

Holistic management strategies of pink bollworm in *Bt* cotton in north cotton growing zone of India

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Cotton is one of the most remunerative crops of the northern zone after rice and is an economically important cash crop in the states of Haryana, Punjab and Rajasthan. The major limiting factors in cotton productivity are insect-pests, diseases, prolonged drought stress, excessive rains and poor nutrition management, especially the cotton bollworm. The double gene (Cry1Ac+Cry2Ab) *Bt* cotton, Bollgard-II (BG-II), was approved for cultivation in all cotton growing zones of India during 2006 as a resistance management strategy since stacked genes (Cry1Ac+Cry2Ab) act synergistically and become more toxic to cotton bollworm (*Helicoverpa armigera*) as well as other lepidopteran pests that include spotted bollworm (*Earias vittella*), spiny bollworm (*Earias insulana*), and pink bollworm (*Pectinophora gossypiella*). Among bollworms, pink bollworm acquired resistance to BG-I and BG-II cotton due to its feeding behaviour and after its reappearance, it became a serious concern. Therefore, proper understanding and knowledge about the lifecycle, survival during season and off-season, integrated management of the pest is essentially required to further boost the sustainable cotton production in the country.

Keywords: Cotton bollworm, Oligophagous, Pyrethroids, Rosette flower

PINK bollworm (PBW), *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae), is an oligophagous but functionally monophagous, feeding only in cotton crop during the cropping season. Its infestation often remained undetectable due to its internal feeding behaviour, and becomes difficult to manage, causing significant yield reduction and quality but many a times managed through insecticides application targeted to other cotton bollworm. After introduction of Bollgard (BG-I and BG-II) cotton hybrids, the incidence and damage due to pink bollworm was negligible in *Bt* cotton and remained low to medium in non-*Bt* cotton genotypes. Initially, the *Bt* cotton proved successful in controlling the cotton bollworms but they acquired resistance to cry protein because of its reclusive feeding behaviour, late-season occurrence and increased exposure

to sublethal concentrations of *Bt* toxins, particularly in extended cotton crop in absence of adequate refuge compliance which facilitated the development of resistance in PBW in the central and southern cotton-growing zones. Though PBW acquired resistance to *Bt* cotton during 2009-14, it was recorded in 2017 in Bollgard-II in many central (Gujarat, Maharashtra) and southern (Andhra Pradesh, Telangana) zone states.

In north cotton growing zone of India, pink bollworm infestation on *Bt* cotton was noticed in 2018 season in cotton fields adjoining to cotton ginning-cum-oil extraction mills in Jind districts of Haryana and Bathinda districts of Punjab. According to ICAR-Central Institute for Cotton Research (CICR) under Insecticide Resistance Management (IRM)-Dissemination of Pink Bollworm Management Strategies Project, the infestation initiated due

to transportation of resistant larvae along with cotton seed procured from southern states by ginning-cum-oil extraction mills to maintain round the year supply of cotton seed cake. The incidence slowly spread in Haryana, Punjab and Rajasthan over the years leading to establishment of resistant larvae in the zone. During 2023, pink bollworm damage at farmer's field reached at highest level (5–90% green boll damage) in northern zone. Pink bollworm can be managed if monitored round the year, therefore it is very important for cotton farmers to have a good understanding and knowledge about the biology, nature of damage, and monitoring to manage pink bollworm.

Sources of pink bollworm

Farmers should have a clear understanding about the off season survival of PBW. In off-season with the onset of unfavourable conditions,

PBW survive as diapausing larvae (dormant) in cotton seed and unopened or damaged bolls of cotton. Whenever the favourable conditions appears, PBW starts its life cycle again and lay eggs on early sown crop or ratoon crop plants on the early/first appearing fruiting bodies. According to ICAR-CICR, Regional Station Sirsa, unopened bolls available in infested stalks stacked adjoining to cotton field for domestic fuel purpose are major source of initial infestation.

Damage symptoms

Pink bollworm generally damages the fruiting body parts of cotton plants. Since the initial incidence remains undetectable, following damage symptoms can help in detection of incidence.

- **Shedding of squares:** Pink bollworm attack initiates with appearance of squares, larva bore and feed inside the square. Due to internal feeding, squares shed automatically after sometime. Prior to *Bt* cotton introduction, square shedding was rarely observed as the pest was appearing in late season. With more than 95% cotton area under *Bt* cotton and absence of cotton bollworm, PBW appears in beginning of the season and feed on squares resulting in shedding.
- **Rosette flower:** After opening of flower, larvae start feeding in flower buds and spins web to close flower for feeding in closed fruiting body parts. The closed flower appear like rose flower, referred as 'Rosette flower'.
- **Green boll damage:** Green bolls are most preferred feeding site. When boll formation starts in cotton, PBW prefers to feed on 10–15 days old bolls only. The larva enters into the boll and closes the entry hole and move to feed on immature seeds inside the bolls till completion of larval period. Larva can feed on 1–5 immature seeds to reach pupal stage. Prior to beginning of pupal stage, larvae come out and pupate in plant debris. Under severe incidence, a single



Rosette flower



Damaged green boll



Poorly opened boll



Exit hole



Stained lint



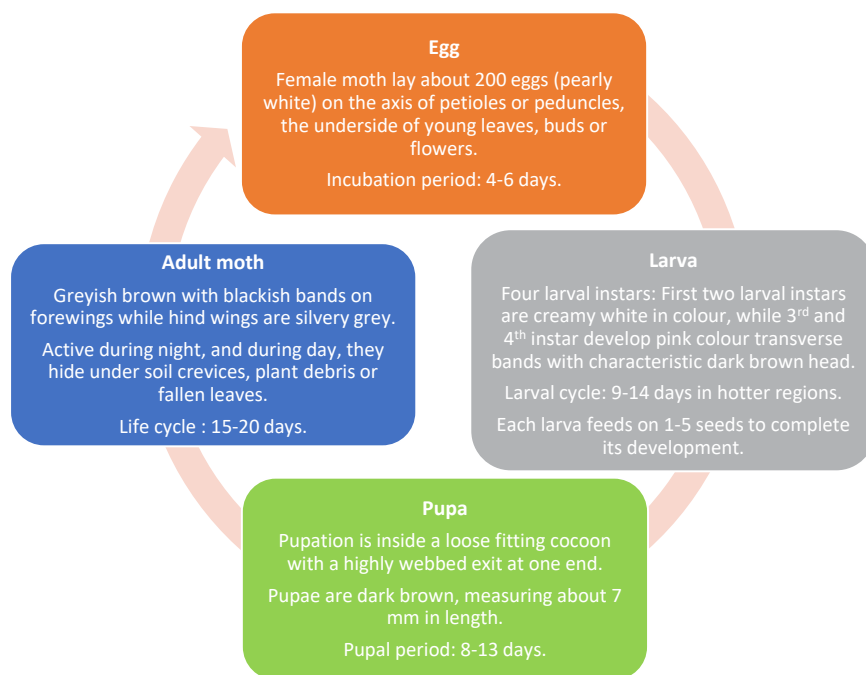
Pheromone trap

boll may have more than one larva, leading to very serious damage to crop, affecting cotton yield and quality.

- **Exit hole on green bolls:** Exit hole is noticeable once the larvae exit out from the damage boll, however, this condition can help in further and fast damage by the next generation of PBW. The feeding damage predisposes the

bolls to other insects and fungi to enter inside the bolls and cause secondary damage.

- **Premature/abnormal opening of bolls:** Pink bollworm incidence results into poor boll opening with damaged cotton and seeds apparently visual as small round holes on the locules of opened bolls.
- **Damaged open bolls and lint**



Life cycle of pink bollworm

staining: In open bolls, pink colour-stained lint around feeding areas is visual wherein poor-quality cotton seed as well as lint are produced. This is a major damage symptom leading to direct yield as well as economic loss to farmers.

Peculiar feature of pink bollworm life cycle in northern India

Generally PBW life cycle is completed within 3–6 weeks in peak flowering stages in cotton and late season has invariably overlapping broods. But in case of northern zone, the last generation of the year have a long cycle period. In winter, the larvae of last generation enter into diapause, where mature un-opened bolls are present, the larvae often diapause inside the bolls or seed cotton or seeds. In case of cotton seed, larvae survive by joining two seeds and remain in diapause in these double seed formation. The resting larvae undergo diapauses of varying intensity, ranging from 31–157 days depending upon the existing climatic condition and availability of food source.

Monitoring and management during off-season

- Do not store infested or stained cotton in house/godowns.
- Install pheromone traps near stacks of cotton stalks, ginneries, and market yards for monitoring and trapping of adults. Trapped adults should be disposed of.
- Remove all seeds from the ginneries by the end of March and fumigation of the seed left uncrushed in the mills before end of March with celphos/phostoxin/delicia@one3gtablet/m³ exposed to 48 h or in case of 24 h exposure, use two tablets (6 g/m³) (Package of practices for crops of Punjab, Kharif 2026-27, Punjab Agricultural University, Ludhiana).
- Do not retain un-fumigated seed in the ginneries. Even for cattle feeding, only cotton-seed cake should be used and no seed should be stored for this purpose.
- Destroy all trash collected

during the ginning process.

- The seed meant for sowing must be acid-delinted. The acid treatment kills the larvae of the pink bollworm. It also removes fuzz and thereby facilitates mechanical sowing and good seed germination.
- The cotton retained by the farmers for sowing should be ginned by the end of March and seed should be acid-delinted/fumigated or thoroughly dried in the sun in a thin layer for 3–4 consecutive days in first fortnight of April. The extra recovered seed from this should either be fed to cattle or to be retained, it should be properly acid delinted and fumigated.
- Destroy previous year infested cotton residual stalk, unopened bolls and partially opened bolls before cotton sowing.
- Prior to sowing, if possible, use the stalks stacked before the end of March or dislodge the unopened and damaged bolls and other trash by beating on the ground and mix them in soil.
- Avoid movement of cotton stalks from the heavily infested field of pink bollworm to new area of cotton.

Monitoring and management during season

Cultural practices:

- Follow crop rotation to break the life cycle of pink bollworm.
- Ensure heavy pre-sowing irrigation to obtain good germination and early establishment of plants.
- Grow only recommended varieties/hybrids of cotton for the zone.
- Complete the sowing up to 15th

May.

- Avoid excessive use of nitrogen fertilisers.
- Grow two dense rows of sorghum or pearl-millet or maize as border around cotton fields.
- Create ecological diversity by growing *desi* cotton and other non-host crops between the cotton fields.

Monitoring and mechanical practices:

- Inspect the crop at squaring and flowering stage for the presence of pink bollworm larvae within flowers.
- Remove and destroy rosette flowers. Collect and destroy fallen squares, flowers and bolls in the field.
- Install 2 pheromone traps per acre after 45 days of sowing (DAS) for monitoring of moths activity of pink bollworm and for mass trapping of male moths, install 8 traps/acre.
- Normally non-*Bt* seeds as refuge-in-bag are mixed with *Bt* seeds but in case separate packet is provided in *Bt* packet, it (20% non *Bt* seeds) should be planted on the boundary of *Bt* cotton fields.
- In case of cotton field, adjoining to ginning mills-cum-oil extraction mills or cotton stalk stack of previous season, one spray of neem based insecticide may be applied at initiation of squaring (square on 10% plants).

Behavioural management:

CREMIT PBW or NATMAT PBW: CREMIT PBW or NATMAT PBW, gel based product, as mating disruption technique for pink bollworm is advised wherever incidence of PBW is observed

Table 1. Methods to verify economic threshold level of pink bollworm in cotton

Method	Economic Threshold Level (ETL)	Crop stage
Based on pheromone trap catches	Install two pheromone traps/acre for monitoring and in case 5–8 moths catch observed per trap for consecutive three nights	During off season and beginning of season
Based on rosette flower	>10% rosette flowers (10 out of 100 flowers are damaged or rosette shape)	In early-stage crop
Based on green boll damage (Destructive sampling)	>10% green bolls damage (at least two out of 20 bolls having white or pink larvae or exit holes)	After 75 days old crop

continuously over the years. Use pheromone gossyplure 4% i.e. 125 g/acre for 3–4 times. In cotton crop, first application should be done at 30–35 DAS before initiation of squares, on randomly selected 400 plants/acre. Apply it in the size of gram or pea size dollop near the joint of fifth main stem leaf from top of the plant. Repeat it three times at an interval of 30 days and avoid the plants selected during previous application. To get good benefits of this technique (SPLAT), it is necessary to apply it at the right crop stage and on a large scale at least in 10 hectare plot. If rain received within 4–5 h of application, apply it again. If even after using this technique, the infestation of pink bollworm noticed above the ETL based on green boll damage, then spray recommended insecticides.

PB Rope-L: PB Rope-L is a polythene hollow tube supported with aluminium wire to twist easily around stem of cotton plant, containing Gossyplure an approximately 1:1 blend of Z, Z-7, 11-Hexdecadien-1-yl acetate and Z, E-7, 11-Hexdecadien-1-yl acetate 42.7% w/w (CIB&RC 2026) as active ingredient which is used as mating disruption techniques for management of pink bollworm in cotton. Timely application is very important i.e. before square formation between 35–40 DAS for better results. The total 9,875 dispenser/block i.e. 25 ha, may be used. First, install the PB rope along the border at one meter spacing around the field. Thereafter, remaining rope can be applied as filler in evenly distribution manner on plants in the field at approximately 5 m spacing. For installation of PB ropes, twist the rope two times loosely on main stem as it is. After installation of the PB rope, regularly monitor the infestation in the field through appearance of rosette flower and green boll dissection method. If incidence noticed above ETL, then apply recommended insecticide to manage the damage.

Biological measures: To manage PBW through biological measures, conserve and augment

Table 2. List of insecticide for window based management of PBW in cotton

Period (days after sowing)	Chemical name	Doses/acre (Use 200 L water)	Waiting period (Days)	Toxicity label colour
0–60	NSKE 5% + Neem oil 5 mL/L + 1 g laundry detergent powder/L water	NSKE 10 L + Neem oil 1 L + 0.2 kg laundry detergent powder	-	Green
	Neem oil-based insecticide (300 or 1,500 ppm)	1,000 mL	05	Green
61–120	Enamectin benzoate 5 SG (Proclaim)	100 g	10	Yellow
	Profenofos 50 EC (Curacron/Carina/Profex/Celcron)	500–800 mL	15	Yellow
	Indoxacarb 14.5 SC (Avaunt)	200 mL	16	Yellow
	Thiodicarb 75 WP (Larvin)	250–400 g	30	Yellow
	Spinetoram 11.7 SC (Delegate)	170 mL	30	Green
	Chlorpyrifos 20 EC (Coroban/Dursban/ Durmet/Chlorgaurd/Radar/Lethal/Force)	500–1,000 mL	-	Yellow
121–150	Ethion 50 EC (Fosmite/E-mite/Volthion)	800 mL	25	Yellow
	Cypermethrin 10 EC (Ripcord/Bullet/Ustad/Cypergaurd)	220–300 mL	07	Yellow
	Cypermethrin 25 EC (Cymbush/Cyperkill/Hilcyper/Colt/ Basathrin/Agrocyper/Cypergaurd)	80–110 mL	-	Yellow
	Lambda cyhalothrin 5 EC (Karate/Reeva)	200 mL	21	Yellow
	Deltamethrin 2.8 EC (Decis)	200 mL	-	Yellow
	Fenprothrin 10 EC (Danitol/Meothrin)	300–400 mL	14	Yellow
	Alphacypermethrin 10 EC (Alphagaurd/Merit Alpha)	100–110 mL	10	Yellow

Note: If more than one spray is required based on ETL, rotate the insecticide with different modes of action. Trade name of insecticide as mentioned in PoP, PAU, Ludhiana.

natural enemies and parasitoids such as *Trichogramma batrae* (egg), *Chelonus* spp. (egg-larval), *Camptoplex chlorideae* (larval), *Bracon* spp. (larval) *Chrysoperla carnea*, lady bird beetles, etc.

Egg parasitoid *T. batrae* may be directly released at the rate of 60,000/acre 2–3 times at the interval of 10–15 days after 90 DAS. As a precautionary measure, application of insecticides should be done accordingly.

Management practices at harvest

- Terminate the crop as early as economically feasible. For this purpose, give last irrigation by end of September in case of northern zone. It would reduce bollworms damage and their carryover to the next cropping season.
- Picking of clean and infested cotton may be carried out separately.

- Clean cotton can be stored or marketed separately.
- Allow sheep, goat or cattle grazing in cotton fields after last picking prior to shredding and mixing of cotton stalks in fields or removal from the field.
- Don't stack the cotton stalk in field or under the shade.
- Prior to stacking, dislodge the unopened bolls and other trash by beating on the ground and mix them in soil.
- Stack cotton stalks vertically away from the field if possible, shredding of cotton stalks with cotton shredder and mix in soil is advisable. If space is a constraint, and vertical stacking is not possible, then small horizontal stack are advisable.
- Avoid movement of cotton stalks from the heavily infested field of pink bollworm to new area of cotton.

Precautions during spray

- Use fix type solid hollow cone nozzle for spray of insecticide.
- Spray insecticide before 12:00 noon or in the evening.
- Do not repeat the insecticides of same group in subsequent sprays.
- Repeat the spray immediately if it rains within 24 h after spray.
- Don't use synthetic pyrethroids on cotton for the control of bollworm complex till September end to avoid resurgence of whitefly population.
- During spray, wear all protective clothes, shoes, mask, goggles and hand gloves.
- Dispose the pesticide container

in proper manner.

- Avoid tank mixing of insecticide, fungicide and micro nutrients.

SUMMARY

Major production issues in cotton include biotic, abiotic (erratic rainfall, sudden drought, fluctuating temperature and humidity) and operational factors (sowing window due to non-availability of canal water, poor insect-pest monitoring mechanism and poor nutrient management). Cotton crop is prone to insect-pests, presently sucking pests and PBW is among the major limiting factor in cotton productivity. Pink bollworm, because of direct feeding on fruiting bodies and internal

feeding behaviour, is difficult to control once larvae entered the fruiting bodies. Therefore, timely monitoring of incidence through rosette flowers, pheromone trap or green boll destructive sampling is a key for successful management through timely decision making and application of management interventions. Similarly, field adjoining to sources of off-season survival need extra awareness. Based on the above information and utilisation of various monitoring and management techniques, this pest can be successfully managed to sustain cotton production.

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