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Technical Bulletin

ADVANCES IN COTTON IPM

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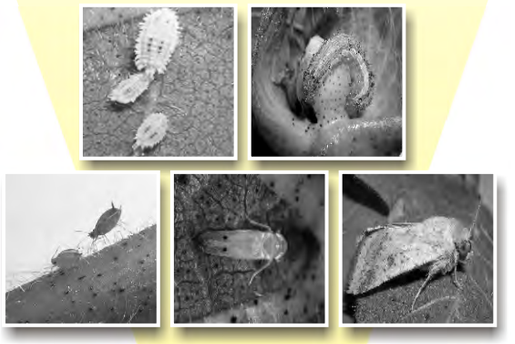

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Introduction

Cotton pest management has always been an immensely challenging task for entomologists all over the world. About 1326 species of insects have been reported on cotton worldwide (Matthews and Tunstall, 1994). For about two decades after 1985, the cotton bollworm *Helicoverpa armigera* had caused immense problems to cotton farmers. Yield losses ranged from 30-80% due to bollworm damage and an estimated 60-70% of the total insecticides used on cotton were targeted for bollworm control. Eventually, when the bollworm developed high levels of resistance to synthetic pyrethroids and also to several other groups of insecticides used for its control, pest management became increasingly difficult despite enhancement in the number of insecticide applications while yields declined.

The introduction of insect resistant GM (genetically modified) Bt-cotton in 2002 in India came as a relief to cotton farmers. The technology represents the latest of the various methods being constantly deployed to fight the insect pest menace in cotton. Bt-cotton is toxic to bollworms and does not control any of the sucking pests of cotton. The Bt-cotton hybrids based on Cry1Ac are only moderately toxic to the leaf eating caterpillar *Spodoptera litura*. Bollgard-II hybrids which express the Cry1Ac+Cry2Ab toxins, are more toxic to the bollworms and *Spodoptera litura* as compared to Bollgard, which has only Cry1Ac. Over the past seven years, subsequent to the introduction of Bt-cotton, cotton cultivators in India have been facing new problems with insect pest management in many parts of the country, presumed to be a consequence of low insecticide usage. New sucking pests have emerged as major pests causing significant economic losses. It is known that the usage of synthetic pyrethroids for bollworm control had significant negative impact on the incidental populations of *Spodoptera* spp. and several miscellaneous bugs including the mirid bugs, *Creontiodes biseratence* (Distant), *Ragmus* sp. The reduction of pyrethroids and several conventional insecticides on Bt-cotton is presumed to have led to an enhanced infestation of several non-target species such as mirid bugs, mealy bugs, thrips and *Spodoptera litura*. Apart from the reports of enhanced disease problems such as grey mildew, leaf spots and rust, a new report of tobacco leaf streak virus damage in cotton, was alarming. The strategies proposed in this book address most of the emerging problems with special emphasis on mealybug management and also mitigation of resistance development in sucking pests against insecticides and bollworms against Bt-cotton.

WINDOW BASED IRM STRATEGIES

Early Sucking Pest Window:
NO FOLIAR SPRAY up to 60 DAS

Cultivation of sucking pest tolerant genotypes (Bt-cotton or non-Bt) to help in delaying the first spray, thereby conserving the initial build-up of natural enemies. There are several Bt-cotton and conventional hybrids, which are highly tolerant to jassids, aphids and other sucking pests. For details contact the respective SAU cotton entomologists.

Use dual genes, such as the 'Bollgard-II' (Cry1Ac+Cry2Ab), that can express additive or synergistic toxicity and preferably with different mechanisms of resistance in bollworms will help in delaying resistance development.

Do not allow illegal Bt-cotton proliferation, especially the fuzzy seeds, which can carry mealy bug crawlers and spread them in fields.

Mealybug crawlers spread through human interventions such as spraying, irrigations, frequent movement through the infected area etc. Therefore **avoid disturbing mealybug affected plants.** It is important to remember that young cotton plants can overcome mealybugs and it is desirable to leave young plants that have slight infestation of the mealy bugs in early stages of the crop, undisturbed.

Inter-cropping with cowpea, soybean and blackgram to encourage predators of sucking pests in the cotton eco-system. One or two border rows of densely planted bajra or pigeonpea (spot applied with chlorpyriphos) were found to reduce mealy bug incidence on cotton.

Mealybugs are initially restricted to a few plants along the border rows, adjacent to the source of infestation and thus can be effectively managed through early detection and initiation of interventions to control early stages of infestation. The infested plants should be removed and destroyed to prevent further spread. However, during initial stages of infestation, if damage exceeds grade-2 (at least one stem completely colonized with mealy bugs) in more than 20 plants per acre, neem oil 10 ml + detergent powder 1 gram, per litre of water must be sprayed thrice at 10-15 day intervals on the crop adjacent to the infested plants and at the base of the infested plants without disturbing the mealy bug colonies. If timely scouting and control measures are not initiated cotton crop is likely to be severely damaged with mealybugs, which multiply and spread and late season control becomes extremely difficult. Some strains of *Verticillium lecanii* have been found to be promising for mealy bug control.

Parthenium weed (Congress grass) which is the main weed host of the mealybugs should be destroyed by using *Zygogramma* beetles which feed on the weed and also by using mechanical control.

Since mealy bugs multiply on weeds on field bunds, and move on to crop plants during the season, it is important to remove and destroy the weed hosts of mealy bugs, that grow on field bunds, water channels and wastelands in the area, before the season.

Avoidance of chloronicotinyl and organosphosphate sprays for sucking pest control. All commercial hybrid seeds available in the market are treated with Gaucho or its equivalent. At the time of introduction, Gaucho seed treatment was found to confer protection against jassids and other sucking pests up to at least 40-45 days after sowing (DAS). Experimental data indicate that now the protections last for 20-25 DAS. Therefore, it is important to avoid the use of Confidor and related chloronicotinyls as foliar sprays so as to prevent further additional selection pressure. Avoid foliar sprays of broad spectrum organophosphates such as Monocrotophos, Methyl demeton, Phosphamidon, Acephate etc. especially as early season sprays as these strongly disrupt the natural enemy populations.

Stem application or soil application (near the root zone) of Dimethoate or Acephate at 30-40 DAS and 50-60 DAS for effective eco-friendly control of thrips, mirid bugs, mealy bugs and other sucking pests.

Neem oil 2.5 lit/ha mixed with 0.1% detergent powder can be used for the management of jassids, whitefly or aphids.

Verticillium lecanii can be used for sucking pest control wherever good formulations are available from reliable manufacturers.

Cheilomenes sexmaculata

Window 1: 60-90 Days after sowing

Initial bollworm infestation: Mostly eggs and young larvae: biological and biopesticides window

Chrysoperla carnea

Use HaNPV on Bt-cotton at 50% bollworm infested plants (plants having flared squares with entry hole) followed by the application of **5% NSKE** a week later**.**

Or, use endosulfan at 50% bollworm infested plants (plants having flared squares with entry hole) or for the management of *Spodoptera* or whitefly.

Do not spray against minor lepidopteran insects such as the cotton leaf folder, *Sylepta derogata* and cotton semilooper, *Anomis flava*. The larvae cause negligible damage to cotton but serve as hosts for parasitoids such as *Trichogramma* spp., *Apanteles* spp and *Sysiropa formosa*, that attack *H. armigera*.

Trichogramma, if available, can be used on non-Bt genotypes at 70-80 DAS. Avoid *Trichogramma* egg parasitoid releases on Bt-cotton since maximum neonates get killed on Bt-cotton.

Do not spray Bt-formulations on Bt cotton to avoid further selection pressure.

Optimize INM & nutrient management for macro and micronutrients. **Foliar spray of $MgSO_4$, 2% Urea followed by 2% DAP**, to ensure proper Cry1Ac expression and also to reduce problems of leaf reddening. Sprays of 1% cobalt chloride and soil drenching with Bavistin 1 % in the initial stage of wilt was found to help in the recovery of plants.

Use Spinosad or Emamectin benzoate on only non-Bt-cotton at ETLs of 50% infested plants (plants having flared squares with entry hole)**. Avoid these insecticides on Bt-cotton** so that the efficacy of these insecticides can be preserved for bollworm control in non-Bt cotton. Spinosad, Emamectin benzoate and Indoxacarb are highly effective on pyrethroid resistant *H. Armigera*. Apart from their toxicity to *H. armigera*, Spinosad and Emamectin benzoate are also effective on *E. vittella* and jassids and are preferred first over Indoxacarb. Both insecticides have a high selective toxicity towards the target pests while being less toxic to many beneficial insects in the cotton ecosystem. These insecticides are ideally suited in eco-sustainable insecticide resistance management programmes.

Window 2: 90-120 Days after sowing
Peak bollworm infestation

American bollworm

Spotted bollworm

Pink bollworm

Flaring up of square

Use Indoxacarb once only on non-Bt cotton for bollworm control at ETLs of 90-100 % plants showing flared up squares: Thus far there is no evidence of any resistance against Spinosad, Emamectin benzoate or Indoxacarb. The three insecticides are expensive. Emamectin costs about Rs 1900/ha, Indoxacarb at Rs 1650/ha and Spinosad at Rs 1200/ha. Therefore care must be taken to ensure that these recommendations are made only in high input systems (generally irrigated), wherein the yields are high and these pesticides are affordable.

Use of one application of an insecticide such as thiodicarb or quinalphos or chlorpyriphos, during 90-120 days after sowing (DAS), on conventional or Bt-cotton at ETLs of 90-100 % plants showing flared up squares, which would effectively reduce the population of bollworm larvae (also possibly heterozygous for the resistant allele) that survive on Bt-cotton due to the decline in the transgene toxin levels. The spray would control incidental populations of pests such as *Spodoptera litura*, mealy bugs, mirid bug, dusky cotton bugs and the pink bollworm that have been reported to increase and cause economic damage in the absence of any insecticide application during the 90-120 DAS window. Resistance levels against certain organophosphate group of insecticides (Quinalphos, Chlorpyriphos and Profenophos) and carbamates (Thiodicarb and Methomyl) have been found to be low in most populations tested. These insecticides are very effective for bollworm control but have low ecological selectivity and can be harmful to beneficial insects. The populations of beneficial insects in cotton ecosystem are generally low in later part of this window and hence the application of organophosphates and carbamates is rational.

Window 3:>120 Days after sowing
Bollworms and mealy bugs

Ectoparasitic mite on jassid nymph

Orius sp

Coccinellid grub and mealybug

ETL based spray: Eight pink bollworm moths per trap per night for 3 consecutive nights. The application of pyrethroids as late season sprays would be effective for pink bollworm management. Pyrethroid resistance in *H. armigera* is generally high, but pyrethroids are very effective against pink and spotted bollworms and are ideally suited for the late season window.

Handpicking of surviving bollworm larvae from Bt-cotton fields during peak bollworm infestation, wherever possible and **destruction of residual pupae** by deep ploughing in Bt-cotton fields immediately after final harvest will help immensely in resistance management.

The mealy bug problem is not as huge as it is projected. The pest starts to occur on late stage crop and generally damages only a few border plants if left undisturbed. The mealy bugs have a slow growth and take more than 40-50 days to establish colonies. Therefore the damage to the crop would be minimum if proper precautions are taken to avoid its spread. **Do not rush for chemical control**. **Ecologically compatible methods are must, since, insecticides are not good for mealybug management.**

Do not use Phosphamidon, Methyl parathion, Phorate, Monocrotophos, Dichlorvos, Carbofuran, Methomyl, Triazophos and Metasystox for mealybug control. These insecticides are not only ecologically hazardous, but are also detrimental to several important predatory insects such as the coccinellid beetles and several parasitoid wasps that control mealy bugs and other insect pests. Insecticide use should be less, so as to conserve naturally occurring control by beetle species and wasps which devour mealy bugs. Up to 58% parasitisation of mealy bugs has been observed with *Anaecius bambawalei* in central India.

If plants are infested severely, the affected stems can be drenched with a systemic insecticide such as malathion or acephate 75% SP @ 2 gm/lit, or insecticides of the slightly hazardous category - buprofezin 5% SC @ 10 ml/lit or buprofezin 25% SP @ 2 gm/lit @ 5ml/lit or acetamiprid 20% SP @ 25 mg/lit to control the pest and ant carriers to prevent its spread. Insecticides such as Chlorpyriphos, Quinalphos, Profenophos, Cabaryl may be used in cases of severe economic damage by the pest. Spot/soil application with acephate or malathion for affected plants. Spray surrounding weeds (especially Parthenium) with chlorpyriphos and destroy later.

Basic operations to ensure minimum pest problems in cotton

Destruction of crop residues to prevent carry over of pest populations and summer ploughing to destroy resting stage insect populations. Especially useful for pink bollworm and mealybug management. Do not stack cotton stalks near fields.

Avoid growing American cotton in orchards as it favours whitefly outbreaks. Grow only arboreum cotton or CLCV resistant varieties in CLCV hot-spot areas. Only recommended varieties/hybrids from reliable sources must be procured. Off-season hosts must be discouraged. Weeds such as *Sida* sp., *Abutilon* sp and *Xanthium* sp. must be uprooted to prevent initial build-up of spotted bollworm, mealybug, whitefly and CLCV.

Hybrids must be grown in medium -deep soils having good drainage. Apply 5-10 tonnes of well decomposed compost or FYM /ha before sowing. Delint the seed with 100 ml sulphuric acid /kg seed for two minutes, wash with water and soak for two minutes in Calcium carbonate (5g/ltr water). Treat seeds with Ceresan wet or Agallol @ 1 g/ltr water, Captan or carbendazim @ 2g/kg, imidacloprid or thiomethoxam. Early sowing on ridges and furrows, especially in areas with drip facility, could be adopted. Sowing must be completed by the third week of May in North India and mid July for central and south India (except Tamilnadu). Sowing can be done at a row spacing of 67.5 cm with 30 cm plant-plant spacing for varieties and 75cm for hybrids.

Application of weedicide Stomp 30EC or Basalin @45EC 2.5 lt/ha and harrow immediately to prevent degradation. Harrowing must be done twice after pre-monsoon showers and field should be levelled.

Apply fertilizers considering the crop history, previous crop and its fertilizer use pattern. Nitrogen rates recommended for *G. hirsutum* varieties range from 40-60 Kg/ha in rainfed and 60-90 Kg/ha in irrigated cotton. For hybrids, 90 Kg/ha in rainfed and 100-120 Kg/ha in irrigated. P and K doses depend on soil test values or in their absence N:P:K is used at a ratio of 2:1:1.

Gap filling must be completed within 10 days after sowing. Thinning should be done within 20 days after sowing. First hoeing can be done 30-40 days after sowing followed by second after 15-20 days.

Spotted bollworm can cause damage to growing points initially, hence **scouting is necessary** during the first two months and removal of affected parts helps in minimizing future damage.

De-topping at 70-80 DAS effectively removes bollworm eggs and terminal parts affected by the spotted bollworm.

Handpicking of larvae 2-3 days after insecticide sprays effectively eliminates any surviving population, which can cause future resistance problems.

Always use insecticides as need based applications as per threshold levels. Always target younger stages of *Helicoverpa* as younger stages of resistant larvae are known to get killed at normal recommended doses.

New chemistries for cotton pest management

Insecticides with novel modes of action were released for cotton pest management. The new insecticides belong to different chemical groups and have been designed to be ecologically safe- as measured by toxicity to beneficial insects, with a novel target site, ideal for targeting resistant insect pests with low toxicity to human beings and are recommended at low delivery rates. However these insecticides are expensive, often not readily available and are likely to be overused due to high perceived efficacy that may lead to associated problems like resistance.

Neonicotinoids The neonicotinoids are structurally similar to nicotine from tobacco. These act agonistically on the nicotinic acetyl choline esterase receptors at the synapses in the insect nervous system, first stimulating the post synaptic membranes and then paralyzing nerve conduction. Using radiolabelled imidacloprid, it was demonstrated that only 5-6 % of the applied radioactivity to the seed was taken up by the plants. Most of the remaining radioactivity was extracted from surrounding soil or seed coats as unchanged parent molecule. Most of the translocated radioactivity was found in the cotyledons. Only 6 % of the extracted radioactivity from the green plant parts represented unchanged parent compound as early as 27 DAS. After 52 days no imidacloprid could be detected in the green parts. Only small amounts of radioactivity are translocated into true leaves but these amounts are sufficient to protect the young plants for 4-6 weeks, which is a shorter period than that

reported for other crops. While imidacloprid is effective in controlling jassids it is not so effective against aphids. Imidacloprid, on uptake, is compartmentalized in the internal glands on the undersurface of cotton leaves. Cotton aphids avoid penetrating these glands during the process of feeding on leaves.

Examples- Imidacloprid, Acetamirid, Thiomethoxam.

Spinosyns Spinosad, an example of the Spinosyn group is a fermentation metabolite of the actinomycetes *Saccharopolyspora spinosa*. It was first registered for use on cotton in 1997. Effective as contact and stomach insecticide against lepidopteran larvae, leaf miners, thrips and termites with long residual activity. Recommended on cotton, pigeon pea and vegetables.

Oxadiazines Indoxacarb an example of the oxadiazine group works by inhibiting the flow of sodium ions into nerve cells. Although it ends with 'carb' it is not a carbamate insecticide. Basically a stomach poison with some contact action too. Exposed insects stop feeding within 0-4h. Paralysis and death occurs within 4-48h.

Avermectins Avermectins are a series of closely related macrocyclic lactone derivatives produced as fermentation metabolites of *Streptomyces avermitilis*. They inhibit signal transduction at the neuromuscular junction. Avermectins also have contact and stomach action with translaminar action. Photodegradation is reported to be rapid.

Eg: Emamectin benzoate, Abamectin

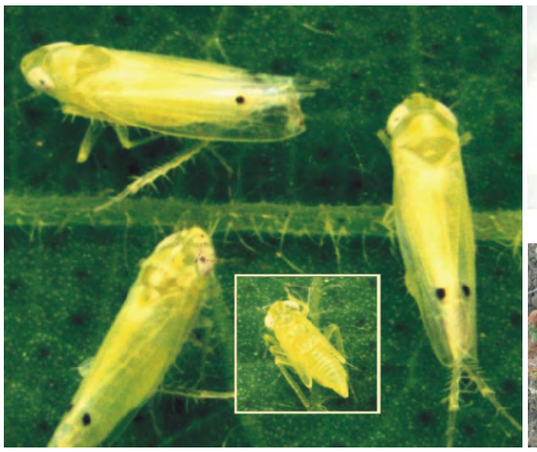
Pyrroles Molecules belonging to this group have a contact and stomach action. They are also effective against mites. Chlorfenapyr is an example of a molecule belonging to pyrroles and was derived from a natural product dioxapyrrolomycin produced from a culture of *Streptomyces fumanus*. Chlorphenapyr acts by disrupting the proton gradient across the mitochondrial membrane and prevents mitochondria from producing ATP that results in loss of energy production.

Insect growth regulators New generation insect growth regulators are represented by benzoyl ureas (eg. Novaluron, Lufenuron, Flufenxuron) thiadiazines (eg. Buprofezin) and thioureas (eg. Diafenthiuron). Novaluron, belonging to the broad group of IGRs is a benzoyl urea that affects the insect hormone system. This group is characterized by low mammalian toxicity with little environmental toxicity. Novaluron demonstrates contact action (as against whiteflies) and stomach action (as against lepidopterans). It interferes in chitin synthesis. Hence adults of non- target species are seldom affected.

Novel chemistries are being tested for efficacy against jassids that seem to have developed enhanced tolerance to neonicotinoids. New chemistries fit well into Bt cotton cultivating systems in terms of ecological selectivity and are in sync with current cotton pest management trends.

INSECT PESTS OF COTTON

Jassids (leaf hoppers), *Amrasca devastans* (Ishida)



Jassid adults and nymph

Jassid damage

Marks of Identification: Adults are wedge shaped insects, greenish yellow with forewings having a black spot on each apical margin and two black spots on vertex. Nymphs are greenish. Both nymphs and adults walk diagonally.

Life History: Female lays 30-35 eggs singly into the leaf veins or stem tissues. Eggs hatch in a week. Nymphs moult five times and survive for 1-2 weeks. Adult longevity is one week. Thus life cycle is completed in 3-6 weeks. Jassids were known as early season pests but now they occur throughout the cotton growing season.

Nature of Damage: Both nymphs and adults suck the cell-sap from the plant tissue; it is believed that during the process of desapping the plant, they also inject a toxin in to the plant tissue resulting in hopperburn.

Symptoms of damage:

Grade I: Entire foliage free from crinkling or curling with no yellowing.
Grade II: Crinkling and curling of few leaves in the lower portion of plant + marginal yellowing of leaves.
Grade III: Crinkling and curling of leaves almost all over the plant. Plant growth hampered.
Grade IV: Extreme curling, crinkling, yellowing bronzing and drying of leaves.

Aphids, *Aphis gossypii* (Glover)

Aphids

Marks of Identification: Tiny (1-4 mm) soft bodied insects. Pale yellowish in color. They possess a pair of tubular processes (cornicles) near the hind end of body. Both apterous and winged forms; when winged, wings are transparent with black veins.

Life History: Aphids reproduce mostly parthenogenetically. Females produce up to 140 offsprings. Life cycle is completed in 7 to 9 days. Cloudy, moist and cold weather favors their multiplication. Heavy rains decrease aphid population.

Nature of Damage: Both nymphs and adults cause damage as phloem feeders. They suck the cell sap from tender plants, hence plants remain stunted. Leaves turn (yellow) pale, curl and dry up. Aphids secret honeydew on plant surfaces which invites the development of black sooty mould and hinders photosynthesis. Ants are also attracted to honey dew. Aphids also damage the crop late in the season coinciding with boll opening, causing serious problems of sooty mould on lint in open boll.

Symptoms of damage:

Grade I: Entire plant free from curling/crumpling.

Grade II: Cupping/crumpling of leaves on the upper portion of plants.

Grade III: Cupping of leaves and aphids all over the plants.

Grade IV: Extreme cupping and black sooty mould all over the plants, stunted growth of the plants.

Whitefly, *Bemesia tabaci* (Gennadius)

Whiteflies

Marks of Identification: Eggs are stalked, yellowish white in colour and sub elliptical in shape. Nymphs are yellowish/brownish and scale like. They are found in large numbers on undersurface of leaves. Pupae also resemble nymphs in shape and have brownish opercula. Adults are minute insects (0.5 to 1.25 mm) having grayish white wings, yellow body and red medially constricted eyes. Body is covered with white waxy powder.

Life History: The female whitefly lays the eggs singly on the undersurface of the leaves and mostly on the top and middle crop canopy. Each female is capable of laying about 120 eggs. The incubation period varies from 3-5 days during spring and summer, 5-17 days during autumn and more than 30 days during winter. The nymphs after hatching fix themselves to the underside of the leaves and moult thrice before pupation. The nymphal period varies from 9-14 days during summer, and 17-19 days during winter. The pupal period is 2-8 days. The total life cycle ranges from 14-107 days depending upon the weather conditions. There are about 12 overlapping generations in a year and the pest also reproduces parthenogenetically at times.

Nature of Damage: Both nymphs and adults suck the cell sap from the leaves which turn pale, curl and dry up. They secrete honeydew on leaves that invites black sooty mould. Ants are also attracted to the honeydew. Whiteflies act as vector for plant diseases such as the cotton leaf curl virus**.**

Symptoms of damage: Shiny sticky appearance of affected plants. Shaking of affected plants cause whiteflies to fly.

Thrips, *Thrips tabaci* Lind

Thrips damage

More than one species of thrips have been recorded on cotton in India.

Marks of identification and life history: Eggs are minute, kidney shaped laid in leaf tissues. Nymphs are small and brownish in color. Adults are slender, yellowish brown with a pair of fringed wings and measure 1.0 mm long with a longevity 2-4 weeks. Egg, nymph and pupal periods are 5, 5 and 4-6 days, respectively. Females can lay 70-100 eggs at the rate of 3-5 eggs/day. Males are wingless (1mm). Females are winged with hair present on both the margins of wings (fringed wings).

Nature of damage: Rolling of margins and shriveling of leaves due to scraping of epidermis. Upper side of older leaves turn brown. Silvery white patches seen on lower side of leaves. Curling, wrinkling drying of leaves. Thrips have been reported to transmit the leaf steak virus in cotton.

Symptoms of damage:

Grade I: Presence of no symptoms.
Grade II: Silvery patches on underside of leaves.
Grade III: Light brown patches visible alongside of veins
Grade IV: Stiffness of leaves to severe rusty appearance of the crop.

Mealybug, *Phenacoccus solenopsis* (Tinsley)

Mealybug on leaf midrib

Mealybug on cotton leaf

Mark of identification: Mealybugs *Phenacoccus solenopsis* (Tinsley) (Hemiptera: Pseudococcildae) are small sap-sucking insects, measuring about 5-6 mm in length and 3-4 mm breadth. The insect body is yellowish green in colour with short to medium sized waxy filaments with two short anal filaments and two dark strips on either side of the middle ridge of the body. This species producse an egg mass or ovisac. The first instar nymphs (crawlers) are highly mobile and devoid of waxy coating . Female completes its life cycle in 35-40 days with 3 nymphal instars. Each female produces 2-3 ovisacs in its life cycle with 300 to 800 eggs in its life time. Eggs hatch within an hour or two and up to 99% crawlers emerge out from the sac. Male is short lived, about 1-2 days with non-functional mouth parts with four caudal filaments. Reproduction is mostly parthenogenic and ovoviviparous.

Nature of damage: Mealybug cause severe economic damage to cotton by sucking sap from all plant parts. Mealybug infested cotton plant shows the symptoms like white fluffy mass on underside of leaves near growing tips along leaf veins and on stem, distorted or bushy shoots, crinkled or twisted or bunchy leaves. Honeydew secreted by the mealybug encourages development of black sooty mould which adversely affects photosynthetic activity.

Infested plants are associated with ant movement that helps the dispersal of mealybug from one place to another. Feeding by sucking leads to stunted growth and subsequent drying of the plant. Incomplete opening of the bolls and reduction in the fiber quality occurs. Infestation on young twigs causes shortening of internodes leading to rosette appearance.

Symptoms of damage

Grade 0: No mealybugs
Grade 1: About 1-10 mealy bugs scattered over the plant
Grade 2: One branch infested heavily with mealy bugs
Grade 3: Two or more branches infested heavily with mealy bugs, up to 50% plant affected.
Grade 4: Complete plant affected

Mirid bugs

Campylomma livida

Creontiades biseratense

Hyalopepsus lineifer

Parrot beaking of boll due to Mirid damage

Three species of mirid bugs occur in India amongst which, *Campylomma lividа* (Reuter), *Hyalopepsus lineifer* (Walker) are the dominant species in north and central India, while *Creontiades biseratense* (Distant) is dominant in south India.

Nature of damage: Both nymph and adult stages cause damage. Feeding on the terminal growth, squares, flowers and bolls of cotton plants with the piercing/sucking mouthparts cause excessive shedding of flowers, small squares and immature bolls. The feeding results in small, dark, sunken lesions on the surface of the boll and in severe cases deformed bolls are formed due to lack of fertilisation of some ovules. This symptom is often referred to as "parrot beaking" of bolls.

Life history: The female mirid lays egg singly, preferentially on the leaf petiole. Eggs are cylindrical, slightly recurved and laterally compressed; shining white in colour, turning to yellow as it matures. Eggs hatch within 4 to 5 days. There are five nymphal instars, each of about 2 to 3 days duration. The wing pads start to develop at the 3rd instar. Adults are elongated, about 7-9 mm long, with long legs and antennae. Development from egg to adult takes about 15 to 18 days. The adults can live for 3 to 5 weeks and a female can lay up to 80 eggs in the life time.

Cotton bollworm/ Gram pod borer, *Helicoverpa armigera* (Hubner)

American bollworm Larva

American bollworm Egg

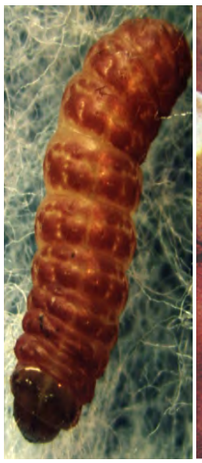
American bollworm Adult

Marks of identification: Egg is sub-spherical with a flattened base; apical area surrounding the micropyle smooth, the rest of the surface sculptured with approximately 24 longitudinal ribs. Colour whitish or creamy white shortly after being laid, developing a central, reddish-brown band as the embryo develops. This gradually darkens, together with the rest of the egg which becomes a uniform grayish brown before hatching. New hatched larvae are a translucent yellowish white, with faint darker longitudinal lines and brown to black head capsules. The full grown larva is about 35 to 42 mm long, the integument having a characteristics granular appearance, consisting of close-set minute tubercles. The head capsule is mottled light brown to reddish brown, the prothoracic and anal plates pale brown, setae dark and the spiracles and claws black. The adults are stout-bodied moths, typical of the Noctuidae, with wingspan of 35-40 mm and body length of 18-19 mm. Females are darker than males and grey-brown in *H. armigera.*

Nature of damage: Newly hatched larvae may often wander for some distance, with occasional surface feeding before settling down at a preferred site: in cotton this is usually on a flower bud or flower, which is eventually hollowed out if it does not first absciss. Older larvae prefer buds and younger bolls. However, most buds and bolls which have been attacked show on accumulation of faeces between the surface and enclosing bracts.

Symptoms of damage: Larvae damage tender squares and cause shedding. Shed squares with marks of insect damage are seen at the base of the plant. Damaged squares retained on the plant flare-up. Larvae feed on bolls with half its body outside the boll. Larvae feed on reproductive parts of flowers. Rarely feed on leaves. Each larva can feed on 8-10 squares and 2-3 bolls.

Pink bollworm, *Pectinophora gossypiella* (Saunders)


Pink bollworm larva


Damaged flower


Damaged green boll


Damaged open boll

Marks of Identification: The adults of the pink bollworm are small moths of dark fuscous brown color and about 1 cm in body length. Larva is colorless and about 1 mm in length. Larva turns pink in third instar/ or last two instars turn pink on account of feeding on necrotic tissues.

Life history: Female lays flattish scale like whitish eggs singly on various parts of young shoot. However half developed bolls are preferred when available. Egg period varies from 3-7 days and neonate larvae are colorless and 1 mm in length.

Nature of damage: The pink bollworm larvae do most spectacular damage to mature cotton bolls in which they enter as tiny neonate larvae. Their entry holes get blocked and they remain inside devouring both seed and fiber forming tissues. The infestation at times is so severe that up to 10 caterpillars are found in each boll, and 75 to 100 percent bolls are found infested. If the attacked bolls are not shed and remain on the plant till they open after ripening, the cotton fiber which escapes damage gets at least stained and even the oil content of the seed, ginning percentage and the spinning quality of the fibre are adversely affected. Also these larvae attack young bolls which may invariably fall down. They also bore into the flower buds and flowers. Like the spotted bollworm they also have alternate hosts in malvaceae family. They cause the appearance of rosette flowers.

Spotted Bollworms


Adult


Larva


Damage

There are two species of spotted bollworms, namely *Earias insulana* (Boisduval) (North India) and *Earias vittella* (Fab.) (Central and South India)

Marks of Identification: The adult is 1cm and wing spans about 2 cm. The body color is generally a shade of bright green and the abdomen is silvery in appearance. The wings have three transverse lines of varying distinctness. *Earias insulana* has green forewings and *Earias vittella* has a band (green) on forewings.

Life History: The moth lays greenish eggs generally singly scattered over fresh leaves, fresh squares. The eggs hatch in less than 3 to more than 10 days. The neonate larva roams about on the plant surface for a very short period of about half an hour and then begins to bore into the plant tissue. The larval period varies from a week to more than two months. Pupation takes place in fallen material on plant surfaces and in cracks and crevices of the soil. Before pupation however the larva spins a dirty white cocoon. The pupal period lasts from a few days to more than two months.

Nature of damage: The larval stages constitute the destructive phase of the pest. This stage bores the stem portion of young seedling and shoots and later eats into young squares as well as buds and bolls. The larvae undergo four or five moults. Larval body surface is irregularly spotted and spiny. Hence they are called spiny bollworms or spotted bollworms.

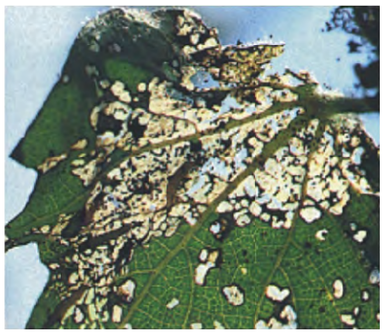
Symptoms of damage: Wilting of growing point in vegetative stage. Shedding of squares and square buds.

Leafworm, *Spodoptera litura* (Fab.)

Egg mass

Larva

Adult



Skeletonised leaf

Marks of identification: Each egg mass contains 300-350 eggs which are arranged in rows up to 3 layers and are covered by scales from the body of the females. Caterpillars are pale green with dark markings initially which later turn dark brown with numerous transverse and longitudinal bands. Pupa is dark brown in color. Pupation occurs in soil. Adult moth measure between 15-20 mm length and have a wingspan of 30-38 mm. Forewings are gray to reddish brown, with a complex pattern of creamy streaks and paler lines along the veins. Hind wings are grayish-white with grayish-brown margins. Males have a blue-gray band in the inner margin of each forewing.

Life history: Females lay eggs in masses that are cream to golden brown in colour. Egg masses are usually covered with body hair, scales and are laid on the underside of the leaf. Egg, larval and pupal periods are 3-4, 3-20 and 8-10 days, respectively. Life cycle completes in 50-60 days.

Nature of damage: The larvae feed gregariously on the undersurface of the leaves and skeletonize them leaving only the midrib and veins in severe cases. They also attack flowers, buds and squares causing considerable loss.

Cotton semilooper, *Anomis flava* (Fab.)

Semilooper

Marks of identification: Eggs are spherical, ribbed about 0.5 mm in diameter deposited on cotton plant. Fully grown larvae are 25-30 mm long, pale yellowish green with five white lines running longitudinally on dorsal surface and with six pairs of black and yellow spots on the back. Pupae are obtect type, brownish and are formed by folding leaf margins on the plants. Adults are reddish brown with forewings traversed by two dark zigzag bands while the hind wings are pale brown.

Life history: Fecundity of the females is about 500-600 eggs. Upon hatching the smaller larvae drop to older leaves and start feeding from lower surface of the leaves. By mid growth stage larvae become gross leaf feeders consuming all the leaf tissues. Life cycle is completed within 28-42 days.

Nature of damage: Outbreak of *Anomis flava* is often sporadic. The young larvae congregate in groups and move actively, feed on the leaf lamina making small punctures. The grown up larvae feed voraciously leaving only the midrib and veins. They feed by chewing the leaves from margin towards the leaf veins. The caterpillars occasionally feed on the tender shoots, buds and bolls. Semilooper in rainfed cotton occurs during peak vegetative stage and is often mistaken as *H. armigera.* Larvae are very susceptible to Cry toxins expressed by the Bt cotton. Importantly, semiloopers function as hosts for several parasitoids that also parasitise *H. Armigera* in the field.

Leaf folder, *Sylepta derogata* (Fab.)

Leaf folder larva

Damage

Marks of identification: Egg is round, smooth and pale white in color. The larva is glistening green in color and semi translucent with dark brown head. They become pinkish before pupation. Fully grown larva measures up to 22-30 mm. Pupa is reddish brown in color and typical in having eight spines with hooked tip at their extremity. Moth is medium sized (12.5 mm long and with a wing expanse of 25 mm) with yellowish wings having series of brown wavy markings. Head and thorax are dotted black.

Life History: Eggs are laid on the under surface of the leaves along the midrib and bigger veins. The moth lays as many as 200 eggs. The egg larva and pupal periods occupy 2-3, 15-18 and 7-8 days, respectively. The larva moults six times before pupation. Pupation takes place in leaves. The life cycle is completed in 25-53 days.

Nature of damage: The larva feeds on the lower surface of the leaves when they are young. As they grow they feed on the edges of leaves and roll inwards up to the midrib in to a trumpet shape fastened by means of silken thread and feed on leaf tissues. The larvae remain inside the roll and feed on the margins of the leaf.

Leaf reddening

Locally called as 'Lalya', is seen as rapid development of deep pink to red colour in leaves. The veins and veinlets are affected first before spreading across the entire leaf lamina. It appears on the leaves causing them to senesce either in the premature stage or towards the end of the growing season. It begins on the lower leaves and subsequently manifests on the upper leaves. Affected leaves ultimately dry and are shed. The problem commences 60-70 days after sowing or before maturity. The reasons attributed to leaf reddening are nitrogen deficiency, phosphorous and potash deficiency, carbohydrate accumulation in the leaves, low night temperature of less than 15°C, as this temperature is reported to stimulate anthocyanin production, micronutrient deficiency, reduced kinetin synthesis, genetic predisposition and moisture stress. Recent studies at CICR demonstrated that leaf reddening was related to sucking pest incidence. In genotypes susceptible to leaf reddening, plots protected with sprays of thiomethoxam for sucking insect pests especially jassids demonstrated a delayed development of the symptoms of leaf reddening.

The recommendation currently being made for the management of leaf reddening is, soil application of $MgSO_4$ @ 20-25 kg/ha or foliar spray with 1% urea or 2% DAP and 0.5-1 % MgSO4 and as soon as the reddening symptoms appear. Effective jassid control at the peak reproductive to late reproductive stage with new insecticides would help mitigate symptoms of leaf reddening.

Leaf streak virus

Chlorosis of young leaves at the growing tip is observed. Discoloration, bronzing, necrosis, curling and dwarfing of affected leaves occur. Affected plants are stunted in growth. Cotton pests such as thrips and more recently aphids have been implicated in spread of the disease. The leaf streak virus on cotton seems endemic to specific regions such as Warangal in Andhra Pradesh. Removal of weed hosts of TSV such as *Parthenium*, *Tridax procumbens*, *Achiranthus aspera* and other weeds around the cotton crop before the onset of the cotton season will help limit the occurrence of this disease.

PACKAGE OF PRACTICES FOR

MANAGING MEALYBUG ON COTTON

What to do	When to do	Why to do	How to do	What not to do	Why not to do
Cultural practices					
Early crop termination	Immediate after last picking and between two cropping seasons	To prevent continuous food supply and shelter for multiplication and carry over of mealybug.	Removal of cotton crop from the fields immedi ately after the last picking and maintenance of host free period.	Ratoon cropping or allowing the cotton crop to continue to stand in the field after final harvest.	Ratoon crop offers shelter for mealybug and provides inoculum for next season.
Destruction of cotton stalks.	After final picking is over.	Destruction of residual cotton stalks reduces the carryover to the next season.	The dry cotton stalks should be pulled out and destroyed	Stacking of cotton stalks in or nearby areas of the fields	Mealybugs survive on stalks and pass on to the next season.
Clean cultivation: Destroy alternate weed hosts growing on field bunds, water channels and waste lands in the area.	During the crop season and off-season	Weeds especially congress grass and Xanthium are the most suitable hosts for mealybugs and assist them to spread on crops.	Biological- inoculative release of *Zygogramma bicolorata*. @500-1000 beetles /ha on parthenium grass. Mechanical- destruction	Do not throw infested plants into irrigation canal. Do not spray only weedicides.	Mealybugs spread through water. If weeds are destroyed, mealybugs move to the adjacent crop.
Use acid-delinted seeds for sowing.	At the time of sowing/planting	Delinted seeds do not carry any infective stages of the mealybug	Delint with sulfuric acid wash with water and neutralize with lime	Using fuzzy seeds for sowing.	Fuzzy seeds harbor infective stages of mealybug crawlers.
Select varieties/ hybrids approved by GEAC or SAUs of that zone.	Before planting and procurement of seed material.	Approved varieties/ hybrids are tested before release for their tolerance to pests and diseases	Consult the SAUs/ICAR institute located in the area while making a choice of genotypes.	Use of nondescript or F2 Bt hybrids. susceptible to mealybug.	Non descript cultivars may be
Grow pigeonpea, bajra or maize as border crop wherever possible.	At the time of planting.	These crops offer least support for the growth & multiplication of mealy-bugs. Border rows act as barrier crop	Growing two rows of densely planted bajra or pigeonpea or maize as border or inter crop	Avoid growing malvaceous and solanaceous crops near cotton fields	Malvaceous and solanaceous crops are good hosts for mealybugs.
Regular monitoring of the pest	After the sowing of cotton crop	The pest is initially restricted to a few plants along the border rows, adjacent to the source of	By weekly observations the pest can be effective-ly managed through early detection	Do not allow free movement of labor/ animals in infested fields.	Mealybugs spread through water, air, human,animal farm implements etc.
Botanical and Biological control					
NSKE 5% 50ml/l+ Neem oil 5 ml/l+ deter-gent powder 1gm/l+ Fish oil rosin liquid 10 ml/l+ Karanj oil 10ml/l can be spot applied on infested stalks.	Initial stage of infest-ation. When 1-2 infested plants obse-rved of grade-2 (at least one stem completely colonized with in more than 40 plant per/acre	Spot application restricts the spread of mealybugs These formulations are less harmful to natural enemies and thus help in conserving ecosystem	Spray on the crop adjacent to the infested plants and at the base of the infested plants without disturbing the mealybug colonies.	Do not use chemical insecticides at early stage of crop.	use of insecticides disrupts native predators and parasitoids.

PACKAGE OF PRACTICES FOR MANAGING MEALYBUG ON COTTON

What to do	When to do	Why to do
Biopesticides and Biological Control		
Spray biopesticides viz., *Verticillium lecanii* (Potency 2 X10^8 C.F.U /gm)10gm/l and *Beauveria bassiana* (Potency 108 spores/ml), 10ml/l.	Initial infestation during August-October i.e high humid months coinciding with vegetative growth phase of crop.	The formulations disrupt growth and multiplication of mealybugs by causing disease without harming other natural enemies and the environment.
Chemical control		
Spray less hazardous insecticides, such as Acephate, 75 SP 1gm/l, Malathion 50 EC 2ml/l, Buprofezin 25 SC1ml/l As the last option, spray moderately hazardous insecticides: Quinalphos 25 EC 5.0 ml/l, Chlorpyriphos 20 EC 3.0 ml/l, Profenophos 50 EC 5.0 ml, Thiodicarb 75 WP 5.0 gm/l	When 10% infested plants observed of grade-2 (at least one stem completely colonized with mealybugs) in more than 20 plants per acre When > 10% infested plants observed to exceed grade 2 infestation in more than 20 plants per acre	WHO class III (Slightly hazardous) - Acephate, Malathion and WHO Class IV (Unlikely hazardous) - Buprofezin 25 % SC1ml/l cause less harm to the environment. WHO class II (Moderately hazardous) - Quinalphosl, Chlorpyriphos, Profenophos , Thiodicarb cause comparatively less harm to the environment.

How to do	What not to do	Why not to do
Spray of biopesticides formulations during morning / evening hours on infested crop area.	Do not use pathogen formulations *Verticillium lecanii* and *Beauveria bassiana* during other months when humidity is low.	Fungal spores germinate and cause disease in the insect when optimum relative humidity (>60%) conditions prevail.
Spray the chemicals first on plants around infested plants and then as spot application at the infested plants.	Avoid use of insecticides with high eco-toxicity such as methyl parathion, (classified by the WHO 1a: extremely hazardous), dichlorvos methomyl, triazophos metasystox and monocrotophos.	Insecticides with high ecotoxicity should be avoided since they are not only ecologically hazardous, but also detrimental to predators , parasitoids that control mealybugs and other beneficial insects.


Mealybug


Anaesius bambawalei


Cryptolaemus sp.


Zygogramma bicolorata

Tips for mealybug management

Mealybug crawlers spread through human interventions such as spraying, irrigations, frequent movement through the infected area etc. Therefore avoid disturbing mealybug affected plants. It is important to remember that young cotton plants can overcome mealybugs and it is better not to resort to chemical sprays on young plants that have slight infestation of the mealy bugs in early vegetative stages of the crop. It has been observed that the mealy bugs were unable to establish colonies on the cotton crop during early vegetative and peak vegetative stages. It is only in rare cases, which is generally possible on a few susceptible genotypes, that mealybugs colonize plants during vegetative stage.

All over the country, several parasitoids (predominantly *Aenasius* sp.) and coccinellid predators are now found to keep mealy bug populations under control, thereby preventing spread and damage. Insecticides such as profenophos, chlorpyriphos, monocrotophos etc. which are being commonly used for mealy bug control, destroy the parasitoids and predators and can result in mealybug outbreaks. Therefore, insecticide applications should be avoided until peak boll formation stage, so as to allow further establishment of the parasitoid and predator complex in the ecosystem. Eco-friendly insecticides such as neem oil based botanicals and Buprofezin can be used if necessary in the initial stages so as to keep mealy bugs under check while causing minimum disturbance to the ecosystem.

However **during peak boll formation stage, mealy bugs can establish colonies** but are initially restricted to a few plants along the border rows, adjacent to the source of infestation and thus can be effectively managed through early detection and initiation of interventions to control early stages of infestation. If timely scouting and appropriate control measures are not initiated cotton crop is likely to be severely damaged by mealybugs.

Insecticides should not be applied all over the field to manage mealybugs. Such a practice disrupts the ecosystem and does not allow naturally occurring parasitoids and predators to establish natural control. Therefore, the following practices are advised:

Do not allow physical contact with the infested plant. Locate infested plants with more than one twig infested completely with mealybug colonies. Do not disturb the plant vigorously. If possible, the affected twig can be gently detached from the plant, collected in plastic bags and taken far away from fields to be destroyed by burning.

If at least 10% infested plants exceed grade-2 (at least one stem completely colonized with mealy bugs) in more than 20 plants randomly sampled plants per acre, chemical control measures may be initiated. Insecticide application should start first on the neighboring plants and then as spot application near the root zone, base of the plant and other infested parts.