Cotton pests, predators and parasitoids
Descriptions and seasonal dynamics

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Introduction
Insect pests are one of the major limiting factors in cotton production. Of 1326 insect pests recorded on cotton worldwide, nearly 130 species occur in India. About a dozen of these arthropods are commonly present in sufficient numbers requiring their management for realizing better cotton yields.

Sucking Pests
Sucking pests are deleterious during early season of the cotton plant growth and developmet. Jassids, aphids, whiteflies and thrips continue in the absence of cotton with continuous production of vegetables. Besides, they survive on a variety of wild hosts during dry season. Even with the small number of immigrants, populations can build up to serious proportions as a result of rapid and prolific breeding in the cotton plant.

Jassids *(Amrasca biguttula biguttula* Ishida)
Jassids also referred, as leafhoppers are important sucking pests. Both nymphs and adults suck the plant sap and apparently introduce salivary toxins that impair photosynthesis in proportion to the amount of feeding. The affected leaves curl downwards, turn yellowish, then to brownish before drying and shedding. Severe “hopper burn” stunts young plants and reduce yields.

Adults are elongate and wedge shaped with pale green body; very active with sideways walk but quick to hop and fly when disturbed. Eggs are curved and deeply embedded in the midribs of large veins on the undersurface of the leaves. Nymphs are flattened , pale yellowish green with sideway movements and remain confined to the lower surface of leaves during day time. Eleven generations have been estimated in a year. Yield loss from jassids can be reduced by growing hairy varieties.

Aphids (*Aphis gossypii,*Glover)
Aphis gossypii, commonly referred as cotton aphid is present in all cotton growing areas causing serious problems at times. Aphids are phloem feeders, causing direct leaf crumpling and downward curling with severe attack. Indirectly decreases cotton fibre quality as a result of sticky cotton due to deposits of honeydew on open bolls.

Aphis gossypii is extremely variable in colour (dirty green, dark green, blackish brown, orange/ dirty yellow), and size with apterate (0.9 - 1.8 mm) and alate (1.1 - 1.8 mm) occuring simultaneously. They have a large range of host plants with varying duration of development and reproductive rate. Aggregating populations are seen at the terminal buds and largest populations are found below the leaves of the lower third of plants , where they are partially protected from high temperature. Outbreaks are common on seedlings and young plants during spells of dry weather.

Heavy rainfall reduces populations by directly washing them off the plant. Host plant traits reported to have impact upon aphid resistance are plant colour, pubescence, gossypol content, chemical makeup of the plant and stem tip stiffness. Role of coccinellids, and to some extent syrphids and chrysopids, in aphid population regulation is recognized. All are density dependent predators however frequently too late in appearance and hence chemical control is often required to reduce the population to acceptable levels.

Whiteflies (*Bemisia tabaci* : Gennadius)
Whitefly has been recorded on cotton in India as early as 1905 and was considered to be an insignificant pest. It assumed major importance on cotton after severe outbreaks during 1984-85 and 1985-86 seasons in the states of Andhra Pradesh, Karnataka and Tamil Nadu and as a vector in transmission of leaf curl virus in states of Rajasthan, Haryana and Punjab.

B. tabaci is a major pest in mid and late periods of cotton growing season. Damage results from direct feeding that reduces the yield. Indirect damage results from lint contamination with honey dew and associated fungi and through transmission of leaf curl virus disease.
Adults are white and small, females are 1.1 -1.2 mm long; the males are slightly smaller. Antennae of females are longer than males. Genitalia of female consists outer and inner vulvulae and rounded, whereas paramors of males are extended , narrow and pointed. Parthenogenetic reproduction is also seen.

Drought coupled with high temperature during crop growth, cultivation of cotton year after year with no crop rotation, excessive use of nitrogenous fertilizers and synthetic pyrethroids lead to outbreak of *B. tabaci.*

Thrips (*Thrips tabaci* Lindeman)
T. tabaci damages young cotton seedlings, flowers and stems. The incidence is severe in the beginning of the season during the periods of low relative humidity. With thrips attack leaves of seedlings become wrinkled and distorted, and the vegetative phase is delayed leading to late harvest.

Thrips are slender and the colour of macropterous adults varies from pale yellow to dark brown. Antennae have seven segments with the first segment always paler than second segment which is usually dark. Anterior edge of the abdominal tergites is marked by a brown band. There is a single pair of pores on tergite IX. Pupation is in the soil. Thrips are usually active round the year moving from one host to another. Heavy rainfall limits the thrips population. Systemic insecticides as seed treatment or sprays offer protection to thrips at earlier stages of crop growth.

Bollworms
Major yield loss to the Indian cotton (even up to 60%) is due to bollworm complex consisting of three genera of bollworms *viz. Earias, Helicoverpa* and *Pectinophora*. The former has two species and the latter two genera with a single species each. While alternate host plants of *Earias* and *Pectinophora* are chiefly Malvales, *Helicoverpa* is polyphagous and has become the most important bollworm of cotton because of the increased severity of attack in almost all cotton growing areas of the country.

Spotted bollworm (*Earias* sp.)
Two species of *Earias viz. E. insulana* (Boisd) and *E. vitella* F. (earlier known as *E. fabia*), collectively known as spotted bollworms, are important pests. It has been found that *E. insulana* breeds on a variety of hosts of different genera whereas the occurrence of *E. vittella* is limited to *Gossypium* and *Abelmoschus.* Neonate larvae cause damage to the terminal bud of the vegetative shoots and channel downwards or into internode during early stages of crop growth. The whole apex of main stem collapses, if the main stem growing point is affected. If the apical bud alone is damaged, there is twinning of the main stem due to the growth of axillary monopodial buds. When flower buds/bolls are attacked, the tunnel opening is blocked by excrement. Tunnel in bolls is often from below, angled to the peduncle. Larvae do not confine their feeding to a complete single boll and hence damage is disproportionate to their numbers. Adult moths differ with species. In *E. insulana*, the head , the thorax, and forewing colour varies from silver green to straw yellow, the distal fringe of wing is of the same colour. There are three distinct transverse lines of darker shade and traces of the fourth at times. Green forms are common during summer, while yellow/brown forms occur toward the end of season.

Eggs are spherical, with less than 0.5 mm diameter and have light blue green colour with longitudinal ridges resembling the fruit of a poppy. Eggs are laid singly on most parts of the cotton plant (flower buds, bolls, peduncles and bracteoles) , the favored one being young shoots.

Full grown larva is about 1.3-1.8 cm long, stout and spindle shaped bearing a number of long setae on each segment. Last two thoracic and all abdominal segments bear two pairs of fleshy tubercles, one of which is dorsal and the other lateral. Larva is light brown, tinged with grey to green, paler along the mid dorsal line with dark spots at the base of the setae, more pronounced on the second and fifth abdominal segments. Yellowish spots are seen at the base of tubercles of thoracic segments. Larvae of *E. insulana* is generally lighter in colour, the pattern being grey and yellow than brown and deep orange. In *E. vittella* larval tubercles are much less prominent especially in the abdomen.

Pupa is enclosed in cocoon shape like an inverted boat and made of tough silk of dirty white or light brown colour, usually attached to plant or plant debris on the ground.
E. insulana is the most abundant species in the Punjab and *E. vittella* is predominant in peninsular India. *Abelmoschus indicum* for *E. insulana* in the north and *Abelmoschus esculentus* for *E. vittella* in the south of India provide means of carry-over from one cotton season to the next.
The braconid, *Rogas aligarhensis* (Qardi), offers better biocontrol of *Earias* spp. Parasitism rates of greater than 25% in eggs and 37% in pupae were recorded in Punjab (Shekhon and Verma,1988).

American Bollworm (*Helicoverpa armigera* Hubner)
Helicoverpa armigera has become the most important insect pest of cotton in almost every cotton growing area because of the wide range of cultivated and wild hosts. Larvae bore into flower buds, bolls and feed upon the internal contents. Squares injured by *H. armigera* usually have a round hole near the base. A small amount of webbing is often present, especially on small squares injured by young larvae. Larval frass and the flaring of bracts on larger squares are apparent by the time larvae reach second instar. A single larva can damage 5-7 bolls. Under conditions of high humidity within plant canopy, boll rot by microbes set in and can result in extensive crop loss. Eggs are spherical with a flattened base laid on the tender foliage and calyx of squares of the cotton plant. Surface is sculptured with longitudinal ribs. Colour is white to creamy white after oviposition. As the embryo develops reddish brown band is seen centrally which gradually darkens and together with rest of egg becomes brown before hatching.

Newly hatched larvae are translucent yellowish white with brown to black head capsules. The thoracic and anal shields, spiracles, thoracic legs, setae and their tubercle bases are also brown to black, giving the larvae a spotted appearance. Second instar is essentially similar but with darkened ground colour and lightened sclerotized head capsule, thoracic and anal shields and thoracic legs. The third instar has a predominantly brown ground colour. The characteristic patterning becomes more prominent and colouring generally darker in later instars, although host diet plays a role to an extent.
There are usually five larval instars. Pupa is smooth surfaced, brown, rounded both anteriorly and posteriorly with two tapering parallel spines at posterior tip. Females are on an average heavier than males. Pupae are formed at a depth of 2.5 - 12.5 cm in the soil. Pupal period ranges from 6 days at 35 °C to over 30 days at 15°C , lasting for about 10-14 days under field conditions in central India.
Adults are stout bodied moths, greenish yellow to buff to brown with darker brown or blackish markings. Females are darker than males. Moths have a circadian rhythm starting at dusk, continues through midnight after which it virtually ceases

Weather, beneficial arthropods and entomopathogens are important factors in mortality of the egg and in early instar stages besides host plant resistance. Much work has been carried out on the multiplication and release of *Trichogramma* spp. egg parasitoids but the technique does not seem feasible for intensive production systems. Among the larval parasitoid the Ichneumonid *Compoletis chloridae,*(Uchida) is the most important against early instar larvae. Tachinids *Carcelia illota* Curran, *Goniopthalmus halli* Mesnil. and *Paleorixa laxa* (Curran) have been recorded on late larval instars of *H. armigera*.

Insect pathogens, mainly the HNPV(*Helicoverpa* nuclear polyhedrosis virus) and strains of Bt. (*Bacillus* thuringiensis) have been in use. A dose of 4.5 X 10^9 PIBS/ larval equivalents (LE) @ 250 LE/ha was found to be effective for field use. Their use in *Helicoverpa* control is limited due to the impact of weather especially high temperature. *Nomuraea rileyi*, a fungal pathogen attacking *H. armigera* during periods of cool weather and epizootics offers promise to prevent the carry-over of this pest between seasons.

Pink Bollworm (*Pectinophora gossypiella* Saunders)
It was first recorded in India in 1842 and it spread to other countries of the world through cottonseeds. It is one of the serious pests of cotton throughout the cotton growing parts of India. *P. gossypiella* attack, lowers quantity of both lint and seeds and also lowers the qualiity of the lint affecting fibre length , fibre bundle strength and micronaire. Pink bollworm attacks all true cottons, cultivated and wild and many species of *Abelmoschus*, belonging to Malvales.

Eggs are pearly iridescent white, flattened, oval measuring approximately 0.5 mm long, 0.25 mm wide and sculptured with longitudinal lines. They are laid singly or in small groups of four to five. Early in the season, eggs are laid in any of the sheltered places of the plant axis of petioles or peduncles, the underside of young leaves, on buds or flowers. Once the bolls are 15 days old, these become favored

sites for oviposition. Incubation period is 3-6 days. First two instars are white, while from third instar pink colour develops. Larva when attacks buds of less than 10 days old, shedding of bud occurs and larva dies. But with older bud larva can complete development. There can be cent percent pink bollworm infestation on bolls but there need not be any shedding. Larva in flower bud spins webbing that prevents proper flower opening leading to " rosetted-bloom". Ten to twenty days old bolls are attacked from under bracteoles. Larvae feed on the developing seeds. While in younger bolls entire content may be destroyed, in older bolls development could be completed on three four seeds. Interloculi movement is also seen. Several larvae can infest a single boll. Larval cycle lasts for 9-14 days in hotter regions.
The mature larvae are either 'short-cycle'and will go on to pupate or 'long cycle' to enter a state of diapause. While the former is the observed phenomenon in south India, diapause is seen in the north and central parts of India. Short cycle larvae pupating may cut a round exit hole through carpel wall and fall to ground or may tunnel the cuticle, leaving it as a transparent window and pupate inside. Pupation is inside a loose fitting cocoon with a highly webbed exit at one end. Pupal period ranges between 8 and 13 days. The long cycle larvae entering diapanse spins a tough thick walled, closely woven, spherical cell referred as " hibernaculum" with no exit hole.

Always, the long term larvae occur during end of crop season, where there are mature bolls present and larvae often form their hibernaculae inside seeds. Hibernacula may occupy single seeds or double seeds. Diapause larvae often spin up in the lint of an open boll and if still active in ginnery, will spin up on bales of lint, bags of seed or in cracks and crevices.

The adult moth is greyish brown with blackish bands on the forewings, hind wings are silvery grey. Moths emerge from pupae in the morning or in the evening, but are nocturnal, hiding amongst soil debris or cracks during the day.

Large number of parasitoids and predators are reported attacking pink bollworm. However, majority of them are mere records with their bio-ecology still unknown. *Apanteles angaleti* carries over in another host (*Santhbrota simplex* Wism.) in cotton sticks, *Chelonus* sp. and *Camptothlipsis* sp. were associated with long cycle pink bollworm larvae (Shekhom and Varma, 1983) and *C. blackburni* Cam. Was reported as overwintering. Mass rearing and release of various parasitoids from India include *Trichogramma brasiliensis* (Ashm.), *Bracon kirkpatricki* and *Chelonus blackburni* .

Predatory mites *Pyemotes ventricosus* (Newport) and *P. herfsi* (Oudemans) are widely reported as preying on and giving good control of long cycle larvae. Taneja and Jayaswal (1981) determined the capture threshold of male moths in traps with glossyplure for timing the insecticidal application. They found that for effective and economic control of *P.gossypiella*, insecticides should be applied within 24-48 hours. when the number of male moths captured in traps reaches eight/trap/night. Surulivelu (1985) found that hand pinning of gossyplure filled hollow fibre on the terminal leaf of cotton plant @ 2.85g/ha reduced the abundance of male moths and reduced infestation by 23.1%.

Cotton Stainers

Stainers are the only insects that attacks previously undamaged cotton seeds in the field, on any scale. There are two stainer bugs, viz. the common stainer bugs *Dysdercus* and the cotton seed bugs *Oxycarenus.* All the active stages of these bugs feed on the seed in open bolls and reduce the germinating capacity and the seed oil content.

Red cotton bugs (*Dysdercus cingulatus* Fabricius)

Dysdercus singulatus nymph and adults feed on developing or mature seeds. Penetration of developing cotton bolls leads to occasional transmission of fungi which develop on the immature lint and seed, rendering the latter unviable and staining the lint to the typical yellow colour. Nymphs and adults are brightly coloured with red head with a white prothoracic collar. Membrane of the hemi-elytron is dark and on the broadest part of the forewing is a black mark as a spot. Eggs are laid in shallow depression in soil or under debris in batches. The nymphal instars are gregarious and feeding is in congregation. Third and subsequent instars can penetrate unopened fruit to feed on developing seeds. Rate of development of egg and five nymphal instars is temperature and nutrition dependent.
Although mite *Hemipteroseius indicus* (Lerontz and Knot) has been recorded on *D. koenigii* (Fabricius) , role of natural enemies appears to be insignificant in controlling cotton stainer numbers.

Dusky Cotton Bug (*Oxycarenus hyalipennis,* Costa)
They are lygus bugs associated with ripe seeds of cotton. Adults are small-elongated bugs with pointed heads, dull black to very dark brown. The hemielytra has a translucent dusky appearance. All stages are characterized by a powerful smell when crushed. They feed on seeds and large numbers can reduce weight and viability of seeds. Bugs can discolour the lint if crushed and so are sometimes referred as dusky cotton stainers. Early harvesting minimizes damage.

Foliage Feeders
Great majority of leaf feeders are chewing insects; mostly lepidopterous larvae, ash weevils and grass hoppers. Lepidopterans are sufficiently extensive at times causing defoliation, thus affecting the photosynthetic efficiency of the plant.

Cotton Semilooper *(Anomis flava* Fabricius*)*
Outbreak of *Anomis flava* are often sporadic. Larval feeding results in significant loss of leaf area when the plants are young. Larvae are long, slender and green with faint whitish longitudinal lines on the sides and can be distinguished by their looping action.

Looper eggs may be deposited anywhere on the cotton plant, but larvae are usually found on the lower leaf surface and are most likely to be observed on the upper third of the plant. Upon hatching these larvae drop to the older leaves, where small larvae make a window like holes by feeding on the lower leaf surface . By mid growth stage, looper larvae become gross leaf feeders consuming everything but larger leaf vein. Feeding of squares by the larvae is rarely noticed. Tachinid parasite *Paliorixa laxa* and fungal pathogen *Nomuraea rileyi* keeps the looper population under control in areas where broad spectrum insecticides have not been widely used.

Cotton Leaf Roller (*Syllepte derogata* Fabricius)
It is commonly found in rainfed cotton growing areas, higher infestations occur in shady and weedy conditions. Larvae are seen in groups during initial stages in folded leaves amidst fecal material. Late/last instar larvae move out and pupate individually. The larvae are greenish white and semi translucent, roll up leaves to protect while feeding. Brown pupae is typical in having 8 short spines with hooked tips at their extremity. Moth is light cream with wings transversed with brown / black wavy lines and a black border with greyish fringe. Head and thorax are dotted black and abdomen has brown rings.

Ash Weevil (*Myllocerus maculosus*)
It is commonly referred as grey or ash weevil which feeds on leaves, bracts and its larvae feed on roots. Although root damage by larvae can kill young seedlings and cause wilting, adult do not cause significant yield losses.