Escalating Resistance of Pink Bollworm in Bt Cotton Across Northern India and Its Strategic Management

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Cotton (*Gossypium hirsutum* L.) stands as a pivotal commercial crop globally, often hailed as the "King of natural fibre" and "White Gold." It belongs to the family Malvaceae which have soft, hairy, or velvety textures with members found in tropical, subtropical, and temperate regions worldwide and the genus *Gossypium*. In India, cotton thrives in three diverse agro-ecological zones, each characterised by distinct climatic and soil conditions: the Northern zone encompassing Punjab, Haryana, and Rajasthan; the Central zone covering Gujarat, Maharashtra, and Madhya Pradesh; and the Southern zone including Andhra Pradesh, Tamil Nadu, and Karnataka. The ideal conditions for cotton growth is well-drained sandy loam soils with moderate fertility.

Among the myriad of pests afflicting cotton, each causing substantial damage to the crops and impacting yield and quality, the pink bollworm (*Pectinophora gossypiella*) stands out as the most formidable and devastating pest worldwide. From the blooming to the harvesting stage, its larvae wreak havoc by consuming anthers, pollens, flowers, green bolls, locule, lint, and seeds, often distorting flowers into twisted formations known as "rosette flowers." *Bt* Cotton was created to be resistant to the bacteria *Bacillus thuringiensis and* was introduced in India in 2002 to protect cotton against the vulnerability of American bollworm (*Helicoverpa armigera*), PBW (*Pectinophora gossypiella*) and spotted bollworm (*Earias vittella*) as it was encoded with Cry1Ac toxin. Bollgard-II (BGII) cotton expressing two proteins, Cry1Ac and Cry2Ab was expected to be effective against the pink bollworm especially after resistance to the single gene Cry1Ac was reported as heavy field infestations of PBW in Bollgard (BG) that was confined to Gujarat state in 2009. The reports of resistance breakdown to pink bollworm in *Bt* cotton in Central and South Zone was noticed into 2010. However, the first field report of pink bollworm damage in the North Zone was during the 2018 season from Jind district of Haryana and two other field locations in Punjab, all from field adjoining to cotton ginning-cum-oil extraction mills.

In 2023, as per government reports, the pink bollworm infestation has affected the entire cotton belt in the north. Approximately 65 per cent of cotton production in Haryana and Punjab has been severely damaged, while Rajasthan has faced losses up to 90 per cent, as stated by Y G Prasad, director at Central Institute for Cotton Research (CICR).

Life cycle of pink bollworm

Eggs are deposited on flowers, young bolls, and axil of petioles as well as underside of young leaves. Within two days of hatching, the young larvae penetrate ovaries of flowers or young bolls within two days of hatching. Larvae turn pink in colour in 3-4 days after hatching. Larvae prefer feeding on developing seeds and generally pupate inside the seeds and bolls. Moths are dirty brown in colour, about 5 mm in length.

Affected bolls either open prematurely or get badly affected due to rotting. Fibre qualities such as length and strength are lowered. Further the cotton lint in the insect infested bolls gets damaged by secondary fungal infection. The seed cotton carried to market yards acts as a source for the pest to spread. Pink bollworm generally arrives with the onset of winter and continues to survive on the crop as long as flowers and bolls are available. Long duration cotton allows the pest to thrive for a longer continued period in multiple cycles, thereby affecting the subsequent cotton crop. In the absence of cotton, or as a genetically pre-disposed condition, the pink bollworm undergoes hibernation or diapause that allows it to be dormant for 6-8 months, until the next season.

Damage Symptoms of Pink Bollworm in cotton

Major symptoms of pink bollworm infestation in cotton crops are:

- **Bud Shedding:** Pink bollworm attack on flower buds causes them to shed prematurely.
- **Formation of Rosette Flower:** Flower infestation can lead to the formation of rosette flowers.
- **Reduced Lint Development:** The larval attack results in reduced lint development and weakened lint quality.

Fig 1 Adult

Fig 2 Rosetted bloom

Fig 3 Larva feeding on boll

- **Premature Boll Opening:** Infested bolls may open prematurely, exposing them to saprophytic fungi growth.
- **Reduced Germination:** If infested seeds are used for sowing, germination rates are reduced.

Reasons for Pink Bollworm Resistance in Bt cotton in northern India

1. Early sowing of cotton in the northern zone of India and late cotton varieties in central and southern India. The ideal time for sowing cotton is April 15 to May 15. But many farmers in the northern belt of Haryana, Rajasthan and Punjab start sowing from March end or the first week of April and extend it up to June end, which is an increase from 45 days to 80 days. This early sowing season coincides with the time the PBW comes out of hibernation or the diapause stage in the winter months.
2. Cultivation of long duration hybrids and mono-cropping that serve as continuous hosts of the pink bollworm.
3. The cry toxin — the chemical that prevents PBW from attacking the cotton seeds — wears off eventually during the end days of the cotton plant. If the pests survive the small quantities of these toxins, they manage to develop resistance to the chemical and create progenies in the next generation that are more immune to it.
4. Non-compliance of refugia non-Bt cotton.
5. Long term storage of raw cotton in ginning mills and market yards that serve as a source of pink bollworms to the ensuing crop.
6. Many oil seed industries and ginning mills in this region have imported cotton from these infested regions, which enabled the spread of disease in the northern cotton belt. Initially, the infestation was detected around cotton oil mills, as some of the infested cotton travelled to northern regions. It has spread widely in recent years.
7. Lack of timely and appropriate management initiatives, which led to continuous proliferation of the insect pest. Farmers do not initiate ant control measures against any bollworms on Bt-cotton.
8. PBW has undergone genetic changes and can resist the Bt toxin.
9. The pest is also elusive and not visible, so farmers find it difficult to control it in its early stages by spraying pesticides and insecticides.

Management Strategies

1. Regular monitoring of *Bt* cotton against bollworm resistance
2. Use of the biorationals *viz.*, parasitoid *Trichogramma* in *Bt* cotton fields for pink bollworm management.
3. Refugia: Recommend planting of desi cotton/ conventional non-*Bt G. hirsutum* cotton and late planted okra as refugia crops.
4. Timely boll picking of the crop by November and avoiding ratoon and/or extended crop.
5. Mandatory utilisation or destruction of cotton stalk and leftovers immediately after harvest.
6. Adoption of crop rotation to break the pest cycle.
7. Encouraging farmers to cultivate short duration varieties (150 days) to obtain high yields in high density and escape pink bollworm infestation.
8. Light traps instalment in fields during the season and also near go-downs, ginning mills, market yards etc., to trap post season moths.
9. Mass trapping and mating disruption using pheromone traps.
10. Use of 'pheromone traps' and 'green boll dissection' for regular monitoring and initiate control interventions based on economic threshold levels of 8 moths per trap per night and/or 10% damage in green bolls.
11. For chemical management of pest, Insecticides such as quinalphos or thiodicarb may be used in initial stages and synthetic pyrethroids after October at economic threshold levels of damage.

Conclusion

With the resurgence of pink bollworm in Indian cotton fields, there's growing concern that the inherent pest resistance of the second-generation *Bt* cotton technology (Bollgard-II) is is no longer

functional. The pink bollworm presents a significant challenge to *Bt* cotton growers, but by adopting an integrated pest management approach, farmers can mitigate its developing resistance against *Bt* cotton. Through a combination of cultural, biological, and chemical control methods, along with the use of resistant cotton varieties, it is possible to reduce pink bollworm populations and protect cotton crops. Implementing management strategies, along with regular monitoring and collaboration, will help sustain cotton production while minimizing economic losses caused by this destructive pest.

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