



## Beyond Bt: Integrated Approaches for sustainable Pink Bollworm Management in India

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### Abstract

The pink bollworm is as a serious constraint to cotton production in India due to widespread resistance to Bt toxins. This resurgence exposes the limitations of prolonged reliance on Bt cotton and the neglect of ecological pest management practices. Resistance evolution has been driven by pest biology, declining toxin expression, poor refuge compliance, and inappropriate agronomic and management practices. The failure of single-technology control highlights the need to re-establish integrated pest management (IPM) as the core strategy. An integrated approach combining cultural, biological, behavioural, and judicious chemical interventions is essential for sustainable pink bollworm management.

**Keywords:** Pink Bollworm; Bt Toxins; Resistance; Management; Pheromone

### Introduction

The pink bollworm, *Pectinophora gossypiella* (Saunders) has emerged as one of the most formidable constraints to cotton productivity in India. Once considered a pest of historical concern, its resurgence in the era of genetically modified Bt cotton has exposed the limitations of single-technology dependence in pest management. The widespread breakdown of Bt efficacy, particularly against Cry1Ac and Cry2Ab toxins, has necessitated a paradigm shift from technology-driven control to ecologically informed, integrated pest management (IPM) strategies.

India's experience with pink bollworm serves as a cautionary tale in transgenic crop deployment. Following the rapid adoption of Bt cotton since 2002, all the bollworm populations were initially suppressed, leading to reduced insecticide usage and enhanced yields. However, within a decade, field-evolved resistance to Bt toxins was reported from several cotton-growing states, including Gujarat, Maharashtra, Madhya Pradesh, and Telangana. The

development of resistance may be attributed to several factors *viz.*, cry toxin expression is highest in leaves followed by squares, bolls, and flowers; Toxin expression decline after 90 days from sowing; Feeding of segregating seeds in F1 Bt cotton hybrids; Non-application of refugia; Extending crop life; Lack of timely and appropriate management initiatives; Hybrids have different flowering and fruiting periods; Cultivation of long duration hybrids; Long term storage of raw cotton in ginneries; Nitrogen deficits and condition reduced the levels of toxin expression has rendered Bt cotton alone insufficient for sustainable pest suppression.

The biology and ecology of pink bollworm inherently favour resistance evolution and persistence. Its concealed larval feeding habit, diapause capability in seeds and crop residues, and multivoltine nature under Indian agro-climatic conditions contribute significantly to its survival and resurgence. Outbreaks can be successfully managed through a combination of cultural practices, synchronized sowing, short-duration varieties, and

regulatory interventions. The erosion of these practices during the Bt cotton boom weakened the agro-ecosystem's resilience, allowing pink bollworm populations to rebound once resistance emerged.

### **Beyond Bt: Reclaiming integrated pest management**

The current scenario underscores the urgent need to re-establish IPM as the cornerstone of pink bollworm management. Cultural strategies remain the first line of defense. Timely sowing, avoidance of staggered planting, use of short-duration cultivars, termination of cotton crops immediately after final picking, and destruction of crop residues significantly reduce carry-over populations. Regulatory enforcement of a cotton-free close season has proven effective in limiting diapause survival and early-season infestations.

Monitoring and decision-making tools play a critical role in IPM implementation. Pheromone traps for adult moth surveillance provide early warning signals and facilitate need-based interventions. Threshold-based insecticide application, guided by trap catches and rosette flower incidence, minimizes indiscriminate chemical use and delays resistance development.

### **Chemical control**

While chemical insecticides continue to be an important component, their role must be rationalized. Novel chemistries such as diamides, spinosyns, and insect growth regulators have shown efficacy against pink bollworm when used judiciously. However, indiscriminate and repetitive applications accelerate resistance not only in pink bollworm but also in secondary pests. Rotation of insecticides with different modes of action, adherence to recommended dosages, and integration with non-chemical tactics are essential to preserve their effectiveness. The application of synthetic pyrethroid recommended after 100-day old crop, to avoid resurgence in whiteflies.

### **Biological and behavioural interventions**

Biological control agents, including *Trichogramma* spp. egg parasitoids and entomopathogenic fungi, offer environmentally benign alternatives that can be integrated into cotton IPM modules. Additionally, mating disruption using pheromone-based technologies (Specialized pheromone lure application technology and PB Rope L) has shown promise in suppressing pink bollworm populations by interfering with mate-finding behaviour, particularly in compact cotton landscapes.

### **Policy, farmer participation, and future directions**

Sustainable management of pink bollworm extends beyond field-level interventions. Strong policy support, farmer education, and community-level action are indispensable. Refuge compliance, synchronized sowing at village or regional levels, and collective crop residue management require coordinated efforts involving farmers, extension agencies, and regulatory bodies.

Looking ahead, diversification of host plant resistance through non-Bt mechanisms, deployment of multi-tactic IPM modules, and integration of emerging tools such as sterile insect technique and molecular resistance monitoring offer new avenues for long-term suppression. India's pink bollworm experience reinforces a fundamental principle of pest management: no single technology, however advanced, can substitute for an integrated, ecologically grounded approach.

### **Conclusion**

The pink bollworm crisis in Indian cotton is not merely a technological failure but a systemic one. Moving beyond Bt cotton towards robust IPM frameworks is no longer optional - it is imperative. Reintegrating cultural wisdom, biological regulation, chemical stewardship, and policy enforcement can restore sustainability to cotton ecosystems and safeguard farmer livelihoods. The future of pink bollworm management in India lies not in replacing Bt with another silver bullet, but in embracing integration, resilience, and ecological balance.