Pink Bollworm (*Pectinophora Gossypiella*) in Cotton: Biology, Damage, Population Dynamics and Integrated Management with Special Reference to Maharashtra, India

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Abstract
The pink bollworm (Pectinophoragossypiella Saunders) is a concealed-feeding lepidopteran pest of cotton that primarily damages flowers and bolls. In India, its management has become increasingly complicated due to its internal feeding habits, the prolonged availability of cotton hosts, the repeated cultivation of long-duration hybrids, and the development of resistance to both Bt toxins and chemical insecticides. This narrative review synthesizes published literature on the biology, damage mechanisms, seasonal population dynamics, monitoring techniques, resistance evolution, and integrated pest management (IPM) of the pink bollworm, with a particular emphasis on evidence generated in Maharashtra.Recent Indian studies demonstrate that adult moth activity and green-boll infestation vary markedly both within and between seasons, underscoring the necessity of regular, proactive surveillance over reliance on late-season damage symptoms. Field evidence highlights the efficacy of multi-pronged management approaches: farmer-participatory initiatives in Jalna show that structured IPM programs can significantly reduce synthetic insecticide applications while enhancing crop yields and overall economic returns, while large-scale demonstrations in Nagpur highlight the promise of pheromone-based mating disruption.Conversely, documented field-evolved resistance to Cry1Ac and Cry2Ab across central and southern India underscores the clear limitations of relying on any single control technology. Looking forward, there remains a critical need for locally generated evidence on pest occurrence, farmer practices, economic losses, and broader ecological impacts within the cotton-growing landscapes surrounding Umarkhed and the Painganga Wildlife Sanctuary region of Yavatmal. Ultimately, a site-specific integrated framework—combining active monitoring, crop-window management, field sanitation, mating disruption, natural enemy conservation, and judicious, need-based chemical interventions is recommended to guide future research and sustainable cotton production.
Keywords: *Pink bollworm, Pectinophoragossypiella, Bt cotton, Umarkhed, Yavatmal*

1. Introduction

Cotton (*Gossypium* spp.) is a vital fibre crop and a key driver of agricultural livelihoods in India. The cotton agroecosystem supports a complex community of insect pests, among which bollworms are particularly critical because their larvae directly attack reproductive structures, severely impacting seed cotton yield and fibre quality. Among these, the pink bollworm, *Pectinophoragossypiella* (Saunders), is exceptionally challenging to manage because its larvae burrow into flowers and bolls to feed within protected internal tissues. A recent review by Bhute*et al.* (2025) highlights the pink bollworm as an economically significant cotton pest, summarizing its distribution, seasonal incidence, life history, damage patterns, and management strategies.

The economic importance and pest status of the pink bollworm in India have shifted substantially since the introduction and widespread adoption of Bt cotton. Although Bt cotton initially offered effective suppression against several lepidopteran pests, field-evolved resistance in pink bollworm populations has since emerged. Naik*et al.* (2018) documented evidence of field-evolved resistance to Cry1Ac and Cry2Ab toxins in central and southern Indian populations. Subsequent analyses indicate that after an initial period of suppressed incidence,

the pest has re-established itself as a major mid-season threat across several key cotton-growing regions.

Maharashtra serves as a highly relevant landscape for pink bollworm research. Studies conducted at Mahatma PhuleKrishiVidyapeeth, Rahuri, have documented marked seasonal variation in adult moth catches, rosette-flower incidence, and green-boll damage. Furthermore, research in Jalna has demonstrated the practical efficacy of farmer-participatory Integrated Pest Management (IPM), while a large-scale mating-disruption demonstration in Nagpur confirmed the viability of non-chemical suppression methods. While these regional studies offer a strong scientific foundation, they emphasize that site-specific investigations remain essential across diverse cotton production environments.To synthesize this knowledge, the present narrative review examines published scientific literature and institutional reports regarding pink bollworm biology, damage, monitoring, resistance, and management strategies, with a specific focus on India and Maharashtra. This work establishes a contextual and scientific baseline for ongoing Ph.D. research on pink bollworm dynamics in the Umarkhed–Painganga region of Yavatmal district; notably, no unpublished field data from the ongoing Ph.D. study are presented as results within this review.

2. Biology and Nature of Damage

The larva is the destructive stage of *P. gossypiella*. Eggs are laid on suitable plant surfaces, including leaves, flowers and bolls, and newly hatched larvae subsequently penetrate reproductive structures. Once inside a boll, larvae are relatively protected from contact insecticides. The pest can therefore cause damage that is not immediately apparent from external inspection.

Characteristic symptoms include rosette flowers, boring and feeding inside green bolls, larval presence in locules, damage to seeds and lint, and abnormal or incomplete boll opening. The internal feeding habit is a key reason why late chemical intervention can provide inconsistent control. Extension information from TNAU lists rosette flowers, excreta at bore holes, interlocular boring, double seeds and discoloured lint among characteristic symptoms.Because infestation may occur before external symptoms become obvious, monitoring should combine adult-moth surveillance with direct assessment of reproductive structures. This is particularly important when developing regional pest-management programmes.

3. Population Dynamics and Monitoring

Pheromone trapping is a practical method for detecting adult male activity and identifying periods of increasing population. Earlier studies established the value of gossyplure-baited traps for monitoring male moth populations, while recent Indian studies continue to use pheromone traps together with destructive sampling of green bolls.

A 2025 study at Rahuri, Maharashtra recorded weekly adult moth catches ranging from 1 to 185 moths during 2020 and identified the highest catch in the 50th standard meteorological week. In 2021, the peak was 153 moths per week in the 49th standard meteorological week. Rosette-flower incidence and green-boll damage also varied strongly with crop stage and season. These findings demonstrate that a single observation or end-of-season inspection is insufficient for describing PBW population dynamics.

Recent multi-location Indian research has also used standardized examination of green bolls to detect infestation. Such destructive sampling is valuable because larvae may be concealed inside the boll. For a future Umarkhed–Painganga study, combining pheromone-trap records, rosette-flower observations and systematic green-boll sampling would provide complementary measures of pest activity.

4. Bt Cotton and Resistance Development

The introduction of Bt cotton substantially changed cotton pest management in India. However, dependence on a single or limited number of toxin combinations creates selection pressure on pest populations. Field-evolved resistance of pink bollworm to Cry1Ac and Cry2Ab has been documented in India. Naik et al. (2018) reported increasing resistance ratios in central and southern Indian populations between 2013 and 2017, providing strong evidence that the problem was not simply a temporary increase in pest abundance.

More recent national analyses indicate that pink bollworm became established on Bt/BG-II cotton in parts of the central and southern zones after the first decade of Bt cotton cultivation.

Factors discussed in the literature include prolonged crop duration, continuous availability of cotton host material, refuge-related issues, cultivation of long-duration hybrids, survival of resistant individuals and movement of infested cotton material.

The implication for management is that Bt cotton should not be considered a complete stand-alone solution. Resistance management requires surveillance, appropriate crop-window management, removal or destruction of crop residues and other sources of carry-over populations, and integration of multiple compatible tactics.

5. Integrated Management Approaches

5.1 Cultural and crop-window management: Field sanitation and management of the cotton crop after harvest are important because surviving stages can provide a bridge to the next crop. Avoiding unnecessarily prolonged availability of cotton host material can reduce the opportunity for population carry-over. Management recommendations should be synchronized among neighbouring farms where possible because PBW is capable of dispersal among fields.

5.2 Pheromone-based monitoring and mating disruption: Pheromone technology has two distinct roles: monitoring adult activity and disrupting mating. A large-area demonstration in Nagpur district, Maharashtra using a pheromone-based mating-disruption dispenser reported reductions in flower, boll and locule damage in treated clusters. Such evidence supports area-wide approaches, although local performance should be evaluated under the specific crop, weather and management conditions of each region.

5.3 Biological control and conservation of natural enemies: Cotton fields contain predators and parasitoids that can contribute to pest suppression. Excessive or unnecessary broad-spectrum insecticide use may reduce these beneficial organisms. Therefore, conservation of natural enemies should be incorporated into IPM rather than treating chemical control as the first response to every observation.

5.4 Need-based chemical intervention: Chemical intervention should be guided by surveillance and locally validated economic thresholds rather than routine calendar spraying. Older threshold studies and current Indian extension systems use infestation or trap catch criteria to support decisions. Because insecticide susceptibility can change over time, product choice and rotation should follow current locally approved recommendations and resistance-management guidance. The present review deliberately avoids prescribing a fixed insecticide schedule for the Umarkhed- Painganga area because such a recommendation requires current label, regulatory and field-efficacy verification.

6. Evidence from Maharashtra

SN	Location / study	Main focus	Key finding	Relevance
1	Rahuri, Maharashtra (2020–21)	Population dynamics	Large seasonal variation in moth catches, rosette flowers and green-boll infestation.	Supports repeated seasonal monitoring.
2	Jalna, Maharashtra (2018–21)	Farmer-participatory IPM	IPM reduced insecticidal sprays and increased cotton yield versus farmer practice.	Demonstrates feasibility of integrated management.
3	Nagpur, Maharashtra (2021–22)	Mating disruption	Large-area pheromone intervention reduced flower, boll and locule damage in the demonstration.	Supports area-wide non-chemical tactics.
4	Nanded/Akola/Rahuri and other central-zone sites	Bt cotton incidence	Recent multi-location work documents PBW establishment and substantial variation among sites.	Shows need for local surveillance.

The Maharashtra evidence indicates that PBW behavior is spatially and temporally variable. Therefore, management recommendations developed at one location should be validated before being directly transferred to another landscape.

7. Research Gap and Relevance to the Umarkhed–Painganga Region

Published studies provide substantial information on PBW biology, resistance, population dynamics and management in India, including several studies from Maharashtra. However, the available literature identified for this review does not provide a comprehensive, site-specific

assessment integrating pest occurrence, farmer management practices, economic impact and ecological considerations for cotton-growing areas around Umarkhed and the Painganga Wildlife Sanctuary region of Yavatmal district.

This gap is important because agricultural landscapes near ecologically sensitive areas may require management strategies that consider both crop protection and non-target organisms. The author's approved Ph.D. research therefore proposes field monitoring, pheromone trapping, assessment of infested flowers and bolls, farmer surveys, documentation of management practices, economic assessment and evaluation of ecological considerations. The present review provides the literature background for those planned investigations, but the outcomes of the field study must be determined from primary data.

8. Proposed Site-Specific IPM Framework

Effective management of pink bollworm (PBW) relies on a structured, multi-stage strategy throughout the crop cycle. Prior to the season, farmers should remove or destroy residual cotton material to eliminate carry-over pest stages and encourage coordinated community action. During crop establishment, it is essential to document the cotton variety, sowing date, crop duration, and field-level management factors. As the crop reaches the flowering stage, regular pheromone-trap monitoring should begin alongside the systematic recording of rosette flowers. Once boll formation starts, destructive sampling of green bolls must be conducted at defined intervals to assess infestation levels.

When making pest control decisions, field observations should be carefully evaluated against locally validated economic-threshold guidelines. Management strategies ought to prioritize cultural, pheromone-based, and biological approaches; registered insecticides should be used only when strictly justified, rotating modes of action in alignment with current resistance-management recommendations. Furthermore, an important ecological component involves monitoring natural enemies and avoiding unnecessary broad-spectrum pesticide exposure, especially in fields bordering sensitive habitats. Finally, post-harvest practices should focus on timely crop termination and field sanitation to minimize PBW survival and prevent pest carry-over into the following season.

9. Conclusion

Pink bollworm remains a significant constraint to sustainable cotton production because of its concealed larval feeding habit, seasonal variability and evolving resistance to important control technologies. Evidence from Maharashtra demonstrates that regular monitoring, farmer participation and integrated tactics can improve the management framework while reducing unnecessary insecticide dependence. Pheromone-based technologies provide additional opportunities for both surveillance and area-wide suppression. Nevertheless, no single tactic is sufficient across all cotton-growing environments. For the Umarkhed–Painganga landscape, the priority is to generate local evidence on pest occurrence, damage, farmer practices, economic impact and ecological implications. The ongoing Ph.D. investigation can fill this gap through systematic field observations and statistically supported analysis. Until those observations are completed, conclusions about local infestation levels or treatment efficacy should not be assumed.

10. Author's Declaration

This manuscript is a narrative review prepared from published scientific and institutional sources and is not a report of completed field experiments from the author's ongoing Ph.D. research. No unpublished experimental result has been presented as an observed finding.

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