सत्यमेव जयते

INTEGRATED PEST MANAGEMENT PACKAGE FOR COTTON

NCIPM

Government of India
Ministry of Agriculture, Department of Agriculture & Cooperation
Directorate of Plant Protection, Quarantine & Storage
CGO Complex, NH IV, Faridabad
Haryana- 121001

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FOREWORD

Intensive agricultural practices relying heavily on chemical pesticides are a major cause of wide spread ecological imbalances resulting in serious problems of insecticide resistance, pest resurgence, pest replacement and pesticide residues. There is a growing awareness world over of the need for promoting environmentally sustainable agriculture practices.

Integrated Pest Management (IPM) is a globally accepted strategy for promoting sustainable agriculture. There is a conscious shift from the reliance on economic threshold level and chemical pesticides driven approaches in the past to more ecologically sustainable Agro-Eco System Analysis (AESA) based IPM strategies. These focus on the relationship among various components of an agro-ecosystem with special focus on pest-defender dynamics, innate abilities of plant to compensate for the damages caused by the pests and the influence of abiotic factors on pest buildup. In addition, Ecological Engineering for pest management - a new paradigm to enhance the natural enemies in an agro-ecosystem, is being considered as an important strategy.The ecological approach stresses the need for relying on bio intensive strategies prior to use of chemical pesticides.

Sincere efforts have been made by resource personnel to incorporate AESA based principles and field proven technologies for guidance of the extension officers to educate, motivate and guide the farmers to adopt AESA based IPM strategies, which are environmentally sustainable. I hope that these IPM packages will be relied upon by various Central and State government functionaries involved in extension and Scientists of SAUs and ICAR institutions in their endeavour to promote environmentally sustainable agriculture practices.

A Srivastava

(Avinash K. Srivastava)

PREFACE

Pests are major biotic constraint to achieve self sufficiency in ensuring food security. Losses due to pest vary between 10-30% depending upon the genetic constituent of crop, its health and the governing environment. General national estimate of annual crop losses due to pest amounts to Rs. 260000 million per year, however negligence of endemic areas can results in complete crop failures. In view of ineffectiveness of chemical pesticides and environmental problems Integrated Pest Management (IPM) has been accepted as a cardinal principle of Plant Protection in the overall Crop Protection Programme under the National Agricultural Policy of the Govt. of India. IPM being an eco-friendly approach, socially acceptable and economically viable has been widely accepted across the country. The IPM package encompasses various management strategies for pest and disease problems. Pest monitoring is also one of the important component of IPM to take proper decision to manage any pest problem. It can be done through Agro-Ecosystem Analysis (AESA), field scouting, light, pheromone, sticky/yellow pan traps. The economic threshold level (ETL) of important pests and diseases are also given in the package to take appropriate control measures when pest population crosses ETL.

With a view to provide technical knowledge to the extension functionaries and farmers in the States, a National Workshop on IPM for harmonization of Package of Practices was organized at National Centre for Integrated Pest Management, New Delhi, during 25-26th Feb., 2013. The IPM packages has been developed with the technical inputs from experts from PIs of respective crop (AICRIP), Indian Council of Agricultural Research (NCIPM), State Agricultural Universities, and DPPQ & S, Faridabad.

It will also be useful in reducing the pesticide residues in exportable agricultural commodities and would also help in the management of pests/diseases/weeds/nematodes which may get inadvertently introduce in the country. These packages will be useful for the researchers, extension workers and farmers alike who are engaged in the agricultural practices.

Editors

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1. Introduction

Integrated Pest Management (IPM) in cotton involves using all available techniques for managing pest populations with the aim of reducing pesticide use while maintaining profitability, yield and fibre quality. IPM is a practice for improving the quality of the environment and the quality of an IPM programme depends on how environmental friendly it is. A good IPM programme would necessarily result in good integrated crop management. The framework of IPM under any given circumstance has enormous accommodative power of function in terms of goals and objectives, and incorporates holism by continually updating the technological inputs besides removing the shortfalls of current plant protection practices.

Commercial cultivation of cotton in India is taken up in three designated cotton growing zones *viz.,* North, Central and South zones falling under varied agro climatic conditions, seasons and cropping systems. North zone, traditionally designated as *hirsutum* and *arboreum* zone comprises States of Punjab, Haryana and Rajasthan. While Central (*hirsutum, arboreum, herbaceum* and hybrid) zone has states of Gujarat, Madhya Pradesh and Maharashtra, the South (*hirsutum, arboreum, herbaceum, barbadense* and hybrid) zone spreads across states of Karnataka, Andhra Pradesh and Tamil Nadu. Currently, all zones are growing Bt cotton hybrids at large. The commercial cultivation of Bt transgenic hybrids from 2002, a shift from erstwhile conventional varieties and hybrids changed the paradigm of cotton cultivation in India. The increase of area, production and productivity in the post Bt era was appreciable indicating 116.14 lakh ha., 334 lakh bales and 489 Kg lint/ha, respectively during 2012-13. However, multifarious problems of changing rainfall pattern and temperatures during cotton crop growth and development, emergence of alternate cotton pests such as mealybugs, mirids, cotton leaf curl virus, resistance and resurgence of sucking pests to insecticidal measures and sub optimal suppression of Lepidopterous larvae especially *Spodoptera litura* and pink bollworm by the Bt transgenics are the plant protection associated issues on Bt cotton. In addition maladies of parawilt and leaf reddening add woes to the cotton growers. Under the changed scenario of cotton cultivation not only the production practices changed but also the protection practices. The Bt cotton brought out as a protection technology changed the paradigm of pest scenario and hence the approach to development of IPM in conjunction with the challenges. Crop, insect pests, diseases, natural enemies, cropping practices and patterns and prevalent weather are essentially to be considered simultaneously to improve decision making for profitable and sustainable IPM. With more than 90% cotton area under Bt cotton hybrids across three different cotton growing zones of the country, the necessity is to bring out a package of IPM to suit to the Bt cotton cultivation, notwithstanding the possibility that there would always be a tendency and scope for the past continuing into the future to a certain proportion. Irrespective of the scenario of cotton cultivation, IPM strategies have to cope up with complex of pests as always and the strategies to cope the resistance development in insects.

IPM and its role in crop production

IPM has evolved as an economical, environmental and eco-friendly approach to manage biotic stresses to crop plants in terms of insects, diseases, physiological disorders, weeds and rodents that cause economic yield loss and limit the agriculture production. IPM aims at reducing farmer risks from pesticide poisoning and consumer risks from residues in food chain at community level, low production costs and greater yield savings at farm level, and increased biodiversity especially of productive biota and improved quality of natural resources such as soil and water quality at agricultural ecosystem level.IPM is all about pests, all control methods, management strategies and

information. IPM aims to reduce pest populations below the economic injury level. IPM utilizes the various methods of pest suppression in a compatible manner towards sustainable crop production.

The present IPM package on cotton integrates the pest management practices based on the IPM research outputs of the post Bt era for use by the extension functionaries and IPM practitioners in the country.

2. BIOTIC CONSTRAINTS

2.1. Insect Pests of National and Regional Significance

1. Leaf hopper (*Amrasca devastans* Distant)
2. Whitefly (*Bemisia tabaci* Genn.)
3. Thrips (*Thrips tabaci* Lindeman)
4. Aphids (*Aphis gossypii* Glover)
5. Mirids (*Creontiades biseratense* Distant) South Zone, (*Campylomma livida* Reuter) Central and North Zone
6. Mealybugs (*Phenacoccus solenopsis* Tinsley) All Zones (*Paracoccus marginatus* Williams and Granara de Willink) South Zone
7. Tobacco caterpillar (*Spodoptera litura* Fabricius)
8. Pink boll worm (*Pectinophora gossypiella* Saund.)
9. Spotted and spiny bollworm (*Earias vittella* Fab.) & (*Earias insulana* Boisd.)
10. *Helicoverpa* bollworm (*Helicoverpa armigera* Hub.)
11. Leaf roller (*Sylepta derogata* Fabricius)
12. Red cotton bug (*Dysdercus cingulatus* Fab.)
13. Dusky cotton bug (*Oxycarenus hyalipennis* Costa.)
14. Semi-looper (*Anomis flava* Fabricius)
15. Stem Weevil (*Pempherulus affinis* Fst.) (TamilNadu)
16. Shoot weevil (*Alcidodes affaber*Auriv.) (Karnataka)

2.2. Major Diseases of National and Regional Significance

1. Blackarm/Angular leaf spot/Bacterial blight (*Xanthomonas axonopodis* p.v. *malvacearum* (Smith) Dye) (All zones)
2. Alternaria leaf spot (*Alternaria macrospora* Zimm /*Alternata sp*.) (All zones)
3. Myrothecium leaf spot (*Myrothecium roridum* Tode) (All zones)
4. Root rot (*Rhizoctonia solani* Kuhn.& *R .bataticola* (Taub) Butler) (All zones)
5. Fusarium wilt (*Fusarium oxysporum* f.sp *vasinfectum* (Atk.) Snyder and Hansen) (All zones)
6. Cotton leaf Curl Virus Disease (CLCuD) (North Zone only)
7. Grey Mildew (*Ramularia areola* Atk.) (Central & South Zone only)

8. Verticillium wilt (*Verticillium dahliae* Khleb) (South Zone only)
9. Leaf rust (*Phakopsora gossypii* (Arth) Hirat F) (South Zone only)

2.3. Physiological Disorders

1. Leaf reddening
2. Para wilt

2.4. Major Weeds of National and Regional Importance

2.4.1. Monocots weeds

1. Doob grass (*Cynodon dactylon* Pers.)
2. Barnyard grass (*Echinochloa crus-galli* (L.) P. Beauv).
3. Makra (*Dactylocterium aegytipum* (L.) Willd.)
4. Signal grass (*Brachiaria humidicola* (Rendle) Schweick)
5. Torpedo grass (*Panicum repens* L.)
6. Nut grass (*Cyprus rotundus* L.)

2.4.2. Dicots weeds

1. Datura (*Xanthium strumarium* L.)
2. Wild jute (*Corchorus trilocularis* L.)
3. Cox comb (*Celosia argentia* L.)
4. Carpetweed (*Trianthema portulacastrum* L.)
5. Purselane (*Portulaca oleracea* L.)
6. Coat Buttons (*Tridax procumbens* L.)
7. Hiran khuri (*Convolvulus arvensis* L.)
8. Velvet leaf (*Abutilon theophrasti* Sweet)
9. Kanghi buti (*Sida cordifolia* L.)
10. Spurge (*Euphorbia heterophylla* L.)
11. Carrot grass (*Parthenium hysterophorus* L.)
12. Silk leaf (*Lagascea mollis* Cavanilles)

2.5. Nematodes of National and Regional Importance

1. Root Knot Nematode (*Meloidogyne incognita*) North India and parts of Central India and Gujarat
2. ReniformNematode (*Rotylenchulus reniformis*) Central and South India

3. Description of insect pests and their damage

Leaf hoppers/Jassids

Description of Insect Stages

Eggs are curved, elongated and yellowish white in colour, and deeply embedded in the midribs of large veins on the undersurface of the leaves. Nymphs are flattened, pale yellowish green with characteristic way of moving diagonally in relation to their body, and remain confined to the lower surface of leaves during daytime. Adults are about 3.5 mm in length. They are elongate and wedge shaped with pale green body. Forewings and vertex have black spots. Adults are very active with sideway movements but quick to hop (hence referred as leaf hoppers) and fly when disturbed.

Nature of Damage and Symptoms

Both nymphs and adults suck the plant sap and introduce salivary toxins that impair photosynthesis in proportion to the amount of feeding. 1st and 2nd instar nymphs feed near bases of the leaf veins, later instars get distributed all over the leaves but feed chiefly on the under surface of leaves. The affected leaves curl downwards; turn yellowish, then brownish before drying and shedding. Severe incidence lead to stunting of young plants and results in "hopper burn" injury. The fruiting capacity of the infested plants is significantly affected and in many cases heavy infestation on young plants causes death of plants. Severe incidence during the late season leads to reduced yields.

Life History

The female inserts about 15 eggs inside leaf veins. The incubation period ranges from 4-11 days. The nymphal period occupies 7-21 days depending upon weather conditions. Eleven generations have been estimated to occur in a year. Nymphs moult five times. Average number of eggs laid by female is about 15 with a maximum of 29.

Whiteflies

Description of Insect Stages

Eggs are yellowish white laid singly on the under surface of leaves. They are stalked and sub elliptical in shape. Nymphs are yellowish and brownish, sub elliptical and scale like. They are found in large numbers on underside of leaves. Pupae also resemble nymphs in shape and have brownish opercula. Adults are tiny and white in color. They have a yellow body dusted lightly with a white waxy powder. Females are 1.1 –1.2 mm long; males are slightly smaller. Antennae of females are longer than males. Hind legs are larger than anterior pair of legs. Genitalia of female consists of outer and inner vulvulae that are rounded. Parameres of males are extended, narrow and pointed. Large numbers of adults are found in middle region of the plant.

Nature of Damage and Symptoms

Whiteflies cause damage to cotton plants in two ways firstly by sucking the sap and secondly by excreting honey dew on which sooty mould grows. Damage from direct feeding reduces the photosynthetic activities of the plant and hence the yield. Indirect damage results from lint contamination with honeydew and associated fungi and through transmission of leaf curl virus disease. Late season severity affects the seed development and the lint quality. Leaves curl upwards and the plant vigour reduces. Leaves become shiny with honeydew or darkened by sooty mould growing on honeydew. Lint contamination with honeydew and associated fungi occur during heavy infestations after boll opening.

Life History

The female whitefly lays the eggs singly on the under surface of 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 during autumn and >30 days during winter. The nymphs after hatching fix themselves to the underside of the leaves and they 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 to 107 days depending upon the weather conditions. There are about 12 overlapping generations in a year and the pest also reproduces parthenogenetically at times. Whiteflies have extremely wide host range.

Thrips

Description of Insect Stages

Eggs are minute, kidney shaped laid in slits in leaf tissues. Nymphs are creamy to pale yellow in color, resemble adults but wingless. Adults are straw colored, yellowish brown and elongated measuring 1mm in length. Adults are slender and lice like. Antennae have seven segments with the first segment paler than the second which is usually dark. A brown band marks anterior edge of the abdominal tergites. There is a single pair of pores on tergite nine.

Nature of Damage and Symptoms

Nymphs and adults lacerate the tissue and suck the sap from the upper and lower surfaces of leaves. They inject saliva and suck the lysed contents of plant cells resulting in silvery or brown necrotic spots of 3-5 mm. Seedlings infested with thrips grow slow and the leaves become wrinkled, curl upwards and distorted with white shiny patches. Rusty appearances in patches develop on undersurface of leaves. Thrips infested crop in a field presents rusty appearance from a distance. Higher infestation during vegetative crop growth results in late bud formation. During the fruiting phase there is premature dropping of squares, and the crop maturity is delayed combined with yield reductions. The feeding by thrips on the developing bolls late in the season cause spots or wounds on the pericarp but that do not affect the ripening of the boll or the quality of the seed.

Life History

Thrips thrive on the weeds during the off-season and migrate to cotton as soon as the seedlings emerge above ground. Males are rare and the reproduction is parthenogenetic. Eggs hatch in 5 days time, nymphal and pupal period lasts for 5 and 4-6 days, respectively. The preimaginal stage is spent in soil without feeding. The adults survive for 2-4 weeks. Life cycle of *T. tabaci* from egg to adult lasts for 13-19 days and they have about 15 overlapping generations per year including their development on wild plants. Thrips inhabit on leaves of cotton up to mid season and colonise on bolls during the late season.

Aphids

Description of Insect Stages

Nymphs are small, yellowish or brownish on the undersurface of the leaves and on the terminal shoots and are mostly wingless. Adults are yellowish brown to black, 1.25 mm long with black cornicles and yellowish green abdominal tip. Both apterous (0.9-1.8 mm) and winged form (1.1-1.8mm) occur together.

Nature of Damage and Symptoms

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. Younger plants suffer more attack than older plants. Aggregating populations are seen at the terminal buds and largest populations are found below leaves of lower third of plants where they are partially protected from sunlight and higher temperature. Leaves show downward crumpling. Leaves are shiny with honeydew or darkened by sooty mould growing on the honeydew. Contamination of lint with honeydew and associated fungi leads to poor quality cotton. Activity of ants on the aphid-infested plants is common.

Life History

Aphids live in colonies and the females multiply parthenogenetically and viviparously. In a day female may give birth to 8-22 nymphs. Nymphal period lasts for 7-9 days and the adults live for 12-20 days. In all, the pest has 12-14 generations per year. It is a polyphagous pest. Aphids produce sugary excretion called 'honey dew' on which sooty mould grows. Ant activity is associated due to the honey excretion by aphids. Ants transmit aphids from plant to plant. Aphids have a large host range with varying durations of development and reproductive rate.

Mirids

Description of Insect Stages

Mirid lays eggs singly. Eggs inserted into the plant tissue with an oval egg cap. Nymphs resemble aphids because of their small size (6.7mm) however mirid bug nymphs move much faster than aphids. The antennae are long and slender. All instars are highly mobile with long antennae. The late instar nymphs and adults have black glands /spots distributed on the femur and tibial segments of all three pairs of legs. *Campylomma livida* Reuter. Adults are flat, green, straw yellow or brown coloured, 0.25" long and 0.12" wide with long and slender antennae, and have an oval body outline with a conspicuous greenish or yellowish triangle in the center of the back. Late instar nymphs and adults have black spots distributed on the femur and tibial segments of all three pairs of legs. Adult bugs running on leaves of the plant terminal during early morning hours could be seen *C. biseratense* is bigger than *C. livida.*

Nature of Damage and Symptoms

C. livida feeding on pre fruiting plants causes abortion of plant terminals, resulting in many branched plants. When small to medium sized squares are fed, drying and abscission ('blasting') of squares occur within 3-4 days. Large sized squares do not necessarily shed but the developing anthers are destroyed which present a darker or dried appearance, if cut open. Flowers that develop from injured squares have some black and shriveled anthers besides wrinkled and distorted petals. Feeding injury on bolls results in development of sunken black spots on the outer surface, and shrunken and stained seeds inside. "Parrot beaking" of bolls is a significant indicator of boll damage due to mirids. In squares injured by mirids anthers are shriveled and the pistil may be missing. If young bolls of ten days old are attacked black sunken spots develop on their surface. Their feeding injury on bolls results in shrunken and stained seeds. On open bolls the damage is seen as yellowish to brownish stained lint and the affected seeds are shriveled.

Life History

Eggs laid preferentially on the leaf petiole and hatch within 4-5 days. There are five nymphal instars, each of about 2-3 days duration at 30-32^{0}C (average temperature). Under summer conditions a

generation (egg-adult) can be completed in about 3 weeks. Adult can live for 3-4 weeks. The duration of different life stages prolong at lower temperature.

Mealybug

Description of Insect Stages

The female mealybug is oval shaped, 3-4 mm in size, wingless and covered with white hydrophobic (water repellent) mealy wax. There are dark bare spots on the thorax and abdomen, which appear as dark longitudinal lines. Mature females are often found with waxy pouches called ovisacs containing eggs. The adult male is about 1 mm long, with a grey body and a single pair of transparent wings. Two filaments of white wax project from the end of its abdomen. The adult male has no feeding mouthparts and causes no damage.

Nature of Damage

Mealybugs are small sap-sucking insects cause severe economic damage to cotton and a wide range of vegetable, horticultural and other field crops. Plants infested by mealybugs during vegetative phase exhibit symptoms of distorted, bushy shoots, crinkled and/or twisted bunchy leaves and stunted plants that dry completely in severe cases. Late season infestations during reproductive crop stage result in reduced plant vigour and early crop senescence. While feeding mealybugs injects a toxic substance into the plant parts resulting in chlorosis, stunting, deformation and death of plants. Mealybugs attacks cotton growing parts *viz*., main stem, branches and fruit, underdeveloped flowers produced bolls of smaller size; boll opening adversely affected resulting in serious reduction in yield. Excretion of honeydew attracts ants and also contributes to the development of black sooty mould. Plants severely affected with sooty mould have the appearance of burn symptoms. 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. Human activities too aid in transport of mealybugs. Juvenile mealybugs crawl from an infected plant to another and crawlers are readily transported by wind, rain, birds, ants, clothing, and vehicle and may settle in cracks and crevices, usually on new plants. The wax, which sticks to each egg, also facilitates passive transport by equipments, animals. As the plant dies the colonies of mealybugs migrate from shoot tips to twigs, branches and finally down the trunk. Ants, attracted by the honeydew, have been seen carrying mealybugs from plant to plant.

Symptoms

- White fluffy mass on underside of leaves, near growing tips, along leaf veins and on stems.
- Distorted or bushy shoots
- Crinkled or twisted or bunched leaves
- Presence of honey dew and black sooty mould
- Small deformed squares, flowers and bolls

Tobacco caterpillar

Description of Insect Stages

Each egg mass contains 300-350 eggs which are arranged in rows up to three 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. They are gregarious at first but later spread over the plant and become brown to grey brown or black with irregular spots and lines.

Pupae are dark brown on colour. Pupation occurs in soil. The adult is stout with brownish forewings with paler lines along the veins, and pearly whitish hind wings.

Nature of Damage and Symptoms

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. Skeletenization resulting in papery appearance of leaves with only veins left out is the typical damage. Leaves defoliate and shedding of squares with feeding holes occur when larvae are in large numbers.

Life History

Egg, larva and pupal periods are 3-4, 13-20 and 8-10 days, respectively. Life cycle is completed in 50-60 days.

Pink bollworm

Description of Insect Stages

Eggs are pearly iridescent white, flattened, oval measuring approximately 0.5 mm long, 0.25 mm wide and sculptured with longitudinal lines. Eggs are laid singly or in groups of four to five. First two instars are white, while from third instar pink colour develops. The larvae have the characteristic dark brown head due to the sclerotised prothoracic shield. Pupae are light brown when fresh, gradually become dark brown as the pupation proceeds. Pupa measures up to 7mm in length. The adult moth is greyish brown with blackish bands on the forewings and the 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.

Nature of Damage and Symptoms

Larva when attacks the bud of less than 10 days old, shedding of bud occurs and larva dies. But with older bud, larva can complete development. 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. 'Rosetted flower' (improper opening of petals) is typical of bollworm attack. Small exit holes (smaller than the feeding holes of other two bollworms *viz, Earias* & *Helicoverpa*) are seen on developing green bolls. Stained lint around feeding areas resulting in bad quality kapas is seen in open bolls. Improper boll opening with damaged seeds are obvious. Small round holes are seen on the septa between locules of open bolls. Lint of pink bollworm attacked bolls is of inferior quality.

Life History

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. 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 life cycle is completed in 3-6 weeks. Late season has invariably overlapping broods. The long cycle larvae entering diapause, 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. *P. gossypiella* hibernate as full fed larvae during cold weather. 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. Moths emerging from the hibernating larvae are long lived with females and males alive for 56 and 20 days, respectively.

Spotted and spiny bollworms

Description of Insect Stages

Eggs are spherical bluish green, sculptured and less than 0.5 mm diameter. Eggs are laid singly on most part of the cotton plant (flower buds, bolls, peduncles and bracteoles); the favoured region 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, pale along the mid dorsal line with dark spots at the base of tubercles of the thoracic segments. Larva 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. Pupation is in a boat shaped tough silken cocoon that is dirty, white to brownish in colour. Pupae are found on plants or on fallen buds and bolls. 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. *E. vittella*, moths are quite distinctively creamy white or peach with a central green wedge running from proximal to the distal edge of the forewing.

Nature of Damage and Symptoms

Neonate larvae cause damage to the terminal bud of the vegetative shoots and channel downwards or into auxiliary nodes 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 twining of the main stem due to the growth of auxiliary 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. Damaged bolls often succumb to secondary infection by bacterial and fungal pathogens. Terminals shoots dry and wither away when the larvae bore into the pre squaring plants. Shoots when split open show downward channels with or without larvae. Feeding holes in squares and on bolls are seen with or without larvae however blocked by excrement. Flare up of squares and their shedding, premature dropping or opening of the attacked bolls are common.

Life History

The female moth deposits 2 or 3 eggs on bracts, leaf axils and veins on the under surface of leaf. A female may lay about 385 eggs and the incubation period is about 3 days. The larva becomes fully grown in 10-12 days. The pupal period is 7-10 days. The total life cycle ranges from 20-22 days. *E. insulana* is the most abundant species in northern states and *E. vittella* is predominant in Peninsular India. Okra or bhendi crop provides effective means of carryover from one to the next season.

Helicoverpa caterpillar

Description of Insect Stages

Eggs are spherical with a flattened base laid on the tender foliage and calyx of squares and stem of the cotton plants. 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. Considerable variations occur with shades ranging from green, fawn yellow to brown and their combinations. Host diet also plays a role to some extent in determining the colour of the larvae. There are usually six 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. Adults are stout bodied moths, greenish yellow to buff to brown with darker brown or blackish markings. Males are light brown with greenish cast. Females are darker than males. Moths have a circadian rhythm starting at dusk, continues through midnight after which it virtually ceases. Moths disperse over long distances to suitable crops from source hosts.

Nature of Damage and Symptoms

The larvae feed on the leaves initially and then bore on to the square/bolls and seeds with their head thrust into the boll, leaving the rest of the body outside. Larvae show preference for feeding on squares and flowers when present, however, feed on young bolls also. A single larva can damage 30-40 fruiting forms during its developmental period. The entry holes are large and circular at the base of the boll. Feeding on bolls can be extensive or only brief. These larvae spread Boll rot microbes, and the damaged bolls rot resulting in yield loss. Presence of frass held in place by delicate webbing is seen on squares fed by early instars. Damaged squares flare off and have feeding or damage holes on them. Excessive shedding of squares of variable sizes noticed. Clear-cut round feeding holes on squares and bolls with or without larvae are seen.

Life History

Egg period is for 3 to 5 days. Larval and pupal periods last for 17-35 and 17-20 days, respectively. The life cycle is completed in 25-60 days. On an average female moth lays 700 eggs during its longevity of 8-12 days. The pest is polyphagous, voracious in feeding and has wide host range, various colour forms and continues to occur year round. They are multivoltine and have overlapping generations. The moths are highly mobile able to fly up to 200 KM and thus have wider regional distribution.

Semi-looper

Description of Insect Stages

Eggs are spherical, ribbed about 0.5mm in diameter. They are deposited anywhere on the cotton plant. Larva is a semi-looper having three pairs of prolegs on the 5th, 6th and 10th abdominal segments. Fully grown larvae are 25-30 mm long, pale yellowish green with five white lines running longitudinally on the dorsal surface, and with six pairs of black and yellow spots on the back. The larvae are usually found on the lower leaf surface and are most likely to be observed on the upper third of the plant. Pupae are obtect type, brownish and are formed by folding leaf margins on the plants. Pupae also occur in

plant debris. Adult is reddish brown with forewings traversed by two dark zigzag bands, while the hind wings are pale brown.

Nature of Damage and Symptoms

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 feed on tender shoots, buds and bolls, but occasionally. Leaf area is eaten up from edges. Windows / holes on leaves are seen. Black faeces on leaf surface are common. Larvae found amidst the terminal part of the plant and with looping movements.

Life History

Fecundity of the female 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.

Leaf roller

Description of Insect Stages

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

Nature of Damage and Symptoms

The larvae feed on the lower surface of leaves when they are young and as they grow, they feed on the edges of leaves and roll inwards up to the midrib into a trumpet shape fastened by means of silken thread and feed on leaf tissues. The larvae remain inside the roll and feed outside the marginal portion of the leaves. Severe infestation results in complete defoliation of the plant. Leaves are folded downwards individually or in groups, and larvae are seen in groups amidst faecal materials inside the folds. Leaves at the bottom of the crop canopy show symptoms at low infestation levels. Defoliation of the whole plant is seen under severe infestations. Infestation spreads to neighbouring plants and hence the symptoms of the pest are patchy. The plants under shades along the field borders are more vulnerable for the attack by the pest.

Life History

Eggs are laid singly on the under surface of the leaves along the mid ribs and bigger veins. The moth lays as many as 200 eggs. The egg, larval and pupal periods occupy 2-3, 15-18 and 7-8 days, respectively. The larva moults six times before pupation. Pupation takes place mostly on the plants, inside the rolled leaves and sometimes on the shed leaves on the ground. The life cycle is completed in 23-53 days.

Red cotton bug

Description of Insect Stages

Eggs are laid in moist soil or in crevices in the ground. They are spherical and bright yellow in colour. Nymphs are red coloured with black median dorsal spots on the inter-targal membrane of ¾, 4/5 and 5/6 abdominal segments. There is a pair of white dorsal spot on each of the third, fourth and fifth

targal plates on the abdomen. Adults are 12-13 mm in length and have deep red legs and antennae. The membranous portion of the forewings and the eyes are black in colour. There is also a black spot in each forewing. The transverse bands along the posterior margins of each thoracic and abdominal sterna, the collar behind the head and the spots at the base of the head are white in colour.

Nature of Damage and Symptoms

Adults and nymphs suck the sap from leaves, green bolls and seeds of partially opened bolls. Vitality of the plant is lowered, in general. Affected boll open badly with their lint stained with the excreta or body juices. Quality of the lint is affected and the attacked seeds become unfit for either sowing or oil extraction. Boll rot is caused by the secondary infection due to bacteria wherein rotting of the entire contents of the boll occur following the initial discolouration of the lint to yellow or brown. Stained or discoloured lint turns to typical yellow colour. Reddish nymphs are seen in aggregation around developing and open bolls. Adult movement on the soil and over the plants is common sight once they occur in the cotton fields.

Life History

The eggs are laid under the soil in cracks and are covered with loose earth or with small dry leaves. Eggs are round and light yellowish. Each female is capable of laying between 100-130 eggs. Egg period lasts 7-8 days. Nymphs after hatching are wingless with their abdomen red with central row of black spots and row of white spots on either side. Nymphal period lasts for 5-7 days. Nymphs pass through five moults with wings developing from the third instar and attaining full form after the fifth. The development is completed in 50-90 days. Males are smaller than the females and the swollen abdomen can differentiate females from males.

Dusky cotton bug

Description of Insect Stages

Eggs are cigar shaped and whitish immediate to oviposition. They turn pale then to pink before hatching. Early instar nymph is about 2.5 mm long with its rostrum extending the abdomen. They are orange in colour when about to moult. After the first moult the nymphs become reddish brown then become darker after each moult. Adults are 4-5 mm elongated with pointed heads, dusky brown with dirty white transparent wings and black spots on fore wings and having deep red legs.

Nature of Damage

Nymphs and adults suck the sap gregariously from immature seeds which do not ripe, remain light weight. Adults found in the lint get crushed during ginning and stain the lint emitting bad odour.

Symptoms

Being associated with the open bolls, they cause nuisance to workers during cotton picking. Discoloration of the lint with large number of nymphs and adults of brown to black colour are common.

Life History

Egg and nymphal period last for 7 and 26 days, respectively. Nymphs moult 6 times before reaching adult stage. Development is completed in 40-50 days. It appears late in the season of the cotton crop.

Stem Weevil

Description of Insect Stages

Eggs are brown and clothed with flat scales. The grubs are slightly curved creamy white, with a distinct head. Adult weevil is small dark coloured with brown and white markings. The ventral surface of weevil is white.

Nature of Damage and Symptoms

Adult weevil excavates a small hole on the stem and oviposits. The grubs tunnel into the stems and branches. Grubs also damage roots of young seedlings. Swelling of the stem just above the ground resulting in a gall and wilting of seedlings is seen.

Life History

A single female lays eggs in the range of 50-121. The eggs, larval and pupal periods are 6-9, 35-57 and 9-12 days, respectively. Adult lives for about 50 days.

4. Description of diseases and their damage

Blackarm/Angular Leaf Spot /Bacterial Blight

Cotton plant is affected by bacterial blight at all stages of the crop development starting from seedling. The pathogen is seed-borne and the disease is transmitted from the cotyledons to leaves, followed by the main stem and bolls. Symptoms at each stage has been given different descriptive nature which is based on plant organ or the growth stage affected, viz., seedling blight, angular leaf spot, vein blight, blackarm and boll lesions. The earliest signs of disease may be observed on the cotyledons of young seedlings which is known as `cotyledons or seedling blight'. Small dark green `water-soaked' spots, which are circular or irregular in shape become visible on the underside, and then on the upper surface of the cotyledons, usually along the margin. The lesions spread inward and in the susceptible cultivars, the cotyledons become distorted. Under favourable conditions, infection spreads from cotyledon down to petiole and the stem, often resulting in stunting and death of seedlings. Foliar symptoms are known as angular leaf spot (ALS). Initially, the spots are water-soaked and more obvious on the dorsal surface of the leaf. Another common leaf symptom occurs when lesions extend along the sides of the main veins. This may be seen together with or in the absence of ALS and is referred to as `vein blight'. In susceptible cultivars, infection spreads from the leaf lamina down the petiole to the stem. The resulting sooty black lesions give rise to the term` 'black-arm' by which the disease is commonly called. The lesion may completely girdle the stem, causing it to break in high windy conditions or under the weight of developing bolls. In India, where the crop is grown under irrigation, losses of 5-20% are often experienced.

Alternaria Leaf Spot

Alternaria leaf spot incited by *Alternaria macrospora* Zimm. and *A. alternata* (Fr.) Keissler is a common disease in all the cotton growing areas of the country. It appears in a severe form in diploid cotton (*G. herbaceum*) in Karnataka especially in "Arabhavi which is considered as hot bed for this disease. The disease affected Jayadhar variety in its epidemic form caused not only the leaf spot but also twig blight, dry boll rot, and badly affected opening of bolls. The earliest symptom of the disease is the appearance of spots on the cotyledons of seedlings. In favourable conditions the spots can enlarge to 10 mm in diameter. Large numbers of spots coalesce together causing cotyledons to shed. *A. macrospora* is well known to attack the seedlings in Indian conditions. On green leaves, there is pronounced purple

coloured margin all around the spot. On older leaves, the necrotic tissues/spot is often marked by a pattern of concentric structure. In humid weather conditions, the necrotic tissues turn a sooty black colour due to prolific sporulation by the fungus. Severe infection of upper canopy leads to premature defoliation, and is very common among *G. barbadense* and certain cultivars of *G. herbaceum*, widely grown in our country.

Myrothecium Leaf Spot

Myrothecium leaf spot is caused by *Myrothecium roridum*. The fungus (5 patho types) also attacks young and woody stem tissues, causing the development of stem lesions and dieback. Earlier, it was known to occur mainly in `Haryana but during 70s, it was observed in almost all cotton growing tract of India. At times, it appears in severe form causing even the defoliation. The disease first appears on the young plant leaves only (4 to 6 week), but later may cause pre-emergence and post-emergence damping-off of seedlings. The leaf spots are initially circular with tan coloured with violet-brown margins. The diseased spots are often surrounded by translucent areas which are concentrically zoned bearing black pinhead sized sporodochia. In severe cases, the stem may also break. It does affect the bolls and boll lesions damage the lint by making them brittle and discoloured.

Cotton Leaf Curl Virus Disease (CLCuD)

The disease has been reported affecting most of the *G. hirsutum* varieties grown in Punjab, Haryana and Rajasthan. The affected plants remain stunted and their leaves show distinct upward or downward curling. The curling occurs due to the increase in veinal tissues on the abaxial side of leaves. At a later stage, the diseased leaves may develop enations which become prominent with time often originating from the nectaries. The disease is caused by Cotton Leaf Curl Gemini Virus (CLCuD). The virus has two components in their genomes. In nature, the disease is spread by whitefly (*Bemisia tabaci*). The initiation of disease is characterized by small vein thickening (SVT) type symptoms on young upper leaves of plants. Upward/downward leaf curling followed by formation of cup shaped leaf laminar outgrowth of venial tissue on the abaxial side of the leaves are other important symptoms. In severe cases reduction of intermodal length leading to stunting and reduced flowering/fruiting is also noted. The disease generally appears in the end of June about 45-55 days after sowing and spread rapidly in July. The disease progress becomes slow in August and almost comes to a halt by mid September. Cotton leaf curl virus disease (CLCuD) is caused by a single standard circular Gemini virus consisting of DNA-A and two satellites *i. e* DNA-1 and DNA beta and transmitted by white fly (*Bemisia tabaci*).

Grey Mildew

The disease has been reported from almost all cotton growing areas of the world and known as false mildew. However, in India, it is commonly known as grey mildew. The disease appears first on the lower canopy of older leaves when the plant attains maturity, usually after first boll-set. It appears in the form of irregular angular, pale translucent spots 1-10 mm in diameter with a definite or irregular margin formed by the veins of leaves (called 'areolae'). The dorsal surface of the leaves show profuse sporulation (giving the lesions a white mildew-like appearance) causing light green to yellow green coloration on the ventral (upper) leaf surface which in due course becomes necrotic and dark brown in color at this stage, they can be easily mistaken from the angular leaf spot phase of bacterial blight. The severely affected leaves often defoliate and results in premature boll opening with immature lint. Conidial stage is known as *Ramularia areola* (Atk.) [synonyms, *Ramularia gossypii* Speg. Ciferi, *Cercosporella gossypii* Speg.]. It has an ascomycete sexual stage which is known as *Mycosphaerella areola* Ehrlich and Wolf. The fungus develops into three distinct stages during its life cycle. The conidial stage appears on living tissues, mainly on the underside of leaves while they are still attached to plants for a short time after abscission.

The spermogonial stage occurs later on the fallen leaves, and this is followed by ascogenous stage which develops on partially decayed leaves which, in turn, help the pathogen to survive in soil.

Verticillium Wilt

The disease is caused by *Verticillium dahlia*. In India, the disease occurs mainly in Tamil Nadu. Symptoms of the wilt first appear on relatively young plants before the maximum temperature reaches 20 to 24^{0}C and then disappear in summer. They reappear when the temperature declines. The affected plants show yellowing and drooping of young shoots, and ultimately defoliation. Plants affected during the fruiting stage develop characteristically mosaic pattern on the affected leaves, which usually begin at the base of plant and progresses towards the top. Leaf symptoms first appear as yellowing of tissues along the margins and between the major veins. With the advancement in the intensity of infestation, these areas become more intensely yellow, and occasionally red before becoming white and necrotic giving the appearance of tiger stripes. a genus of hyphomycetes.

Leaf Rust

The disease is characterized by redish brown coloured pustules scattered over the whole green surface of leaves. The incidence is more on older leaves than the younger ones. The uredia are formed in small, purplish brown spots which coalesce to turn into large patches. The disease appears in dry season during December-March and is prevalent in Karnataka, Andhra Pradesh and Gujrat states. The disease is caused by *Phakopsora gossypii* (Arth) Hirat F.

Root Rot

The disease occurs in the form of circular patches affecting the plant at seedling stage or after wood formation. A yellow patch appears on the lower part which later blackens leading to drying of seedlings. Affected plants can easily be pulled out of the ground due to the rotting of secondary roots. Tips of roots are mostly discolored, yellow and become sticky. In severe cases black dot like sclerotia may be seen on the wood beneath the bark and between the shredded bands of bark. The most common symptom is dry or wet dark rot of the lower stem. On split opening, the affected plant can be easily distinguished by discolored stele of main root and pith of stem. In severe cases, there is dissolution of stem and root tissues. Many a times, tissue strands have been found full of minute sclerotia. The most characteristic symptom of root rot in North zone is shedding of bark and sudden wilting of plants with leaves remaining attached to plants.

The disease is caused by *R. solani* and *R. bataticola* (pycnidial stage *Macrophomina phaseolina*). The pathogen is characterized morphologically by brown pigmented vegetative hyphae, branching at right angle to the hyphal cell and close to the distal septum. The perfect state is a basidiomycetous, *Thanatephorus cucumeris*.

Fusarium Wilt

Symptoms of this wilt may appear at any stage of crop development, depending on inoculum density, temperature and the host susceptibility. A high inoculum density or in the very beginning of infection, plants may be killed at the seedling stage itself. Usually the first symptoms become apparent in the field between 30-60 days after planting, quite often on the onset of flowering. The pathogen colonizes in plant roots and penetrates into the vascular tissues where it proliferates within the xylem vessels eventually spreading throughout the plant in advanced stage of infection. It grows out of the vascular tissues in the advanced stages of the infection and after the death of host sporulates on crop residues. It has the ability to survive in soil for long by producing sclerotized, thick walled resting bodies (chlamydospores) which can resist desiccation and lysis. Disease can be recognized at seedling stage with symptoms first

appearing on the cotyledons as the darkening of veins, followed by peripheral chlorosis. The cotyledons become progressively more chlorotic and then necrotic before they shed. In older plants the first external evidence of infection is yellowing at the margin of one or more of the lower leaves. As the disease progresses within the plant more leaves develop chlorosis, which characteristically appears in patches between the main veins, the rest of the leaf remaining green. Under the optimal conditions for disease development, all the leaves of affected plants succumb and shed before the stem dries out. The disease affect only diploid cotton in India as only race 4 is known in India. The causal organism is described as *Fusarium oxysporum* Schlecht f. sp. *vasinfectum* Atk., Sny. and Hans. The species *F. oxysporum* is variable, containing a large number of saprophytic and pathogenic forms which have certain morphological features in common. Optimal temperature for spore germination and growth through soil is 25^0C, but maximum sporulation occurs at 30^0C. Spore production and germination are maximum at 100% relative humidity. No germination has been observed below 80% RH. Mycelial growth in soil is maximum at 40% moisture holding capacity and pH 5.6 - 7.2.

5. Description of disorders with unknown etiology

Leaf Reddening

Symptoms

Leaf reddening is initially seen in mature leaves and gradually spreads throughout the canopy. Reddening begin with the leaf margins turn yellow, red colour is developed on the fringes of the leaves or patches or intervascular portions. Later red pigmentation is formed over the whole leaf area. The affected leaves start drying from the edges and ultimately prematurely shed. A change in colour from green to red may also occur without yellowing. Red leaf generally appeared during flowering or early boll filling stage of growth and arrested further development of bolls, which cracked prematurely. As the red leaf affected crops ceased to grow further, reduction in yield occurs.

Causes

- Nitrogen deficiency in leaf (< 2-2.5%). Generally 1.5-2.0% Nitrogen is considered as the critical level. Low Nitrogen (N) level in the leaves could be due to low soil N availability, impaired Nitrogen uptake (water logging/moisture stress), diversion of leaf N to the developing bolls or synchronized boll development- high boll N demand.
- Deficiency of P and K also hastens leaf reddening.
- Low night temperature: when night temperature falls below 150C, it stimulates the formation of anthocyanin pigment in the leaf and the appearance of red colour of the foliage.
- Deficiency of micronutrients particularly Zn.
- Severe leaf hopper infestation.
- High wind velocity leading to desiccation injury. Hot desiccating wind during the fruiting period leads to rapid maturation of the crop. This leads to rapid depletion of N and photo- assimilates from the leaves.
- Moisture stress – Low moisture level in leaf tissue brings in adverse chemical reactions leading to degradation of chlorophyll and formation of anthocyanin pigment in the leaf.
- High water table and soil compaction causing low oxygen in the rhizosphere.

Para-wilt/ New wilt

Symptoms

- Leaves show wilt like drooping, became chlorotic and turned bronze or red followed by drying and premature abscission of leaves and fruiting parts.
- Squares and young bolls are shed and immature bolls are forcefully opened.
- Some of the wilted plants gradually recover and produce new flushes; however their contribution to yield is negligible.
- Plants at grand growth phase *i.e.* squaring, flowering and early boll development are more sensitive to wilt.
- Para-wilt was noticed to be sporadic (random) in distribution.

Causes

- Environmental conditions like high temperature, bright sunlight followed by heavy rainfall were found to favor the occurrence of wilt.
- Plants with large canopy and heavy boll load are more prone to wilting.
- Incidence motivated under ill-drained conditions as compared to well-drained situations in the field.

6. IPM Approach

There are over seventy two (72) definitions of IPM, issued by governments, research organizations, NGOs, and universities (Bajwa and Kogan, 2002). Some assume that IPM will eliminate the use of crop protection products specially the chemical pesticides, which is most unlikely. Extreme views equating IPM with "pest free" farming will become increasingly marginalised and more balanced views will prevail. There is no reason not to support IPM as defined by the FAO International Code of Conduct on the Distribution and Use of Pesticides (Article 2): *Integrated Pest Management (IPM) means a pest management system that in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in a compatible manner as possible and maintains the pest populations at levels below those causing economically unacceptable damage or loss* (FAO, 1967). Thus, IPM is the best combination of cultural, biological and chemical measures that provides the most cost effective, environmentally sound and socially acceptable method of managing diseases, insects, weeds and other pests.

IPM is a knowledge intensive sustainable approach for managing pests by combining compatible cultural, biological, chemical, and physical tools in a way that minimizes economic, health, and environmental risks with the help of pest scouts. IPM relies heavily on knowledge of pests and crop interaction to choose the best combination of locally available pest management tools (Fig.1). Therefore, IPM is not a single product that can be stored on shelves like pesticide, and it does not rely on single method to solve all our pest problems. Pests also co-evolve and adapt very quickly to single control tactics through natural selection, and that multiple methods used simultaneously, or an "integrated" approach, is the most effective for long-term, sustainable management programs.

IPM is neither organic nor it rely solely on biological control to achieve the desired sustainable outcomes. It does often try to assist and augment the effectiveness of natural enemies by limiting the

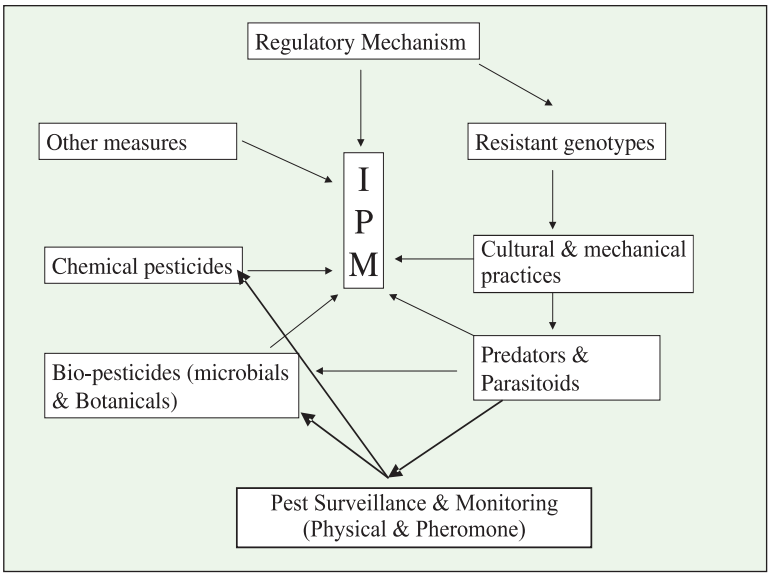


Fig 1. Diagrammatic sketch of IPM system

impact of pesticide on their populations and provide clean and safe niche. It seeks to conserve balance between the crop and the natural environment. The World Bank policy (OP 4.04 - Natural Habitats) also promotes the conservation of natural habitats, and enhancement of the environment for long-term sustainable development. In the IPM concept, use of pesticides involves a trade-off between pest control and the risks of adverse effects on non-target organisms, such as natural enemies, pollinators, wildlife, and plants, contamination of soil and water.

Agro Eco System Analysis (AESA)

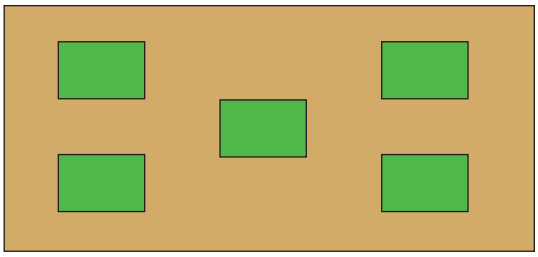
IPM has been evolving over the decades to address the deleterious impacts of synthetic chemical pesticides on environment ultimately affecting the interests of the farmers. In modern IPM (FAO, 2002) emphasis is given to Agro Eco System Analysis (AESA) where farmers take decisions based on larger range of field observations. The health of a plant is determined by its environment which includes physical factors (i.e. sun, rain, wind and soil nutrients) and biological factors (i.e. pests, diseases and weeds). All these factors can play a role in the balance which exists between herbivore insects and their natural enemies. Understanding the intricate interactions in an ecosystem can play a critical role in pest management.

It is an approach, which can be gainfully employed by extension functionaries and farmers to analyse field situations with regard to pests, defenders, soil conditions, plant health, the influence of climatic factors and their interrelationship for growing healthy crop. Such a critical analysis of the field situations will help in taking appropriate decision on management practice. The basic components of AESA are

1. Plant health at different stages.
2. Built-in-compensation abilities of the plants.
3. Pest and defender population dynamics.
4. Soil conditions.
5. Climatic factors.
6. Farmers past experience.

AESA Methodology

Field observations on insect pests and diseases are to be initiated after 20 days of sowing. In each field select five spots randomly as shown in the figure (four in the corner, at least 5 feet inside the border and one in the centre). At each spot select 10 plants randomly/ field for recording observations.



Data recording

- Farmers should record data in a notebook and drawing on a chart
- Keep records of what has happened
- Help us making an analysis and draw conclusions

Data to be recorded

- **Plant growth (weekly)**
  - Plant length
  - Number of dead plant
- **Crop situation (e.g. for AESA)**
  - Plant health: Observe the crop stage and deficiency symptoms etc
  - Pests, diseases, weeds: Count insect pests at different places on the plant, and identify any visible disease symptoms and severity. Observe weeds in the field and their intensity. For rats, count number of plants affected by rats.
  - Natural enemies: Count parasitoids and predators
  - Soil condition
  - Irrigation
  - Weather conditions
- **Input costs**
  - Seeds
  - Fertilizer
  - Pesticides
  - Labour
- **Harvest**
  - Yield (kg/ha.)
  - Price of produce (₹/kg)

Important instructions while taking observations

- While walking in the field, manually collect insects in plastic bags. Use a sweep net to collect additional insects. Collect plant parts with disease symptoms.
- Find a shady place to sit as a group in a small circle for drawing and discussion.
- If needed, kill the insects with some chloroform (if available) on a piece of cotton.
- Each group will first identify the pests, defenders and diseases collected.

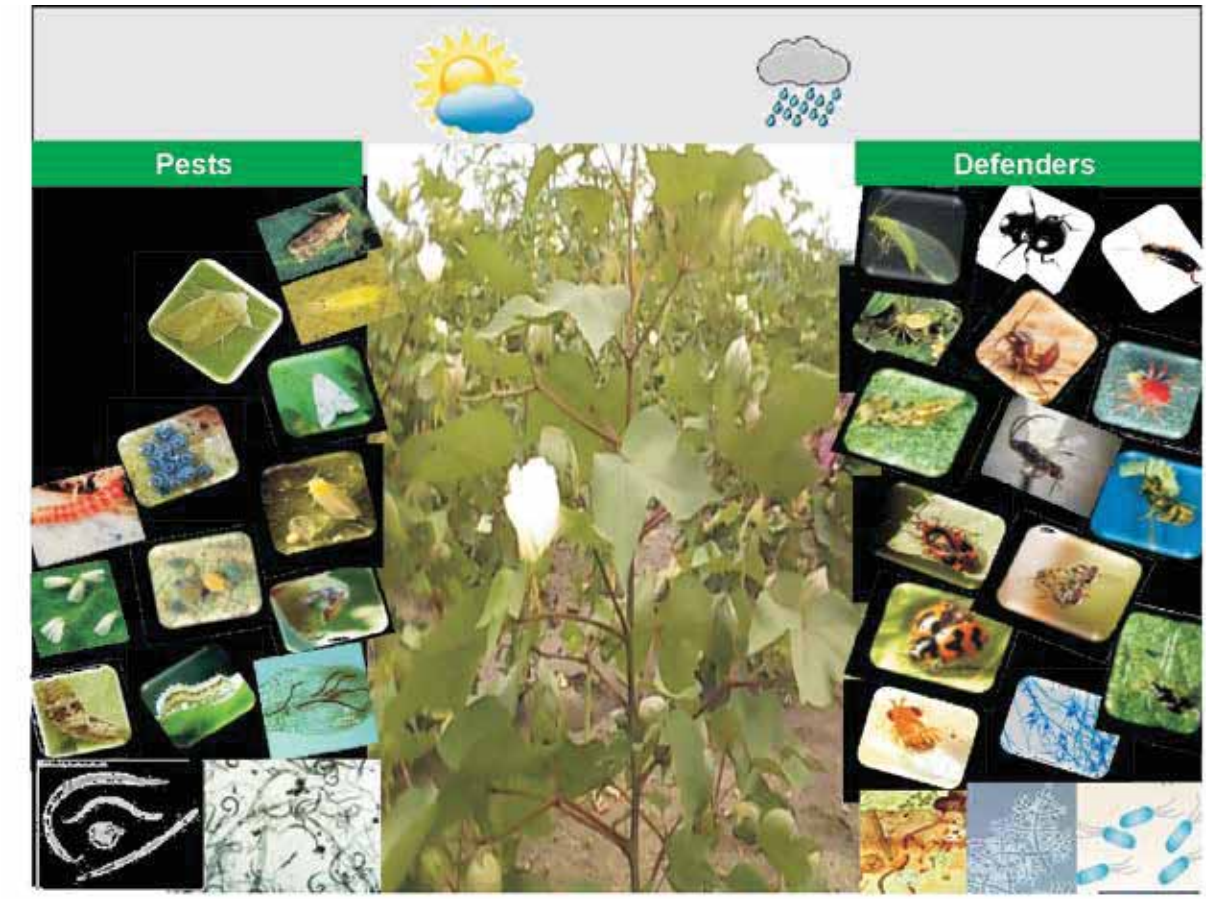
- Each group will then analyze the field situation in detail and present their observations and analysis in a drawing (the AESA drawing as shown in MODEL AESA CHART).
- Each drawing will show a plant representing the field situation. The weather condition, water level, disease symptoms, etc. will be shown in the drawing. Pest insects will be drawn on one side. Defenders (beneficial insects) will be drawn on another side.
- Write the number next to each insect. Indicate the plant part where the pests and defenders were found. Try to show the interaction between pests and defenders.
- Each group will discuss the situation and make a crop management recommendation.
- The small groups then join each other and a member of each group will now present their analysis in front of all participants.
- The facilitator will facilitate the discussion by asking guiding questions and makes sure that all participants (also shy or illiterate persons) are actively involved in this process.
- Formulate a common conclusion. The whole group should support the decision on what field management is required in the AESA plot.
- Make sure that the required activities (based on the decision) will be carried out.
- Keep the drawing for comparison purpose in the following weeks.

Pest: Defender ratio (P: D ratio):

Identifying the number of pests and beneficial insects helps the farmers to make appropriate pest management decisions. Sweep net, visual counts etc. can be adopted to arrive at the numbers of pests and defenders. The P: D ratio can vary depending on the feeding potential of natural enemy as well as the type of pest. The natural enemies of cotton pests can be divided into 3 categories 1. parasitoids; 2. predators; and 3. pathogens.

Model agro-ecosystem analysis chart

Date: ..... Village: ..... Farmer:.....



Courtesy: NIPHM, Hyderabad

Decision taken based on the analysis of field situation:

Soil condition :

Weather condition :

Diseases types and severity :

Weeds types and intensity :

Rodent damage (if any) :

No. of insect pests :

No. of natural enemies :

P: D ratio :

The general rule to be adopted for management decisions relying on the P: D ratio is 2:1. However, some of the parasitoids and predators will be able to control more than 2 pests. Wherever specific P: D ratios are not found, it is safer to adopt the 2: 1, as P: D ratio. Whenever the P: D ratio is found to be favourable, there is no need for adoption of other management strategies. In cases where the P: D ratio is found to be unfavourable, the farmers can be advised to resort to inundative release of parasitoids/ predators depending upon the type of pest. In addition to inundative release of parasitoids and predators, the usage of microbial biopesticides and biochemical biopesticides such as insect growth regulators, botanicals etc. can be relied upon before resorting to synthetic chemical pesticides.

Predators/ Parasitoids feeding potential/ Egg laying capacity

Lady bird beetle	Predatory rate of adult coccinellid on aphids is 50 aphids per day
Green lacewing	Each grub can consume 100 aphids, 329 pupa of whitefly and 288 nymphs of jassids.
Hover fly	1st instar larva can consume 15-19 aphids/day 2nd instar larva can consume 45-52 aphids/day 3rd instar larva can consume 80-90 aphids/day In total life cycle they can consume approx. 400 aphids.
Spider	5 big larvae/day
Predatory mite	Predatory rate of adult is 20-35 phytophagous mites/female/day
Bracon hebetor	Egg laying capacity is 100-200 eggs/female. 1-8 eggs/larva.
Trichogramma sp.	Egg laying capacity is 20-200 eggs/female

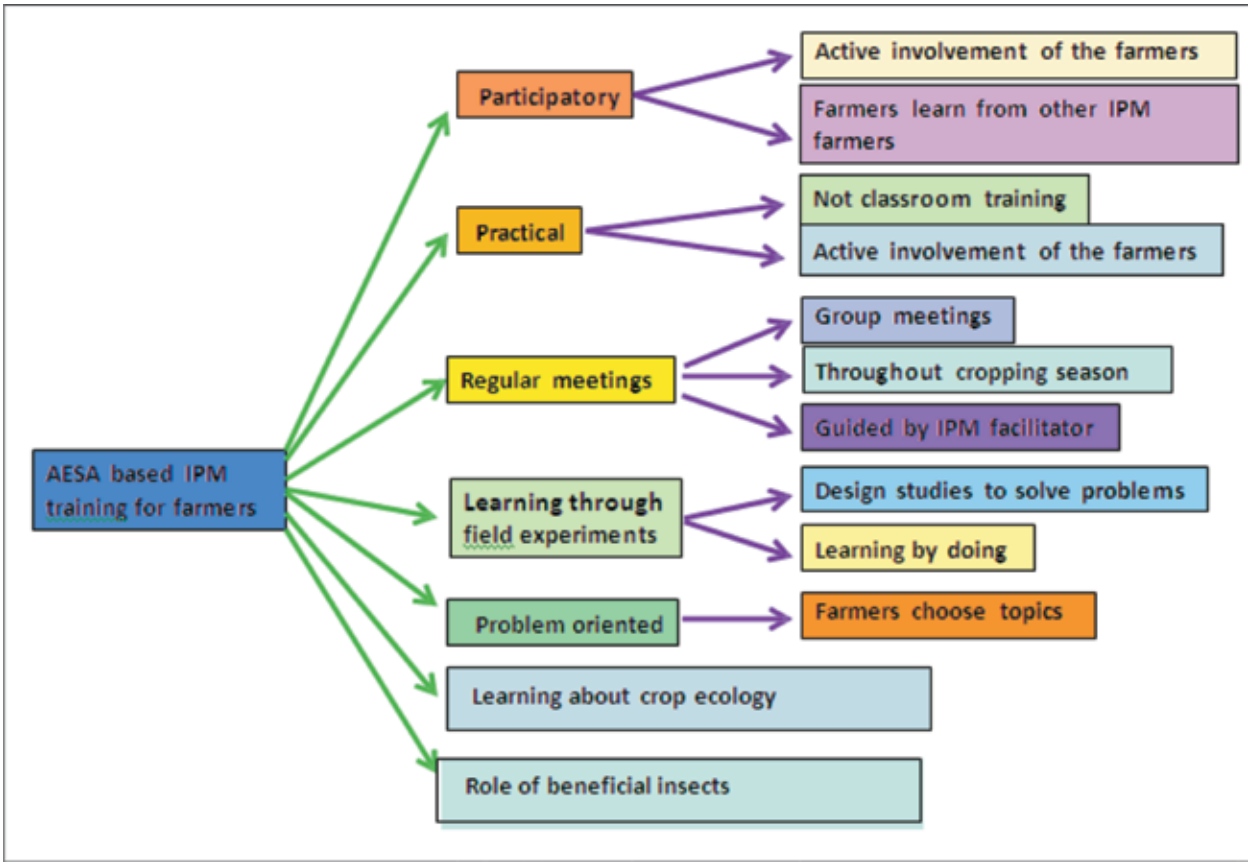
AESA and farmer field school (FFS)

AESA is a season-long training activity that takes place in the farmer field. It is season-long so that it covers all the different developmental stages of the crop and their related management practices. The process is always learner-centered, participatory and relying on an experiential learning approach and therefore it has become an integral part of FFS.

Farmers can be benefited from AESA

- Identification of pests and their nature of damage
- Identification of natural enemies
- Management of pests
- Water and nutrient management
- Influence of weather factors on pest buildup
- Role of natural enemies in pest management

FFS to teach AESA based IPM skills



6.1. Pest Monitoring

6.1.1.Rapid roving survey and field scouting

The objective of pest monitoring through rapid roving surveys is to monitor the initial development of insect pests and diseases in endemic areas. Therefore, in the beginning of' crop season survey routes based upon the endemic areas are required to be identified to undertake roving surveys. Based upon the results of the roving surveys, the State extension functionaries have to concentrate for greater efforts at Block and village levels as well as through farmers to initiate field scouting. Therefore, for field scouting, farmers should be mobilized to observe the pest and disease occurrence at the intervals as stipulated hereunder. The plant protection measures are required to be taken only when pests and diseases cross ETL as per result of field scouting.

Undertake roving survey at every 10 km distance initially at weekly intervals. Observe for the occurrence and severity of insect pests and diseases besides the biocontrol fauna in the selected field on 20 plants/acre selected randomly. The data sheet (Annexure-I) for recording observations on insect pests, diseases and beneficials should be used following the guidelines (Annexure-II).

The State Departments of Agriculture should make all possible efforts by using different media, mode and publicity to inform the farmers for field scouting in the specific crop area shaving pest or disease build up.

6.1.2. Pest Monitoring by use of Pheromones traps/ Yellow Sticky traps

Certain pests require positioning of various kinds of traps like pheromones for Helicoverpa, Spodoptera, Spotted bollworm and Pink bollworm and yellow sticky traps to monitor the pest build up. Therefore, the State Department of Agriculture has to initiate action for installation of different kinds of traps based upon the results of roving surveys at the strategic locations at village level. While the concept needs to be popularized amongst farming community, the State Department of Agriculture is to take greater initiatives for pest monitoring through specific pheromone / yellow sticky trapping / light trap methods as per recommendations of SAUs & SDA.

Pheromone trap	Number	Remark
Pink bollworm	1 trap/ha	North and Central zone
	1 trap/ha	Central zone
	5 traps/ha	South zone
Spodoptera	5 traps/ha	All zones
Helicoverpa	5 traps/ha	All zones
Earias spp.	2 traps/ha	North zone

6.1.3. Economic Threshold Levels (ETL)

Surveillance on pest occurrence at the main field should commence soon after crop establishment after sowing and at weekly intervals thereafter. In each of the fields, select five spots randomly. Select five random plants at each spot for recording counts of insects as per procedure finalized for individual insects.

Aphids, whitefly and mealybugs:

Count and record the number of both nymphs and adults on five randomlyselected leaves per plant.

Thrips:

Count and record the number of nymphs and adults of thrips present on five terminal leaves per plant (tapping method also can be used to count thrips).

Helicoverpa, Spodoptera, Earias,* and *Pectinophora:

Total number of flower buds, squares and boll, damaged due to *Helicoverpa, Spodoptera, Earias,* and *Pectinophora* number of larvae on individual plants should be counted and recorded.

Economic threshold levels in respect of insect pests indicate the "when" of taking up curative measures especially chemical sprays towards management of pests. It is the level at which control measures are to be implemented to prevent the economic damage and hence the loss in yield. Use of ETL requires the regular monitoring of pests at field level during the crop season.

The ETLs for major pests are as under

S. No.	Insect	ETL
1.	Leaf hoppers/ Jassids	More than 2 leaf hopper per leaf and appearance of crinkling and curling of few leaves in the lower portion of plant + marginal yellowing of leaves
2.	Whiteflies	More than 10 whiteflies found in middle region of the plant in >50% (two out of four) of plants. Flight of adults producing a smoky appearance when plants are shaken mildly
3.	Thrips	More than 10 thrips / leaf or silvery patches on underside of leaves above mid canopy in a sample of 10 plants/ acre
4.	Aphids	More than 10 % affected plants counted randomly showing symptoms cupping/ crumpling of few leaves on the upper portion of plant.
5.	Mealybug	More than 40 plants per acre exceeds grade-2 (at least one stem completely colonized by mealybugs)
6.	Spodoptera	More than 1 egg mass or skeletonized leaf / 10 plants or more than 5 solitary larvae/plant
7.	*Helicoverpa* & Spotted bollworm	More than 5 % damaged fruiting bodies or 1 larva per plant or 3 damaged squares / plant taken from 20 plants selected at random for counting.
8.	Pink bollworm	More than 8 moths / trap per nights for 3 consecutive nights or more than 10 % infested flowers or bolls with live larvae.
9.	Nematode	1-2 larvae per gm of soil

Nematode sampling

Collect 100 to 300 cm^3 (200-300 g) soil sample. Mix soil sample and pass through a coarse sieve to remove rocks, roots, etc. Take a 600 cc subsample of soil, pack lightly into a beaker uniformly. Place soil in one of the buckets or pans half filled with water. Mix soil and water by stirring with paddle; allow to stand until water almost stops swirling. Pour all but heavy sediment through 20-mesh sieve into second bucket; discard residue in first bucket; discard material caught on sieve. Stir material in second bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 200-mesh sieve into first bucket; discard residue in second bucket. Backwash material caught on 200-mesh sieve (which includes large nematodes) into 250-ml beaker. Stir material in first bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 325-mesh sieve into second bucket; discard residue in first bucket. Backwash material caught on 325-mesh sieve (which includes small to mid-sized nematodes and silty material) into 250-ml beaker. More than 90% of the live nematodes are recovered in the first 5-8 mm of water drawn from the rubber tubing and the sample is placed in a shallow dish for examination.

Insecticide Resistance Management (IRM) Strategies

Formulating resistance management strategies for Indian conditions has been fairly complicated. The diversity and complexity of cotton farmers, cultivation practices and cropping situations has always posed a challenge. The strategies need to be uncomplicated, simple, robust, available, affordable, compatible with current cropping practices, easy to understand etc. Most IPM proponents would now agree that some of the biological intervention components of cotton IPM have been tricky due to their

inconsistency in performance and importantly their non - availability. Insecticides in most situations have usually been found to be counterproductive due to resistance and resurgence problems. The current strategies hence blend all crop production practices to incorporate proper use of insecticides to ensure that each of these groups are applied at such time of the cropping phase when resistance is low, natural enemy populations are least disturbed and different groups of chemicals are alternated. Some important practices to be adhered for prevention of insecticide resistance are

- 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. The keys to obtain better result from the use of insecticide are:
- Right time - use insecticides - only when the need arises
- Right chemical - choose - appropriate insecticide
- Right dosage - use - only recommended dose
- Right method - use - proper sprayers and spray methods.
- Always target younger stages of *Helicoverpa* as younger stages of resistant larvae are known to get killed at normal recommended doses.
- Rotation of chemical groups helps in preventing the build of resistance against most insecticides, especially carbamates and organophosphates.

7. Integrated Pest Management Strategies

7.1. Cultural practices

- Summer deep ploughing to expose soil inhabiting/resting stages of insects, pathogen and nematode population.
- Application of FYM * @ 5 tonnes/acre (* subject to availability of quality products)
- In view of increasing incidence of mealybug and soil borne diseases, growing cotton after cotton should be avoided. Adopt proper crop rotation.
- Select cotton cultivars suitable and recommended as per state government notification.(Annexure -VII)
- Only sucking pest tolerant Bt cultivars for particular zones should be used.
- Seed treatment with imidacloprid 70%WS@5-7g/kg or thiamethoxam 30% FS 10 g/kg of seeds for early sucking pest management.
- Acid delinting of seed should be done using commercial grade sulphuric acid @100g/kg seed. Acid delinting should be carried out in plastic containers and only 2-3 vigrous shakings are required. Wash the seeds 3-4 times, to remove toxic effect of the acid. Delinted seeds should be treated with 0.5g emisan-6 and 0.25 g streptocycline /kg of seed.
- Seed treatment with thiram 75% WS @ 2.5-3.0 gm/kg seeds for the management of seed born disease.
- Sowing should be done timely within 10 to15 days in a village or block in the season. Sowing in Northern region should be completed by first week of May.
- Adopt proper spacing, irrigation and fertilizer management as per state government recommendations. Avoid application of high nitrogenous fertilizers.

- The crop should be maintained weed free for at least 8-9 weeks after sowing till canopy starts closing in by timely inter-culture. A hoeing in between crop rows is to be given18-20 days after emergence of cotton seedlings to control primary perennial weeds.
- Remove and destroy weeds that serve as alternate hosts *viz. Sida* sp., *Abutilon* sp., *Lagascea mollis* and other malvaceous plants in the cultivated area. The general and zone specific cultural practices towards the management of cotton mealybug *Phenacoccus solenopsis* are given in Annexure (VIII).
- The following inter-cropping system is recommended for Central and South Zone to conserve and help colonize the bioagents fauna such as lady bird beetles, *Chrysoperla* and syrphid flies (Plate 3):
  - Cotton+Pigeonpea (Central Zone)
  - Cotton+Groundnut (South Zone)
  - Cotton+Pulses (Green gram/Blackgram/ Cowpea) (South Zone)
- Use of trap/ border crops like okra (only in Karnataka for shoot weevil), cannabis, castor, marigold, early pigeonpea, jowar and maize crops is recommended. In North Zone cotton should not be grown in and around citrus orchards to avoid spread of CLCuD disease.
- Do not extend the normal crop period and avoid ratooning.
- Allowing grazing of animals after last picking is recommended for checking the carry over population of bollworms.
- Shredding of cotton stalks after harvest and incorporation into soil.
- Staking the cotton stalks near the field should be avoided.

7.2. Mechanical practices

- Hand picking and destruction of various insect stages *viz*., egg masses and gregarious larvae of *Spodoptera litura*, grown up larva of *Helicoverpa armigera*, affected plant parts, rosetted flowers due to pink boll worm and rotted bolls.
- Clipping of terminal shoots on 90-110 days in case of conventional hybrids.
- Growing of *Setaria* as intercrop to serve as live bird perches. Install 8-10 bird perches per ha after 90 days of crop growth for the benefit of predatory birds.
- Grow maize interspersed with cowpea on border to attract predators and parasitoids,

7.3. Biocontrol practices

- Conservation of predators (lacewings, lady bird beetles, staphylinids, predatory wasps, surface bugs like *Geocoris, Anthocorid,* Nabids, Reduviids and Spiders by growing two rows of maize/sorghum or cowpea along the border.
- *Ha*NPV 0.43% AS @ 2700 ml/ha can be applied during the early infestation of *Helicoverpa.*
- Azadirachtin 0.15%, (Neem Seed Kernel Based EC) @ 2.5-5.0 l/ha against whiteflies and bollworms; Azadirachtin 0.3% (3000 ppm) (Neem Seed Kernel Based EC) @ 4.0 l/ha against *Helicoverpa* bollworm infestation; Azadirachtin 0.03% (Neem Oil Based EC) @ 2.5-5.0 l/ha, against *Helicoverpa* bollworm infestation and aphids;. Azadirachtin 0.03% (300ppm) (Neem Oil Based WSP) @ 2.5-5.0 l/ha against aphids, leaf hoppers, whiteflies and bollworms and Azadirachtin 5%w/w (Neem Extract Concentrate) @ 375 ml/ha for whiteflies, leafhoppers and *Helicoverpa* are recommended.
- *Bacillus thuriengiensis* var *galleriae* 1593 M sero type H 59 5b @ 2.0-2.5 kg/ha for *Helicoverpa* bollworm and *Bacillus thuriengiensis* var *kurstaki* H 3a, 3b, 3c. 5% WP @ 0.50-1.00 kg/ha for *Helicoverpa* and spotted bollworm; *Bacillus thuriengiensis* var *kurstaki* strain HD-1, serotype 3a, 3b, 3.5% ES (Potency17600 IU/mg) @ 750-1000 ml/ha for control of bollworms are recommended.

Bacillus thuriengiensis var *kurstaki* serotype H-3a, 3b, strain Z-52 @ 0.75-1.0 kg/ha is recommended for bollworm and *Spodoptera*. [recommended only for non Bt cotton).

- *Beauveria bassiana* 1.15% WP is recommended @ 2kg/ha in 400 lit water for bollworm control.
- *Verticillium lecanii* 1.15%WP is recommended @ 2.5 kg/ha in 500 lit water against white flies.

Description of parasitoids and predators in cotton ecosystem

Egg parasitoids:

1. *Gonatocerus* spp.

Gonatocerus spp. are tiny mymarid wasps measuring 1.8 mm in length. The adults are brown to dark yellow brown with short waists or petioles. The female is parthenogenetic. It can parasitize as many as 15 leafhopper eggs per day. Parasitized eggs are brownish yellow to reddish yellow. Normal eggs are white. Development from egg to adult takes about 11-17 days.

2. *Encarsia formosa*

Encarsia formosa is a species of wasp and a well known parasitoid of greenhouse whitefly. The tiny females (about 0.6 mm long) are black with a yellow abdomen and opalescent wings. They are slightly larger and are completely black in coloration. Ninty-eight percent of *Encarsia* population is female, so all wasps can parasitise whiteflies. Females lay 15 eggs per day for an average of 150 eggs per female.

3. *Bracon hebetor*

Bracon hebetor is a minute Braconidae wasp that is an internal parasite to the caterpillar stage of lepidoptera. The gut enzymes from the *B. hebetor* wasp quickly destroy the blood proteins in the moth larvae; thus it is an effective biocontrol agent. The adult female lives for about 23 days during which it produces about 100 eggs. It deposits 1 to 8 eggs in individual paralyzed late instar moth larvae.

4. *Trichogrammatoidea* sp. nr. *guamensis*

Trichogrammatoidea parasitize the eggs of many different orders of insects and are among the more important biological biological control agents known, attacking many pest insects (esp. Lepidoptera). They are not strong fliers and are generally moved through the air by the prevailing winds.

5. *Campoletis chlorideae*

Adult female lays on an average 13 and 42 eggs after single mating and throughout its life span, respectively. The sex ratio of male: female in mated progeny is 1: 3.15. Adult longevity can be increased by providing honey. Field release of 1-2 day old parasitoids (15,000 adults/ha; sex ratio 1: 3) in field showed encouraging results.

Predators:

1. *Eocanthecona furcellata*

Eocanthecona furcellata is an important Hemipteran predator on several important insect pests. Males and females live for 12.5 to 15.5 days and 21 to 24 days, respectively. The adults in comparison to nymphal instars are excellent predate

2. Assassin bugs (Reduviidae):

Adults have distinct heads with prominent eyes; their abdomens have a slight waist. The head is elongated with a long curved 'snout' (proboscis). The proboscis is curved only in predatory bugs. Colour is variable, but usually includes brown, orange and/or black. The front legs are enlarged to grasp prey and the back legs are long and slender. The nymphs resemble adults but do not have wings.

The eggs are barrel-shaped and laid upright in clusters or rows on the leaves or stems of plants. Eggs hatch within two weeks and the wingless nymphs pass through five growth stages before reaching adulthood. As adults, assassin bugs may live for a further 6-10 months and lay up to 300 eggs in rafts of 30-60 eggs.

A. Parasitoids

Natural enemy	Pest	Stage attacked
Aphelinus sp	Spotted bollworm	Egg
Erythmelus empoascae	Spotted bollworm	Egg
Gonatocerus sp	Spotted bollworm	Egg
Trichogramma achaeae	Pink bollworm	Egg
	Spotted bollworm	Egg
T. brasiliensis	Spotted bollworm	Egg
T. chilonis	Spotted bollworm	Egg
	Helicoverpa bollworm	Egg
T. chilotraeae	Pink bollworm	Egg
	Spotted bollworm	Egg
Telenomus remus	Spotted bollworm	Egg
Trichogrammatoidea sp	Pink bollworm	Egg
near *guamensis*	Spotted bollworm	Egg
Agathis fabiae	Pink bollworm	Larva
	Spotted bollworm	Larva
Apanteles angaleti	Pink bollworm	Larva
Bracon chinensis	Pink bollworm	Larva
Bracon greeni	Pink bollworm	Larva
	Spotted bollworm	Larva
Bracon kirkpatricki	Spotted bollworm	Larva
Bracon brevicornis	Spotted bollworm	Larva
Bracon habator	Spotted bollworm	Larva
Camptolithlipsis gossypiella	Pink bollworm	Larva
Rogas aligarhensis	Pink bollworm	Larva
	Spotted bollworm	Larva
Goniozus sp	Pink bollworm	Larva
Campoletis chloridae	*Helicoverpa* bollworm	Larva
Elasmus johnstoni	Pink bollworm	Larva
Eriborus argenteopilosus	Semilooper	Larva
	Helicoverpa bollworm	Larva
Pyemotes ventricosus (mite)	Pink bollworm	Larva
Chelonus sp	Bollworms	Egg-Larva
C. blackburni	Pink bollworm	Egg-Larva

Microchelonus versatilis	*Helicoverpa* bollworm	Egg-Larva
Xanthopimpla punctata	Cotton leaf roller	Pupa
Brachymeria sp.n. euploeae	Cotton leaf roller	Pupa
B. apanteles	Spotted bollworm	Pupa
B. nephantidis	Spotted bollworm	Pupa
Encarsia formosa	Whitefly	Nymph
Encarsia shafeei	Whitefly	Nymph
Eretmocerus mundus	Whitefly	Nymph
Aphilinus sp.	Aphids	Nymph, adult

B. Predators

Chrysoperla carnea	Sucking pests & bollworms	Egg, nymph, adult
Brumus saturalis	Sucking pests & bollworm	Egg, nymph
Coccinella septumpunctata	Sucking pests & bollworm	Egg, nymph
Menochilus sexmaculatus	Sucking pests & Bollworm	Egg, nymph
Geocoris ochropterous	Pink bollworm	Egg
	Jassid	Nymph
Geocoris sp	Sucking pests	Nymph, Adult
Zelus sp	Sucking pests	Nymph, Adult
Spiders	Sucking pests & bollworms	Nymph/Larva, Adult
Eocanthecona furcellata	bollworms	Larva
Encarsia sp	Whitefly	Nymph, Adults
Syrphus confracter	Aphids	Nymph, Adults
S. baleatus	Aphids	Nymph, Adults
S. searius	Aphids	Nymph, Adults
Chrysoperla carnea	Aphids, jassids, instars of bollworms	eggs & early
Cheilomenes sexmaculata	Aphids	Adults
Ectomocoris tibialis	*Dysdercus cingulatus*	Nymph, Adult
Rhynocoris fuscipes	*Spodoptera litura*	Larva
	Achea janata	Larva
	Dysdercus cingulatus	Nymph, Adult
	Mylabris indica	Nymph, Adult
R. kumarii	*Helicoverpa armigera*	Larva
	Anomis flava	Larva
R. longifrons	*Spodoptera litura*	Larva
	Helicoverpa armigera	Larva
	Dysdercus cingulatus	Nymph, Adult

C. Pathogens

Aspergillus sp.	Whitefly	Nymph
Nomuraea rileyi	Semi looper & *Helicoverpa* bollworm	Larva

Bacillus thuringiensis	Bollworms	Larva
Beauveria bassiana	Bollworms	Larva
NPV	*Helicoverpa* & *Spodoptera*	Larva
Nematodes	Bollworms	Larva

Some of the good insectory plants

		
Cosmos	Sunflower	Okra
		
Hibiscus	Marigold	Fennel
		
Carrot	Coriander	*Chrysanthemum*
		
Mustard	Radish	*Fagopyrum* sp.
		
Ageratum sp.	Tridax	Alfalfa

Flowering plants that attract natural enemies/repel pests

	Insect	Natural enemies	Flowering plants that attract natural enemies/repel pests
1	Shoot and fruit borer	**Parasitoids:** *Trichogramma achaeae* (egg), *T. chilonis* (egg), *Trichogrammatoidea* sp. *nr. guamensis* (egg), *Telenomus remus* (egg), *Aphelinus* sp, *Erythmelus empoascae* (egg), *Gonatocerus* (egg), *Chelonus heliopae* (egg-larval), *C. rufus* (egg-larval), *Strobliomyianana* (larval), *Actia aegyptia* (larval), *Centrochalcis* sp. (larval), *Phanerotoma hendecasisella* (larval), *Bracon greeni* (larval), *B. brevicornis* (larval), *Rogas aligarhensis* (larval), *R. testaceus* (larval), *R. kampurensis* (larval) *Elasmus johnstoni* (larval), *Brachymeria tachardiae* (pupal), *B. responsator* (pupal), *B. nephantidis* (pupal), *Goryphus nursei* (pupal) *etc.* **Predators:** *Chrysoperla carnea,* coccinellids, King crow, common mynah, wasp, dragonfly, spider, robber fly, reduviid bug, praying mantis, fire ants, earwigs, ground beetle, big-eyed bugs (Geocoris sp), pentatomid bug (Eocanthecona furcellata), earwigs, ground beetles, rove beetles etc.	• Attractant plants: Carrot family, Compositae family, buckwheat (lacewings)
2	*Helicoverpa* bollworm	**Parasitoids:** *Trichogramma chilonis* (egg), *Tetrastichus* spp. (egg), *Telenomus* spp. (egg), *Chelonus blackburni* (egg-larval), *Carcelia* spp. (larval-pupal), *Campoletis chlorideae* (larval), *Goniophthalmus halli* (larval), *Bracon* spp. (larval) etc. **Predators:** *Chrysoperla carnea,* coccinellids, King crow, common mynah, wasp, dragonfly, spider, robber fly, reduviid bug, praying mantis, fire ants, big eyed bugs (*Geocoris* sp), pentatomid bug (*Eocanthecona furcellata*), earwigs, ground beetles, rove beetles etc.	• Repellant plants: Ocimum/ Basil • Attractant plants: Carrot family, sunflower family, buckwheat, alfalfa, corn, shrubs (minute pirate bug and lacewing) • Nectar rich plants with small flowers i.e. anise, caraway, dill, parsley, mustard, sunflower, buckwheat and cowpea (wasp)
3	Tobacco caterpillar	**Parasitoids:** *Trichogramma chilonis* (egg), *Tetrastichus* spp. (egg),*Telenomus* spp. (egg), *Chelonus blackburni* (egg-larval), *Carcelia* spp. (larval-pupal), *Campoletis chlorideae* (larval), *Eriborus argentiopilosus* (larval), *Microplitis* sp (larval) etc. **Predators:** *Chrysoperla carnea*, coccinellids, King crow, common mynah, wasp, dragonfly, spider, robber fly, reduviid bug, praying mantis, fire ants, big eyed bugs (*Geocoris* sp), pentatomid bug (*Eocanthecona furcellata*), earwigs, ground beetles, rove beetles etc.	• Repellant plants: Ocimum/ Basil • Attractant plants: Carrot family, sunflower family, buckwheat, alfalfa, corn, shrubs (minute pirate bug and lacewing) • Nectar rich plants with small flowers *i.e* anise, caraway, dill, parsley, mustard, sunflower, buckwheat and cowpea (wasp)

	Insect	Natural enemies	Flowering plants that attract natural enemies/repel pests
4	Pink bollworm	**Parasitoids:** *Trichogramma brasiliensis* (egg), *Chelonus sp* (egg-larval), *Campoletis chlorideae* (laval), *Bracon lefroyi* (larval), *B. kirkpatricki*, *Apanteles angaleti* **Predators:** *Chrysoperla carnea*, coccinellids, King crow, common mynah, wasp, dragonfly, spider, robber fly, reduviid bug, praying mantis, fire ants, big eyed bugs (*Geocoris* sp), pentatomid bug (*Eocanthecona furcellata*), earwigs, ground beetles, rove beetles, predatory mites (*Pyemotes ventricosus*, *P. herfsi*) etc.	• Attractant plants: Carrot family, sunflower family, buckwheat, alfalfa, corn, shrubs (minute pirate bug and lacewing) • Nectar rich plants with small flowers *i.e* anise, caraway, dill, parsley, mustard, sunflower, buckwheat and cowpea (wasp)
5	Leafhoppers	**Parasitoids:** *Lymaenon empoascae* (egg), *Anagrus flaveolus*, *Stethynium triclavatum* **Predators:** Lady beetle, ants *Distina albino*, *Chrysoperla* sp., mirid bug (*Dicyphus hesperus*), big-eyed bug, (*Geocoris* sp) etc.	• Sunflower family, alfalfa (damsel bug & minute pirate bug) • Carrot family, buckwheat, alfalfa, corn, shrubs (minute pirate bug)
6	Thrips	Predatory mite (*Amblyseius swirskii*), predatory thrips (*Aeolothrips* sp.), insidious flower bugs (*Orius insidiosus*) etc.	• Attractant plant: French bean (predatory thrips)
7	Mealybugs	**Parasitoids:** *Aenasius bambawalei, Promuscidea unfasciativentris* etc. **Predators:** Predatory wasps, syrphid/hover flies, ladybugs or mealybug destroyers (coccinellid, *Cryptolaemus montrouzieri*) etc.	• Attractant plants: Bachelor's buttons or cornflower (*Centaurea cyanus*) and coriander attract wasps.
8	Whitefly	**Parasitoids:** *Encarsia* sp, *Eretmocerus* sp. **Predators:** *Dicyphus hesperus,* (mirid bug), dragonfly, spider, robber fly, praying mantis, fire ants, coccinellids, lace wings, big eyed bugs (*Geocoris* sp) etc.	• Repellant plants: Peppermint • Attractant plant: French bean (predatory thrips)
9	Root knot nematode	Use of biocontrol agents like *Paecilomyces lilacinus* (egg parasite)	• Repellant plants: Marigold • Crop rotation : Marigold,*Chrysanthemum* sp., *Sesbania* sp., *Crotalaria* sp., *Gaillardia* sp, castor bean and *Desmodium* sp., (parasitic nematodes) • Border crops: Strips of Rye, grains, cover crops and mulch beds (rove beetle)

7.4. Chemical control

- Need based, judicious and safe application of pesticides are necessary for chemical control measures under IPM. It involves monitoring of pests so as to check with ETL and decide on the use of chemical pesticides. It is necessary to rely upon pesticides recommended as per the list in Annexure-IX.
- Following suggestions are important bearings for the success of control measures in the context of IPM strategy:
  - Avoid tank mixing of two or more insecticides.
  - Repeated application of same insecticide in succession should be avoided.
  - Avoid using insecticides such as pyrethroids which result in resurgence of sucking pests.
  - Promote use of neem based formulations including crude and oil.
  - Pyrethroids if used should be restricted to once or maximum of twice depending on the incidence of pink bollworms.

Proper spray equipments should be used:

- Knapsack sprayer in the early stage of crop growth. Tractor mounted sprayers are recommended in the North Zone during early vegetative and fruiting phases of crop
- Power sprayer to be used during the later stages of crop growth
- Use proper spray volume as per crop stage canopy is a must

8. Disease management

Black arm/Angular leaf spot /Bacterial blight management

- Avoid dense cropping.
- Soak seeds in 40-50 ppm streptomycin solution before sowing.
- Seed treatment with Carboxin 37.5% + Thiram 37.5% DS @ 3.5 g/kg of seeds for bacterial bight management.
- On the first appearance of field symptoms, the crop should be sprayed with a mixture of streptocyclin (Streptomycin Sulphate 90% + Tetracyclin Hydrocloride 10% SP). This should be repeated at 10-15 days intervals to check the secondary spread.

Leaf Spot Management

- Avoid dense cropping that helps in reducing the disease incidence.
- Crop residues should be removed and while preparing the fields, care must be taken to deeply ploughing in order to bury and destroy the remaining part of plant tissues.
- Weeds which serve as the alternate host should be completely removed and destroyed by burning.
- Use acid-delinted seeds to avoid seed borne inoculum.
- Early sowing (in North India) reduces the disease incidence.
- Wider spacing reduces the build-up of humidity thus curtailing the disease intensity.
- On the first appearance of the disease in field, carbendazim 50% WP @ 250g/ha in 750 lit of water must be sprayed to check and control the disease.

Root rot Management

- Fields having long history of disease should be avoided for sowing.
- Field should be deeply ploughed and left for solarization.
- After harvesting, either plant debris should be completely burried or be removed.
- Early sowing and harvesting is recommended to avoid extreme temperatures. Sowing in April or June instead of May reduces disease incidence.
- Crop should be rotated. Intercropping using *Vigna acontifolia* reduces the incidence quite significantly.
- Seed treatment with Carboxin 37.5% + Thiram 37.5% DS @ 3.5 g/kg of seeds effectively reduces the root rot incidence.
- Green manuring with *Sesbania acubeata* + planting during second week of July, and application of ammonium sulphate and intercropping with moth (*Vigna aconitifolia*) considerably reduces the disease incidence.

Fusarium Wilt Management

- Fields having long history of disease should be avoided.
- For wilt management, crop rotation with *G.hirsutum* or non host crops is also effective in maangement of the pathogen.
- Fields should be deeply ploughed and left for solarization.
- Use of nitrogenous fertilizers, particularly ammonium nitrate should be discouraged and calcium ammonium nitrate should be used in place of urea or ammonium sulphate. Use of potassium fertilizers should also be encouraged.
- Resistant varieties e.g., *G. herbaceum* (Jayadhar, Vijalpa, Digvijay & Sujaya with hybrids; G Cot DH7 & G Cot DH9) should be cultivated. *G. arboreum* (Girnar, Daulat, G-22, G-46, Y-1 & Sanjay).

Verticillium Wilt management

- Fields with long history of disease occurrence should be avoided and should have good drainage system. Crop should not be over-irrigated
- Seed should be acid-delinted

Cotton Leaf Curl Virus (CLCuD) Management:

- Cultivation of susceptible varieties in the established endemic areas should be discouraged
- Sowing of resistant varieties /hybrids released in North India *i. e* H-1117, H-1226, H-1236, F-1861, LH-2076, RS-875, RS-810, RS-2013, LHH-144, CSHH-198, CSHH-238 and CSHH-243 should be encouraged
- Quarantine measures must be implemented to restrict the movement of diseased plants and its parts
- Removal of weed hosts during the growing season and off season, which are alternate hosts to CLCuD *i.e Sida* sp, *Abutilon* sp, *Ageratum* sp, *Convolvulus arvensis*, *Capsicum* sp, *Parthenium* sp, *Solanum nigrum*, *Digeria arvensis*, *Lantana camara*, *Achryranthus aspera*, *Chenopodium album* and *Xanthium strumarium*
- Avoid growing of American cotton in and around citrus orchards
- Growing of okra (Bhindi) crop in and around the cotton fields should be discouraged, and intercropping with wild brinjal (*Solanum khasianum*) could be followed
- Destroy volunteer/ratoon cotton plants during the off season
- Excessive use of nitrogenous fertilizers should be avoided.
- Use yellow sticky traps for mass trapping of whiteflies

- Crop sown during the period of May first fortnight escapes the attack of CLCuD over the late sown crop
- The following insecticides may alternatively be used: neem formulations *i.e* Azadirachtin 0.03% (300 ppm) (Neem Oil Based WSP) or Azadirachtin 0.15% W/W (Neem Seed Kernel Based EC) @ 2.5-5.0 l/ha, or Triazophos 40% EC @1.5 l/ha or Ethion 50% EC@ 2.0 l/ha
- Avoid use of synthetic pyrethroids when whitefly population exists
- While spraying, ensure thorough coverage of the lower surface of cotton leaves for effective control of whitefly
- Encourage sowing of Desi cotton (*Gossypium arboreum*) in CLCuD hot spot areas

Grey mildew management

- Crop residues should be removed and the fields must be deeply ploughed in order to bury and destroy the remaining plant tissues
- Crop cultivation should be rotated with cereals, and preference should be given to tolerant varieties such as Sujata, Suvin, ERB 4492 and SB 289 E (*barbadense*), Laxmi and Sangam (*hirsutum*) and Varalaxmi (intraspecific) in disease endemic areas

9. Management of Physiological Disorders

Leaf reddening management

- The following remedial measures are suggested to mitigate the problem of leaf reddening. However, it should be noted that leaf reddening is not a problem of common occurrence and is very much restricted to certain areas and that too during prevalence of certain specific ambient environmental conditions, in addition to the varietals intricacies
- Timely correction of N status either by optimum supply in the soil or through foliar application (DAP 2 % or Urea 1-2 %) during boll development stage
- Preventing water logging, since this result is non-availability of magnesium and other nutrients
- Providing protective irrigation to avoid stress and maintain RWC of the leaf above 55-60%.
- Soil application of magnesium sulphate (MgSO4) @ 20-25 kg/ha to the soil or foliar spray with 0.5-1.0 % MgSO4 and 1.0 % urea as soon as the reddening symptoms appear in leaf reduces this disorder
- Leaf hopper management with recommended pesticides
- Foliar application of urea (1-2 %) with 15-20 ppm chlormequat chloride and 0.10 % citric acid, 2-3 times at weekly intervals
- Spray ascorbic acid (500 ppm) + 10 ppm PMA (AA increases leaf respiration and leaf N).
- Soil moisture conservation and water harvesting/recycling to minimize soil moisture stress during boll formation

Parawilt management

- Provide adequate drainage to avoid water-logging in the fields to maintain adequate oxygen content of the soil.
- Irrigation if available may be provided during grand growth phase to avoid prolonged exposure of plants to dry condition.

- Cobalt chloride spray at 10 ppm within 24-48 hours of symptom appearance

10. Weed Management

Preventive Measures

- Summer deep plouging during May/June to expose and destroy the underground vegetative parts of the deep rooted perennial weeds. The field should be kept exposed to sun at least for 2-3 weeks
- Follow recommended agronomic practices for land preparation, stubble management, seed rate, sowing time, fertilizer and irrigation management etc. so as to have a desirable crop stand
- Field should be maintained weed free initially for 8-9 weeks after sowing of crop by resorting timely inter-culture and hand weeding
- Use of tractor drawn harrows for interculture, and removal of weeds are more common in northern zone, while bullock drawn blade harrows are common in central and southern states for weed control
- Inter cropping of short duration legume for green manure as much in between wide spaced cotton crop can reduce the weed intensity
- Smothering of weeds by polyethylene mulch of 30 micron thickness reduces weed growth.
- Use power or hand operated implements for maintaining crop weed free for initial 8-9 weeks DAS (days after sowing)

Curative Measures

- Application of fluchloralin 45% EC @ 2.0-2.68 l/ha or pendimethalin 30% EC @ 2.5-4.165 l/ ha as pre-planting application
- Pre-emergence application of alachlor 50% EC @ 4-5 l/ha or alachlor 10% GR @ 20-25 kg/ha or diuron 80% WP @ 1-2.2 Kg/ha controls both mono and dicot weeds effectively.
- At post-emergence stage (15 to 30 DAS) paraquat dichloride 24% SL @ 1.25-2.0 l/ha may be applied as direct spray and give good control of weeds in later stages
- Pyrithiobac sodium 10% EC @ 625-750 ml/ha or quizalofop-ethyl 5% EC @ 1000 ml/ha or glufosinate ammonium 13.5% SL (15% w/v) @ 2.5-3.0 l/ha or fenoxaprop-p-ethyl 9.3% w/w EC (9% w/v) @ 750ml/ha (20 -25 DAS) can also be opted

11. Nematode Management

- Bikaneri Narma and Sharada have been reported as resistant varieties to root knot nematode
- Field sanitation- keep field weed free
- Summer ploughing and/or soil solarization with polythene cover
- Crop rotation - growing crops such as marigold, zinnia, sugarcane, maize, mustard, wheat, barley, jowar, safflower, custard apple and karela in rotation with cotton
- Trap crop- grow *Crotalaria spectabilis* as trap crop for root knot nematode and uproot and plough in after 30-45 days of sowing

12. Rodents in Cotton

- Lesser bandicoot: *Bandicota bengalensis* (Gray) (throughout India)
- Indian Gerbil: *Tatera indica* (Hardwicke) (throughout India)
- Soft furred field rat: *Millardia meltada* Gray (throughout India)

Damage

After sowing, seeds may damaged/eat by rodents due to high oil substances present in the seeds which attracts rodents. Rodent infestation will be observed during Boll formation and Maturity stage is highly due to the sweet oily seeds found inside the boll and also rodent pick up the cotton inside the burrow to make the bed.

Management Practices

- Plough the fields to demolish the rodent habitat and maintain weed free fields to reduce alternate source of food and habitat.
- Practice burrow smoking using natural smoking materials in ANGRAU/ NIPHM burrow fumigator for 2-3 min. for each burrow.
- Application of 0.005% bromadiolone in ready to use form (wax blocks) or loose bait in packets near rodent burrow. Apply 2% Zinc phosphide poison baits when the rodent infestation is very high. Practice pre-baiting incase of ZNP poison baiting. Don't apply ZNP poisons more than one time in a crop season.

13. Stage wise IPM Practices for management of cotton pests

S. No.	Crop stage/pest	Stage-wise IPM Practices
1	**Pre-sowing**	Deep ploughing in summer for removal of weeds as well as towards destruction of insect stages Clean up of the fields free of weeds and alternate host plants including vegetable crops Adopt crop rotation with cereals (sorghum) or pulses (soybean) or green manure crops (sun hemp or dhaincha) at least once in two to three years
2	**At sowing**	
	Soil & seed borne diseases	Select tolerant/resistant cultivars (Annexure VII) Acid delinting treatment for seeds. (Heading-G.1.Cultural practices) Seed treatment with Thiram 75% WS @ 2.5-3.0 gm/kg seeds. Seed borne infection can be eliminated by soaking the seeds in 40 to 50 ppm solution of Streptomycin Sulphate 90% + Tetracycline Hydrochloride 10% SP for a period of two hours
	Sucking pests	Timely sowing of sucking pest tolerant genotypes- Immediate to receipt of monsoon keeping the fields ready for sowing after the receipt of first rains, and taking up dry sowing Growing refugia (for Bt cotton). Two border rows of non-Bt along with Bt cultivars Seed treatment with insecticide Imidacloprid 48% FS or Imidacloprid 70% WS @ 500 – 1000g per 100kg seeds
	Weeds	Use pre-emergence/post emergence herbicides (Annexure XI)
3	***Vegetative growth stage (20-50 days)**	
	Weeds	Inter culture and hand weeding
	Sucking pests	Monitoring pest and natural enemy population on attractant/ trap & inter crops Inoculative release of *Chrysoperla* grubs @ 10,000/ha**. Spray of neem based insecticides as initial sprays (Azadirachtin 0.03% (300 ppm) Neem Oil Based WSP @ 2.5-0.5 l/ha) Spray recommended insecticides (Annexure IX) when pest crosses ETL (F.1.3.ETL)
	Whitefly	Fix yellow sticky traps for monitoring population
	Spotted & spiny bollworm	Crushing of larvae in the shoots mechanically
	Bollworms	Set up pheromone traps @ 5 traps/ha for monitoring
	Stem weevil	Soil application of carbofuran 3%CG @ 33300 g/ha
	Root rot & wilt	Remove & destroy root rot/wilt affected plants.
4	**Early fruiting stage (50-80 days)**	
	Weeds	Inter culturing & hand weeding
	Sucking pests	Release *Chrysoperla* @ 10,000 /ha*
	Whitefly	Use yellow sticky traps for monitoring population Spray recommended insecticides (Annexure IX)
	Bollworms	Use pheromone traps and change lures Management of population in trap crops, release of *Trichogramma* @80,000/ha. Set up bird perches

S. No.	Crop stage/pest	Stage-wise IPM Practices
	CLCuD Disease	Destroy affected plants (for Northern India)
	Parawilt	Foliar application of 10ppm cobalt chloride on infected plants
5	**Peak flowering & fruiting stage (80-120 days)**	
	Whitefly	Use yellow sticky trap for monitoring population
		Spray recommended insecticides (Annexure IX)
	Bollworms	Use pheromone traps @ 5 traps/ha
		Physical collection & destruction of grown up larvae
		Use of *Ha*NPV 0.43% AS @ 2700 ml/ha
		Removal of terminals (topping) to be done at times of high oviposition by *Helicoverpa*
		IRM strategies should be followed (Heading-F.1.4. IRM Strategies)
	Spodoptera	Use pheromone traps@ 5 traps/ha
		Sowing castor seeds at field borders serves as an indicator cum trap crop
		Hand collection & destruction of egg masses & early instar gregarious larvae
		Spray recommended insecticides (Annexure IX)
	Black arm disease	Spray recommended chemicals (Streptomycin Sulphate 90% + Tetracyline Hydrocloride 10% SP). Streptocycline 25-40 ppm to be sprayed thrice - Before flowering, after flowering and twenty days after second spray
	Leaf reddening	Foliar application of urea (1-2 %) with 15-20 ppm chlormequat chloride and 0.10 % citric acid, 2-3 times at weekly intervals.
	Parawilt	Foliar application of 10 ppm cobalt chloride on infected plants
6	**Boll opening stage (120-150 days)**	
	Whitefly	Use yellow sticky trap for monitoring population
	Bollworm complex	Need-based application of recommended insecticides
		Do not extend the crop period Use pheromone traps for monitoring of *Helicoverpa, Spodoptera* and pink bollworm
		Spray recommended insecticides keeping IRM strategies in focus (F.1.4. IRM Strategies)
7	**After last picking of cotton**	
	Bollworms and mealybugs	Allow grazing by animals (cow, buffalo, sheep, goat, etc.) immediate to final picking
		Avoid staking of the cotton stalks near the fields. Pulled out stalks should be burnt off *in situ* before ploughing the field.
		Shredding and incorporation of crop residues.

** In case of conventional genotypes, it is recommended to use higher seed rate in hot spot areas and uproot the CLCuD affected plants keeping the plant population in consideration.*

***: depending on timely availability of quality products*

14. Safety parameters

Safety parameters deal with the selection and use of insecticides based on classification of toxicity as per Insecticides Rules, 1971, WHO classification of hazards, colour of toxicity triangle besides symptoms of poisoning, first aid measures and treatment of poisoning that the extension functionaries of the State Department of Agriculture have to be acquainted with.

- Basic precautions which are required to be taken as per classification of toxicity as well as hazard criteria by WHO given against the recommended insecticides for use on cotton (Annexure-IX).
- The extension functionaries are to educate the farmers on safe use of pesticides with the help of colour toxicity triangle as the farming community can follow the colour and corresponding safety precautions.
- The symptom of poisoning must be known to the extension functionaries to enable them to extend first aid measures to affected persons to the extent possible.
- Basically, the information on first aid measures and treatment of poisoning is required to be passed on by the extension functionaries to the doctors at Primary Health Centers as well as to the Private Doctors in the vicinity of spraying of pesticides.
- Extension functionaries must ensure that names of common pesticides during plant protection measures along with a copy of the leaflet which is an integral part of a pesticide container must be made available to the doctors in the vicinity of plant protection operations.
- Extension functionaries are to request the doctors to intervene procurement of antidotes for different pesticides as cited under “Treatment of poisoning".

Data sheet for cotton pest monitoring: Insect pests

Location/Village name : _____ Date of Observation : _____

Plant no.	Aphid injury grade*	Leaf hopper injury grade*	Mealy-bug injury grade*	Number / 3 leaves			Number / plant											
				Leaf hopper	White-flies	Thrips	Mirid bug	ABW		SBW Larva	PBW		*Spodoptera*@		Squares		Green bolls	
								Egg	Larva		Rosette flowers#	Larva	Egg & greg. larvae	Solitary larvae	Total	Dam-aged	Total	Dam-aged
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
16																		
17																		
18																		
19																		
20																		
Average																		
% incidence																		

**To follow the grading scale given in Annexure III, IV and V for aphids, leaf hoppers and mealybugs, respectively; # Number of rosette flowers / plant; @: Egg masses or bunch of larvae/ plant;*

Data sheet for cotton pest monitoring: Beneficials & Diseases

Location/Village name : _____ Date of Observation : _____

Plant no.	Beneficials (No./plant)			Bacterial blight (grade 1-4)#	Fungal leaf spots (grade 1-4)$		CLCuD (Grade 1-6)^	Grey mildew (grade 1-4)*	Disorders (mark 1 for presence and 0 for absence)		Remark**
	Coccinellids (grubs/adults)	**Chrysoperla** (eggs/grubs)	**Spiders** (spiderlings /adults)		*Alternaria*	*Myrothecium*			**Para wilt**	**Red leaf**	
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
Average											
% incidence											

Severity grade for # Bacterial blight :0-nil; 1-spots few, scattered, veins free; 2-spots several , larger, reddish brown; 3-lesions large brown or black; 4-lesions larger, water soaked first later turning to brown or black, coalescing, more than 20% leaf area covered; $ Fungal leaf spots:0-nil, 1- few small brown spots , scattered; 2- bigger brown spots, coalescing,; 3-irregular bigger size spots tending to coalesce; 4- spots coalesce to form bigger lesions 40% leaf area covered; ^ CLCuD: 0 – nil; 1– Top few leaves showing few small vein thickening symptoms; 2-Thickening of small group of veins; 3–Thickening of all veins, minor leaf curling, leafy enations, deformity of internodes with minor reduction in leaf size; 4– Severe vein thickening, minor reduction in leaf size and boll setting; 5- severe deformity of internode with moderate reduction in leaf size and boll setting followed by moderate stunting; 6- Severe stunting of plant with no or few boll setting; * Grey mildew: 0- nil; 1- small spots; 2-spots bigger & covered 6-20% leaf area; 3-some spots coalescing & 21-40% leaf area covered; 4- many spots coalescing & more than 40% leaf area covered, many leaves fall off; ** Mention the field operations if any carried out in detail and other pests if any observed as severe or any other significant findings.

Pheromone trap catches (number of adults / trap / week)

Location/Village name : _____ Date of Observation : _____

Trap no.	ABW *(H. armigera)*	SBW *(Earias)*	PBW *(P. gossypiella)*	*Spodoptera*
1				
2				
3				
4				
5				

Annexure -II

GUIDELINES FOR RECORDING INSECT PESTS AND DISEASES OF COTTON

(Simultaneous observations to be carried out on 20 plants per field)

Sucking Pests

Aphids	:	% incidence (Observe for aphids on terminal shoots)
Aphids Injury grade	:	0, 1, 2, 3 or 4 as per Annexure III
Leaf hoppers (nymphs)	:	No. / 3 leaves
Leaf hopper Injury grade	:	0, 1, 2, 3 or 4 as per Annexure IV
Whitefly (adults)	:	No. / 3 leaves
Thrips	:	No. / 3 leaves
Mirid bug (Nymphs and adults)	:	No. / plant
Mealybug Injury grade	:	0, 1, 2, 3 or 4 as per Annexure V
Mealy bug (Incidence)	:	% incidence to be worked out

Bollworms

Helicoverpa	:	No. of eggs / plant & No. of larvae / plant
Spotted bollworm	:	No. of larvae / plant
Fruiting body damage	:	No. of squares and green bolls damaged by bollworm (*Helicoverpa armigera*, *Spodoptera* sp.) complex and total no. in a plant
Pink bollworm	:	No. of rosette flowers per plant during the 50% flowering to peak boll formation stage
Pink bollworm	:	No. of larvae / 20 green bolls (to be recorded through destructive sampling of green bolls on 100, 120 and 135 days after sowing)
Spodoptera	:	No. of egg masses or bunch of first instar larvae / plant Should be recorded as egg mass and number of big larvae/plant also should be recorded

Predators

Coccinellids	:	Grubs+adults / plant
Chrysoperla	:	Egg and grubs / plant
Spiders	:	No. / plant

Diseases : The rating scales for Bacterial blight, Cotton leaf curl virus (CLCuD), Grey mildew and Fungal leaf spots are given in Annexure VI

Bacterial blight	:	1-4 grade
Fungal leaf spots	:	1-4 grade
CLCuD	:	1-6 grade
Grey mildew	:	1-4 grade (Observe 20 plants per field)

Disorders

Parawilt	:	% incidence (Observe 20 plants per field)
Red leaf in terminal 10 leaves	:	% incidence (Observe 20 plants per field)

Pheromone trap catches:

The **traps, two each per acre**, for ABW, SBW, PBW and *Spodoptera* should be installed at 50 days after sowing. Recordings to be done on fixed day of each week: No. of adults / trap/ week. Lures should be changed at fortnightly intervals

***: Observations made on Any other abundant insect pests/diseases/predators should be incorporated in the remarks column of the data sheet. The observations should be taken in the forenoon (8.0-11.0 am) preferably.*

Annexure -III

Assessment of Aphid severity

Grade 0 : Healthy plants free from aphid infestation

Grade I: Entire plant free from cupping/ crumpling

Grade II: Cupping / crumpling of few leaves on the upper portion of plant

Grade III: Cupping of upper leaves and aphid all over the plant

Grade IV: Extreme cupping, sickness/ sooty mould

Grade I

Grade II

Grade III

Grade IV

Annexure -IV

Assessment of Leaf hopper/Jassid severity

Grade 0 : Healthy plants free from leaf hopper infestation

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

Grade I

Grade II

Grade III

Grade IV

Annexure -V

Assessment of Mealybug severity

Grade 0: Healthy plants with no mealybug infestation

Grade I: About 1-10 mealy bugs scattered over the plant

Grade II: One branch infested heavily with mealy bugs

Grade III: Two or more branches infested heavily with mealy bugs, up to 50% plant affected

Grade IV: Complete plant affected

Grade I

Grade II

Grade III

Grade IV

Annexure -VI

Rating scales for cotton diseases

Bacterial blight

Scale	Symptoms
0	Plant completely free from infection
1	Spots few, Scattered, nearly 1 mm in diameter, dry, not coalescing, reddish, not angular, veins free
2	Spots initially wet but rapidly drying, several, larger, nearly 2 mm not coalescing, reddish, brown, veins and veinlets free or with dry lesions leaf area covered up to 10 per cent
3	Lesions large, 2 mm or more in diameter, angular, turning brown and black, coalescing, spreading linearly along the smaller veins. 11-20 per cent leaf area covered, or water-soaked vein infection along the main veins
4	Lesions larger, water-soaked coalescing as above but covering more than 20 per cent leaf area, and or veins infected and extending up to pulvinus and petioles, lesions larger and coalescing , water-soaked at first later turning to brown or black, in severe cases branches and stem also attacked

Fungal leaf spots

Scale	Symptoms
0	No infection
1	A few small spots less than 2 mm, scattered brown in colour, leaf area covered is less than 5%
2	Bigger spots up to 3 mm coalescing, brown in colour, 6-20 per cent leaf area covered
3	Spots increasing in size 3-5 mm and irregular in shape tending to coalescing and 21-40 per cent leaf area covered
4	Spots coalescing to form bigger lesions, irregular in shape and size, more than 40% leaf area covered

Cotton leaf curl

Scale	Symptoms
0	Complete absence of symptoms
1	Thickening of few small scattered veins on one or few leaves of a plant observed after careful observations
2	Thickening of small group of veins, no leaf curling, no reduction in leaf size and boll setting
3	Thickening of all veins, minor leaf curling, leafy enations, deformity of internodes with minor reduction in leaf size but no reduction in boll setting
4	Severe vein thickening, moderate leaf curling, leafy enations, minor deformity of internodes and minor reduction in leaf size and boll setting
5	Severe vein thickening, moderate leaf curling, leafy enations & deformity of internodes with moderate reduction in leaf size and boll setting followed by moderate stunting
6	Severe vein thickening, leaf curling, reduction in leaf size, leafy enations, deformed internodes and severe stunting of plant with no or few boll setting

Grey mildew

Scale	Symptoms
0	No infection
1	Small spots which cover up to 5 per cent area
2	Spots bigger in size and cover 6-20 per cent leaf area
3	Some spots coalescing and 21-40 per cent leaf area covered
4	Many spots coalescing covering more than 40% leaf area and leaves fall off.

Note: One or few or all the symptoms mentioned against each disease severity (grade) may be present.

Annexure -VII

RESISTANT / TOLERANT VARIETIES OF COTTON

Bacterial blight

A	Zonewise	Resistant / Tolerant
1	North Zone	Bikaneri Nerma, LH 900, F 414, F505, H 777, RST-9, LD-327, RG-8, LH-1134, LH-886, F-1054, LHH-144, RS-875, RS-810, RS-2013
2	Central Zone	Eknath, Purnima, Y-1, Khandwa-2, Badnawar-1, G-Cot-12, NHH-44, AKH-81, LRK 516
3	South Zone	MCU -5VT, Supriya, Abhadita, LK-861, Suraj, LRA-5166, LRK-516, Jayadhar, Malgari
B	**Pestwise**	
1	Leafhopper	Bikaneri Nerma, H-777, G.Cot-12, G.Cot-10, RS-875, RST-9, Fateh, RS 2063, Suraj
2	White fly	Supriya, Kanchana, LK-861, RS-875, RS-2013
3	Nematode	Bikaneri Nerma, Khandwa 2 and Sharada
4	*Verticillium* wilt	MCU -5VT, Surabhi
5	*Fusarium* wilt	AK-145, Sanjay, Digvijay, G.Cot-11, G.Cot-13, LD-327, PA-32 (Eknath)
6	Bollworms	LH-900, F-414, Abhadita, RS-2013
7	Root rot	LH-900
8	Leaf curl virus	H-1117, H-1226, H-1236, F-1861, LH-2076, RS-875, RS-810, RS-2013, LHH-144, CSHH-198, CSHH-238, CSHH-243

Annexure -VIII

General recommendations for the management of *Phenacoccus* solenopsis

- Large number of incidental hosts that have low population of *P. solenopsis* found within fields, field borders and roadside during offseason should be removed and disposed by burial or burning.
- Management of *P. solenopsis* on weed hosts on roadside and field borders should be a priority in all zones to prevent spatial spread and limit severity on cotton crop.
- Ornamentals and vegetables in urban landscapes and home backyards should be monitored closely.
- The extent of offseason management determines the magnitude of incidence and severity of *P. solenopsis*.
- Cotton season cultural practices should focus on field sanitations and proper weed management.

List of alternate host plants to be monitored for *P. solenopsis* cultural management

Region	Host plants	Season	Location
All cotton growing zones	Papaya *Carica papaya*	Throughout the year	Orchards and kitchen gardens
	Shoe flower *Hibiscus rosa-sinensis*		Backyards and roadside
	Tomato *Lycopersicon esculentum*		Cultivated fields
	Congress grass *Parthenium hysterophorus*		Fields, field borders and roadside
	Indian Mallow *Abutilon indicum*		Within fields, field borders, roadside and irrigation channels
	Potato *Solanum tuberosum*	Cotton season	Cultivated fields
	Brinjal *Solanum melongena*		
	Giant pigweed *Trianthema portulacastrum*	Off season	Within fields and roadside
North and Central zones	Burdock datura *Xanthium strumarium*	Cotton season	Within fields, field borders and roadside
	Bhindi *Abelmoschus esculentus*	Off season	Cultivated fields
Central and South zones	Curry leaf *Murrya koenigii*	Throughout the year	Backyards and roadside
	Oleander *Nerium oleander*		Roadside
	Common spurge *Euphorbia hirta*	Off season	Within fields, field borders, roadside and irrigation channels
	Lantana *Lantana camara*		Field borders, roadside and irrigation channels

Region	Host plants	Season	Location
	Coat buttons *Tridax procumbens*		Within fields, field borders and roadside
	Custard apple *Annona squamosa*		Roadside
	Commelina benghalensis		
North zone	Kanghi buti *Sida cordifolia*	Throughout the year	Roadside
	Ashwagandha *Withania somnifera*		Roadside and irrigation channels
	Gule dupehri *Portulaca grandiflora*	Cotton season	Within fields and roadside
	Moong *Vignaradiata*		Cultivated fields
	Beach sunflower *Helianthus debilis*		
	Guar *Cyamopsis tetragonoloba*		
Central zone	Wild Jute *Corchorus trilocularis*	Throughout the year	Within fields, field borders and roadside
	Red hogweed *Boerhavia diffusa*		
	Hazardani *Phyllanthus niruri*		Within fields
	Ambadi *Hibiscus sabdariffa*		
	Marsh Para Cress *Acmella uliginosa*		Within fields and field borders
	Ran bhendi *Abelmoschus ficulneus*		
	Jangli-bhendi *Azanza lampas*	Cotton season	Border and roadside
	Wild purslane *Portulaca quadrifida*		
	Pathari *Lactucaruncinata*		Within fields
	Chilly *Capsicum annum*		
	False Amaranth *Digera muricata*		Within fields and field borders
	Water spiny ball *Asteracantha longifolia*		Within fields , field borders and roadside

Region	Host plants	Season	Location
	Burr Bush *Triumfetta rhomboidea*		Roadside
	Ran shevanti *Vicoa indica*	Off season	Within fields and field borders
	Sonkadi *Pentanema indicum*		
	Pala aku *Euphorbia geniculata*		Within fields, field borders, roadside and water channels
South zone	Mountain knot grass *Aerva lanata*	Throughout the year	Within fields and roadside
	Jangali amla *Phyllanthus amarus*		Within fields, field borders and roadside
	Gliricidia *Gliricidia sepium*		Within fields and roadside
	Chilaka paraka *Sida acuta*		Roadside
	Pulicheru *Phyllanthus reticulatus*		
	Wild Jute *Corchorus trilocularis*		Within fields, field borders and roadside
	Wild poinsettia *Euphorbia geniculata*		Within fields and roadside
	Purslane *Portulaca oleracea*		Field borders, roadside and water channels

Annexure -IX

Recommended Pesticides for Cotton (CIBRC Approved)

S. No.	Name of insect pests	Name of insecticide	Dosage/ha a.i (gm)	Formulation (g or ml)/ha	Dilution in water/ha. (Litre)
A	Aphids	Azadirachtin 0.03% (300 ppm) Neem Oil Based WSP Containing	0	2500-5000	500-1000
		Acetamiprid 20% SP	10	50	500-600
		Carbaryl 5% D.P.	1000	20000	
		Carbaryl 10% DP	25000	25000	-
		Carbaryl 50% WP	1000	2000	500-1000
		Carbosulfan 25% DS	15 gm/kg	60	Seed treatment
		Chlorpyrifos 20% EC	250	1250	500-1000
		Dinotefuran 20% SG	25-30	125-150	500
		Diafenthiuron 50%WP	300	600	500-1000
		Dimethoate 30% EC	200	660	500-1000
		*Endosulfan 35%EC	210	600	500-1000
		*Endosulfan 4% DP	280	7000	500-1000
		Fenvalerate 20% EC	25-40	125-200	250-400
		Fipronil 5% SC	75-100	1500-2000	500
		Flonicamid 50% WG	75	100	500
		Fluvalinate 25% EC	50-100	200-400	500-1000
		Imidaclopride 70% WG	21 - 24.5	30 - 35	375 - 500
		Imidacloprid 48% FS Per 100kg seed	300 – 540	500 – 900	Seed treatment
		Imidacloprid 70% WS per 100kg seed	350-700	500-1000	Seed treatment
		Imidacloprid 30.5% m/m SC	21-26.25	60-75	500 - 750
		Imidacloprid 17.8% SL	20 - 25	100 - 125	500 - 700
		Malathion 50% EC	500	1000	500-1000
		Methyl parathion 2% DP	300	15000	
		Methyl parathion 50% EC	500	1000	500-1000
		Monocrotophos 15% SG	200	1333	500-1000
		Monocrotophos 36% SL	175	437	500-1000
		Oxydemeton – methyl 25% EC	300	1200	500-1000
		Phorate 10% CG	1000	10000	

S. No.	Name of insect pests	Name of insecticide	Dosage/ha a.i (gm)	Formulation (g or ml)/ha	Dilution in water/ha. (Litre)
		Profenofos 50% EC	500	1000	500-1000
		Quinalphos 1.5% DP	300	20000	
		Thiacloprid 21.7% SC	24-30	100-125	500
		Thiamethoxam 30% FS	3	10	
		Thiamethoxam 70% WS	300	430	
		Thiamethoxam 25% WG	25	100	500-750
		Acephate 50% + Imidacloprid 1.8% SP	518	1000	500
		Chlorpyrifos 50% + Cypermethrin 5%EC	500+50	1000	500-1000
		Thiamethoxam 12.6%+Lambda cyhalothrin 9.5%ZC	44	200	500
B	Jassids/ leaf hopper	Acephate 75% SP	292	390	500-1000
		Acetamiprid 20% SP	10	50	500-600
		Azadirachtin 0.03% (300 ppm) Neem Oil Based WSP Containing	0	2500-5000	500-1000
		Buprofezin 25% SC	250	1000	500-750
		Carbaryl 50% WP	1000	2000	500-1000
		Carbaryl 5% D.P.	1000	20000	
		Carbaryl 85% W.P.	1200	1411	500-1000
		Carbofuran 3% CG	750	25000	
		Carbosulfan 25% DS	15 gm/kg	60	Seed treatment
		Clothianidin 50% WDG	15-20	30-40	500
		Cypermethrin 25% EC	20-30	80-120	200-300
		Diafenthiuron 50%WP	300	600	500-1000
		Dinotefuran 20% SG	25-30	125-150	500
		Dimethoate 30% EC	300	660	500-1000
		*Endosulfan 35%EC	210	600	500-1000
		*Endosulfan 4% DP	210	5250	
		Fenvalerate 20% EC	25-40	125-200	250-400
		Fipronil 5% SC	75-100	1500-2000	500
		Imidacloprid 70% WS per 100kg seed	350-700	500-1000	Seed treatment
		Imidacloprid 30.5% m/m SC	21-26.25	60-75	500 - 750
		Imidacloprid 17.8% SL	20 - 25	100 - 125	500 - 700
		Lambda-Cyhalothrin 2.5% EC	15-25	600-1000	400-600

S. No.	Name of insect pests	Name of insecticide	Dosage/ha a.i (gm)	Formulation (g or ml)/ha	Dilution in water/ha. (Litre)
		Lambda-Cyhalothrin 5% EC	15-25	300-500	400-600
		Malathion 50% EC	500	1000	500-1000
		Methyl parathion 2% DP	500	25000	
		Methyl parathion 50% EC	250	500	500-1000
		Monocrotophos 15% SG	200	1333	500-1000
		Oxydemeton – methyl 25% EC	300	1200	500-1000
		Phorate 10% CG	1000	10000	Soil application
		Phosalone 35% EC	300	857	500-1000
		Phosalone 4% DP	1000	25000	
		Profenofos 50% EC	500	1000	500-1000
		Quinalphos 1.5% DP	300	20000	
		Thiacloprid 21.7% SC	24-30	100-125	500
		Thiamethoxam 30% FS	3	10	
		Thiamethoxam 70% WS	300	430	
		Thiamethoxam 25% WG	25	100	500-750
		Acephate 50% + Imidacloprid 1.8% SP	518	1000	500
		Cypermethrin 3% + Quinalphos 20% EC	1000-1250	500-600	15
		Cypermethrin 10% + Indoxacarb 10%SC	50+50	500	400-1000
		Chlorpyrifos 50% + Cypermethrin 5%EC	500+50	1000	500-1000
		Indoxacarb 14.5% + Acetamiprid 7.7% w/w SC	88.8-111	400-500	500
		Thiamethoxam 12.6%+Lambda cyhalothrin 9.5%ZC	44	200	500
C	Thrips	Buprofezin 25% SC	250	1000	500-750
		Carbaryl 10% DP	25000	25000	-
		Carbaryl 50% WP	1000	2000	500-1000
		Carbaryl 85% W.P.	1200	1411	500-1000
		Carbosulfan 25% DS	15 gm/kg	60	Seed treatment
		Cypermethrin 25% EC	20-30	80-120	200-300
		Diafenthiuron 50%WP	300	600	500-1000
		Dinotefuran 20% SG	25-30	125-150	500
		Dimethoate 30% EC	200	660	500-1000

S. No.	Name of insect pests	Name of insecticide	Dosage/ha a.i (gm)	Formulation (g or ml)/ha	Dilution in water/ha. (Litre)
		*Endosulfan 35%EC	280	800	500-1000
		*Endosulfan 4% DP	280	7000	
		Fenvalerate 20% EC	25-40	125-200	250-400
		Fipronil 5% SC	75-100	1500-2000	500
		Flonicamid 50% WG	75	100	500
		Imidaclopride 70% WG	21 - 24.5	30 - 35	375 - 500
		Imidacloprid 48% FS Per 100kg seed	300 – 540	500 – 900	Seed treatment
		Imidacloprid 70% WS per 100kg seed	350-700	500-1000	Seed treatment
		Imidacloprid 30.5% m/m SC	21-26.25	60-75	500 - 750
		Imidacloprid 17.8% SL	20 - 25	100 - 125	500 - 700
		Lambda-Cyhalothrin 2.5% EC	15-25	600-1000	400-600
		Lambda-Cyhalothrin 5% EC	15-25	300-500	400-600
		Malathion 50% EC	500	1000	500-1000
		Methyl parathion 2% DP	500	25000	
		Methyl parathion 50% EC	500	1000	500-1000
		Monocrotophos 15% SG	200	1333	500-1000
		Monocrotophos 36% SL	500	1250	500-1000
		Phorate 10% CG	1000	10000	
		Phosalone 4% DP	800	20000	
		Profenofos 50% EC	500	1000	500-1000
		Quinalphos 1.5% DP	300	20000	
		Thiacloprid 21.7% SC	24-30	100-125	500
		Thiamethoxam 70% WS	300	430	
		Thiamethoxam 25% WG	25	100	500-750
		Acephate 50% + Imidacloprid 1.8% SP	518	1000	500
		Chlorpyrifos 50% + Cypermethrin 5%EC	500+50	1000	500-1000
		Cypermethrin 10% + Indoxacarb 10%SC	50+50	500	400-1000
		Thiamethoxam 12.6%+Lambda cyhalothrin 9.5%ZC	44	200	500

S. No.	Name of insect pests	Name of insecticide	Dosage/ha a.i (gm)	Formulation (g or ml)/ha	Dilution in water/ha. (Litre)
D	Whiteflies	Acetamiprid 20% SP	200	100	500-600
		Azadirachtin 0.03% (300 ppm) Neem Oil Based WSP Containing	200	2500-5000	500-1000
		Azadirachtin 0.15% W/W Min. Neem Seed Kernel Based E.C	200	2500-5000	500-1000
		Azadirachtin 5% w/w Min. Neem Extract Concentrate Containing	200	375	750
		Bifenthrin 10% EC	80	800	500
		Buprofezin 25% SC	250	1000	500-750
		Carbaryl 85% W.P.	1200	1411	500-1000
		Chlorpyrifos 20% EC	250	1250	500-1000
		Clothianidin 50% WDG	20-25	40-50	500
		Diafenthiuron 50%WP	300	600	500-1000
		Dinotefuran 20% SG	25-30	125-150	500
		*Endosulfan 35%EC	280	800	500-1000
		*Endosulfan 4% DP	350-420	8750-10500	500-1000
		Ethion 50% EC	750-1000	1500-2000	500-1000
		Fenpropathrin 30% EC	75-100	250-340	750-1000
		Fipronil 5% SC	75-100	1500-2000	500
		Flonicamid 50% WG	75	100	500
		Imidacloprid 48% FS Per 100kg seed	300 – 540	500 – 900	Seed treatment
		Imidacloprid 70% WS per 100kg seed	350-700	500-1000	Seed treatment
		Imidacloprid 17.8% SL	20 - 25	100 - 125	500 - 700
		Monocrotophos 15% SG	200	1333	500-1000
		Monocrotophos 36% SL	150	375	500-1000
		Phorate 10% CG	1000	10000	
		Profenofos 50% EC	500	1000	500-1000
		Spiromesifen 22.9% SC	144	600	500
		Thiacloprid 21.7% SC	120-144	500-600	500
		Thiamethoxam 30% FS	3	10	500
		Thiamethoxam 70% WS	300	430	500
		Thiamethoxam 25% WG	50	200	500-750

S. No.	Name of insect pests	Name of insecticide	Dosage/ha a.i (gm)	Formulation (g or ml)/ha	Dilution in water/ha. (Litre)
		Triazophos 40% EC	600-800	1500-2000	500-1000
		Verticillium Lecanii 1.15%WP (formulated)	2500	500 litres of water	
		Acephate 50% + Imidacloprid 1.8% SP	518	1000	500
		Chlorpyrifos 50% + Cypermethrin 5%EC	500+50	1000	500-1000
		Deltamethrin 1% + Trizophos 35%EC	10+350-12.5+450	1000-1250	600-1000
		Deltamethrin 1% + Trizophos 35%EC	10+350-12.5+450	1000-1250	600-1000
		Indoxacarb 14.5% + Acetamiprid 7.7% w/w SC	88.8-111	400-500	500
		Pyriproxyfen 5% EC + Fenpropathrin 15% EC	25+75 – 37.5 +112.5	500-750	500-750
E	Sucking insects	Deltamethrin 1.8% EC	10	625	400-600
		Deltamethrin 2.8% EC	10	400	400-600
		Acephate 25% w/w + Fenvalerate 3% w/w EC	500+60	2000	500
		Azadirachtin 0.03% Min. Neem Oil Based E.C. Containing	0	2500-5000	500
		Acephate 75% SP	584	780	500-1000
		Alphacypermethrin 10% EC	15-25	165-280	600-1000
		Azadirachtin 0.15% W/W Min. Neem Seed Kernel Based E.C	200	2500-5000	500-1000
F	Bollworm complex	Azadirachtin 0.03% (300 ppm) Neem Oil Based WSP Containing	200	2500-5000	500-1000
		Alphacypermethrin 10% SC	25-30	250-300	500-1000
		Bacillus thuringiensis var. *galleriae*	-	2000-2500	1000
		Bacillus thuringiensis-k	-	750-1000	750-1000
		Bacillus thuringiensis var. *Kurstaki,* Serotype H-3a, 3b, Strain Z-52	-	750-1000	500-750
		Beauveria bassiana 1.15% W.P.	-	2000	400
		Bifenthrin 10% EC	80	800	500

S. No.	Name of insect pests	Name of insecticide	Dosage/ha a.i (gm)	Formulation (g or ml)/ha	Dilution in water/ha. (Litre)
		Beta Cyfluthrin 2.45% SC	12.5-18.75	500-750	500-1000
		Chlorpyrifos 20% EC	250	1250	500-1000
		Chlorpyrifos 50% EC	500-600	1000-1200	500-1000
		Cypermethrin 25% EC	40-70	160-280	400-800
		Deltamethrin 11% w/w EC	12.5	125	400-600
		Deltamethrin 25% tablet	12.5	50	400-600
		Deltamethrin 1.8% EC	12.5	781	400-600
		Deltamethrin 2.8% EC	12.5	500	400-600
		Diflubenzuron 25% WP	75	300	500-1000
		Emamectin benzoate 5% SG	9.5-11.0	190-220	500
		Ethion 50% EC	1000	2000	500-1000
		Fenvalerate 20% EC	75-100	375-500	700-900
		Fenvalerate 0.4% DP	80-100	20000-25000	
		Fipronil 5% SC	100	2000	500
		Fluvalinate 25% EC	50-100	200-400	500-1000
		Indoxacarb 14.5% SC	75	500	600-1000
		Indoxacarb 15.8% EC	75	500	500-1000
		Lambda-Cyhalothrin 4.9% CS	25	500	500
		Lambda-Cyhalothrin 2.5% EC	15-25	600-1000	400-600
		Lambda-Cyhalothrin 5% EC	15-25	300-500	400-600
		Methomyl 40% SP	300-450	750-1125	500-1000
		Monocrotophos 36% SL	450-800	1125-2250	500-1000
		Permethrin 25% EC	100-125	400-500	1000
		Profenofos 50% EC	750-1000	1500-2000	500-1000
		Pyridalyl 10% EC	75-100	750-1000	500-750
		Quinalphos 20% AF	350-500	1750-2500	750-1000
		Quinalphos 1.5% DP	450	30000	
		Thiodicarb 75% WP	750	1000	500
		Triazophos 40% EC	600-800	1500-2000	500-1000
		Acephate 50% + Imidacloprid 1.8% SP	518	1000	500
		* Endosulfan 35% + Cypermethrin 5% EC	875 + 125	2500	500-1000
		Indoxacarb 14.5% + Acetamiprid 7.7% w/w SC	88.8-111	400-500	500
		Profenofos 40% + Cypermethrin 4% EC	440-660	1000-1500	500-1000

S. No.	Name of insect pests	Name of insecticide	Dosage/ha a.i (gm)	Formulation (g or ml)/ha	Dilution in water/ha. (Litre)
		Pyriproxyfen 5% EC + Fenpropathrin 15% EC	25+75 – 37.5 +112.5	500-750	500-750
		Cypermethrin 10% + Indoxacarb 10%SC	50+50	500	400-1000
		Thiamethoxam 12.6%+Lambda cyhalothrin 9.5%ZC	44	200	500
G	*Helicoverpa*	Azadirachtin 0.3% (3000 PPM) Min. Neem Seed Kernel Based E.C.		4000	1000
		Bacillus thuringiensis Serovar *kurstaki* (3a, 3b, 3c) 5% WP	25.00-50.00	500-1000	500-1000
		Carbaryl 10% DP	25000	25000	-
		Carbaryl 50% WP	1000	2000	500-1000
		Chlorantraniliprole 18.5% SC	30	150	500
		Chlorfluazuron 5.4% EC (w/w)	75-100	1500-2000	500
		Cypermethrin 10% EC	50-70	550-760	150-1000
		Flubendiamide 39.35% M/M SC	48-60	100-125	375-500
		Fenpropathrin 10% EC	75-100	750-1000	750-1000
		Fenpropathrin 30% EC	75-100	250-340	750-1000
		Flubendiamide 20% WG	50	250	500
		Lufenuron 5.4% EC	30	600	500-750
		Novaluron 10% EC	100	1000	500p-1000
		Novaluron 8.8% SC	100	1000	500-1000
		Phenthoate 50% EC	1000	2000	500-1000
		Quinalphos 20% AF	350-500	1750-2500	750-1000
		Spinosad 45.0% SC	75-100	165-220	500
		Acephate 25% w/w + Fenvalerate 3% w/w EC	500+60	2000	500
		Cypermethrin 3% + Quinalphos 20% EC	1000-1250	500-600	15
		Chlorpyrifos 50% + Cypermethrin 5%EC	500+50	1000	500-1000
		Chlorpyriphos 16% + Alphacypermethrin 1%	425	2500	500-750
		Deltamethrin 1% + Trizophos 35%EC	10+350-12.5+450	1000-1250	600-1000
		Deltamethrin 1% + Trizophos 35%EC	10+350-12.5+450	1000-1250	600-1000

S. No.	Name of insect pests	Name of insecticide	Dosage/ha a.i (gm)	Formulation (g or ml)/ha	Dilution in water/ha. (Litre)
		Ethion 40% + Cypermethrin 5% w/w EC	400+50	1000	500
		Azadirachtin 0.03% Min. Neem Oil Based E.C. Containing	0	2500-5000	500
		NPV of *Helicoverpa armigera* 0.43% AS Strain No. BIL/HV-9	-	2700 ml	400-600
		Azadirachtin 5% w/w Min. Neem Extract Concentrate Containing		375	750
H	Spotted Bollworm	*Bacillus thuringiensis* Serovar *kurstaki* (3a, 3b, 3c) 5% WP	37.50-50.00	750-1000	500-1000
		Carbaryl 50% WP	1000	2000	500-1000
		Carbaryl 85% W.P.	1200	1411	500-1000
		Chlorantraniliprole 18.5% SC	30	150	500
		Cypermethrin 10% EC	50-70	550-760	150-1000
		Fenpropathrin 10% EC	75-100	750-1000	750-1000
		Fenpropathrin 30% EC	75-100	250-340	750-1000
		Fenvalerate 0.4% DP	80-100	20000-25000	
		Flubendiamide 39.35% M/M SC	48-60	100-125	375-500
		Phenthoate 50% EC	1000	2000	500-1000
		Phosalone 35% EC	600	1714	500-1000
		Phosalone 4% DP	1000	25000	
		Quinalphos 20% AF	350-500	1750-2500	750-1000
		Cypermethrin 3% + Quinalphos 20% EC	1000-1250	500-600	15
		Chlorpyrifos 50% + Cypermethrin 5%EC	500+50	1000	500-1000
		Chlorpyriphos 16% + Alphacypermethrin 1%	425	2500	500-750
		Deltamethrin 1% + Trizophos 35%EC	10+350-12.5+450	1000-1250	600-1000
		Deltamethrin 1% + Trizophos 35%EC	10+350-12.5+450	1000-1250	600-1000
		Fenvalerate 2% Conc.	80-100	4000-5000	

S. No.	Name of insect pests	Name of insecticide	Dosage/ha a.i (gm)	Formulation (g or ml)/ha	Dilution in water/ha. (Litre)
I	Pink bollworm	Carbaryl 85% W.P.	1200	1411	500-1000
		Carbaryl 50% WP	1000	2000	500-1000
		Cypermethrin 10% EC	50-70	550-760	150-1000
		Fenpropathrin 10% EC	75-100	750-1000	750-1000
		Fenpropathrin 30% EC	75-100	250-340	750-1000
		Fenvalerate 2% Conc.	80-100	4000-5000	
		Phenthoate 50% EC	1000	2000	500-1000
		Phosalone 35% EC	700	2000	500-1000
		Quinalphos 20% AF	350-500	1750-2500	750-1000
		Chlorpyrifos 50% + Cypermethrin 5%EC	500+50	1000	500-1000
		Chlorpyriphos 16% + Alphacypermethrin 1%	425	2500	500-750
		Deltamethrin 1% + Trizophos 35%EC	10+350-12.5+450	1000-1250	600-1000
		Deltamethrin 1% + Trizophos 35%EC	10+350-12.5+450	1000-1250	600-1000
	Egyptian boll worm	Fenvalerate 2% Conc.	80-100	4000-5000	600-1000
J	Leaf folder & bollworms (*Helicoverpa* and spotted bollworm)	Flubendiamide 39.35% M/M SC	48-60	100-125	375-500
		Carbaryl 50% WP	1000	2000	500-1000
K	Leaf hopper	Monocrotophos 36% SL	175	437	500-1000
		Azadirachtin 5% w/w Min. Neem Extract Concentrate Containing	0	375	750
		Oxydemeton – methyl 25% EC	300	1200	500-1000
L	Tobacco caterpillar *(Spodoptera)*	Chlorantraniliprole 18.5% SC	30	150	500
		Chlorfluazuron 5.4% EC (w/w)	75-100	1500-2000	500
		Diflubenzuron 25% WP	75-87.5	300-350	500-1000
		Novaluron 8.8% SC	100	1000	500-1000
		Bacillus thuringiensis var. *kurstaki*, Serotype H-3a, 3b, Strain Z-52	-	750-1000	500-750

S. No.	Name of insect pests	Name of insecticide	Dosage/ha a.i (gm)	Formulation (g or ml)/ha	Dilution in water/ha. (Litre)
		Chlorpyrifos 50% + Cypermethrin 5%EC	500+50	1000	500-1000
M	Earhead midge	Carbaryl 5% D.P.	1000	20000	
N	Diamond back moth	Carbaryl 10% D.P.	2500	25000	-
O	Army worm	Carbaryl 10% D.P.	2500	25000	-
P	Grey weevil	Carbofuran 3% CG	1000	33300	
		Dimethoate 30% EC	200	990	500-1000
		Monocrotophos 36% SL	175	437	500-1000
Q	Stem weevil	Carbofuran 3% CG	1000	33300	
		Carbaryl 10% DP	25000	25000	-
R	Cut worm	Chlorpyrifos 20% EC	750	3750	500-1000
S	Red Spider mite	Dicofol 18.5% EC	500-1000	2700-5400	500-1000
		Phosalone 35% EC	600	1714	500-1000
		Spiromesifen 22.9% SC	144	600	500
T	Yellow mite	Dicofol 18.5% EC	500-1000	2700-5400	500-1000
U	Red cotton bug	Fluvalinate 25% EC	50-100	200-400	500-1000

Source: CIBRC, 2013 GOI, Faridabad Available at http://cibrc.nic.in/

*As on now use of endosulfan has been banned vide Supreme Court order from 31-05-2011

ANNEXURE-X

Recommended Fungicides for Cotton

Name of diseases	Name of fungicide	Dosage/ha a.i(gm)	Formulation (g or ml)/ha	Dilution in water/ ha. (Litre)
Leaf spot	Carbendazim 50% WP	125	250	750
Angular leaf spot	Carboxin 75% WP	1.5 - 1.875	2 -2.5	Only one time seed treatment required
Seedling blight angular leaf spot or black arm disease	(Streptomycin Sulphate 9% + Tetracylin Hydrocloride 1%) SP		Seed treatment: Seed borne infection can be eliminated by soaking the seeds in 40 to 50 ppm solution for a period of two hours. Spray: Streptocyclin 25 to 40 ppm to be sprayed thrice. Before flowering. After flowering. Twenty days after second spray. For prevention of accompanying fungal infection use copper fungicide with streptocyclin.	
Root rot, Bacterial bight	Carboxin 37.5% + Thiram 37.5% DS	2.5 gm/Kg seed	3.5 gm/Kg	0
Seed born diseases	Thiram 75% WS	18.8-22.5 gm	25-30 gm	1
Mites	Sulphur 40% WP	1.50-2.00 Kg	3.75-5.00 kg	750-1000

Source: CIBRC, 2013 GOI, Faridabad Available at http://cibrc.nic.in/

ANNEXURE-XI

Recommended Herbicides for Cotton

Name of weeds	Name of herbicide	Dosage/ ha a.i(gm)	Formulation (g or ml)/ha	Dilution in water/ha. (Litre)
Digera arvensis *Echinochloa colonum,* *Eragrostis major* *Euphorbia hirta* *Phyllanthus niruri* *Portulaca oleracea* *Trianthema portulacastrum* *Flaveria australasica* *Gynandropsis pentaphylla*	Alachlor 50% EC	2-2.5 kg	4-5 lit.	250-500
Dactyloctenium aegyptium	Alachlor 10% GR	2.0-2.5 Kg	20-25 Kg	0
Amaranthus spp, *Chenopodium album, Convolvulas arvensis Setaria glauca, Digitaria* sp, *Portulaca oleracea, Xanthium strumerium, Anagallis arvensis, Asphodelus temifolius, Euphorbia* sp, *Visia sativa Paspalum conjugatum,*	Diuron 80% WP	0.75-1.5 kg	1-2.2Kg.	625
Echinochloa sp. *Eluesine indica* *Dactylocteneum* *Aegyptium* *Eragrostit minor*	Fenoxaprop-p-ethyl 9.3% w/w EC (9% w/v)	67.5 g	750 ml.(20 -25 DAS)	375-500
Acanthospermum hispidum, Cleome viscosa, Datura sp. *Trianthema monogyna Tridax procumbens, Cynodon dactylon (germinating) Amaranthus* spp., *Portulaca* spp, *Achyranthus aspera, Euphorbia hirta, Cenchrus cathorticus, Digitaria sanguinalis, Eleusine* sp, *Panicum* sp, *Lagascea mollis, Gynandropsis pentaphylla, Acalypha indica*	Fluchloralin 45% EC	0.9-1.2kg	2.0-2.68 ltrs.	500-800
Echinochloa sp. *Cynodon dactylon* *Cyperus rotundus* *Digitaria marginata* *Dactylocteneum* *aegyptium*	Glufosinate Ammonium 13.5% SL (15% w/v)	375-450	2.5-3.0	500
Echinochloa spp. *Euphorbia hirta* *Amarnanthus viridis* *Portulaca oleracea* *Trianthema* spp. *Eleusine indica*	Pendimethalin 30% EC	0.75-1.25kg	2.5-4.165 ltrs	500-700

Name of weeds	Name of herbicide	Dosage/ ha a.i(gm)	Formulation (g or ml)/ha	Dilution in water/ha. (Litre)
Panicum repens, Digitaria sanguinalis, Brachiaria mutica (Grasses), *Pennisetum purpureum, Cyperus rotundus* (sedge), *Lantana camjara, Portulaca oleracea, Eclipta prostrate, Commelina benghalensis* (Broad leaves weeds)	Pendimethalin 38.7% CS	677.27	1500-1750	500
(Post-emergence directed inter row application at 2-3 leaf stage of weeds) *Digera arvensis, Cyperus iria, Trianthema monogyna, Corchorus* spp., *Leucas aspera, Euphorbia* spp.	Paraquat dichloride 24% SL	0.3-0.5 kg	1.25-2.0	500
Trianthema spp. *Amaranthus* spp. *Chenopodium* spp. *Digera* spp. *Celosia argentia*	Pyrithiobac Sodium 10% EC	62.5-75 gm	625-750	500
Echinolchloa crusgalli Echinochloa colonum Dinebra retroflexa Digiteria marginata	Quizalofop-ethyl 5% EC	50.5	1000	500

Source: CIBRC, 2013 GOI, Faridabad Available at http://cibrc.nic.in/

ANNEXURE-XII

BASIC PRECAUTIONS IN PESTICIDE USAGE

A. Purchase:

1. Purchase only JUST required quantity e.g. 100,250, 500 or 1000 g/ml for single application in specified area.
2. Do not purchase leaking containers, loose, unsealed or tom bags.
3. Do not purchase pesticides without proper/ approved LABELS.

B. Storage:

1. Avoid storage of pesticides in the house premises.
2. Keep only in original container with intact seal.
3. Do not transfer pesticides to other container.
4. Never keep them together with food or feed/ fodder.
5. Keep away from the reach of children and livestock.
6. Do not expose to sun-light or rain water.
7. Do not store weedicides along with other pesticides.

C. Handling:

1. Never carry/ transport pesticides along with food materials.
2. Avoid carrying bulk - pesticides (dusts / granules) on head, shoulders or on the back.

D. Precautions for Preparing Spray Solution:

1. Use clean water.
2. Always protect your NOSE, EYES, MOUTH, EARS and HANDS.
3. Use hand gloves, face mask and cover your head with cap.
4. Use polyethylene bags as hand gloves, handkerchiefs or piece of clean cloth as mask and a cap or towel to cover the head (Do not use polyethylene bag contaminated with pesticides).
5. Read the label on the container before preparing spray solution,
6. Prepare spray solution as per requirement.
7. Do not mix granules with water.
8. Concentrated pesticides must not fall on hands etc. while opening sealed containers.
9. Do not smell the sprayer tank.
10. Avoid spilling of pesticide solution while filling the sprayer tank.
11. Do not eat, drink smoke or chew while preparing solution.
12. The operator should protect his bare feet and hands with polyethylene bags.

E. Equipment:

1. Select right kind of equipment.

2. Do not use leaky, defective equipment.
3. Select right kind of nozzle.
4. Don't blow/clean clogged- nozzle with mouth. Use old tooth- brush tied with the sprayer and cleans with water.
5. Do not use same sprayer for weedicide and insecticide.

F. Precautions for applying pesticides:

1. Apply only at recommended dosage and dilution.
2. Do not apply on hot sunny day or strong windy condition.
3. Do not apply just before the rains and also after the rains.
4. Do not apply against the wind direction.
5. Emulsifiable concentrate formulations should not be used for spraying with battery operated ULV sprayer.
6. Wash the sprayer and bucket etc. with soap water after spraying.
7. Containers, buckets etc. used for mixing pesticides should not be used for domestic purposes.
8. Avoid entry of animals and workers in the fields immediately after the spraying.

G. Disposal:

1. Leftover spray solution should not be drained in ponds or water lines etc.
2. Throw it in barren isolated area, if possible.
3. The used empty containers should be crushed with a stone /stick and buried deep into soil away from water source.
4. Never re-use empty pesticide container for any purpose.

Protocol for Pesticide application techniques, equipment and nozzle specifications

Category A: Stationary, crawling pest/ disease		
Vegetative stage	Insecticides and fungicides	• Lever operated knapsack sprayer (Droplets of big size) • Hollow cone nozzle @ 35 to 40 psi • Lever operating speed = 15 to 20 strokes/min or • Motorized knapsack sprayer or mist blower (Droplets of small size) • Air blast nozzle • Operating speed: 2/3rd throttle
1. For crawling and soil borne pests		
2. For small sucking leaf borne pests		
Reproductive stage	Insecticides and fungicides	• Lever operated knapsack sprayer (Droplets of big size) • Hollow cone nozzle @ 35 to 40 psi • Lever operating speed = 15 to 20 strokes/min

Category B: Field Flying pest/airborne pest		
Vegetative stage	Insecticides and fungicides	• Motorized knapsack sprayer or mist blower (Droplets of small size) • Air blast nozzle • Operating speed: 2/3rd throttle or • Battery operated low volume sprayer (Droplets of small size) spinning disc nozzle
Reproductive stage (Field Pests)		
Category C: Weeds		
Post-emergence application	Weedicide	• Lever operated knapsack sprayer (Droplets of big size) • Flat fan or flood jet nozzle @ 15 to 20 psi • Lever operating speed = 7 to 10 strokes/min
Pre-emergence		• Trolley mounted low volume sprayer (Droplets of small size) • Battery operated low volume sprayer (Droplets of small size)

Operational, calibration and maintenance guidelines in brief

1	For application rate and dosage see the label and leaflet of the particular pesticide.
2	It is advisable to check the output of the sprayer (calibration) before commencement of spraying under guidance of trained person.
3	Clean and wash the machines and nozzles and store in dry place after use.
4	It is advisable to use protective clothing, face mask and gloves while preparing and applying pesticides. Do not apply pesticides without protective clothing and wash clothes immediately after spray application.
5	Do not apply in hot or windy conditions.
6	Operator should maintain normal walking speed while undertaking application.
7	Do not smoke, chew or eat while undertaking the spraying operation
8	Operator should take proper bath with soap after completing spraying
9	Do not blow the nozzle with mouth for any blockages. Clean with water and a soft brush.

Method for calculation of pesticides for application

(i) **Solid formulations** such as dust, wettable powder or gr anules, the active ingredient is mixed with inert material. The concentration is expressed as -
Active ingredient (%) in the total weight of commercial product

$$\text{Active ingredient (\%) in dust, WP or granules} = \frac{\text{Weight of a.i. x 100}}{\text{Total weight of WP , dust, etc.}}$$

Example. Carbendazim 50% WP means there are 50 g of carbendazim in every 100 g of commercial WP (50 % a.i.).

Calculations when recommendation is in kg a.i. per ha.
For WP, dust, granules, etc.
Specification required:
1) Area to be sprayed
2) Concentration of a.i in formulation
3) Recommended rate as kg a.i. ha^{-1}.

$$\text{Formula: kg of WP/dust/granules} = \frac{\text{Recommended rate x spray area (sq.m)}}{\text{a.i (\%) in WP x 100}}$$

Example: If Carbendazim 50% WP is used at the rate of 2 kg a.i ha^{-1}, then amount of Carbendazim 50% WP required for 1 ha (10000 m^2) is:

$$\text{kg of Carbendazim 50\% WP required} = \frac{2 \times 10000}{50 \times 100} = 4 \text{ kg/ha}$$

(ii) **Liquid of formulation** Here the a.i. is dissolved in a solvent with an emulsifying agent. It is expressed as in emulsifiable concentrate (EC). The concentration can be expressed in two ways.

a) $$\text{Active ingredient (\%) in EC} = \frac{\text{Weight of a.i. x 100}}{\text{Volume of EC}}$$

b) Grams L^{-1}

Example: **Hexaconazole 5% EC** means, 100 ml of commercial product has 5 ml of pure Hexaconazole

For emulsiflable concentrates
Specification required:

i) Area to be treated
ii) Recommended rate as kg a.i. ha^{-1}
iii) Concentration of commercial EC as a.i (%) or kg L^{-1}

When concentration of EC is in a.i. (%)
Formula:

$$\text{kg of EC required} = \frac{\text{Recommended rate x area } (m^2)}{\text{ai (\%) in commercial EC x 100}} \quad \text{or}$$

$$= \frac{\text{Recommended rate x area (ha) x 100}}{\text{a.i. (\%) in commercial EC}}$$

Example: Hexaconazole 5% EC to be sprayed at the rate of 2 kg a.i. ha^{-1} for 10000 m^2 and Hexaconazole 5% EC has 5 % a.i. How much liters of Hexaconazole is required?

$$\text{Liters of 5 \% Hexaconazole required} = \frac{2 \times 10000}{5 \times 100} = 40 \text{ L}$$

When concentration expressed is in kg a.i. L^{-1}
Formula:

$$= \frac{\text{Recommended rate in kg a.i. } ha^{-1} \text{ x area (ha)}}{\text{Concentration of a.i. in product (kg } L^{-1})}$$

Example: Acetamprid (0.01 kg a.i. L^{-1}) is to be applied at the rate of 0.05 kg a.i. ha^{-1} How much will be required for 3 ha?

Liters of Acetamprid required = $\frac{0.05 \times 3.0}{0.01}$ = 15 liters

When recommendation is based on a.i (%) in the spray fluid

i) Wettable powders (when diluted with water)

Specifications required:
1 Spray volume as L ha^{-1}
2 Concentration desired as a.i. (%) in spray
3 Concentration of commercial product as a.i. (%)

Formula :

$$WP = \frac{\text{a.i. (\%) desired x spray volume (L)}}{\text{a.i. (\%) in commercial WP}}$$

Example: To control Spodoptera in a plot. 2000 L of 2% Methyl Parathion DP is to be prepared. The commercial product to be used is Methyl parathion 50% EC. How much Methyl parathion is required?

Litre of Methyl parathion required = $\frac{2 \times 2000}{50}$ = 80 liters

ii) Emulsifiable concentrates (EC)
Specification required:

1) Spray volume as L ha^{-1}
2) Concentration as percentage of a.i desired.
3) Concentration of commercial EC as a.i. (%).

Formula:

$$\text{Liter of EC} = \frac{\text{a. i. (\%) desired x spray volume (L)}}{\text{a.i. (\%) in commercial EC}}$$

Example : 2000 L of 2 % Methyl parathion spray is to be prepared. Howmuch commercial 50 % EC is required?

Liters of Methyl parathion = $\frac{2 \times 2000}{50}$ = 80 L

SAFETY PARAMETERS IN PESTICIDES USAGE IN COTTON

S.No.	Name of pesticide	*Classification as per Insecticides Rules, 1971	WHO classification by hazards	Symptoms of poisoning	First aid measures	Treatment of poisoning
1	**ORGANOPHOSPHATES**					
2	Quinalphos	Highly toxic	Class II Moderately Hazardous	Mild-anorexia, headache, weakness, dizziness, anxiety.	Remove the person from the contaminated environment. In case of (a) Skin contact-Remove all contaminated clothings and immediately wash with lot of water and soap: (b) Eye contamination -Wash the eyes with plenty of cool and clean water; (c) Inhalation - Carry the person to the open fresh air, loosen the clothings around neck and chest, and' (d) Ingestion -If the victim is fully conscious. Induce vomiting by tickling back of the throat. Do not administer milk alcohol and fatty substances. In case the person is unconscious make sure the breathing passage is kept clear without any obstruction. Victim's head should be little lowered and face should be turned to one side in the lying down position. In case of breathing difficulty. give mouth to mouth or mouth to nose breathing. Medical aid: Take the patient to the doctor /Primary Health Centre immediately along with the original container, leaflet and label.	For extreme symptoms of OP poisoning, injection of atropine (2-4 mg for adults. 0.5-1.0 mg for children) is recommended, repeated at 5-10 minute intervals until signs of atropinization occur. Speed is imperative Atropine injection 1 to 4 mg. Repeat 2mg when toxic symptoms begin to recur (15-16 minute intervals), Excessive salivation - good sign, more atropine needed: Keep airways open, Aspirate, use oxygen insert endotracheal tube. Do tracheotomy and give artificial respiration as needed. For ingestion lavage stomach with 5% sodium bicarbonate, if not vomiting. For skin contact, wash with soap and water (eyes- wash with isotonic saline). Wear rubber gloves while washing contact areas. In addition to atropine give 2-PAM (2-pyridinc aldoxime methiodide). 1g and 0.25g for infants intravenously at a slow rate over a period of 5 minutes and administer again periodically as indicated. More than one injection may be required. Avoid morphine, theophyllin, aminophyllin. Barbiturates or phenothiazincs. Do not give atropine to a Cyanotic patient. Give artificial respiration first then administer atropine
3	Monocrotophos	Extremely toxic	Class 1 b-Highly hazardous	Tremors of tongue and eyelids, miosis, impairment of visual acuity.		
4	Profenophos	Highly toxic	Class II b-Moderately hazardous	Moderate-nausea. salivation, lacrimation, abdominal cramp, vomiting. sweating. Slow pulse. Muscular tremors, miosis.		
5	Phosphamidon	Extremely toxic	Class I a-Extremely hazardous			
6	Acephate	Moderately toxic	Class III Slightly hazardous	Severe-diarrhoea, pinpoint and non-reactive pupils, respiratory difficulty, pulmonary edema, cyanosis, loss of sphincter control, convulsions, coma and heart block.		
7	Phosalone	Highly toxic	Class II -Moderately hazardous			
8	Triazophos	Highly toxic	Class 1 b-Highly hazardous			
9	Chlorpyriphos	Highly toxic	Class II -Moderately hazardous			

S.No.	Name of pesticide	*Classification as per Insecticides Rules, 1971	WHO classification by hazards	Symptoms of poisoning	First aid measures	Treatment of poisoning
	CARBAMATES					
10	Carbosulfan	Highly toxic	Class II -Moderately hazardous	Constriction of pupils. salivation. swearing. Profuse lassitude. muscle incoordination nausea. vomiting diarrhoea. epigastric pain. tightness in chest		
11	Thiocarb					
	HERBICIDES					
12	Alachlor	Moderately toxic	Class III Slightly hazardous	Headache. Palpitation, nausea, vomiting flushed face. Irritation of nose, throat eyes and skin etc.		No specific antidote treatment is essentially symptomatic.
13	Pendimethalin					
14	Diuron		Acute hazard in normal use			
15	Trifluralin					
16	Fluchloralin					
17	Paraquat	Highly toxic	Class II -Moderately hazardous			
18	Diflubenzuron	Moderately toxic	Acute hazard in normal use			
	SYNTHETIC PYRETHROIDS					
19	Fenvalerate	Highly toxic	Class II -Moderately hazardous	Headache. Palpitation, nausea, vomiting flushed face. Irritation of nose, throat eyes and skin, allergic manifestations etc.		No specific antidote treatment is essentially symptomatic.
20	Deltamethrin					
21	Alphamethrin	Moderately toxic				
22	Cypermethrin	Highly toxic				
23	Lamda cyhalothrin					
	OTHERS					
24	Imidacloprid	Highly toxic	Class II -Moderately hazardous	Headache. Palpitation, nausea, vomiting flushed face. Irritation of nose, throat eyes and skin etc.		No specific antidote treatment is essentially symptomatic.

*Colour of identification band on the label

1. Extremely toxic – red, 2. Highly toxic- yellow, 3. Moderately toxic- blue, 4. Slightly toxic- green

Safe use of Pesticides
कीटनाशकों का सुरक्षित इस्तेमाल

कीटनाशकों की विषाक्तता की श्रेणियों के पहचान-चिह्न

भारत सरकार
कृषि मंत्रालय
कृषि एवं सहकारिता विभाग
वनस्पति संरक्षण, संगरोध एवं संग्रह निदेशालय

केंद्रीय एकीकृत नाशीजीव प्रबंधन केंद्र

एन. एच. – 4, फरीदाबाद – 121001 हरियाणा

Plate-1

Key Insect Pests		
		
Leaf hopper nymphs	Damage (downward curling) due to leaf hoppers	Whitefly adults
		
CLCuD infected plant	Thrips colony	Damage due to thrips on seedlings
		
Aphid colony	Deposits of aphid honey dew on leaves	Mirid adult : *Creontiades biseratense*
		
Parrot beaking of green bolls due to mirid feeding	Mirid adult: *Campylomma livida*	Mirid damage : Distorted petals & blackened anthers

		
Adult female mealybug : *P. solenopsis*	Mealybug infested plant	Larva of tobacco caterpillar *S. litura*
		
Boll damage due to *S. litura*	Larva of pink bollworm	'Rosette flower' caused by pink bollworm
		
Larva of *Earias*	Boll damage due to *Earias*	Larva of *H. armigera*
		
Boll damage by *H. armigera*	Larva of leaf roller	Leaf roller infested plant

		
Red cotton bug	Dusky cotton bug	Leaf damage due to Semi-looper feeding
		
	Stem weevil	

Plate-2

Key Diseases		
		
Bacterial blight	*Alternaria* leaf spot	*Myrothecium* leaf spot
		
Root rot	*Fusarium* wilt	Leaf curl (CLCuD)

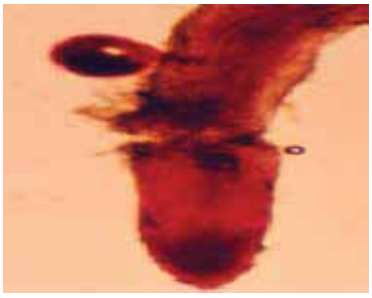
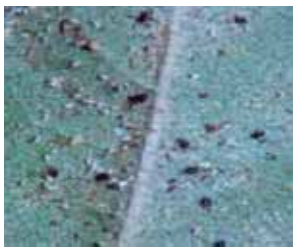
	
Grey mildew	*Verticillium* wilt
Disorders	
	
Leaf reddening	Para-wilt
Nematode	
	
Reniform nematode attached to cotton root	Nematode infested cotton field

Plate 3

Common parasitoids of cotton ecosystem			
Name of the parasitoid	**Host**	**Image**	**Type of parasitoid**
Aphelinus sp. (Aphelinidae: Hymenoptera)	*Aphids*		Nymphal and adult parasitoid
Microchelonus versatilis (Braconidae : Hymenoptera)	*Helicoverpa (H. armigera)*		Egg larval parasitoid
Eucarcelia illota Curran (Tachinidae : Diptera)	Semi looper (*Anomis flava*) & *Helicoverpa (H. armigera)*		Larval parasitoid
Eriborus argenteopilosus Cameron (Ichneumonidae : Hymenoptera)	Semi looper *(Anomis flava)* & *Helicoverpa (H. armigera)*		Larval parasitoid
Campoletis chlorideae Uchida (Ichneumonidae : Hymenoptera)	*H. armigera*		Larval parasitoid
Rogas aligarhensis Quadri (Braconidae : Hymenoptera)	Spotted bollworm *Earias vittella*		Larval parasitoid

Common parasitoids of cotton ecosystem			
Name of the parasitoid	**Host**	**Image**	**Type of parasitoid**
Apanteles angaleti Mues. (Braconidae : Hymenoptera)	Pink bollworm *Pectinophora gossypiella*		Larval parasitoid
Bracon greeni Ashm. (Braconidae : Hymenoptera)	Pink bollworm *Pectinophora gossypiella*		Larval parasitoid

Common predators of cotton ecosystem			
Name of the parasitoid	**Host**	**Image**	**Type of parasitoid**
Green lacewing *Chrysoperla zastrowi* (Chrysopidae : Neuroptera)	On aphids, jassids, thrips and eggs of bollworms		Grubs are highly predatory
Lady bird beetles (Coccinellidae: Coleoptera)	Aphids		Grubs are predatory
Hoverflies (Syrphidae: Diptera)	Aphids		Maggots are predatory

Common predators of cotton ecosystem			
Name of the parasitoid	**Host**	**Image**	**Type of parasitoid**
Spiders (Arachinidae)	On aphids, jassids, thrips and larvae of bollworms		Nymphs and adults are predatory

Insects pathogens of cotton insect pests			
Name of the parasitoid	**Host**	**Image**	**Type of parasitoid**
Nomuraea rileyi (Fungal pathogen)	Semi looper (*Anomis flava*) & *Helicoverpa (H. armigera)*		Pathogenic to larvae
Nuclear polyhedrosis virus (Viral pathogen)	*Helicoverpa (H. armigera)*		Pathogenic to larvae

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