2017). Infestations of *Hyblaea puera* negatively affect timber quality and output in several ways:

4.2.1 Stunted Growth and Wood Density:

The tree's capacity to photosynthesise effectively is diminished by frequent defoliation, which results in stunted growth and lower wood volume. Research indicates that yearly growth increments in defoliated trees can be reduced by as much as 40% (Rashid *et al.*, 2021).

4.2.2 Poor Timber Quality:

Constant defoliation under stress affects the structure of trees, resulting in fractures, discoloration, and greater susceptibility to fungal decay. These faults reduce the timber's marketability (Hussain *et al.*, 2020).

4.2.3 Financial Losses to the Forestry Sector:

As Shisham production declines, logging expenses rise and timber dealers' profit margins shrink. Large-scale infestations have already led to a decline in income in Pakistan, where Shisham plays an important role in the forestry economy (Ahmed & Rafiq, 2018).

4.3 Impact on local livelihoods and rural economy

Thousands of rural households, especially in Punjab and Sindh, are employed in the shisham-based agroforestry and wood trade (Bakewell-Stone, P. *Dalbergia sissoo*). Infestations of *Hyblaea puera* have the following negative economic effects:

4.3.1 Income Loss for Farmers and Wood Traders:

Because of lower tree survival and worse-quality wood, farmers who depend on Shisham plantings suffer large losses. Economic instability has increased as a result of many switching to alternate crops (Ali *et al.*, 2019).

4.3.2 Enhanced Management Costs:

Small-scale farmers' production costs rise as a result of the need to invest more in pest management strategies to contain *H. puera* outbreaks (Grzywacz *et al.*, 2023). Losses are exacerbated by the fact that many cannot afford chemical or biological control techniques (Maru *et al.*, 2020).

4.3.3 Impact on Furniture and Handicraft Industries:

The dearth of high-quality raw materials affects the Shisham wood sector, which employs laborer's, carpenters, and craftsmen (Mustafa *et al.*, 2017). As a result, there is less demand for wooden items both domestically and abroad, which impacts output and drives up prices (Hāṇḍā, and Jain, 2000).

4.4 Climate change factors influencing infestation patterns

By changing the environmental factors that support *Hyblaea puera's* survival and growth, climate change is increasing the frequency and intensity of infestations (Shafae *et al.*, 2023).

Table 2: Environmental Factors Influencing *Hyblaea puera* Infestation

Environmental Factors	Impact on Infestation
Increased Temperature	Faster life cycles mean more generations and higher severity (Sharma and Kumar, 2020).
Extended Rainfall Periods	Ideal conditions for larvae, widespread defoliation (Rahman, 2016).
Drought-Induced Tree Stress	Reduced defences and increased susceptibility to pests (Naveed <i>et al.</i> , 2021)
Geographic Expansion	Infestation is spreading to new regions, including semi-arid regions (Remadevi, 2022).

5 Management and control strategies

A sustainable Integrated Pest Management (IPM) framework that incorporates cultural, biological, and chemical control techniques is necessary for the efficient management of *Hyblaea puera* infestations on *Dalbergia sissoo*. Considering Shisham's ecological and economic significance, lowering infestation levels while preserving biodiversity and ecosystem health requires the use of economical and ecologically appropriate methods.

5.1 Cultural control

To lower pest numbers and lessen the harm that *Hyblaea puera* causes, cultural management methods concentrate on altering the surroundings (Lodge *et al.*, 1998). For farmers and foresters, these techniques are useful and economical.

Table 3: Management strategy: Cultural control

Management Strategy	Impact on Pest Control
Pruning and Sanitation	Reduces larval numbers Efficient disposal prevents pupation
Optimal Plantation Practices	Increases air circulation Intercropping interrupts pest colonisation (Löhmus, & Balbus, 2015)
Soil and Nutrient Management	Ensure balanced soil fertility Water availability Improves tree resiliency Organic mulching encourages beneficial microorganisms
Light Traps and Mechanical Barriers	Captures adult moths Sticky bands impede larval migration (Vaishampayan, 2007)

5.2 Biological control

Natural predators, parasitoids, and microbiological agents all contribute to biological control of *Hyblaea puera* populations while preserving ecological balance (Uma *et al.*, 2025). Several natural enemies of the Teak Defoliator have been discovered and can be used in forestry applications.

Table 4 Management Strategy: Biological Control

Biological Control Method	Key Agents	Mode of Action
Natural Predators	Birds (Drongos, Flycatchers)	Feed on larvae, reducing caterpillar numbers (Dinesh <i>et al.</i> , 2022).
	Predatory insects (Coccinellidae, Carabidae)	Actively prey on young larvae (Weseloh <i>et al.</i> , 2009).
Parasitoids	Trichogramma chilonis (Egg parasitoid)	Destroys eggs, preventing outbreaks (Masry <i>et al.</i> , 2019).
	Bracon brevicornis, Apanteles spp. (Larval parasitoids)	Develop inside larvae, leading to death (Elbehery <i>et al.</i> , 2020).
Microbial Control Agents	Bacillus thuringiensis (Bt)	Causes paralysis and death in larvae (Upadhyay <i>et al.</i> , 2016).
	<i>Beauveria bassiana</i> , <i>Metarhizium anisopliae</i>	Infect larvae, reducing populations naturally
	<i>Nucleopolyhedrovirus</i> (NPV)	Controls defoliator outbreaks (Meyling <i>et al.</i> , 2007).

5.3 Chemical control and its limitations

Chemical pesticides are frequently employed to control pests quickly, but they have serious environmental and economic consequences (Naveed and Shafae, 2023).

Table 5 Management strategy: Chemical control

Insecticide Type	Examples	Mode of Action
Synthetic Pyrethroids	Cypermethrin Deltamethrin	Disrupt larval neuronal systems for quick control (Werner and Moran, 2008).
Organophosphates	Chlorpyrifos Quinalphos	Effective yet harmful to non-target creatures and human health (Mulla <i>et al.</i> , 2020).
Neem-Based Botanical Pesticides	Azadirachtin	Provide a safer alternative by lowering eating and reproduction in larvae (Chaudhary <i>et al.</i> , 2017).

5.4 Integrated Pest Management (IPM) approach for sustainable control

A sustainable Integrated Pest Management (IPM) strategy incorporates a variety of management measures to reduce environmental impact while efficiently managing *Hyblaea puera* infestations.

5.4.1 Key components of IPM for *Hyblaea puera*

Regular Monitoring and Early Detection

Conduct field surveys to monitor population patterns and discover epidemics before severe defoliation occurs. Use pheromone and light traps to track adult moth activity and forecast infestation cycles (Brockhoff *et al.*, 2023).

5.4.2 Conservation of natural enemies

Reduce pesticide usage to allow predator and parasite populations to grow. The introduction of egg and larval parasitoids (*Trichogramma spp.*, *Bracon spp.*) in damaged plantations (Singh, 2023).

5.4.3 Cultural and Mechanical Controls

To disrupt the pest's life cycle, practice cleanliness, trimming and removal of contaminated foliage (Svihra, 1994). Encourage mixed planting systems to limit insect spread.

5.4.4 Biopesticides and Microbial Agents

Bacillus thuringiensis (Bt) sprays can be used to effectively suppress larvae in their early stages (Keshavareddy & Kumar 2016). Using neem-based formulations to prevent feeding and development.

5.4.5 Judicious Use of Chemical Insecticides

Selective pesticides should be used as a last option, used in specific locations rather than blanket spraying. Rotating pesticides to avoid resistance development (Matthews, 2018).

5.4.6 Community-Based IPM Programs

Engage local farmers and forestry officials in sustainable pest control training programs by promoting participative research to create regionally specific solutions (Task, 2024).

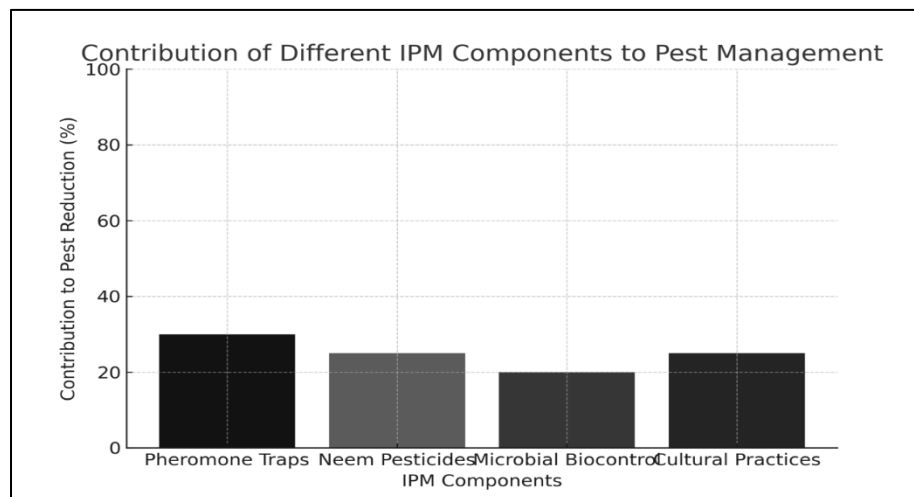


Figure 3: Optimizing Integrated Pest Management (IPM)

The above stacked bar chart shows the relative contribution of different IPM components (pheromone traps, neem-based pesticides, microbial biocontrol, and cultural practices) in pest suppression. It highlights the importance of integrated approaches.

6 Future research needs and recommendations

Hyblaea puera infestations on *Dalbergia sissoo* continue to be difficult to manage due to the pest's adaptability, climate change effects, and the limits of present control techniques. To maintain the long-term viability of Shisham forests, further scientific study and strategic policy proposals are needed.

6.1 Importance of further studies on pest biology and infestation patterns

Understanding *Hyblaea puera*'s behaviour, life cycle, and infestation dynamics is crucial for anticipating and controlling epidemics. Key issues that need additional exploration include:

6.1.1 Population Dynamics and Climatic Influence:

Future studies on *Hyblaea puera* should focus on understanding the environmental and biological aspects that influence outbreaks and adaptation. Investigating how temperature, humidity, and seasonal fluctuations influence infection dynamics will reveal information about the pest's population patterns. Furthermore, building climate-based prediction models can aid in forecasting infestation threats and improving early warning systems, resulting in improved pest management.

6.1.2 Genetic Studies on Pest Adaptability:

Genetic research on *Hyblaea puera* populations is extremely important, particularly for understanding genetic diversity and adaptation to novel habitats. Identifying genetic markers associated with pesticide resistance can help build more focused pest management tactics.

6.1.3 Host-Pest Interactions:

Research into host-pest interactions is required to understand how *Hyblaea puera* chooses and destroys Shisham trees at various growth stages. Evaluating tree defense systems and their efficiency against larval feeding will lead to the development of resistant tree varieties and integrated management approaches.

6.2 Need for developing resistant shisham varieties

Breeding and genetic engineering techniques can help reduce Shisham's vulnerability to *Hyblaea puera*, assuring long-term pest resistance and sustainability in forestry systems. One important area of study is natural resistance screening, which involves discovering Shisham genotypes with intrinsic tolerance to defoliation by large field experiments and genetic analysis. Furthermore, investigating biochemical components in leaves that prevent insect eating may give useful information for developing resistant cultivars. Biotechnological breakthroughs, like as genetic modification and CRISPR-based genome editing, hold promise for improving pest resistance in Shisham. Transgenic techniques, such as the use of *Bacillus thuringiensis* (Bt) genes, have the potential to drastically minimize larval damage by providing built-in insecticidal characteristics. Furthermore, selective breeding procedures should be implemented to produce high-yield, pest-resistant Shisham cultivars. Collaborating with forestry institutes to introduce and assess resistant cultivars in agroforestry systems will be critical for widespread adoption. Shisham plantations can be better protected against *Hyblaea puera* by using modern breeding and genetic methods, minimizing the need for chemical control measures and improving sustainable pest management.

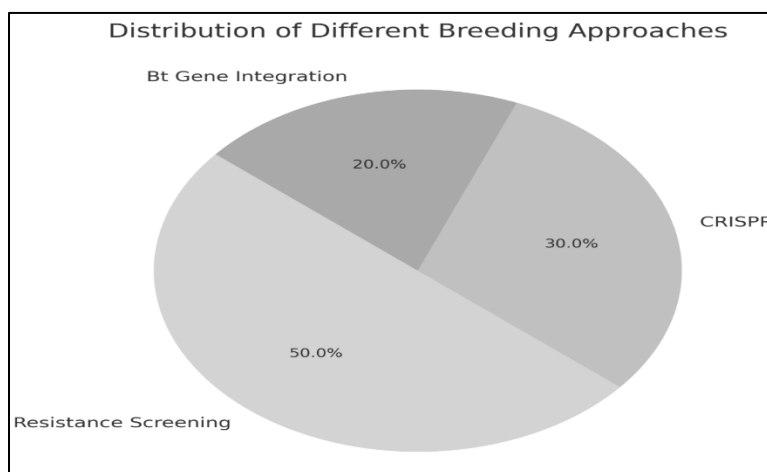


Figure 4: Biotechnological approaches in breeding

This figure illustrates the distribution of different breeding approaches to enhance Shisham resistance to *Hyblaea puera* (natural resistance screening, CRISPR modification, and Bt gene integration), which highlights the role of biotechnology in pest-resistant tree development.

6.3 Sustainable pest management strategies for long-term control

To lessen dependency on chemical pesticides and encourage biodiversity conservation, long-term, environmentally friendly pest control techniques are crucial. Priorities for research include:

6.3.1 Enhancing Biological Control Measures:

For the management of *Hyblaea puera*, concentrate on strengthening biological control methods, refining Integrated Pest Management (IPM) tactics, and determining the socioeconomic viability of pest control techniques. Finding the most effective natural enemies of *H. puera* requires research on the efficiency of native parasitoids, predators, and entomopathogenic fungi. Furthermore, creating mass-rearing and release plans for important biological control agents can aid in the development of long-term pest management strategies.

6.3.2 Optimizing Integrated Pest Management (IPM):

Creating frameworks that are suited to various ecological zones and plantation sizes is necessary to optimise IPM techniques. Including microbial biocontrol agents, neem-based insecticides, and pheromone traps in regular pest management would guarantee an efficient and eco-friendly strategy.

6.3.3 Assessing Socioeconomic Feasibility of Control Strategies:

The successful implementation of control techniques depends on evaluating their socioeconomic viability. Policymakers and farmers may select the most effective solutions by comparing the costs and benefits of various pest management strategies. Extension initiatives that teach local farmers and forestry authorities sustainable, low-cost control methods will improve grassroots pest management techniques and increase community involvement.

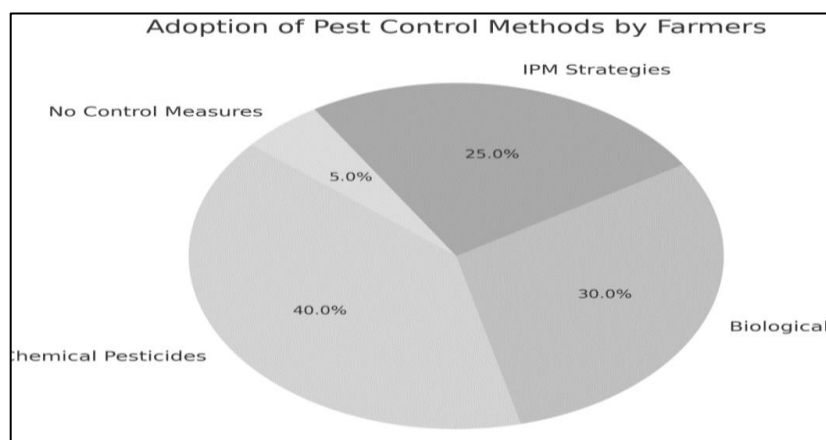


Figure 1: Assessing socioeconomic feasibility of control strategies

This pie chart in the above figure represents the percentage of farmers using different pest control methods (chemical pesticides, biological control, IPM strategies, and no control). It provides insights into current adoption rates and areas for improvement in sustainable pest management.

7 Conclusion

The infestation of *Hyblaea puera* on *Dalbergia sissoo* poses a tremendous danger to Shisham woods, with serious environmental and economic effects. This paper examines the pest's biology, infestation patterns, and the harm it does, emphasising the need to implement appropriate control techniques. The extensive defoliation weakens Shisham trees, lowers wood output, affects biodiversity, and harms rural livelihoods. Timely intervention via integrated and sustainable pest control is critical for mitigating these impacts. Pruning, cleanliness, and mixed plantation systems are all cultural practices that can assist in decreasing infestations. Biological control, which includes natural predators, parasitoids, and microbiological agents, provides an environmentally benign pest management solution. While chemical control produces quick results, its detrimental impact on biodiversity, human health, and resistance development makes it an unsuitable long-term option. As a result, the most successful and long-term strategy is Integrated Pest Management (IPM), which combines numerous strategies. Shisham woods require ongoing study and aggressive management. Future research should concentrate on developing resistant Shisham cultivars, understanding pest population dynamics under climate change, and enhancing biological control methods. Sustainable solutions need collaborative efforts from scholars, politicians, and local communities. We can safeguard Shisham woods by using scientifically proven, environmentally friendly pest control measures that ensure their ecological, economic, and environmental benefits for future generations.

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