



Biology and Ecology of Bollworm Complex of Cotton

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The bollworm complex of cotton refers to a group of lepidopteran insects that commonly infest cotton crops, causing significant damage to the crop and economical loss to the farmers. Key pests include the cotton bollworm (*Helicoverpa armigera*), pink bollworm (*Pectinophora gossypiella*), spiny bollworm and spotted bollworm (*Earias* sp.). Understanding their biology and ecology is crucial for developing effective management strategies.

Keywords: Biology, Ecology, Bollworm Complex, Cotton

Introduction

The bollworms form the major polyphagous lepidopteran insect group that have successfully exploited cotton crop over several decades. These include American bollworms, pink bollworms, spiny boll worms and spotted bollworms (Table 1).

Table 1: Major bollworms of cotton

Sl. No.	Scientific name	Family	Order
1.	American bollworm, <i>Helicoverpa armigera</i> (Hübner)	Noctuidae	Lepidoptera
2.	Pink bollworm, <i>Pectinophora gossypiella</i> (Saunders)	Gelechiidae	Lepidoptera
3.	Spiny bollworm, <i>Earias insulana</i> (Boisduval)	Nolidae	Lepidoptera
4.	Spotted bollworm, <i>Earias vittella</i> (Fabricius)	Nolidae	Lepidoptera

1. American bollworm, *Helicoverpa armigera* (Hübner)

This polyphagous noctuid insect, known as the American bollworm in India, was the single most troublesome pest in cotton crops over the world. Their resource use pattern on highly proteinaceous fruiting bodies makes them more successful as noctuid moths in agro-ecologies than in other associated habitats. Because of extensive agriculture for food production, the insect is frequently referred to as a 'man-made national pest'.

Description

- Whitish or creamy-white eggs, subspherical with a flattened base; apical area surrounding the micropyle smooth, the rest of the surface sculptured with approximately 24 longitudinal ribs, alternate ones being shorter, with numerous much finer transverse ridges (carinae) between them are laid singly on young fruiting bodies, leaves and terminal growing tissues of cotton plants.
- The neonate caterpillars are translucent, with faint longitudinal lines and brown to black head capsules; the thoracic and anal shields, thoracic legs, setae and their tubercle bases and spiracles are also brown to black and giving the larvae spotted appearance. There are prolegs on the third to sixth and tenth abdominal segments.
- While the second instar bollworms are similar in colour with darker shades, the third instar is characterized by two colour types; green ones and red-brown ground colour, with

greenish-fawn or cream- to fawn-coloured head capsule. The colour and patterns always lose intensity prior to each moult.

- The fully grown caterpillars are 35 to 42 mm long, the integument having granular appearance, consisting of close-set minute light brown to reddish brown, setae dark and spiracles and claws black. The colour pattern is guided by single or paired median dark with pale transverse bands, continuous broad white or yellowish lateral band bearing dark spiracles.
- The ventral body colour is pale yellow. The final instar has varying colours ranging from dirty brown to yellowish or reddish brown. Variation in colours of same instar larvae on the same plant is common and hence confusing.
- The caterpillars are cannibalistic, and in captive rearing, this behaviour increases cost and space for their mass production. With five to seven larval instars being usual, the fully grown six instars occur on cotton crop. Growth under lower temperature produces extra moults. Pupae are 14 to 22 mm long by 4.5 to 6.5 mm thoracic width, mahogany brown and smooth surfaced, with two parallel spines at posterior spines.
- Larval food quality and sex determine pupal size and weight, with males being small. The stout moths have 35 to 40 mm wing span and body length of 18 to 19 mm. Forewings are buff to greyish and light brown with dark brown or blackening markings on both wings.
- Females are darker than males. Moths emerge based on circadian rhythm, starting at dusk to midnight, peaking in the latter half of this period.

Biology:

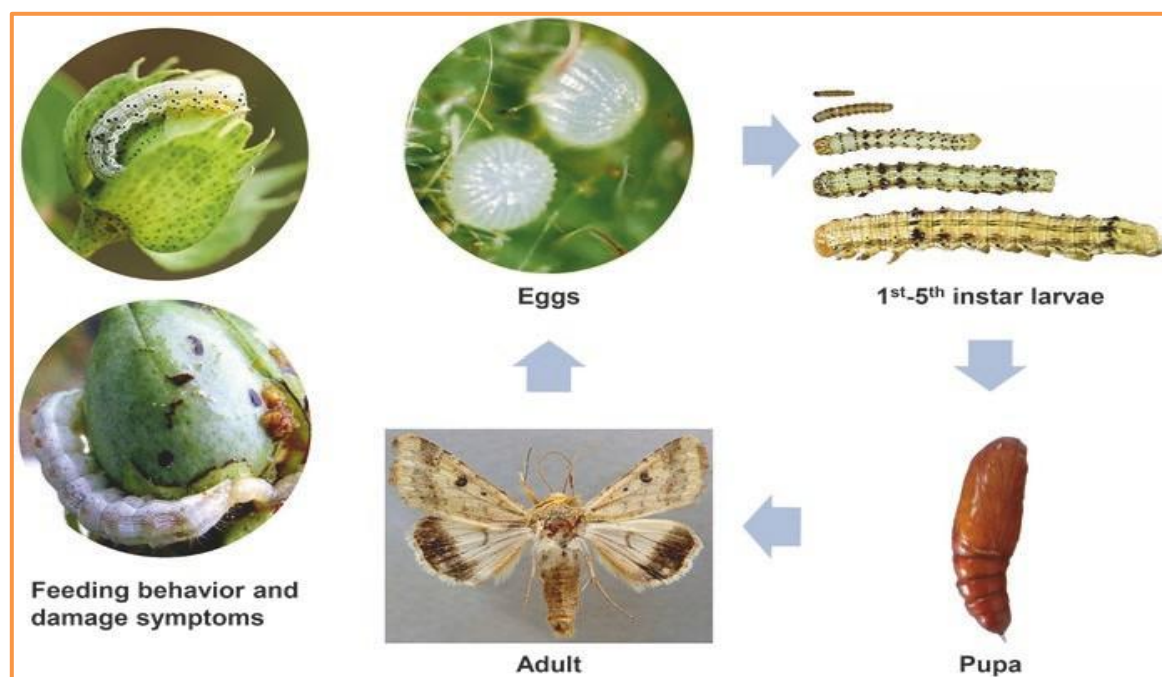


Fig. 1: Life cycle of cotton bollworm, *Helicoverpa armigera* (Hübner)

- Oviposition is done after dusk alternating with feeding and completed by midnight. Eggs are laid singly on fruiting parts, on leaves and in growing tissues.
- The mother moth selectively lays more eggs on tissues with high soluble nitrogen levels ensuring high-quality larval food. Geographic variations on the pattern of host preferences, distribution pattern and host plant utilization are seen, denoting the presence of varying races and subspecies in large populations in geographical areas (Bhattacharjee and Gupta 1972; Jayaraj 1982; Reed and Pawar 1982; Ramaswamy 1990; Fitt 1990).
- The adult longevity varies during season between 10 and 21 days, with females living longer over males. Quiescence to tide over summers and winters is seen in pupae. Oviposition cue for selection of sites is a determinant of crop volatiles and its canopy colour and is known to guide even fast flying moths for landing to lay eggs.

- Diel cycles of moths are well known, and they rest under the leaf of any plant during daytime and fly to feed on nectar in available plants and lay eggs in cotton. The number of eggs laid by a moth in its lifetime is about 200 to 500 in 10 to 15 days in each of the generation in cotton crop. Three to four generations are common in cotton season for this pest. The incubation period of eggs varies between hosts and seasons within two and five days.
- On eclosion, the neonate eats on the chorion before taking to plant tissue epidermis. Neonate moves around to fix to the feeding sites and grow. Older caterpillars keep out posterior half of the body out of the feeding bolls and boreholes making them vulnerable for being preyed/parasitized upon. The caterpillars move between plants and within plants to extensively feed on fruiting bodies such as squares, flowers and flowers of all age.
- Moulting's occur in the leaf surface in bright sunlight. It takes about 15 to 21 days in different months of cotton growth including prepupal stage. Pupation of fully fed caterpillars occurs in soil crevices. Jayaraj (1982) recorded pupal period as 2.5 to 17.5 days. In black cotton soils, the last stage of crop season makes these larvae to form cocoons even below 20 cm to overcome harsh summer heat.
- Pre-pupal stage is short for 1 to 3 days. The moths emerge after first few showers and become active in the growing cotton crop that is at bud break stage. They lay eggs on growing squares and exploit all the fruiting forms intensely. Moths are to fly locally for great distance although their migratory behaviour is studied to indicate that a flight speed of 4.8 km h⁻¹ and a median distance of 40 km per night can take them to 200 km over a week (Armes and Cooter 1991).
- Pheromone of the female moth is known for this species; (Z)-11-hexadecenal with minor components of (Z)-9-hexadecenal and (Z)-11-hexadecenal-1-ol is its chemical composition (Piccardi *et al.*, 1977; Nesbitt *et al.*, 1979). The females on emergence after feeding release plumes of this pheromone to attract mates in the neighbourhood.
- Downwind pheromone plumes attract males to fly good distance to reach the females. Mated females live longer than virgin females. Males live shorter than females. Based on the availability of food, the moths can be alive between nine and 25 days. But the effective laying period shall be only two-thirds of its life. Wind speed, wind direction and moonlight on trap catch are known to influence trap catch of the moths (Vickers and Baker 1992)

2. Pink Bollworm, *Pectinophora gossypiella* (Saunders)

This oligophagous insect is a widespread cotton pest in all cotton-growing regions and countries. This gelechiid insect, which may have originated in the Indian subcontinent, has resulted in significant crop loss in both diploid and tetraploid cotton cultivars. The lint damage is so severe that the crop is frequently abandoned during harvesting because poor seed cotton has no market value.

Description

- This old-world insect is oligophagous pest that is debated to have originated along with the origin of diploid cottons, such as *Gossypium arboreum* and *G. herbaceum* from the Indus basin. First reported from India in 1842, Saunders identified it as *Depressaria* (Gelechia) *gossypiella* Saunders from specimens of American upland cotton cultivated in Bharuch, Gujarat, in 1843. It was revised as *Platyedra gossypiella* Saunders and finally as *Pectinophora gossypiella* (Saunders).
- Pearson (1958) suggested this pest to have originated in Indian subcontinent. The number of parasitoids recorded in Pakistan (Cheema *et al.*, 1980) indicates the origin of this pest to Indo-Pak region. Being of high economic importance in cotton crop across several parts of India and in all cotton-growing continents, the biology of this insect is well worked out all over the world. Another related species under the same genus is *P. scutigera* (Holdaway), pink spotted bollworm from Australia in the 1960s.

Biology

- Singly laid or in small groups of three to five eggs, flattened oval eggs measuring 0.5 mm long by 0.25 mm width with sculptured longitudinal lines, pearly iridescent white when laid afresh, turning into yellowish and finally into orange at eclosion, with incubation period of 3.5 to 6.0 days.
- The eggs are laid in protected locations on the plant, such as axils of petioles, peduncles, lower side of leaves, old leaves at the junction of main vein, bracts, squares, flowers and 2-week-old bolls (in the sutures at boll tip or on bracteoles at the base of bolls), which ultimately become the most favoured site for egg laying. Eggs get protected from prowling predators or from contact pesticides.
- The hatching is a three-hour process in the early mornings. One mm long, black-headed neonate caterpillars with translucent body hatch out. The neonates move to the nearest food substrates such as squares, open flowers or bolls and commence feeding on tissues. Second instar caterpillars have creamy white body, dark brown head and paler thoracic shields. Third instar larvae are 6 mm long and have creamy-white body with two transverse dorsolateral pink streaks in each body segment.
- Those larvae that feed on flowers or on shed rotting fruit bodies have no pink colour. The fourth and final instar caterpillars measure 11 to 15 mm long and 2.5 mm round when fully grown. However, Watson and Johnson (1974) reported that 25% larvae had fifth instar moulting with 3 or more days' growth. Larvae in older squares web the unopened petal rims and feed inside, causing 'rosetted' flowers.
- They pollinate the flowers and continue feeding on the growing bolls. Such larvae are secure and are never subjected to attack by natural enemies. This oligophage has such wonderful adaptations for survivorship and is highly successful to survive in all cotton-growing countries over centuries.
- Average larval period is 12 to 20 days, while hotter regions may have 9 to 14 days. Fifteen to twenty crotchets in single row, forming an incomplete circle on the third to sixth abdominal segment, are unique to this insect of cotton crop.
- Mature caterpillars may be of 'short' or of 'long' cycle. The short-cycle ones proceed to pupate, while the long-cycle ones turn to diapause. Pupation is generally in soil; the mature larvae cut a round hole on boll wall and fall out into soil. They may also eat the boll wall up to cuticle, to form transparent wall and pupate there itself. The pink bollworms spin an elongated cocoon with lightly webbed exit at one end.
- Major abiotic conditions to convert into 'long-cycle' pink bollworms are fluctuating temperature and short decreasing photo phase. Gutierrez *et al.*, (1981) developed models to fix the time for change of field population into long cycle ones in order to fix the chemical control action threshold.
- The diapause terminated caterpillars pupated inside the same resting cocoons. The 'long-day' caterpillars spin thick closely woven spherical cocoon, called hibernaculum, without exit hole. Mature larvae remain quiescent and curl inside the hibernaculum for weeks or

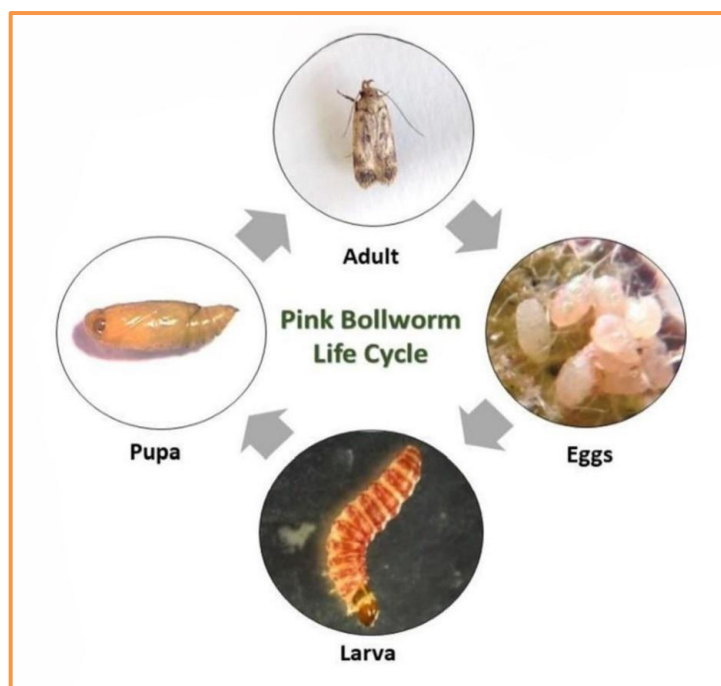


Fig.2: Life cycle of pink bollworm, *Pectinophora gossypiella*

months. Towards the end of cotton season, they are seen to occupy single big seeds or unite two to three small seeds to make hibernaculum; double seeds used to be characteristically observed in northern Indian cotton, till the mid-1990s of the last century, especially small-seeded diploid and tetraploid cottons.

- This trend changed with the cultivation of new high-yielding cotton hybrids with large seeds. Interestingly, many larvae which spin up in the lint of open boll can spin on bales of lint after ginning, bags of seeds, cracks and crevices of buildings, etc. Birds' nests made of cotton lint also are reported having diapausing pink bollworms in West Indies (Pearson 1958).
- Pre-pupal stage lasts for 2.5 to 3.5 days, and larvae turn into shining brown pupa, measuring 6 to 8 mm long by 2.5 mm wide. Pupae emerge between 8 and 13 days during cotton season. The greyish-brown adult moths with black bands on forewings and silver-grey hindwings emerge from pupae in early mornings or in the evenings.
- The nocturnal moths measure 8 to 9 mm long with 15 to 20 mm wing span. Sex ratio in cotton fields is 1:1. They are attracted to mercury vapour lamp and black light as much as to molasses and fermented brew. After feeding on nectar, they mate at 3 ft. candle light intensity in the first night after emergence, on crop canopy leaves, and in the shade during moonlit nights (Ingram 1994).
- Oviposition starts from the second night after emergence and peaks by the third night to release 80% eggs. One hundred to five hundred eggs, based on size and longevity of female moths, are recorded under ideal conditions.
- Adult longevity varied between five and 31 days. Short cycle-derived moths in India lived for 7 to 9 days, while it was 14 days in the USA. High humidity prolonged adult life, while increasing temperature reduced longevity.
- The moths are known to disperse through both long-range and short-range movement.
- The damage to fruiting bodies of cotton crop is extensive due to the feeding of pink bollworms. Cotton plants produce three to six flushes of reproductive bodies in the active phase when the lint quality is at its best. The pest feeds on the seeds affecting the growing lint. Immature fibres with poor technical property make the country lose valuable raw material for textile industry. Its discolouration due to excrements of the caterpillar as also due to microbial growth reduces market value of cotton.
- Twelve to twenty percent damaged lint is the national loss of marketable lint each year. With the advent of GM cotton cultivation, this has been narrowed to 3 to 5%. Cotton farmers lose money when they sell contaminated seed cotton for a very cheap price.

3. Spiny Bollworm, *Earias insulana* (Boisduval), and Spotted Bollworm, *Earias vittella* (Fabricius)

- In India, early-season pests of cotton crop that become terminal shoot borers are spiny bollworms (Fig. 3a). and spotted bollworms (Fig. 3b). These pests were of common occurrence till the widespread cultivation of GM cotton hybrids with Bt delta-endotoxin-expressing genes. They are seen from 35 days of crop growth in different parts of the country in American cotton (*G. hirsutum*) and *G. arboreum* and *G. herbaceum* varieties and hybrids. The spiny bollworms are pre dominant in drier North Indian states in irrigated crop. This species was widespread in states where *G. arboreum* and *G. herbaceum* cotton varieties are cultivated. The spotted bollworms are more widespread in distribution, having their presence in the crop in all cotton-growing states.
- In many ways, their early infestation as terminal shoot boring stopped apical dominance of the crop and enabled the production of sympodial (fruiting) branches. These species have geographical variation in their distribution based on weather conditions, the spiny bollworm more in northern states while spotted bollworms in central and southern region.

Description

- Spherical under 0.5 mm diameter, light blue green. They are decorated with 30 longitudinal ridges of which alternate one's project upwards to look like a crown.

- The egg looks like miniature poppy or pomegranate fruit. The caterpillars are stout, spindle-shaped and measuring 13 to 18 mm long. They vary in colour, light brown, tinged with green and grey, distinctly pale on the dorsal line with dark brown or black spots at the base of the setae in the second and fifth abdominal segments.
- These larvae are characterized by fleshy tubercles, one of which is dorsal and the other lateral in position, prominently seen in the last two thoracic and all abdominal segments, each bearing one hair at its apex.
- In spotted bollworms, the tubercles are less prominent. Yellow to chocolate-brown pupae is seen inside cocoons, inverted boat shape and made of tough felt-like silk, dirty white to pale brown in colour, attached to the plants or with plant debris on the ground. Colour variation based on substrate on which pupation happens is recorded (Reed 1994).
- The adult moth, while at rest, keeps wings snugly folded. *E. insulana* moths have pale-green wing with silky sheen due to dense scales, 20 to 22 mm long; the abdomen and hindwing are silvery or creamy white in colour.
- The spotted bollworm moths have folded forewings with creamy-white plume bearing green colour and wedge-like band crossing linearly to the wing's length

Biology

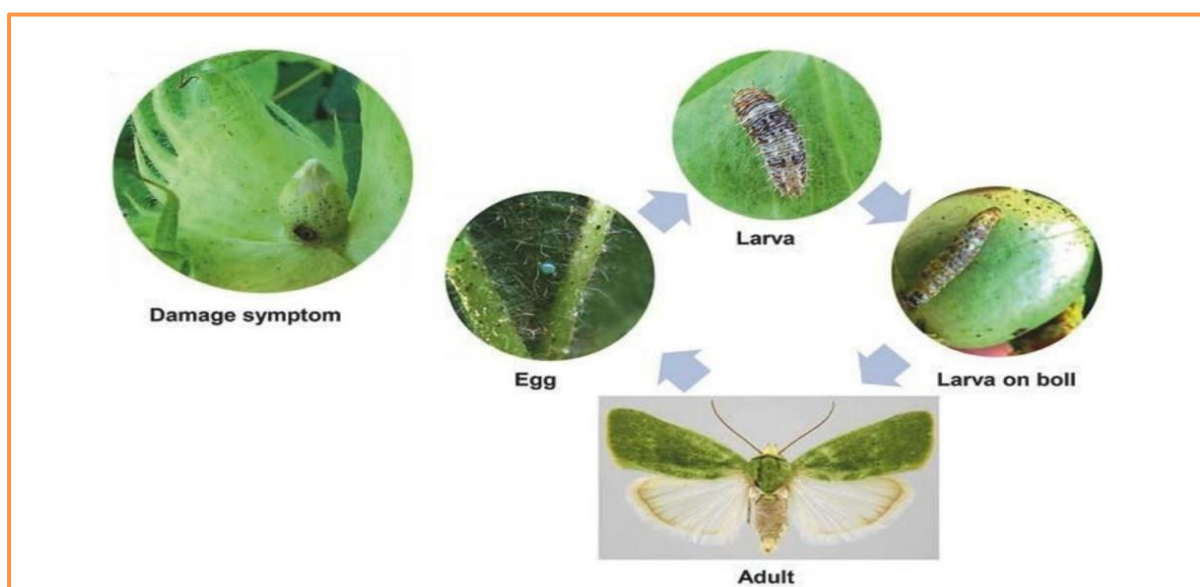


Fig. 3a: Life cycle of spiny bollworm, *Earias insulana* (Boisduval)

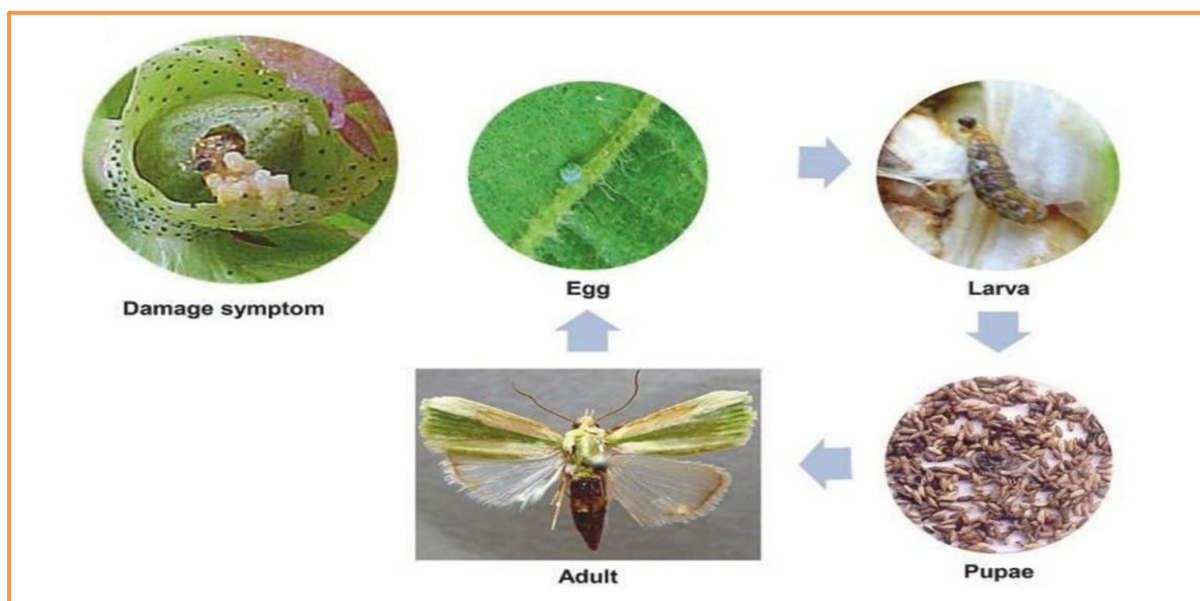


Fig. 3b: Life cycle of spotted bollworm, *Earias vittella* (Fabricius)

- Eggs are laid singly on young shoots and further on peduncles and bracteoles or squares (flower buds) and young bolls as they are formed.
- Their incubation period in summer is about three days, while larval and pupal stages could be about 13 to 15 days. One generation can be completed in five weeks. Variation in duration of life cycle of these insects is recorded from shorter one in equable climatic condition of tropics to longer ones in other regions, especially in winters. Their adaptation to sustain short variations in weather is well recognized (Reed 1994).
- Variation in the egg numbers laid by moths, emerging from white cocoons and brown cocoons, the latter has lower numbers (Mani and Krishna 1984).
- The Indian host plant genera, supporting *Earias* Hübner, are *Abelmoschus* Medik, *Abutilon* Mill, *Gossypium* L., *Hibiscus* L., *Malva* L., *Malvastrum* A. Gray, *Sida* L., *Urena* L., *Theobroma* L., *Corchorus* L., etc. The distribution pattern of *E. vittella* and *E. insulana* in India is dependent on weather conditions, the former avoiding cooler conditions of northern India for survivorship, indicating variation in specialization (Reed 1994) with host plants.
- Adaptation of life stages to weather conditions of various agro-ecologies by various species of *Earias* is noteworthy. Propensity for stem boring, either through the growing point downwards or directly at internodes, makes it distinguishable from other bollworms.
- Dichotomous growth of stem by axillary monopodial buds is typical symptom in early cotton crop. The squares are fed through borehole that is blocked by excrement pellets. The damaged squares and young bolls are shed by plants. They bore on big unripe bolls from bottom. The grown-up caterpillars spin cocoons between boll wall and bracteole for pupation.
- *E. insulana* has four instars, while spotted bollworms have five instars. The latter species are known to pupate in soil crevices up to 30 cm depth in dry vertisol cotton-growing regions of India. The quiescent moths hide under leaves and flutter away when disturbed. Newly emerged moths feed on nectar in the extra floral nectaries.

Conclusion

The bollworm pest complex of cotton, primarily *Helicoverpa armigera* and *Pectinophora gossypiella*, and *Earias* sp. poses a significant threat to cotton production globally due to their ability to cause severe damage to developing bolls and reduce lint quality. Understanding the biology and ecology of the cotton bollworm borers is crucial for effective pest management. This knowledge allows for targeted interventions, minimizing crop damage and reducing reliance on broad-spectrum insecticides. By understanding the bollworm's life cycle, feeding habits, and interactions with its environment, farmers can implement integrated pest management (IPM) strategies that are more sustainable and environmentally friendly.

References

1. Armes NJ, Cooter RJ (1991) Effects of age and mated status on flight potential of *Helicoverpa armigera* (Lepidoptera: Noctuidae). *Physiol Entomol* 16:131–144
2. Bhattacharjee NS, Gupta SL (1972) A new species of *Heliothis* Ochsenheimer (Noctuidae, Lepidoptera) infesting cotton and *tur* (*Cajanus indicus*) in India with observations on the three other common species of the genus. *J Nat Hist* 6:147–151
3. Cheema MA, Muzaffar N, Ghani MA (1980) Biology, host range and incidence of parasites of *Pectinophora gossypiella* (Saunders) in Pakistan. *Pak Cottons* 24:37–73
4. Fitt GP (1990) Host selection in the Heliothinae. In: Bailey WJ, Ridsdill-Smith TJ (eds) Reproductive behaviour in insects – individuals and populations. Chapman & Hall, London, pp 172–202
5. Gutierrez AP, Butler GD, Ellis CK (1981) Pink bollworm diapause induction and termination in relation to fluctuating temperatures and decreasing photophases. *Environ Entomol* 10:936–942

6. Ingram WR (1981) Pests of West Indian Sea Island cotton. Centre for Overseas Pest Research, London, 35pp.
7. Jayaraj S (1982) Biological and ecological studies of *Heliothis*. In: Reed W, Kumble V (eds) Proceedings of the international workshop on Heliothis management. ICRISAT Centre, Pattancheru, pp 17–28
8. Mani HC, Krishna SS (1984) Pupal cocoon color of mated males and females influencing reproductive potential in *Earias fabia* (Lepidoptera: Noctuidae). *J Adv Zool* 5:52–54
9. Nesbitt BF, Beevor PS, Hall DR, Lester R (1979) Female sex pheromone components of the cotton bollworm *Heliothis armigera*. *J Insect Physiol* 25:535–541
10. Pearson EO (1958) The insect pests of cotton in tropical Africa. Empire Cotton Growing Corporation and Commonwealth Institute of Entomology, Lodo, pp 74–95
11. Piccardi P, Capizza A, Casani G, Spinelli P, Arsura E, Massardo P (1977) A sex pheromone component of the old world bollworm, *Heliothis armigera*. *J Insect Physiol* 23:1443–1445
12. Reed W (1994) *Earias* spp. In: Mathews GA, Tunstall JP (eds) Insect pests of cotton. CAB International, London, pp 151–176, 593 p
13. Reed W, Pawar CS (1982) *Heliothis*: a global problem. In: Reed W, Kumble V (eds) Proceedings of the international workshop on Heliothis management. ICRISAT Centre, Pattancheru, pp 9–14
14. Ramaswamy SB (1990) Periodicity of oviposition, feeding and calling by mated female *Heliothis virescens* in a field cage. *J Insect Behav* 3:417–427
15. Vickers J, Baker TC (1992) Male *Heliothis virescens* maintain upwind flight in response to experimentally pulsed filaments of their sex pheromone (Lepidoptera: Noctuidae). *J Insect Behav* 5(6):669–687
16. Watson TF, Johnson PH (1974) Larval stages of the pink bollworm, *Pectinophora gossypiella*. *Ann Entomol Soc Am* 67:812–814