INTEGRATED PEST MANAGEMENT PACKAGE FOR COTTON

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.

AKSrivastava

(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. 1^{st} and 2^{nd} 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

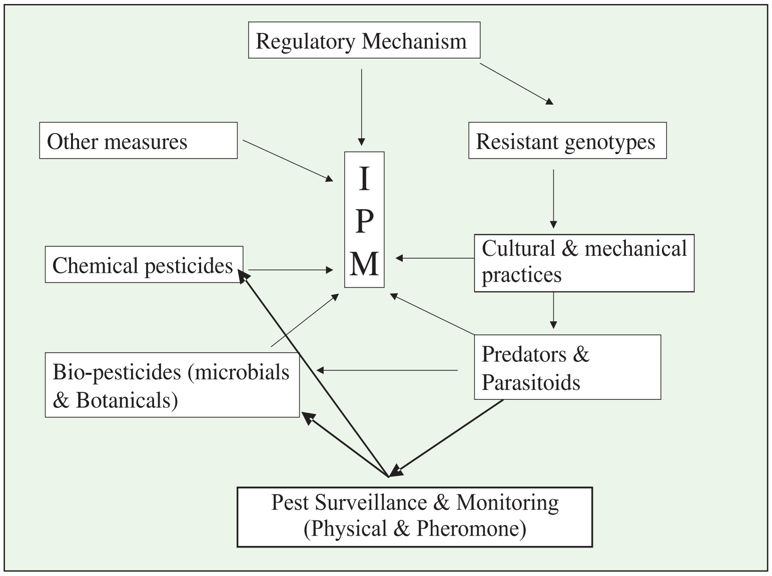


Fig 1. Diagrammatic sketch of IPM system

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.

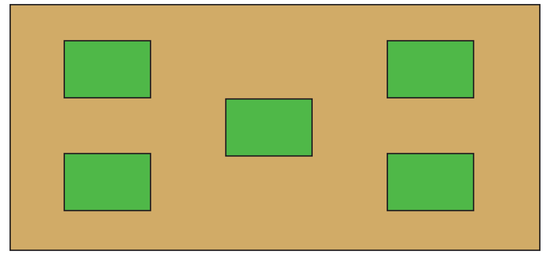
Agro Eco System Analysis (AESA)

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.

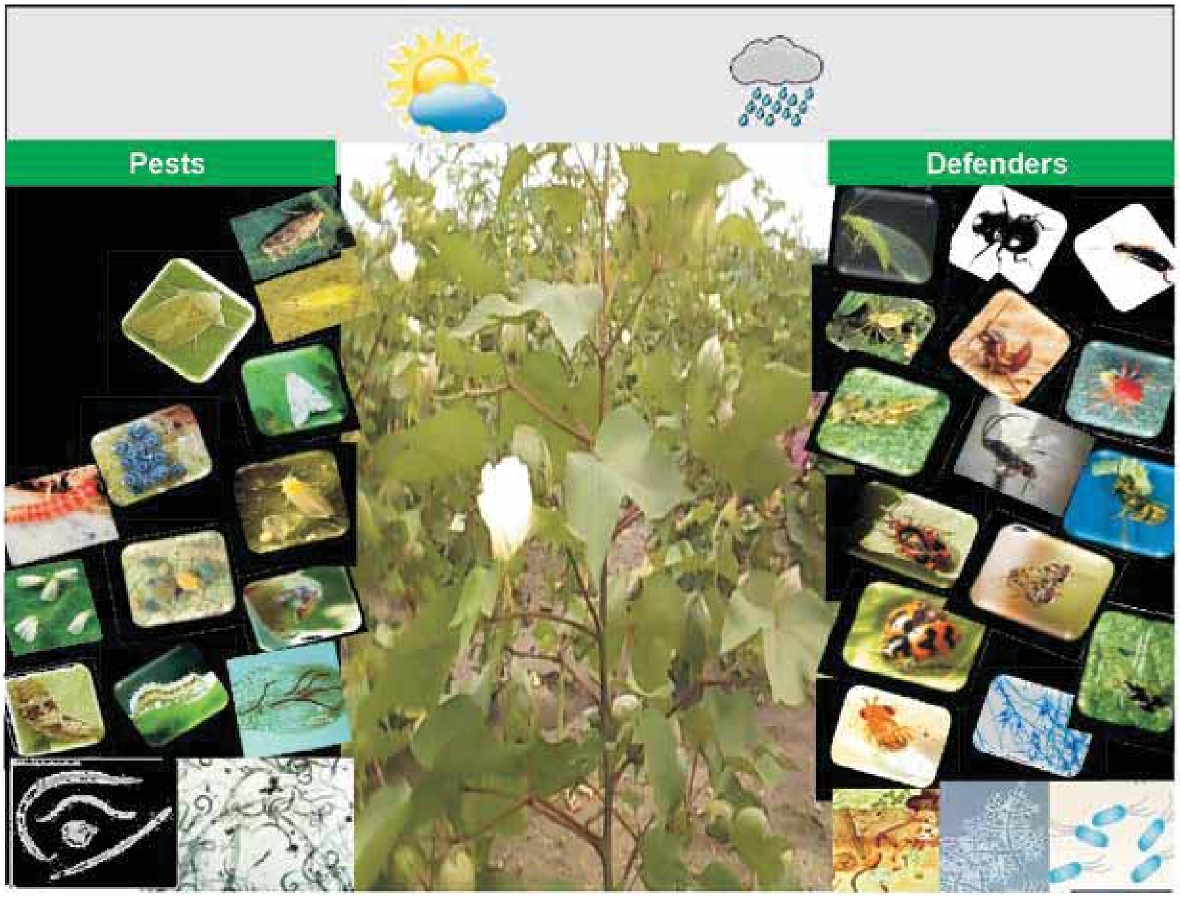
- Each group will then analyze the field situation in detail and present their observations and analysis in a drawing (the AESA drawing as shown in MODEL AESA CHART).
- Each drawing will show a plant representing the field situation. The weather condition, water level, disease symptoms, etc. will be 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

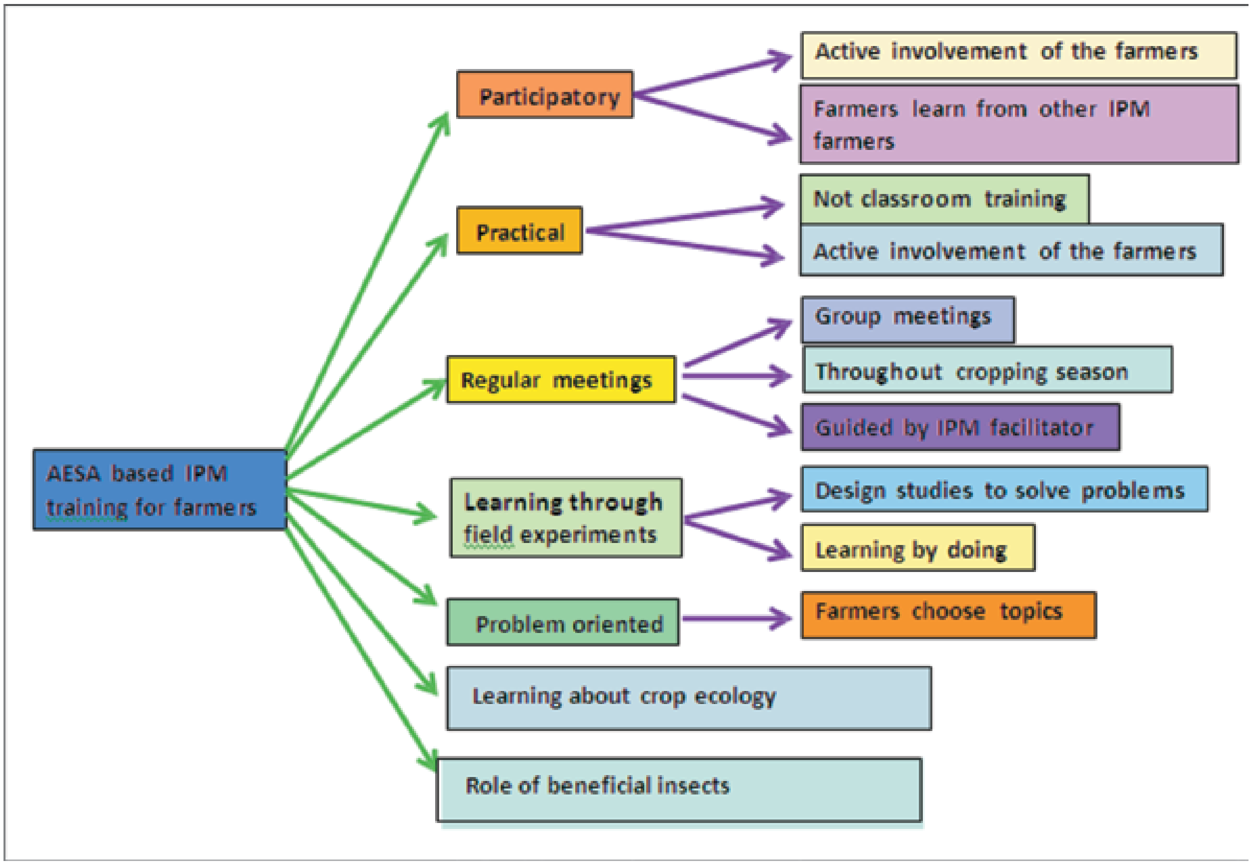
AESA and farmer field school (FFS)

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

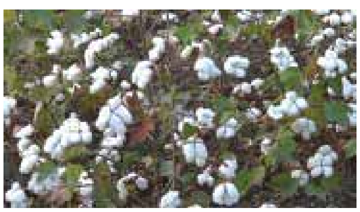

Sunflower


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".

Annexure –I

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** (spider-lings /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

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}.

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

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:

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

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

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:

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

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

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 m u c h liters of Hexaconazole is required?
Liters of 5 % Hexaconazole required = $\dfrac{2 \times 10000}{5 \times 100} = 40 \text{ L}$

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

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

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?

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

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 :

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

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?

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

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?

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

ANNEXURE-XIII

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 को पदार्थों के साथ यहाँ–वहाँ न ले जाएं
ताला चाबी लगा कर रखें
बच्चों की पहुच से दूर रखें
मूल पैंकिंग वाले कीटनाशक ही खरीदे
इस्तेमाल से पहले लेबल और पुस्तिका पढे
सुरक्षात्मक कपड़े पहने।
सुझाई गई मात्रा को सही–सही प्रमाण में इस्तेमाल करे।
लकड़ी या पैडल से पानी को अच्छी तरह मिलाए
कुप्पी का इस्तेमाल करते हुए बिना गिराए भरे।
खाद्य पदार्थों या पानी के संग्रह के लिए कीटनाशक के डिब्बें का इस्तेमाल न करे।
हवा की दिशा में ही छिड़काव करें
नौजल को साफ करने के लिए मुंह से हवा भीतर न डालें
छिड़काव करते समय कुछ खाए–पीएं नहीं तथा न ही धुम्रपान करें
रिसाव वाले स्प्रेयर व डस्टर का प्रयोग न करें
यदि गलती से कपड़े व शरीर पर लग जाए तो दूषित कपड़े व शरीर के हिस्से को अच्छी तरह धो डालें
बच्चों को छिड़काव न करने दें
इस्तेमाल किए जाने वाले स्थान पर खाद्य वस्तु न रखें
खाने–पीने या धुम्रपान करने के पहले हाथ व मुंह को धो लें।
विषैला असर दिखाई देने पर प्राथमिक उपचार व डॉक्टर को बुलाए।
डॉक्टर को डिब्बा व पुस्तिका बताएं
तुरंत विशेष चिकित्सा प्राप्त करें
खाली डिब्बें को तोड़–फोड़ कर नष्ट कर दें तथा गाड़ दे
इस्तेमाल के बाद स्नान करे व कपड़े धो लें
वातावरण को दूषित न होने दें
उपचार किए गए खेतों में चेतावनी सूचना लगा दें
कीटनाशकों की विषाक्तता की श्रेणियों के पहचान-चिह्न
अत्यंत विषैला
POISON
अत्यधिक विषैला
POISON
सामान्य रूप से विषैला
DANGER
थोड़ा से विषैला
CAUTION
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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AGS 322- Diseases of field and horticultural crops and their management

1. Diseases of Wheat

Black or stem rust - ***Puccinia graminis tritici***

Symptoms

Symptoms are produced on almost all aerial parts of the wheat plant but are most common on stem, leaf sheaths and upper and lower leaf surfaces. Uredial pustules (or sori) are oval to spindle shaped and dark reddish brown (rust) in color. They erupt through the epidermis of the host and are surrounded by tattered host tissue. The pustules are dusty in appearance due to the vast number of spores produced. Spores are readily released when touched.

Symptoms

As the infection advances teliospores are produced in the same pustule. The color of the pustule changes from rust color to black as teliospore production progresses. If a large number of pustules are produced, stems become weakened and lodge. The pathogen attacks other host (barberry) to complete its life cycle. Symptoms are very different on this woody host. Other spores are Pycnia (spermagonia) produced on the upper leaf surface of barberry which appears as raised orange spots. Small amounts of honeydew that attracts insects are produced in this structure. Aecia, produced on the lower leaf surface, are yellow. They are bell-shaped and extend as far as 5 mm from the leaf surface.

Brown or leaf rust - ***Puccinia triticina (P. recondita)***

Symptom

The most common site for symptoms is on leaf blades, however, sheaths, glumes and awns may occasionally become infected and exhibit symptoms. Uredia are seen as small, circular orange blisters or pustules on the upper surface of leaves.

Symptoms

Orange spores are easily dislodged and may cover clothing, hands or implements. When the infection is severe leaves dry out and die. Since inoculum is blown into a given area, symptoms are often seen on upper leaves first. As plants mature, the orange urediospores are replaced by black teliospores. Pustules containing these spores are black and shiny since the epidermis does not rupture. Yield loss often occurs as a result of infection by *Puccinia recondita* f. sp. *tritici*. Heavy infection which extends to the flag leaf results in a shorter period of grain fill and small kernels.

Yellow or stripe rust - *Puccinia striiformis*

Symptom

Mainly occur on leaves than the leaf sheaths and stem. Bright yellow pustules (Uredia) appear on leaves at early stage of crop and pustules are arranged in linear rows as stripes. The stripes are yellow to orange yellow. The teliospores are also arranged in long stripes and are dull black in colour.

Symptoms

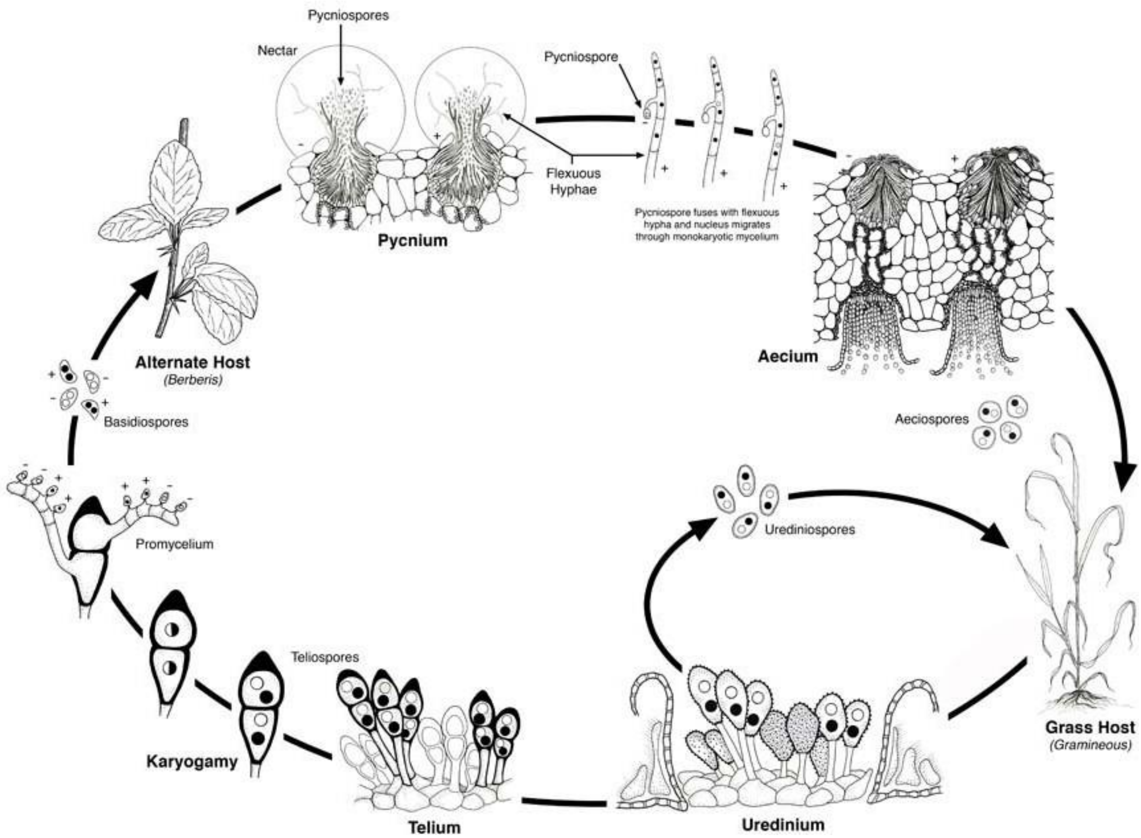
Pathogen

The uredospores of rust pathogen are almost round or oval in shape and bright orange in colour. The teliospores are bright organge to dark brown, two celled and flattened at the top. Sterile paraphyses are also present at the end of sorus.

Disease Cycle

In India, all these rusts appear in wheat growing belt during Rabi crop season. Uredosori turn into teliosori as summer approaches. The inoculum survives in the form of uredospores / teliospores in the hills during off season on self sown crop or volunteer hosts, which provide an excellent source of inoculum. In India, role of alternate host (Barberis) is not there in completing the life cycle.

The fungus is inhibited by temperatures over 20˚C although strains tolerant of high temperatures do exist. The complete cycle from infection to the production of new spores can take as little as 7 days during ideal conditions. The disease cycle may therefore be repeated many times in one season. During late summer, the dark teliospores may be produced. These can germinate to produce yet another spore type, the basidiospore, but no alternate host has been found. Although the teliospores seem to have no function in the disease cycle they may contribute to the development of new races through sexual recombination.



Life cycle of *Puccinia graminis*

Favourable Conditions

- Low temperature (15-20˚C) and high humidity during November – December favour black and brown rusts.
- Temperature less < 10^{o} favours yellow rusts.

Disease cycle

Uredospores and dormant mycelium survive on stubbles and straws and also on weed hosts and self sown wheat crops. Wind borne uredospores from hills are lifted due to cyclonic winds and infect the crop in the plains during crop season.

Management

- Mixed cropping with suitable crops.
- Avoid excess dose of nitrogenous fertilizers.
- Spray Zineb at 2.5 kg/ha or Propioconazole @ 0.1 %.

- Grow resistant varieties like PBW 343, PBW 550, PBW 17

Loose smut - *Ustilago nuda tritici* (*Ustilago tritici*)

Symptoms

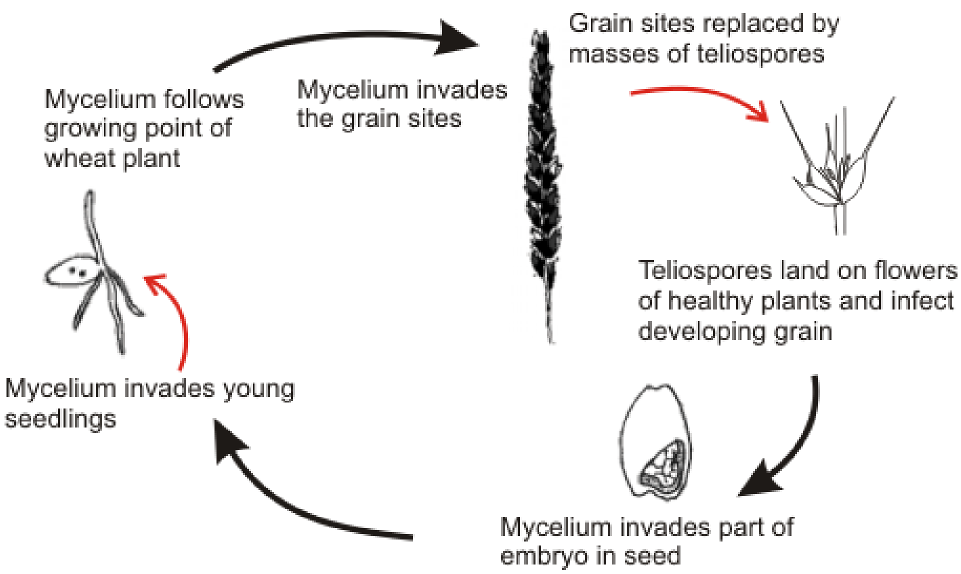
It is very difficult to detect infected plants in the field until heading. At this time, infected heads emerge earlier than normal heads. The entire inflorescence is commonly affected and appears as a mass of olive-black spores, initially covered by a thin gray membrane. Once the membrane ruptures, the head appears powdery.

Symptoms

Spores are dislodged, leaving only the rachis intact. In some cases remnants of glumes and awns may be present on the exposed rachis. Smutted heads are shorter than healthy heads due to a reduction in the length of the rachis and peduncle. All or a portion of the heads on an infected plant may exhibit these symptoms. While infected heads are shorter, the rest of the plant is slightly taller than healthy plants. Prior to heading affected plants have dark green erect leaves. Chlorotic streaks may also be visible on the leaves.

Disease Cycle

Ears of infected plants emerge early. The spores released from the infected heads land on the later emerging florets and infect the developing seed. Infection during flowering is favored by frequent rain showers, high humidity and temperature. The disease is internally seed borne, where pathogen infects the embryo in the seed.



Management

Treat the seed with Vitavax @ 2g/kg seed before sowing. Burry the infected ear heads in the soil, so that secondary spread is avoided.

Flag smut - *Urocystis tritici*

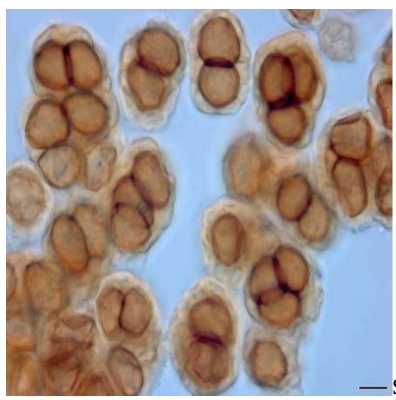
Symptoms

The symptoms can be seen on stem, clum and leaves from late seedling stage to maturity. The seedling infection leads to twisting and drooping of leaves followed by withering. Grey to grayish black sori occurs on leaf blade and sheath. The sorus contains black powdery mass of spores.

Symptoms

Pathogen

Aggregated spore balls, consisting 1-6 bright globose, brown smoth walled spores surrounded by a layer of flat sterile cells.



Spore balls

Favourable Conditions

- Temperature of 18-24˚C.
- Relative humidity 65% and above.

Disease cycle

Seed and soil borne. Smut spores are viable for more than 10 years.

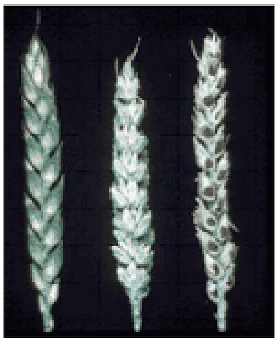
Management

- Treat the seeds with carboxin at 2g /kg.
- Grow resistant varieties like Pusa 44 and WG 377.

Hill bunt or Stinking smut - *Tilletia caries* / *T.foetida*

Symptoms

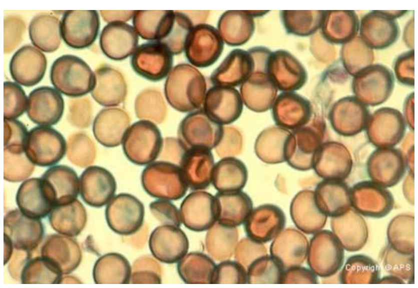
The fungus attacks seedling of 8-10 days old and become systemic and grows along the tip of shoot. At the time of flowering hyphae concentrate in the inflorescence and spikelets and transforming the ovary into smut sorus of dark green color with masses of chlamydospores. The diseased plants mature earlier and all the spikelets are affected.

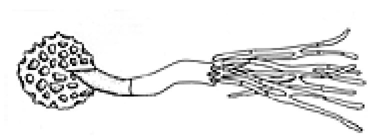


Symptoms on earhead and grains

Pathogen

Reticulate, globose and rough walled. No resting period. Germinate to produce primary sporidia which unite to form 'H' shaped structure.

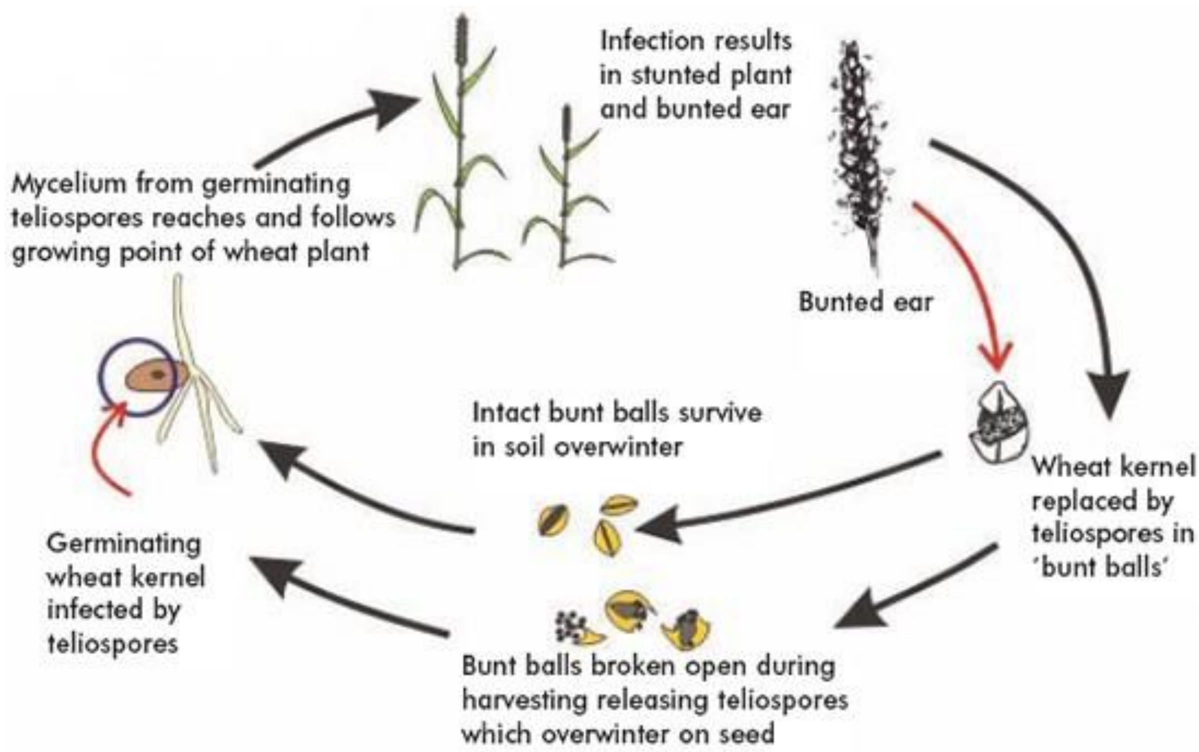




Spores and its germination

Life cycle

The spores on the seed surface germinate along with the seed. Each produces a short fungal thread terminating in a cluster of elongated cells. These then produce secondary spores which infect the coleoptiles of the young seedlings before the emergence of the first true leaves. The mycelium grows internally within the shoot infecting the developing ear. Affected plants develop apparently normally until the ear emerges when it can be seen that grain sites have been replaced by bunt balls. In India disease occurs only in Northern hills, where wheat is grown.



Favourable Conditions

- Temperature of 18-20˚C.
- High soil moisture.

Disease cycle

Externally seed borne

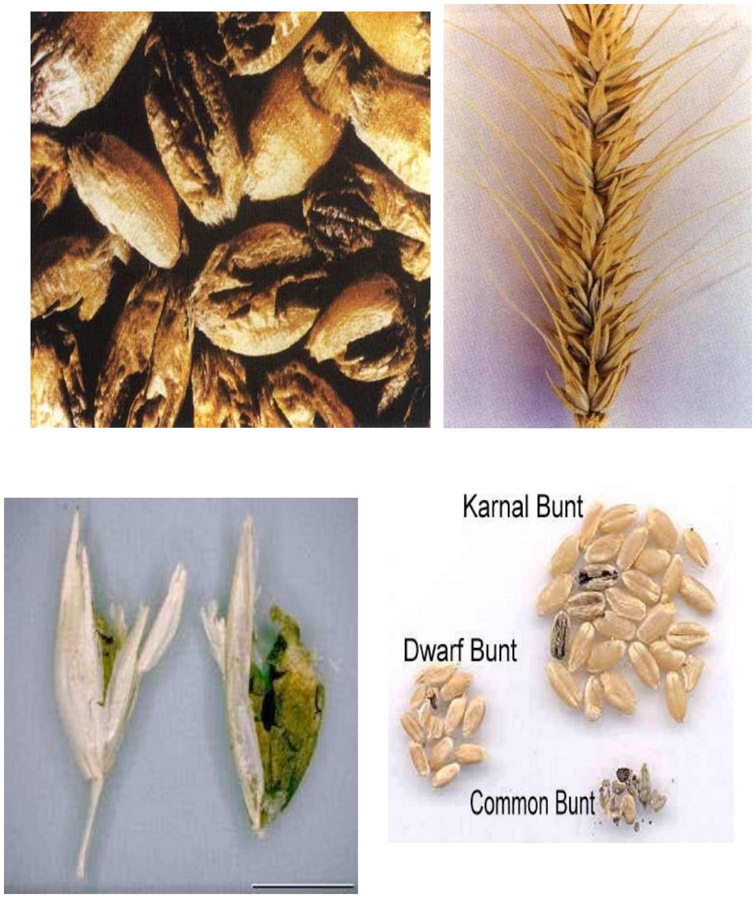
Management

- Treat the seeds with carboxin or carbendazim at 2g/kg.
- Grow the crop during high temperature period.
- Adopt shallow sowing.
- Grow resistant varieties like Kalyan sona, S227, PV18, HD2021, HD4513 and HD4519.

Karnal bunt - *Neovassia indica*

Symptoms

Symptoms of Karnal bunt are often difficult to distinguish in the field due to the fact that incidence of infected kernels on a given head is low. There may be some spreading of the glumes due to sorus production but it is not as extensive as that observed with common bunt. Symptoms are most readily detected on seed after harvest.



Symptoms

The black sorus, containing dusty spores is evident on part of the seed, commonly occurring along the groove. Heavily infected seed is fragile and the pericarp ruptures easily. The foul, fishy odor associated with common bunt is also found with karnal bunt. The odor is caused by the production of trimethylamine by the fungus. Seed that is not extensively infected may germinate and produce healthy plants.

Foot rot - *Pythium graminicolum* and *P. arrhenomanes*

Symptoms

The disease mainly occurs in seedlings and roots and rootlets become brown in colour. Seedlings become pale green and have stunted growth. Fungus produces sporangia and zoospores and oospores.

Favourable Conditions

Wet weather and high rainfall.

Disease cycle

Through soil and irrigation water.

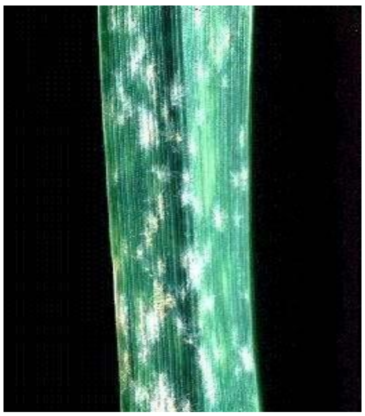
Management

- Follow crop rotation.
- Treat the seeds with Carboxin or Carbendazim at 2g/kg.

Powdery mildew - *Erysiphe graminis var. tritici*

Symptoms

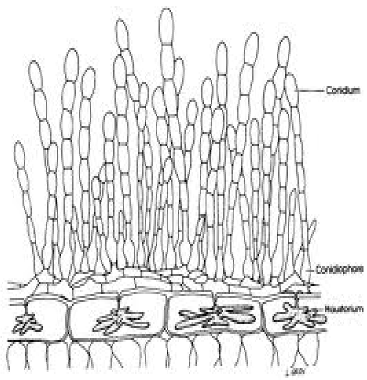
Greyish white powdery growth appears on the leaf, sheath, stem and floral parts. Powdery growth later become black lesion and cause drying of leaves and other parts.



Symptoms

Pathogen

Fungus produces septate, superficial, hyaline mycelium on leaf surface with short conidiophores. The conidia are elliptical, hyaline, single celled, thin walled and produced in chains. Dark globose cleistothecia containing 9-30 asci develop with oblong, hyaline and thinwalled ascospores.



Conidia and conidiophores

Disease cycle

Fungus remains in infected plant debris as dormant mycelium and asci. Primary spread is by the ascospores and secondary spread through airborne conidia.

Favourable Conditions

- Temperature of 20-21˚C.

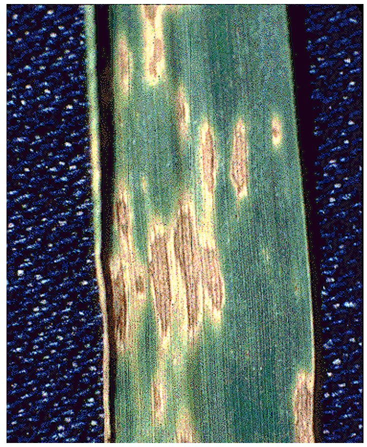
Management

- Spray Wettable Sulphur 0.2% or Carbendazim @ 500 g/ha

Leaf blight - *Alternaria triticina* / *Bipolaris sorokiniana*

Symptoms

Reddish brown oval spots appear on young seedlings with bright yellow margin. In severe cases, several spots coalesce to cause drying of leaves. It is a complex disease, having association of *A.triticina*, *B.sorokiniana* and *A. alternate.*



Symptoms

Disease cycle

Primary spread is by externally seed-borne and soil borne conidia. Secondary spread by air-borne conidia.

Favourable Conditions

- Temperature of 25˚C and high relative humidity.

Management

- Spray the crop with Mancozeb or Zineb at 2 kg/ha.

Other minor diseases

Helminthosporium leaf spot: *Helminthosporium* spp.

Tundu or yellow ear rot: *Corynebacterium tritici* + *Anguina tritici*

Seedling blight: *Rhizoctonia solani* and *Fusarium* sp

Sclerotinia rot: *Sclerotinia sclerotiorum*

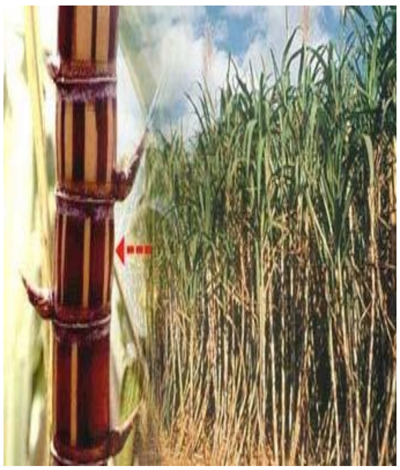
Molya disease: *Heterodera avenae* (Nematode)

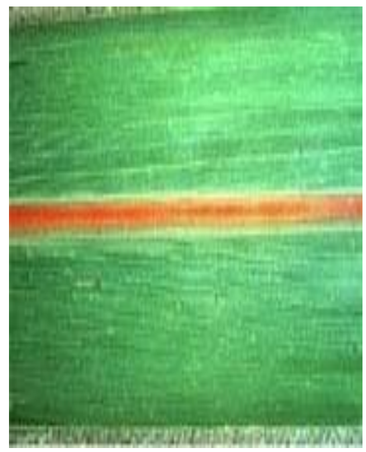
2. Diseases of Sugarcane

Red rot - *Colletotrichum falcatum* (Perfect stage: *Physalospora tucumanensis*)

Symptoms

The first external symptom appears mostly on third or fourth leaf which withers away at the tips along the margins. Typical symptoms of red rot are observed in the internodes of a stalk by splitting it longitudinally. These include the reddening of the internal tissues which are usually elongated at right angles to the long axis of the stalk. The presence of cross-wise white patches are the important diagnostic character of the disease. The diseased cane also emits acidic-sour smell. As the disease advances, the stalk becomes hollow and covered with white mycelial growth.



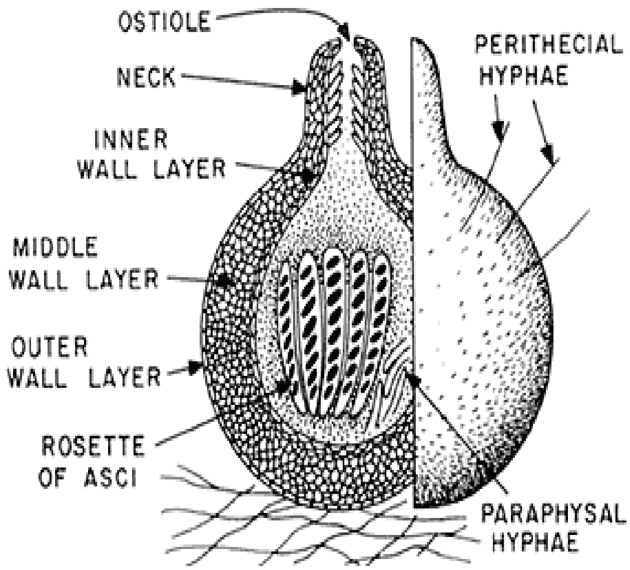


Symptoms

Later the rind shrinks longitudinally with minute black, velvetty fruiting bodies protruding out of it. The pathogen also produces tiny reddish lesions on the upper surface of leaves with dark dots in the centre. The lesions are initially blood red with dark margins and later on with straw coloured centres. Often the infected leaves may break at the lesions and hang down, with large number of minute black dots.

Pathogen

The fungus produces thin, hyaline, septate, profusely branched hyphae containing oil droplets. The fungus produces black, minute velvetty acervuli with long, rigid bristle-like, septate setae. Conidiophores are closely packed inside the acervulus, which are short, hyaline and single celled. The conidia are single celled, hyaline, falcate, granular and guttulate. Fungus also produces large number of globose and dark brown to black perithecia with a papillate ostiole.



Asci are clavate, unitunicate and eight-spored. Large number of hyaline, septate, filiform paraphyses is also present among asci. Ascospores are ellipsoid or fusoid, hyaline, straight or slightly curved and unicellular which measure 18-22 µm x 7-8µm.

Favourable Conditions

- Monoculturing of sugarcane.
- Successive ratoon cropping.
- Water logged conditions and injuries caused by insects.

Disease cycle

The fungus is sett-borne and also persists in the soil on the diseased clumps and stubbles as chlamydospores and dormant mycelium. The primary infection is mainly from infected setts. Secondary spread in the field is through irrigation water and cultivation tools. The rain splash, air currents and dew drops also help in the spread of conidia from the diseased to healthy plants in the field. The fungus also survives on collateral hosts *Sorghum vulgare*, *S. halepense* and *Saccharum spontaneum*.If the conidia settle on the leaves they may germinate and invade the leaves through various types of wounds. Stem infection may take place through insect bores and root primordia. The soil-borne fungus may also enter the healthy setts through cut-ends, and cause early infection of the shoots. Though the perfect stage of the fungus has been observed in nature, the role of ascospores in the disease cycle is not understood.

Management

- Adopt crop rotation by including rice and green manure crops.
- Select the setts from the disease free fields or disease free areas.
- Aviod ratooning of the diseased crop.
- Soak the setts in 0.1% Carbendazim or Triademefon 0.05% solution for 15 minutes before planting.
- Grow resistant varieties CO 62198, CO 7704 and moderately resistant varieties CO 8001, CO8201.
- Setts can be treated with aerated steam at 52 ˚C for 4 to 5 hours and by moist hot air at 54˚C for 2 hours.

Smut - *Ustilago scitaminea*

Symptoms

It is a culmiculous smut. The affected plants are stunted and the central shoot is converted into a long whip-like, dusty black structure. The length of the whip varies from few inches to several feet. In early stages, this structure is covered by a thin, white papery membrane. The whip may be straight or slightly curved.

On maturity it ruptures and millions of tiny black smut spores (teliospores) are liberated and disseminated by the wind. Affected plants are usually thin, stiff and remain at acute angle. The whip like structure, representing the central shoot with its various leaves, may be produced by each one of the shoots/tillers arising from the clump.


Symptoms

The smutted clumps also produce mummified arrows in which lower portion consisted of a normal inflorescence with typical flowers and the upper portion of the rachis is converted into a typical smut whip. Occasionally smut sori may develop on the leaves and stem.

Pathogen

The fungal hyphae are primarily intercellular and collect as a dense mass between the vascular bundles of host cell and produce tiny black spores. The thin membrane which covers the smut whip represents the host epidermis. The smut spores are light brown in colour, spherical, echinulated and measuring 6.5- 8.5µm in diameter. Smut spores germinate to produce 3-4 celled, hyaline promycelium and produce 3-4 sporidia which are hyaline and oval shaped with pointed ends.

Favourable Conditions

- Monoculturing of sugarcane.
- Continuous ratooning and dry weather during tillering stage.

Disease cycle

Teliospores may survive in the soil for long periods, upto 10 years. The spores and sporidia are also present in the infected plant materials in the soil. The smut spores and dormant mycelium also present in or on the infected setts. The primary spread of the disease is through diseased seed-pieces (setts). In addition, sporidia and spores present in the soil also spread through rain and irrigation water and cause soil-borne infection. The secondary spread in the field is mainly through the smut spores developed in the whips, aided by air currents. The fungus also survives on collateral hosts like *Saccharum spontaneum*, *S. robustum*, *Sorghum vulgare*, *Imperata arundinacea* and *Cyperus dilatatus*.

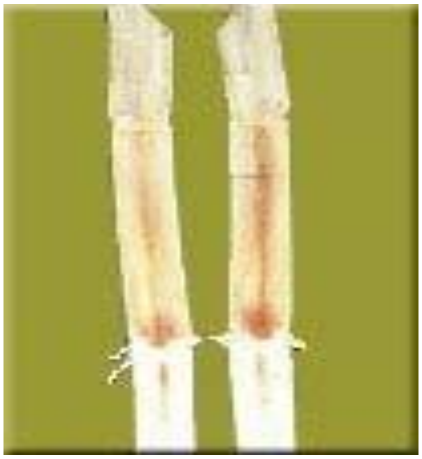
Management

- Plant healthy setts taken from disease free area.
- Remove and destory the smutted clump (collect the whips in a thick cloth bag/polythene bag and immerse in boiling water for 1 hr to kill the spores).
- Discourage ratooning of the diseased crops having more than 10 per cent infection.
- Follow crop rotation with green manure crops or dry fallowing.
- Grow redgram as a companion crop between 2 rows of sugarcane.
- Grow resistant varieties like Co 7704 and moderately resistant varieties COC 85061 and COC 8201.

Sett rot or Pineapple disease - *Ceratocystis paradoxa*

Symptoms

The disease primarily affects the setts usually two to three weeks after planning. The fungus is soil-borne and enters through cut ends and proliferates rapidly in the parenchymatous tissues. The affected tissues first develop a reddish colour which turns to brownish black in the later stages. The severely affected setts show internodal cavities covered with the mycelium and abundant spores. A characteristic pineapple smell is associated with the rotting tissues. The setts may decay before the buds germinate or the shoots may die after reaching a height of about 6-12 inches. Infected shoots are stunted.

Symptoms

Pathogen

The fungus produces both macroconidia and microconidia. Conidiophores are linear, thin walled with short cells at the base and a long terminal cell. The microconidia are hyaline when young but become almost black at maturity. They are thinwalled, cylindrical and produced endogenously in chains in the long cells of conidiophores and pushed out in succession. Macroconidia are produced singly or in chains on a short, lateral conidiophores. Macroconidia are spherical or elliptical or truncate or pyriform and are hyaline to olive green or black measuring 16-19x10-12 um.

The fungus also produces chlamydospores on short lateral hyphae in chains, which are oval, thick walled and brown in colour. The perithecia are flask shaped with a very long neck. The bulbous base of the perithecium is hyaline or pale yellow, 200-300µm in diameter and ornamented with irregularly shaped, knobbed appendages. The ostiole is covered by numerous pale-brown, erect tapering hyphae. Asci are clavate and measures 25x10µm and ascospores are single celled, hyaline, ellipsoid, more convex on one side, measures 7-10 x 2.5-4µm.

Favourable Conditions

- Poorly drained fields.
- Heavy clay soils
- Temperature of 25-30^{o}C
- Prolonged rainfall after planting.

Disease Cycle

The fungus survives as conidia and chlamydospores in the soil and in the infected, burried cane tissues. The inoculum moves from field to field through wind-borne conidia or irrigation or rain water. Inside the sett it spreads rapidly through the parenchymatous tissues and causes sett rot.

The insects like cane borer *(Diatraea dyari)* also helps in the spread of the disease. The pathogen also survives on coconut, cocoa, mango, papaya, coffee, maize and arecanut. Insects also play a part in the dissemination of the pathogen.

Management

- Soak the setts in 0.05% Carbendazim 15 minutes.
- Use long setts having 3 or 4 buds.
- Provide adequate drainage during rainy seasons.

Wilt - *Cephalosporium sacchari*

Symptoms

The first symptom of the disease is visible in the canes of 4-5 month age. The canes may wither in groups. The affected plants are stunted with yellowing and withering of crown leaves. The midribs of all leaves in a crown generally turn yellow, while the leaf lamina may remain green. The leaves dry up and stem develop hollowness in the core. The core shows the reddish discolouration with longitudinal red streaks passing from one internode to another. In severe cases, spindle shaped cavities tapering towards the nodes develop in each internode. The canes emit a disagreeable odour, with lot of mycelial threads of the fungus cover the cavity.

Pathogen

The fungal mycelium is hyaline, septate and thin walled. The conidiophores are simple or branched and produce single celled, hyaline, oval to elliptical microconidia.

Favourable Conditions

- High day temperature (30-35˚C).
- Low humidity (50-60%).
- Low soil moisture and alkaline soils.
- Excess doses of nitrogenous fertilizers.

Disease Cycle

The fungus is soil-borne and remains in the soil as saprophyte for 2-3 years. The disease is primarily transmitted through infected seed pieces. The secondary spread is aided by wind, rain and irrigation water.

Management

- Select the seed material from the disease-free plots.
- Avoid the practice of ratooning in diseased fields.
- Burn the trashes and stubbles in the field.
- Grow coriander or mustard as a companion crop in the early stages of crop.
- Dip the setts in 40ppm Boran or Manganese for 10 minutes or in 0.25% Emisan or 0.05% Carbendazim for 15 minutes.

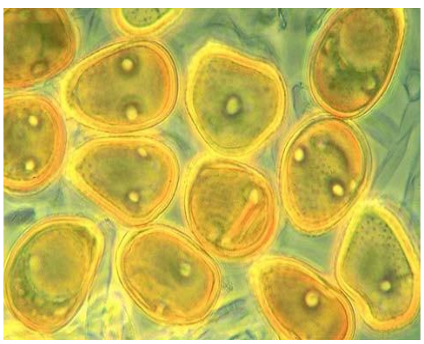
Rust - *Puccinia erianthi* *(*Syn: *P. melanocephala* and *P. kuehnii)*

Symptoms

Minute, elongated, yellow spots (uredia), usually 2-10 x 1-3 mm appear on both the surfaces of young leaves. The pustules turn to brown on maturity. Late in the season, dark brown to black telia appear on the lower surface of leaves. In seversе cases, the uredia also appear on the leaf sheath and the entire foliage looks brownish from a distance.

Pathogen

The mycelium is hyaline, branched and septate. *P.kuehnii* produces ovoid or pear shaped, single celled uredospores measuring 29-57 x 8-37µm with apical thickening and golden yellow in colour. Teliospores are produced in scanty which are yellow in colour, club shaped, two celled, smooth walled and measuring 24- 34 X 18-25µm single celled, dark yellow coloured with 4 equatorial pores.



Uredospores

Teliospores are produced in abundance, which are pale to brick colour, two celled, smooth walled and slight septum. Occurrence of pycnial and aecial stages and the role of alternate host are unknown.

Favourable Conditions

- Temperature of 30˚C.
- Rumidity between 70 and 90 per cent.
- High wind velocity and continuous cloudiness.

Disease Cycle

The fungus survives on collateral hosts like *Erianthus fulvus* and *Saccharum spontaneum*. The uredospores also survive in the infected stubbles in the soil. The disease is mainly spread through air-borne uredospores.

Management

- Remove the collateral hosts.
- Spray Tridemorph 1 kg or Mancozeb 2 kg/ha.

Gummosis - *Xanthomonas axonopodis* pv. *vasculorum*

Symptoms

The bacterium produces two distinct types of symptoms. On the mature leaves, longitudinal stripes or streaks, 3-7mm in width and several cm in length, appear around the affected veins, near the tip. Initially these stripes are pale yellow in colour, later turn to brown. The affected tissues slowly dry up.

The infected canes are stunted with short internodes, giving a bushy appearance. When such canes are cut transversely or split open longitudinally, a dull yellow bacterial ooze comes out from the cut ends and bacterial pockets are seen inside the slitted cane. The fibro vasuclar bundles are deep red and internodal cavities formed in the severe cases are filled with yellow coloured bacterial gums.

Pathogen

The bacterium is a short rod, Gram negative, non spore forming measuring 1.0 to 1.5µm X 0.4 to 0.5µm, with a single polar flagellum. It is facultative anaerobe and it produces yellow slimy growth.

Disease Cycle

The bacterium remains viable in the soil as well as in infected canes. The primary transmission is through naturally affected diseased setts or through soil-borne contamination. The secondary spread may be through wind splashed rain, harvesting implements, animals and insects. The bacterium can survive in the insect's body for a long time and in this way may be transmitted long distances. On entry into the host the bacterium reaches the vascular tissues and becomes systemic. The bacterium also perpetuates on maize, sorghum, pearlmillet and other weed hosts, which also serve as sources of inoculum.

Management

- Remove and burn the affected clumps and the stubbles in the field. Select setts from disease free areas.

- Avoid growing collateral hosts like maize, sorghum and pearlmillet near the sugarcane fields.

Red stripe - *Pseudomonas rubrilineans*

Symptoms

The disease first makes it appearance on the basal part of the young leaves. The stripes appear as water soaked, long, narrow chlorotic streaks and become reddish brown in few days. These stripes are 0.5 to 1 mm in width and 5-100 mm in length, run parallel to the midrib. The stripes remain confined to lower half of the leaf lamina and whitish flakes spreads to growing points of the shoot and yellowish stripes develop, which later turn reddish brown. The rotting may commence from the tip of the shoot and spreads downwards. The core is discoloured to reddish brown and shrivelled and form cavity in the centre. In badly affected fields, a foul and nauseating smell appears.

Symptoms

Pathogen

The bacterium is a short rod (0.7 X 1.67µm), gram negative, non capsulate with a polar flagellum.

Favourable Conditions

- Continuous ratooning and prolonged rainy weather with low temperature (25^0 C)

Disease cycle

The pathogen remains viable in the soil and infected plant residues. The bacterium also survives on sorghum, pearlmillet, maize, fingermillet and other species of *Saccharum*. The bacterium primarily spreads through infected canes. The secondary spread is mainly through rainsplash, irrigation water and insects. Infected parenchymatous cells may collapse and normal functioning of the plant parts may fail. Several grasses, including ragi and bajra, have been reported to be infected by the bacteria and these hosts may also play a role in the perpetuation and spread of the pathogen.

Management

- Whenever the disease is noticed; the affected plants should be removed and burnt.
- Growing resistant varieties Select setts from the healthy fields.
- Avoid growing collateral hosts near the sugarcane fields.

Sugarcane Mosaic - *Sugarcane mosaic potyvirus*

Symptoms

The disease appears more prominently on the basal portion of the younger foliage as chlorotic or yellowish stripes alternate with normal green portion of the leaf. As infection becomes severe, yellow stripes appear on the leaf sheath and stalks. Elongated necrotic lesions are produced on the stalks and stem splitting occurs. The necrotic lesions also develop on the internodes and the entire plant becomes stunted and chlorotic.

Symptoms

Pathogen

Sugarcane mosaic potyvirus is a flexous rod, 650-770nm long X 12-15nm with ss RNA genome.

Disease cycle

The virus is mainly transmitted through infected canes used as seed. The virus also infects *Zea mays* and a number of other cereals (*Sorghum vulgare*, *Pennisetum americanum*, *Eleusine indica*, *Setaria lutescens*, *Echinochloa crusgalli*, *Stenotaphrum secondatum*, *Digitaria didactyla*) which serve as potential sources of virus inoculum. The virus also spreads through viruliferous aphids *viz*., *Melanaphis sacchari*, *Rhopalosiphum maidis* in a non-persistant manner. The virus is also sap-transmissible. The incubation period varies from 7 to 20 days, depending upon the host variety and virus strain. The symptoms may be prominent or masked depending on the environmental conditions and variety.

Management

- Roguing of infected plants and use of disease free planting material.
- Chemical sprays to manage the insect vector population in early crop stage.
- G row mosaic-resistant or, at least, tolerant varieties.
- Breeding mosaic-resistant varieties is needed.
- *Saccharum spontaneum* L. and *S. barberi* (Jesweit) carry resistance to mosaic and so varieties with this background must be preferred.
- Rogue out the diseased clumps periodically. Select setts from the healthy fields as the virus is sett-borne Aerated Steam Therapy (AST) at 56˚C for 3 hrs, for setts before planting is advised.

Grassy shoot - *Phytoplasma*

Symptoms

The disease appears nearly two months after planting. The disease is characterised by the production of numerous lanky tillers from the base of the affected shoots. Leaves become pale yellow to completely chlorotic, thin and narrow. The plants appear bushy and 'grass-like' due to reduction in the length of internodes premature and continuous tillering. The affected clumps are stunted with premature proliferation of auxillary buds. Cane formation rarely occurs in the affected clumps, if formed, thin with shorter internodes having aerial roots at the lower nodes. The buds on such canes usually papery and abnormally elongated.

Pathogen

The disease is caused by a phytoplasma. Two types of bodies are seen in ultrathin sections of phloem cells of infected plants. The spherical bodies of 300-400 nm diameter and filamentous bodies of 30-53 mm diameter in size.

Disease cycle

The primary spread of the phytoplasma is through diseased setts and cutting knifes. The pathogen is transmitted secondarily by aphids *viz*., *Rhopalosiphum maydis, Melanaphis sacchari* and *M. idiosacchari.* Sorghum and maize serves as natural collateral hosts.

Management

- Eradication of diseased parts as soon as symptoms are seen.
- Avoid selection of setts from diseased area.
- Pre-treating the healthy setts with hot water at 52°C for 1 hour before planting
- Treating them with hot air at 54°C for 8 hours.
- Spraying the crop twice a month with insecticides.

Ratoon stunting - *Clavibacter xyli* sub sp. *xyli* (Rickettsia Like Organism - RLO)

Symptoms

Diseased clumps usually display stunted growth, reduced tillering, thin stalks with shortened internodes and yellowish foliage. Orange-red vascular bundles in shades of yellow at the nodes are seen in the infected canes.

Symptoms

Pathogen

The pathogen (*Clavibacter xyli* sub sp. *xyli*) is a RLO known to be present in the xylem cells of infected plants. They are small, thin, rod shaped or coryneform (0.15 to 0.32µm wide and 1.0-2.7µm long) and Gram positive.

Disease cycle

The primary spread is through the use of diseased setts. The disease also spreads through harvesting implements contaminated with the juice of the diseased canes. Maize, sorghum, Sudan grass and *Cynodon* serves as collateral hosts for the pathogen.

Management

- Select the setts from disease free fields or from disease free commercial nursery.
- Remove and burn the clumps showing the disease incidence.
- Treat the setts before planting, as specified for grassy shoot disease.

Minor diseases

Damping-off - *Pythium aphanidermatum*, *P. debaryanum*. *P. graminicola*. *P.ultimum*

Germinating seeds and young seedlings are attacked and killed in pre-emergence phase and seedlings show water soaked lesions at collar region, leading to withering and drying in post emergence stage.

Downy mildew - *Peronosclerospora sacchari*

Downy fungal growth with yellow stripes on upper surface, shredding of older leaves, rapid elongation of internodes of affected canes.

Eye spot - *Helminthosporium sacchari*

The water soaked spot develops on leaves, later elongated and turns to form “eye” shaped spot with reddish brown centre surrounded by straw yellow tissues.

Ring spot –*Leptosphaeria sacchari*

The water soaked spots appear on leaves and turns to straw colour later surrounded by a thin reddish brown band and a diffused discolouration zone.

Leaf scald - *Xanthomonas albilineans*

Whitish lines appear on the leaves, run to the full length of leaves and sheaths. Later leaves wither and dry from tip down-wards, gives a scald appearance to the clump. Sprouting of lateral buds of the matured canes occurs in acropetal fashion.

White leaf - *Phytoplasma*

Sugarcane white leaf is of minor importance and is caused by phytoplasma. The plants exhibit pure white leaves, stripped leaves and mottled leaves. Its vector is *Matsumuratettix hiroglyphicus*.

3. Diseases of Turmeric

Leaf Spot - *Colletotrichum capsici*

Symptoms

Oblong brown spots with grey centres are found on leaves. The spots are about 4-5 cm in length and 2-3 cm in width. In advanced stages of disease black dots representing fungal acervuli occur in concentric rings on spot. The grey centers become thin and gets teared. Severely effected leaves dry and wilt. They are surrounded by yellow halos. Indefinite number of spots may be found on a single leaf and as the disease advances; spots enlarge and cover a major portion of leaf blade.

Symptoms

Favorable condition

- The disease is usually appears in October and November
- Relative humidity of 80% and temperatures of 21 – 230C favours the primary infection

Disease cycle

The fungus is carried on the scales of rhizomes which are the source of primary infection during sowing. The secondary spread is by wind, water and other physical and biological agents. The same pathogen is also reported to cause leaf-spot and fruit rot of chilli where it is transmitted through seed borne infections. If chilli is grown in nearby fields or used in crop rotation with turmeric, the pathogen perpetuates easily, building up inoculum potential for epiphytotic outbreaks.

Management

- Select seed material from disease free areas.
- Treat seed material with mancozeb @ 3g/litre of water or carbendazim @ 1 g/litre of water, for 30 minutes and shade dry before sowing.
- Spray mancozeb @ 2.5 g/litre of water or carbendazim @ 1g/litre; 2-3 sprays at fortnightly intervals.
- The infected and dried leaves should be collected and burnt in order to reduce the inoculum source in the field.
- Spraying Blitox or Blue copper at 3 g/l of water was found effective against leaf spot.
- Crop rotations should be followed whenever possible.
- Cultivate tolerant varieties like Suguna and Sudarshan.

Leaf Blotch -*Taphrina maculans*

Symptoms

This disease usually appears on lower leaves in October and November. The individual spots are small 1-2 mm in width and are mostly rectangular in shape. The disease is characterized by the appearance of several spots on both the surfaces of leaves, being generally numerous on the upper surface. They are arranged in rows along the veins. The spots coalesce freely and form irregular lesions. They first appear as pale yellow discolorations and then become dirty yellow in colour. The infected leaves disort and have reddish brown appearance.

Symptoms

Disease cycle

The fungus is mainly air borne and primary infection occurs on lower leaves with the inoculum surviving in dried leaves of host, left over in the field. The ascospores discharged from successively maturing asci infect fresh leaves without dormancy, thus causing secondary infection. Secondary infection is most dangerous than primary one causing profuse sprouting all over the leaves. The pathogen persists in summer by means of ascogenous cells on leaf debris, and dessicated ascospores and blastospores in soil and among fallen leaves.

Management

- Select seed material from disease free areas.
- Treat the seed material with Mancozeb @ 3g/litre of water or Carbendazim @ 1 g/litre of water for 30 minutes and shade dry before sowing.
- Spray mancozeb @ 2.5 g/litre of water or Carbendazim @ 1g/litre; 2-3 sprays at fortnightly intervals.
- The infected and dried leaves should be collected and burnt in order to reduce the inoculum source in the field.
- Spraying Cpper oxy chloride at 3 g/l of water was found effective against leaf blotch.
- Crop rotations should be followed whenever possible.

Minor diseases

a. Dry rot	-	*Rhizoctonia bataticola*
b. Leaf spot	-	*Cercospora curcuma*
c. Leaf Blight	-	*Rhizoctonia solani*
d. Brown rot	-	It is a complex disease caused by the nematode *Pratylenchus* sp. associated with *Fusarium* sp

4. Diseases of Sunflower

Leaf blight - *Alternaria helianthi*

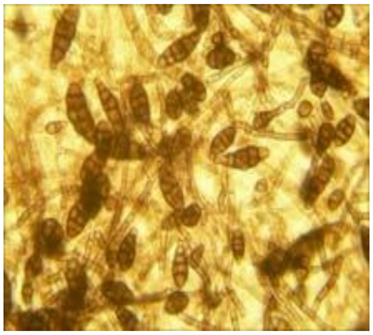
Symptoms

The pathogen produces brown spots on the leaves, but the spots can also be seen on the stem, sepals and petals. The lesions on the leaves are dark brown with pale margin surrounded by a yellow halo. The spots later enlarge in size with concentric rings and become irregular in shape. Several spots coalesce to show bigger irregular lesions leading to drying and defoliation.

Symptoms

Pathogen

The pathogen produces cylindrical conidiophores, which are pale grey-yellow coloured, straight or curved, geniculate, simple or branched, septate and bear single conidium. Conidia are cylindrical to long ellipsoid, straight or slightly curved, pale grey-yellow to pale brown, 1 to 2 septate with longitudinal septa.



Favourable Conditions

- Rainy weather.
- Cool winter climate.
- Late sown crops are highly susceptible.

Disease cycle

The fungus survives in the infected host tissues and weed hosts. The fungus is also seed-borne. The secondary spread is mainly through wind blown conidia.

Management

- Deep summer ploughing.
- Proper spacing
- Clean cultivation and field sanitation.
- Use of resistant or tolerant variety like B.S.H.1 .
- Application of well rotten manures.
- Practicing crop rotation.
- Planting in mid-September.
- Remove and destroy the diseased plants
- Treat the seeds with Thiram or Carbendazim at 2 g/kg. Spray Mancozeb at 2 kg/ha.

5. Diseases of Cotton

Wilt - *Fusarium oxysporum* f.sp. *vasinfectum*

Symptoms

The disease affects the crop at all stages. The earliest symptoms appear on the seedlings in the cotyledons which turn yellow and then brown. The base of petiole shows brown ring, followed by wilting and drying of the seedlings. In young and grown up plants, the first symptom is yellowing of edges of leaves and area around the veins i.e. discoloration starts from the margin and spreads towards the midrib. The leaves loose their turgidity, gradually turn brown, droop and finally drop off.

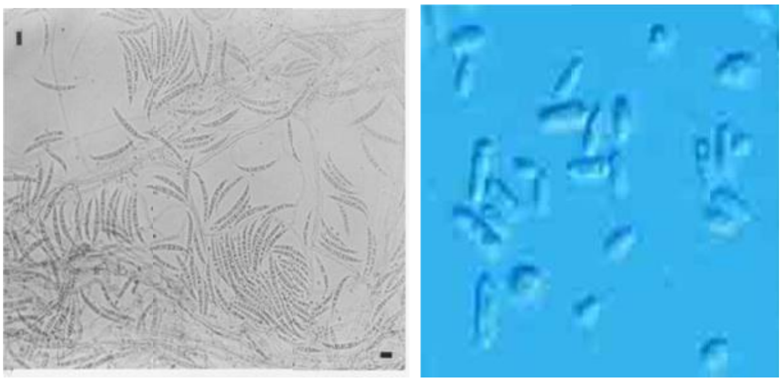
Symptoms start from the older leaves at the base, followed by younger ones towards the top, finally involving the branches and the whole plant. The defoliation or wilting may be complete leaving the stem alone standing in the field. Sometimes partial wilting occurs; where in only one portion of the plant is affected, the other remaining free. The taproot is usually stunted with less abundant laterals.

oms

Browning or blackening of vascular tissues is the other important symptom, black streaks or stripes may be seen extending upwards to the branches and downwards to lateral roots. In severe cases, discolouration may extend throughout the plant starting from roots extending to stem, leaves and even bolls. In transverse section, discoloured ring is seen in the woody tissues of stem. The plants affected later in the season are stunted with fewer bolls which are very small and open before they mature.

Pathogen

Macroconidia are 1 to 5 septate, hyaline, thin walled, falcate with tappering ends. The microconidia are hyaline, thin walled, spherical or elliptical, single or two celled. Chlamydospores are dark coloured and thick walled. The fungus also produces a vivotoxin, Fusaric acid which is partially responsible for wilting of the plants.



Favourable Conditions

- Soil temperature of 20-30˚C
- Hot and dry periods followed by rains
- Heavy black soils with an alkaline reaction
- Increased doses of nitrogen and phosphatic fertilizers
- Wounds caused by nematode (*Meloidogyne incognita*) and grubs of Ash weevil (*Myllocerus pustulatus*).

Disease cycle

The fungus can survive in soil as saprophyte for many years and chlamydospores act as resting spores. The pathogen is both externally and internally seed-borne. The primary infection is mainly from dormant hyphae and chlamydospores in the soil. The secondary spread is through conidia and chlamydospores which are disseminated by wind and irrigation water.

Management

- Treat the acid delinted seeds with Carboxin or Carbendazim at 2 g/kg.
- Remove and burn the infected plant debris in the soil after deep summer ploughing during June-July.
- Apply increased doses of potash with a balanced dose of nitrogenous and phosphatic fertilizers.
- Apply heavy doses of farm yard manure or other organic manures. Follow mixed cropping with non-host plants.
- Grow disease resistant varieties of *G. hirsutum* and *G. barbadense* like Varalakshmi, Vijay Pratap, Jayadhar and Verum.
- Spot drench with Carbendazim 1g/litre.

Verticillium wilt - *Verticillium dahliae*

Symptoms

The symptoms are seen when the crop is in squares and bolls. Plants infected at early stages are severely stunted. The first symptoms can be seen as bronzing of veins. It is followed by interveinal chlorosis and yellowing of leaves. Finally the leaves begin to dry, giving a scorched appearence. At this stage, the characteristic diagnostic feature is the drying of the leaf margins and areas between veins, which gives a "Tiger stripe" or "Tiger claw" appearance.

The affected leaves fall off leaving the branches barren. Infected stem and roots, when split open, show a pinkish discolouration of the woody tissue which may taper off into longitudinal streaks in the upper parts and branches. The infected leaf also shows brown spots at the end of the petioles. The affected plants may bear a few smaller bolls with immature lint.

s

Pathogen

The fungus produces hyaline, septate mycelium and two types of spores. The conidia are single celled, hyaline, spherical to oval, borne singly on verticillate condiophores. The micro sclerotia are globose to oblong, measuring 48-120 X 26-45um.

Favourable Conditions

- Low temperature of 15-20˚C,
- Low lying and ill-drained soils,
- Heavy soils with alkaline reaction
- Heavy doses of nitrogenous fertilizers.

Disease Cycle

The fungus also infects the other hosts like brinjal, chilli, tobacco and bhendi. The fungus can survive in the infected plant debris and in soils as micro sclerotia upto 14 years. The seeds also carry the micro sclerotia and conidia in the fuzz. The primary spread is through the micro sclerotia or conidia in the soil. The secondary spread is through the contact of diseased roots to healthy ones and through dissemination of infected plant parts through irrigation water and other implements.

Management

- Treat the delinted seeds with Carboxin or Carbendazim at 2 g/kg.
- Remove and destroy the infected plant debris after deep ploughing in summer months (June-July).
- Apply heavy doses of farmy and manure or compost at 100t/ha.
- Follow crop rotation by growing paddy or lucerne or chrysanthemum for 2-3 years.
- Spot drench with 0.05g/l benomyl or carbendazim 500mg/l.
- Grow disease resistant varieties like Sujatha, Suvin and CBS 156 and tolerant variety like MCU 5 WT.

- Apply farm yard manure at 10t/ha or neem cake at 150 Kg/ha.
- Adjust the sowing time, early sowing (First Week of April) or late sowing (Last week of June) so that crop escapes the high soil temperature conditions.
- Adopt intercropping with sorghum or moth bean (*Phaseolus aconitifolius*) to lower the soil temperature.

Anthracnose - *Colletotrichum capsici*

Symptoms

The pathogen infects the seedlings and produces small reddish circular spots on the cotyledons and primary leaves. The lesions develop on the collar region, stem may be girdled, causing seedling to wilt and die. In mature plants, the fungus attacks the stem, leading to stem splitting and shredding of bark. The most common symptom is boll spotting. Small water soaked, circular, reddish brown depressed spots appear on the bolls. The lint is stained to yellow or brown, becomes a solid brittle mass of fibre. The infected bolls cease to grow and burst and dry up prematurely.

oms

Pathogen

The pathogen forms large number of acervuli on the infected parts. The conidiophores are slightly curved, short, and club shaped. The conidia are hyaline and falcate, borne single on the conidiophores. Numerous black coloured and thick walled setae are also produced in acervulus.

Favourable Conditions

- Prolonged rainfall at the time of boll formation
- Close planting.

Disease Cycle

The pathogen survives as dormant mycelium in the seed or as conidia on the Surface of seeds for about a year. The pathogen also perpetuates on the rotten bolls and other plant debris in the soil. The secondary spread is by air-borne conidia. The pathogen also survives in the weed hosts viz., *Aristolachia bractiata* and *Hibiscus diversifolius.*

Management

- Treat the delinted seeds with Carbendazim or Carboxin or Thiram or Captan at 2g/kg.
- Remove and burn the infected plant debris and bolls in the soil.
- Rogue out the weed hosts.
- Spray the crop at boll formation stage with Mancozeb 2kg or Copper oxychloride 2.5 kg or or Carbendazim 500g/ha.

Bacterial blight - *Xanthomonas axonopodis* pv. *malvacearum*

Symptoms

The bacterium attacks all stages from seed to harvest. Usually five common phases of symptoms are noticed.

i) Seedling blight:

Small, water-soaked, circular or irregular lesions develop on the cotyledons, later, the infection spreads to stem through petiole and cause withering and death of seedlings.

ii) Angular leaf spot:

Small, dark green, water soaked areas develop on lower surface of leaves, enlarge gradually and become angular when restricted by veins and veinlets and spots are visible on both the surface of leaves. As the lesions become older, they turn to reddish brown colour and infection spreads to veins and veinlets.

iii) Vein blight or vein necrosis or black vein:

The infection of veins cause blackening of the veins and veinlets, gives a typical 'blighting' appearance. On the lower surface of the leaf, bacterial oozes are formed as crusts or scales. The affected leaves become crinkled and twisted inward and show withering. The infection also spreads from veins to petiole and cause blighting leading to defoliation.

iv) Black arm: **Symptom**

On the stem and fruiting branches, dark brown to black lesions are formed, which may girdle the stem and branches to cause premature drooping off of the leaves, cracking of stem and gummosis, resulting in breaking of the stem and hang typically as dry black twig to give a characteristic “black arm” symptom.

v) Square rot / Boll rot:

On the bolls, water soaked lesions appear and turn into dark black and sunken irregular spots. The infection slowly spreads to entire boll and shedding occurs. The infection on mature bolls lead to premature bursting. The bacterium spreads inside the boll and lint gets stained yellow because of bacterial ooze and looses its appearance and market value. The pathogen also infects the seed and causes reduction in size and viability of the seeds.

Angular leaf spot

Bacterial blight lesions on leaf and the blackleg symptom on the leaf petiole

Boll rot

Pathogen

The bacterium is a short rod with a single polar flagellum. It is Gram negative, non-spore forming and measures 1.0-1.2 X 0.7-0.9 µm.

Favorable Conditions

- Optimum soil temperature of 28˚C,
- High atmospheric temperature of 30-40˚C,
- Relative humidity of 85 per cent, early sowing,
- Delayed thinning,
- Poor tillage, late irrigation and
- Potassium deficiency in soil.
- Rain followed by bright sunshine during the months of October and November are highly favorable.

Disease Cycle

The bacterium survives on infected, dried plant debris in soil for several years. The bacterium is also seed-borne and remains in the form of slimy mass on the fuzz of seed coat. The bacterium also attacks other hosts like *Thumbergia thespesioides, Eriodendron anfructuosum* and *Jatropha curcus*. The primary infection starts mainly from the seed-borne bacterium. The secondary spread of the bacteria may be through wind, wind blown rain splash, irrigation water, insects and other implements.

Management

- Delint the cotton seeds with concentrated sulphuric acid at 100ml/kg of seed. Treat the delinted seeds with carboxin or oxycarboxin at 2 g/kg or soak the seeds in 1000 ppm Streptomycin sulphate overnight.
- Remove and destory the infected plant debris. Rogue out the volunteer cotton plants and weed hosts.

- Follow crop rotation with non-host crops.
- Early thinning and early earthing up with potash.
- Grow resistant varieties like Sujatha, 1412 and CRH 71.
- Spray with Streptomycin sulphate +Ttetracycline mixture 100g along with Copper oxychloride at 1.25 Kg/ha.

Leaf Curl Disease- *Cotton leaf curl virus*

Symptoms

Downward and upward curling of leaves and thickening of veins and enation on underside of leaves are the characteristic symptoms of the disease. In serve infection all the leaves are curled and growth retarded. Boll bearing capacity is reduced

Pathogen

It is caused by *Cotton leaf curl virus* - a begomovirus of family geminiviridae. The virions are typical geminate particles, ss circular DNA, bipartite genome with DNA-A and DNA- B components.

Disease Cycle

The primary source is the viruliferous whitefly vector *Bemisia tabaci*. The alternate hosts and cultivated hosts serve as virus reservoirs throughout the year. Not transmitted by seed or contact.

Management

- Management of planting date to avoid peak vector population.
- Elimination of volunteer perennial cotton and alternate hosts including malvaceous hosts like wild okra
- Use of fungus *Paecilomyces farinosus* which parasitizes *B.tabaci*. It brings down vector population.
- Foliar application of neem leaf extract and 1% neem oil resulted in 80% reduction of virus transmission.
- Vector management by application of granular systemic insecticides.

6. Diseases of Bengal gram

Ascochyta blight - *Ascochyta rabiei*

Symptoms

All above ground parts of the plant are infected. On leaf, the lesions are round or elongated, bearing irregularly depressed brown spot and surrounded by a brownish red margin. Similar spots may appear on the stem and pods. The spots on the stem and pods have pycnidia arranged in concentric circles as minute block dots. When the lesions girdle the stem, the portion above the point of attack rapidly dies. If the main stem is girdles at the collar region, the whole plant dies.



Symptoms

Pathogen

The fungus produces hyaline to brown and septate mycelium. Pycnidia are spherical to sub-globose with a prominent ostiole. Pycnidiospores are hyaline, oval to oblong, straight or slightly curved and single celled, occasionally bicelled.

Favourable conditions

- High rainfall during flowering.
- Temperature of 20-25˚C.
- Relative humidity of 60%.

Disease cycle

The fungus survives in the infected plant debris as pycnidia. The pathogen is also externally and internally seed-borne. The primary spread is from seed-borne pycnidia and plant debris in the soil. The secondary spreads is mainly through air-borne pycnidiopores (conidia). Rain splash also helps in the spread of the disease.

Management

- Remove and destroy the infected plant debris in the field.
- Treat the seeds with Thiram 2g or Carbendazim 2 g or Thiram + Carbendazim (1:1 ratio) at 2 g/kg.
- Exposure of seed at 40-50˚C reduced the survival of *A. rabiei* by about 40-70 per cent.
- Spray with Carbendazim at 500 g/ha or Chlorothalonil 1kg/ha.
- Follow crop rotation with cereals.

Rust - *Uromyces ciceris-arietini*

Symptoms

The infection appears as small oval, brown, powdery lesions on both the surface, especially more on lower surface or leaf. The lesions, which are uredosori, cover the entire leaf surface. Late in the season dark teliosori appear on the leaves. The rust pustules may appear on petioles, stems and pods. The pycnial and aecial stages are unknown.

Pathogen

The uredospores are spherical, brownish yellow in colour, loosey echinulated with 4-8 germ pores. Teliospores are round to oval, brown, single celled with unthickened apex and the walls are rough, brown and warty.

Mode of Spread and Survival

The fungus survives as uredospores in the legume weed *Trigonella polycerata* during summer months and serve as primary source of infection. The spread is through wind-borne uredospores.

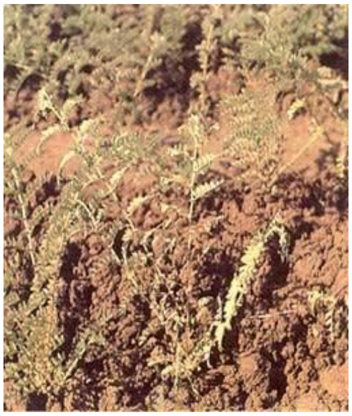
Management

- Destory weed host.
- Spray Carbendazim 500 g/ha or Propiconazole 1L/ha.

Wilt - *Fusarium oxysporum* f.sp. *ciceris*

Symptoms

The disease occurs at two stages of crop growth, seedling stage and flowering stage stage. The main symptoms on seedlings are yellowing and drying of leaves, drooping of petioles and rachis, withering of plants. In the case of adult plants drooping of leaves is observed initially in upper part of plant, and soon observed in entire plant. Vascular browning is conspicuously seen on the stem and root portion



Symptoms

Pathogen

The fungus produces hyaline to light brown, septate and profusely branched hyphae. Microconidia are oval to cylindrical, hyaline, single celled, normally arise on short conidiophores. Macroconidia which borne on branched conidiophores, are thin walled, 3 to 5septate, fusoid and pointed at both ends. Chlamydospores are roughwalled or smooth, terminal or intercalary, may be formed singly or in chains.

Favourable conditions

- High soil temperature (above 25˚C).
- High soil moisture.

Disease cycle

The disease is seed and soil borne. The primary infection is through chlamydospores in soil, which remain viable upto next crop season. The secondary spread is through irrigation water, cultural operations and implements.

Management

- Treat the seeds with Carbendazim or Thiram at 2 g/kg or Carbendazim 1 g+Thiram 1g/kg or treat the seeds with *Trichoderma viride* at 4 g/kg (10^6cfu/g) *Pseudonomas fluorescens* @ 10g/kg (10^6cfu/g) of seed.
- Apply heavy doses of organic manure or green manure.
- Grow resistant cultures like ICCC 42, H82-2, Avrodhi, Alok Samrat, Pusa-212, JG- 322, GPF-2, Haryanachana-1 and Kabuli chickpea like Pusa-1073 and Pusa-2024.

Management of diseases of important Agriculture Crops of Tamil Nadu

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Introduction:

Productivity of food crops grown for human consumption is at risk due to the incidence of pathogens, insect pests and weeds. Crop losses due to these harmful organisms can be substantial and may be prevented, or reduced, by crop protection measures. Crop management requires a multidisciplinary approach because pathogens (fungi, bacteria, viruses. nematodes) not only interact with each other, but with other biotic and abiotic factors to create heavy yield loss. The best way to ensure success of a disease-management program is to adapt it to the diseases expected and to use integrated disease-control measures. The implementation of integrated disease management involves usage of resistant or tolerant varieties, crop rotations, fungicides, nematicides, pesticides for vector control and suggested agronomic practices. The success of any one or all of these measures may depend on how carefully we scout our crops. This chapter gives information on symptoms and management of major diseases of important agricultural crops of Tamil Nadu.

1.DISEASES OF RICE

1. Blast

Causal organism : *Magnoporthe grisea*

Symptoms: The fungus infects leaf, leaf sheath, culm, node and neck of the panicle. On leaves, the spots are typically spindle shaped (Eye shaped) with dark brown margin and grey center **(Leaf blast).** Spots are sometimes encircled by yellow halo. Several spots coalesce resulting in bigger lesions, leading to drying of foliage.

Node infection(Node blast) :On nodes, necrotic black lesions are observed which cause weakening and breaking of nodes.

Neck infection (Neck blast) :The neck region of affected panicle becomes black, brittle, necrotic and breaks. Grains become chaffy or partially filled.

Favourable Conditions : Intermittent drizzles, cloudy weather, more of rainy days, longer duration of dew high relative humidity (93-99 per cent);Low night temperature (between 15-20˚C or less than 26˚C);Aavailability of collateral hosts and excess dose of nitrogen.

2.Brown leaf spot ((Sesame leaf spot)

Causal organism : *Helminthsporium oryzae (Drechslera oryzae)*

Symptoms: Symptoms of the disease appear on leaves, leaf sheath, glumes and grains.

On leaves, the spots are rectangular or oval resembling a sesame seed. They are uniformly brown or reddish brown with discrete margin; Spots have a halo. On the surface of **glumes and grains**, brown lesions are observed leading to grain discolouration.

Favourable Conditions : Temperature of 25-30˚C with relative humidity above 80 per cent are highly favourable; Excess of nitrogen aggravates the disease severity.

3. Sheath rot

Causal organism : *Sarocladium oryzae*

Stage of infection: Boot leaf stage

Symptoms: Upper most leaf sheath enclosing the ear head exhibits dark brown or black, circular to irregular patches. The panicle does not emerge fully from the flag leaf. The glumes are discoloured. White powdery growth of mycelium is seen inside the leaf sheath and also on the panicle. Grains get discoloured. Young panicles may not emerge from infected sheaths.

Favourable Conditions : Closer planting ;High doses of nitrogen; High humidity and temperature around 25-30˚C; Injuries made by leaf folder, brown plant hopper and mites increase infection

4. Sheath blight

Causal organism : *Rhizoctonia solani*

Stage of infection: Tillering stage

Symptoms: Lesions are formed on the leaf sheath near water level. The lesions become oval or ellipsoid and greyish green. As the disease progresses lesions enlarge and their centers turn greyish white with brown margin. Under favourable conditions lesions are formed on upper leaf sheath and on leaf blades resulting in leaf blight. Infection may extend to culm leading to rot. Inside the culm and on the leaf sheath, large number of small spherical, brown sclerotia are formed.

Favourable Conditions : High relative humidity (96-97 per cent), high temperature (30-32˚C);Closer planting;Heavy doses of nitrogenous fertilizers

5. Stem rot

Causal organism : *Sclerotium oryzae*

Symptoms: The fungus affects leaf sheath during later stages of crop growth near water level. Dark brown to black lesions are formed on the outer leaf sheath. The affected tissues rot and abundant small, spherical, black sclerotia are seen in the rotting tissue and visible to naked eye as dots. The culm collapses and plants lodge. If the diseased tiller is opened, profuse mycelial growth and large number of sclerotia can be seen.

Favourable Conditions : Infestation of leaf hoppers and stem borer ; High doses of nitrogenous fertilizers.

6. False smut (Lakshmi Disease)

Causal organism : *Ustilaginoidea virens*

Symptoms: Few grains in the earhead exhibit the symptoms. Affected grains get converted into green velvety mass that are much bigger than the normal grains. Spore balls are visible between glumes, and the glumes are not affected. Rainfall and cloudy weather during flowering and maturity favours the disease development.The fungus produces chlamydospores which later develop to sclerotia. Severe outbreak of this disease is recorded in recent years.

7. Oodubathi disease

Causal organism : *Ephelis oryzae*

Symptoms: The panicle emerges as a slender, dirty grey, cylindrical, spike since the spikelets are cemented by the fungal mycelium. No grains are formed on affected earhead.

8. Grain discolouration

Causal organism : *Helminthosporium, Curvularia , Alternaria Fusarium*

Symptoms: The grains are discoloured red, yellow, orange, pink or black, depending upon the organism involved and the degree of infection. The infection may be external or internal leading to discolouration of glumes, kernels or both. Dark brown or black spots appear on grains. Under humid conditions, the fungal growth may be prominently seen on grains .

9. Bacterial leaf blight

Causal organism : *Xanthomonas oryzae pv oryzae*

Symptoms: Blighting of seedling occurs in nursery.In main field, "Kresek' phase i.e. death of seedling is usually observed one or two weeks after transplanting. Symptoms are chiefly confined to leaves. Initial infection is seen as water-soaked lesion at the tip of leaf. Infection proceeds along the leaf margin in an irregular wavy manner. The affected portion turns straw coloured and the central leaf blade remains green for some time. Finally the entire leaf gets blighted. Bacterial ooze can be seen on the infected leaf surface, which dries up forming encrustation. Bacterial ooze can be observed from the cut end of the infected leaf when immersed in clear water.

Favorable Conditions : Clipping of tip of the seedling at the time of transplanting; Heavy rain, heavy dew, flooding, deep irrigation water ;Severe wind and temperature of 25-30 C; Application of excessive nitrogen, especially late top dressing

VIRAL AND PHYTOPLASMAL DISEASES

10. Rice Tungro Disease (RTD)

Causal organism : ***Rice tungro virus***

Symptoms: Infection occurs in nursery and main field. The chief symptoms are stunted growth of plant, reduced tillering, discolouration of leaves in various shades of yellow to orange. The discolouration starts from the tip and proceeds downwards. Older leaves exhibit rusty spots or dots of different sizes. The earheads are small and grains are ill-filled. The virus is transmitted by green leaf hoppers

11. Rice Yellow Dwarf Disease

Causal organism : Candidatus Phytoplasma

Symptoms: Plants become pale green, chlorotic and stunted. Large number of thin and pale tillers with yellowish green leaves are seen. There is excessive tillering . Affected plant looks like a clump of grass. Infected plants remain sterile. The disease in transmitted by Green leaf hoppers Disease management

Prophylactic measures as seed treatments

Dry seed treatment

Thiram or captan or carboxin or carbendazim at 2 g/kg of seeds.

Treat the seeds at least 24 hours prior to soaking for sprouting.

The treated seeds can be stored for 30 days without any loss in viability.

Wet seed treatment

Carbendazim or Tricyclozole at 2 g/lit of water for 1 kg of seed.

Soak the seeds in the solution for 2 h Drain the solution, sprout the seeds and sow in the nursery bed. This wet seed treatment gives protection to the seedlings up to 40 days from seedling disease such as blast and this method is better than dry seed treatment **or** Treat the seeds with talc based formulation of *P. fluorescens* (Pf1) @ 10g/kg of seed and soak in 1lit of water overnight. Decant the excess water and allow to sprout the seeds for 24 h and then sow.

Seedling dip with *Pseudomonas fluorescens*

Stagnate water to a depth of 2.5cm over an area of $25m^2$ in the main field. Sprinkle 2.5 kg of the talc based formulation of *Pseudomonas fluorescens* (Pf1) and mix with stagnated water. The seedlings pulled out from the nursery are to be soaked for 30 min. in the stagnated water and then transplanted. Biocontrol agents are compatible with biofertilizers

Biofertilizers and biocontrol agents can be mixed together for seed soaking

Fungicides and biocontrol agents are incompatible

i.) Nursery Diseases

1.Blast:Spray any one of the following: (for 20 cents): Carbendazim 50WP @ 1g/l or Tricyclozole 75 WP @ 1g/l or Metominostrobin 20 SC @ 1ml/l or

Azoxystrobin 25 SC @ 1 ml/l

2.Brown spot

Spray **(for 20 cents)** Metominostrobin @ 1ml /lit of water

3.Rice Tungro Disease (RTD)

To control Vector- hoppers

Apply Carbofuran 3G @ 3.5kg at 10 DAS or

Spray 2 rounds (10 and 20 DAS) with any one of the following insecticides for 20 cents area

Thiamethoxam 25 WDG 8g or Imidacloprid 17.8 SL 8ml

ii.) Main Field

Blast

Cultural method

- Remove collateral weed hosts from bunds and channels
- Use only disease free seedlings
- Avoid excess nitrogen
- Apply N in three split doses (50% basal, 25% in tillering phase and 25% N in panicle initiation stage)

Use resistant variety CO 47.

Chemical

Spray after observing initial infection of the disease,

- Carbendazim 50WP @ 500g/ha (or)
- Tricyclozole 75 WP @ 500g/ha (or)
- Metominostrobin 20 SC @ 500ml/ha (or)
- Azoxystrobin 25 SC @ 500 ml/ha

Biological control

- Seed Treatment with TNAU Pf 1liquid formulation @ 10 ml/kg of seeds
- Seedling root dipping with TNAU Pf 1liquid formulation (500 ml for

one hectare seedlings)

 Soil application with TNAU Pf 1liquid formulation (500ml/ha)

Foliar spray with TNAU Pf 1liquid formulation @ 5ml/lit

2.Brown spot

Spray Metominostrobin @ 500ml/ha

3.Sheath rot

Cultural

Apply Gypsum @ 500 kg/ha at two equal splits once basally and another at active tillering stage.

Botanicals

Neem oil 3%

Ipomoea leaf powder extract (25 kg/ha)

Prosopis leaf powder extract (25 kg/ha). First spray at boot leaf stage and second 15 days later

Chemical

Spray any one of the following:

Carbendazim @ 500g/ha

Metominostrobin @ 500 ml/ha

Hexaconazole 75% WG @ 100 mg/ lit 1st spray at the time of disease appearance and 2nd spray 15 days later

Biological control

 Seed Treatment with TNAU Pf 1liquid formulation @ 10 ml/kg of seeds

 Seedling root dipping with TNAU Pf 1liquid formulation (500 ml for one hectare seedlings)

Soil application with TNAU Pf 1liquid formulation (500ml/ha)

Foliar spray with TNAU Pf 1liquid formulation @ 5ml/lit

4.Sheath blight

Cultural

Apply Neem cake at 150 kg/ha

Botanical

Foliar spray with Neem oil at 3% (15 lit /ha) starting from disease appearance

Chemicial

Carbendazim 50 WP @ 500g/ha

Azoxystrobin @ 500ml/ha

Hexaconazole 75% WG @ 100mg/ lit 1st spray at the time of disease appearance and 2nd spray 15 days later

Biological control

 Seed Treatment with TNAU Pf 1liquid formulation @ 10 ml/kg of seeds

 Seedling root dipping with TNAU Pf 1liquid formulation (500 ml for one hectare seedlings)

Soil application with TNAU Pf 1liquid formulation (500ml/ha)

Foliar spray with TNAU Pf 1liquid formulation @ 5ml/lit

5.False smut

Two sprayings of Propiconazole 25 EC @ 500ml/ha **(or)** Copper hydroxide 77 WP @ 1.25 kg/ha at boot leaf and 50% flowering

6.Rice grain discoloration

Chemical Spray : Carbendazim + Thiram + Mancozeb (1:1:1) 0.2% at 50% flowering stage.

7.Bacterial blight

Two sprays of Copper hydroxide 77 WP@1.25 kg/ha 30 DAP & 45 DAP

Botanical / others

Spray fresh cowdung extract 20% twice (starting from initial appearance of the disease and another at fortnightly interval)

Neem oil 60 EC 3% (or) NSKE 5% is recommended for the control of sheath rot, sheath blight, grain discolouration and bacterial blight

For viral and Phytoplasma diseases

Cultural method

Plough the stubbles as soon as the crop is harvested to prevent the survival of yellow dwarf pathogen during off-season.

Physical methods

Light traps are to be set up to attract and control the leaf hopper vectors as well as to monitor the population.

In the early morning, the population of leafhopper alighting near the light trap should be killed by spraying/dusting the insecticides. This should be practiced every day.

Spray Two rounds of any one of the following insecticides

Thiamethoxam 25 WDG 100g/ha Imidacloprid 17.8 SL 100ml/ha at 15 and 30 days after transplanting. The vegetation on the bunds should also be sprayed with the insecticides.

2. DISEASES OF PEARL MILLET

1. Downy mildew or Green ear

Causal organism : *Sclerospora graminicola*

Symptoms: Two stages (i) Downy mildew stage (ii) Green ear stage

Downy mildew stage: Affected leaf exhibits white downy growth in patches on its lower surface. These patches expand and cover the entire lamina which turns yellow in due course. The downy growth consists of sporangiophores and sporangia.

Green ear stage : The earheads are converted into green leafy structures either partially or fully. The oospores serve as primary source of inoculum.

Favourable Conditions : Very high humidity (90%);Presence of water on the leaves; Low temperature of 15-25˚C favor the formation of sporangiophore and sporangia.

2. Rust

Causal organism: *Puccinia penniseti*

Symptoms: Infection is seen in the form of brownish yellow pustules on both the leaf surfaces. These represent the uredia of the fungus. Teliosori are black and seen on leaf and leaf sheath. Brinjal is the alternate host.

Favourable Conditions : Closer spacing ;Presence of abundant brinjal plants and other species of *Solanum* viz., *S.torvum, S. xanthocarpum* and *S. pubescents.*

3. Smut

Causal organism : *Tolyposporium penicillariae*

Symptoms: The disease becomes apparent at the time of grain set. A few grains, sporadically distributed on the earhead are replaced by green to black sori, which are much bigger than normal grains. The sorus wall is tough, surrounding the powdery mass of smut spores which are in balls.

Favourable Conditions : High relative humidity; Successive cropping with pearlmillet

4. Ergot / Sugary disease

Causal organism: *Claviceps fusiformis*

Symptoms: Small droplets of pinkish sticky fluid oozes out of the spikelets. The affected spikelets turn black and several such dark sticky patches are seen on the earhead. Grain formation is inhibited. The honey dew contains large number of hyaline single celled conidia. Later infected ovaries get converted into sclerotia.

A. Management of pearl millet diseases

1.Seed treatment

Removal of ergot / sclerotia to prevent primary infection

Dissolve 1 kg of common salt in 10 litres of water. Drop the seeds into the salt solution. Remove the ergot and sclerotia affected seeds which will float. Wash seeds in fresh water 2 or 3 times to remove the salt on the seeds. Dry the seeds in shade. Treat the seeds with Thiram @ 2g /kg of seed. Treat the seeds with Metalaxyl 6g/kg for the control of downy mildew in endemic areas

2. Downy Mildew: *Sclerospora graminicola*

- Grow downy mildew resistant varieties CO7, WCC 75, CO(Cu)9, TNAU-Cumbu Hybrid-CO9
- Transplanting reduces disease incidence. At the time of planting infected seedlings should be removed.
- In the direct sown crop, infested plants should be removed up to 45 days of sowing as and when the symptoms are noticed.

- Spray any one of the fungicides
- Metalaxyl + Mancozeb @500 g or Mancozeb 1000g/ha

3.Rust: *Puccinia penniseti*

Sowing during December - May result in less incidence.

Adopt control measures when there is rust incidence in the early stages as spread of infection to top leaves results in poor grain filling.

Spray any one of the following fungicides when the initial symptoms of the diseases are noticed.

- Wettable sulphur 2500g / ha
- Mancozeb 1000g/ha
- Repeat application 10 days after if necessary.

4.Sugary or Ergot disease: *Claviceps fusiformis*

Spray any one of the fungicides like Carbendazim 500g or Mancozeb 1000g /ha when 5 - 10% flowers have opened and again at 50% flowering stage.

B.Integrated management strategies for major pest and diseases of pearl millet

Seed treatment with Metalaxyl @ 6g/kg of seeds + Seed treatment with Imidacloprid @ 5g/kg of seeds + Removal of downy mildew infected plants up to 45 days of sowing + Spraying of Mancozeb @ 1000g/ha + Spraying of NSKE 5% @ 50% flowering against downy mildew, rust and shoot fly.

3. DISEASES OF FINGER MILLET

1. Blast

Causal organism: *Pyricularia grisea*

Symptoms: Infection occurs from sowing to crop maturity. On leaves, the spots are spindle shaped with brown margin and necrotic grey center. Conidiophores and conidia are formed in the center of the spots. Stem infection causes blackening of the region on either side of node leading to weakening, shrinking and breaking of plant. Ear head infection results in black discolouration either at neck region or at any portion of rachis. This causes either chaffiness or partial filling of grains.

2. Seedling blight / leaf spot:

Causal organism : *Helminthosporium nodulosum*

Symptoms: The fungus attacks all plant parts. Leaves show small oval elongated brown spots. The spots merge together to form bigger lesions and turn dark brown. Spots are also noticed on culm, leaf sheath, neck and panicle.

3. Mosaic / Mottle streak

Causal organism : *Finger millet mosaic virus / Finger millet mottle streak virus*

Symptoms: Affected leaves exhibit chlorotic streaks. Plants become stunted and pale. Earheads are small and grains are ill-filled. Vector: Jassid

A.Nursery

Seed treatment: Thiram 4 g or Captan 4 g or Carbendazim 2 g/kg or *Pseudomonas fluorescens* @10g/kg of seed.

Main field

1.Blast:

- Spray any one of the fungicides Edifenphos 500 ml or Carbendazim 500 g or Iprobenphos(IBP) @ 500 ml/ha. First spray immediately after noticing the symptoms. Second and third sprays at flowering stage at 15 days interval to control neck and finger infection.
- Foliar spray with Aureofungin sol 100 ppm at 50% earhead emergence followed by a second spray with Mancozeb 1000g/ha or *Pseudomonas fluorescens* @ 0.2% 10 days later

2.Virus diseases:Mosaic and Mottle streak

- Rogue out the affected plants.
- Spray any one of the insecticides like Monocrotophos 36 WSC 700 ml/ha or Methyl dematon 25EC 500 ml/ha on noticing symptoms and repeat twice if necessary at 20 days intervals for control of insect vectors

4. DISEASES OF MAIZE

1. Downy mildew / Crazy top

Causal organism: *Peranosclerospora sorghi*

Symptoms: Chlorotic streaks appear on the leaf and white fungus growth is seen on both the surfaces of leaf. Affected plants become stunted and exhibit bushy appearance due to shortening of internodes. Sometimes leafy growths in the tassel and proliferation of axillary buds on the stalk of the tassel are noticed.

Favourable Conditions : Low temperature (21-33˚C);High relative humidity (90 per cent) and drizzling;Young plants are highly susceptible.

2.Rust

Causal organism: *Puccinia sorghi*

Symptoms: On both the surfaces of the leaf, brown pustules are seen. These represent the uredosori of the fungus. The alternate host is *Oxalis corniunlata*. Cool temperature and high relative humidity favours the disease

3. Leaf Blight

Causal organism: *Exserohilum turcicum* & *Helminthosporium maydis*

Turcicum Leaf Blight Symptoms: The fungus affects the crop at young stage. Early symptoms are oval, water-soaked spots on leaves. Mature symptoms are characteristic cigar shaped lesions that are 3 to 15cm long. Lesions are elliptical and tan in color, developing distinct dark areas as they mature that are associated with fungal sporulation. Lesions typically first appear on lower leaves, spreading to upper leaves and the ear sheaths as the crop matures. Under severe infection, lesions may coalesce, blighting the entire leaf.

Maydis Leaf Blight Symptoms:: Small yellowish round or oval spots appear on the leaves. These spots enlarge become elliptical and the center becomes straw coloured with a reddish brown margin. Conidia and conidiophores are formed in the center.

Favourable Conditions : Optimum temperature for the germination of conidia is 8 to 27˚C provided with freewater on the leaf;Infection takes place early in the wet season.

4.Charcoal rot

Causal organism: ***Macrophomina phaseolina***

Symptoms: The pathogen affects the plant mostly after flowering and the disease is named as Post Flowering Stalk Rot **(PFSR)**. The stalk of the infected plants can be recognized by greyish streak. The pith becomes shredded and greyish black minute sclerotia develop on the vascular bundles. Shredding of the interior of the stalk often causes stalks to break in the region of the crown. The crown region of the infected plant becomes dark in colour. Shredding of root bark and disintegration of root system are the common features. High temperature and low soil moisture (drought) favours the disease

5.Bacterial Stalk rot

Causal organism: ***Erwinia dissolvens*****Symptoms:**The basal internodes develop soft rot and give a water soaked appearance. A mild sweet fermenting odour accompanies such rotting. Leaves some time show signs of wilting and affected plants topple down in few days. Ears and shank may also show rot. They fail to develop further and the ears hang down simply from the plant

B.Disease Management

1.Seed treatment: Carbendazim @ 2 g/kg or Thiram @ 4g/kg or Metalaxyl @ 3g/kg of seed

2. Downy mildew or Crazy top

Use resistant TNAU maize hybrid CO-6 Rogue out affected plants.

Spray Metalaxyl+ Mancozeb @ 1000g, Mancozeb 1000g/ha at 20 days after Sowing

3.Leaf blights

Spray Mancozeb or Zineb @2 -4 g/litre at 10 days interval after first appearance of the disease

4.Post Flowering Stalk rot

Follow crop rotation

Avoid water stress at flowering time reduced disease incidence

Avoid nutrient stress. Apply potash @ 80 kg/ha in endemic areas

Soil application of *P. fluorescens* (or) *T. viride* @ 2.5 kg / ha + 50 kg of well decomposed FYM or sand at 30 days after sowing

5.DISEASES OF PULSES

I. DISEASES OF REDGRAM

1. Wilt

Causal organism : *Fusarium oxysporum f.sp.udum*

Symptoms: The infected plants show gradual wilting and drying. Yellowing and premature drying of leaves and stems are noticed. The basal portion of stem and root region becomes black. When the bark of infected root is peeled, black streaks are seen and vascular tissues show discolouration. Xylem vessel is occupied by the growth of the hyphae which prevent the uptake of nutrients and water resulting in the death of plant.

Favourable conditions : Soil temperature of 17-25˚C; Continuous cultivation of redgram in the same field.

2. Powdery mildew

Causal organism: *Leveillula taurica*

Symptoms: On the lower surface of leaf, white powdery growth is seen in patches. Corresponding areas on the upper surface become yellow. This leads to premature shedding of leaves. Dry humid weather following rainfall favours the disease.

3. Leaf spot

Causal organism: *Cercospora indica*

Symptoms: Leaves show light brown small spots. Shot holes are formed in due course. Lesions develop on petioles and stem.

4. Sterility mosaic

Causal organism : *Pigeonpea sterility mosaic virus*

Symptoms: The affected plants are stunted and the internodes are shortened. Axillary buds are stimulated to grow and the branches are crowded at the top. The plant gives a bushy appearance. Leaves become small and crinkled exhibiting mottling symptom.The Eriophid mite *Aceria cajani* transmits the disease**.**

Disease Management:

1.Seed treatment

Talc formulation of *Trichoderma viride* @ 4g or *P. fluorescens* @ 10 g/kg seed (or) Carbendazim 2 g/kg or Thiram @ 4 g/kg.

2.Wilt

P. fluorescens (or) *T. viride* – 2.5 kg / ha + 50 kg of well decomposed FYM or sand at 30 days after sowing

3.Root rot : ***Spot drenching with Carbendazim @ 1 gm/ lit***

4.**Sterility Mosaic :** Rogue out the infected plants in the early stages of ***growth.***

Spray Fenazaquin @ 1 ml/lit on 45 and 60 DAS as prophylactic spray.

II. DISEASES OF BENGALGRAM

1. Blight

Causal organism : *Ascochyta rabiei*

Symptoms: Infected leaflets exhibit round or elongated lesions bearing depressed brown spots surrounded by a brown margin. Spots also appear on a stems and pods. The spots on the stem and pod have pycnidia arranged in concentric circles as black dots. The fungus is carried through seeds.

Favourable conditions : High rainfall during flowering;Temperature of 20-25˚C;Relative humidity of 60%.

2. Rust

Causal organism : *Uromyces ciceris-arietini*

Symptoms: Small oval, brown powdery lesions appear on the lower surface of the leaf. Later the lesions can be seen on both the surfaces. Uredosori cover the entire leaf area and late in the season dark teliosori appear on the leaves. The fungus survives as uredospores in the legume weed *Trigonella polycerata*

3. Wilt

Causal organism : *Fusarium oxysporum* f.sp. *Ciceris*

Symptoms: Infection may occur at seedling or flowering stage. Affected plant exhibits drooping of leaves in the upper part and quickly the entire plant exhibits the symptom. Dark brown or black discolouration is noticed below and above the collar region. Vascular browning is conspicuously seen as black streaks on the stem and root below the bark. High soil temperature (above 25˚C) and high soil moisture favours the disease.

Disease Management

1.Seed treatment: Talc formulation of *T. viride* @ 4g or *P. fluorescens* @ 10 g/kg seed (or) Carbendazim @ 2 g/kg or Thiram @ 4 g/kg of seed

2. Blight

Exposure of seed at 40-50˚C reduced the survival of *A. rabiei* by about 40-70 per cent. Spray with Carbendazim at 500 g/ha or Chlorothalonil 1kg/ha. Follow crop rotation with cereals.

Rust

Destory weed host.

Spray Carbendazim 500 g/ha or Propiconazole 1L/ha

4.Wilt:

Soil application with P. *fluorescens* @ 2.5 kg/ha + 50 kg of well decomposed FYM or sand.

III. DISEASES OF BLACKGRAM AND GREENGRAM

1. Root rot

Causal organism : *Rhizoctonia bataticola*

Symptoms: Affected plant exhibits drooping and drying of leaves and branches. The basal portion of stem turns brown and the bark of the roots become shredded. Large number of spherical to irregular black sclerotia can be seen in shredded tissues.

Favourable conditions : Day temperature of 30˚C; Prolonged dry season followed by irrigation.

2. Powdery mildew

Causal organism : *Erysiphe polygoni*

Symptoms: On the upper surface of leaf, white powdery growth of the fungus is seen. More often, the entire surface is covered. The colour of the growth later turns grey and the leaves become brown. The disease becomes severe during flowering and maturity stages. The white growth consists of the external mycelium, conidiophores and conidia.

Favourable Conditions : Warm humid weather. The disease is severe generally during late kharif and rabi seasons.

3. Leaf spot

Causal organism : *Cercospora canescens*

Symptoms: Small circular to irregular reddish spots are observed on the surface of leaves. The center later turns grey and defoliation occurs in severe cases. Large number of conidiophores and conidia are formed in the center. Lesions can also be seen on petioles and stem.

Favourable Conditions : Humid weather and dense plant population

4. Rust

Causal organism : *Uromyces phaseoli typical*

Symptoms: On the lower surface of leaf reddish brown pustules are seen in abundance, representing the uredosori of the fungus. Affected leaves turn yellow. The uredospores are brown, echinulate and single celled. Teliospores are elliptical and papillate. The fungus is an autoecious, macrocyclic rust.

Favourable Conditions : Cloudy humid weather, temperature of 21-26° C .Nights with heavy dews.

5. Yellow mosaic

Causal organism : ***Mungbean yellow mosaic virus* (MYMV)**

Symptoms: The initial infection is observed as small irregular, yellow patches on leaves. These patches enlarge in size and cover the entire lamina. The whole leaf later completely turns yellow. Pods become yellow, small and distorted.

Favourable condition: Transmitted by whitefly, *Bemisia tabaci* under favourable conditions. Disease spreads by feeding of plants by viruliferous whiteflies. Summer sown crops are highly susceptible. Weed hosts viz., *Croton sparsiflorus, Acalypha indica, Eclipta alba* and other legume hosts serve as reservoir for inoculum.

6. Disease : Leaf crinkle

Causal organism : *Urdbean leaf crinkle virus* (ULCV)

Symptoms: Initial symptoms appear on young leaves. Affected leaves are puckered and curled. The plants get stunted and appear bushy. Petioles and internodes are shortened. The inflorescence is deformed. Flowers seldom open.

Favourable condition:

Presence of weed hosts like *Aristolochia bracteata* and *Digera arvensis.* Kharif season crop and continuous cropping of other legumes serve as source of inoculum. The virus is seed-borne and primary infection occurs through infected seeds. Perhaps white fly, *Bemisia tabaci* helps in the secondary spread. The virus is also sap transmissible.

Disease management:

1.Seed treatment

a.Talc formulation of *T. viride* @ 4g or *P. fluorescens* @ 10 g/kg seed (or) Carbendazim 2 g/kg or Thiram @ 4 g/kg

b.**Root rot-stem fly complex**

Seed treatment with *Beauveria bassiana* + *Pseudomonas fluorescens* @ 5 g each/kg of seed

2.Powdery Mildew

▪ Spray NSKE 5% or Neem oil 3% twice at 10 days interval from initial disease appearance.

▪ Spray Eucalyptus leaf extract 10% at initiation of the disease and 10 days later.

Spray Carbendazim 500 g or wettable sulphur 1500g/ha or Propiconazole 500 ml/ha at initiation of the disease and 10 days later

3.Rust

Spray Mancozeb 1000g or wettable sulphur 1500g /ha at initiation of the disease and 10 days later.

4.Leaf spot

Spray Carbendazim 500 g/ha or Mancozeb 1000g /ha at initiation of the disease and 10 days later.

5.Yellow mosaic and Leaf Crinkle

Integrated Disease Management

 Growing resistant varieties such as VBN 4, VBN 6 and VBN 7

 Seed treatment with Dimethoate (or) Imidacloprid @ 5 ml /kg

 Installation of yellow sticky traps 12 nos/ha

 Rogue out the infected plants up to 45 days

 Foliar spray of notchi leaf extract 10% at 30 DAS or neem formulation 3 ml/lit Spray methyl demeton 25 EC 500 ml/ha or dimethoate 30 EC 500 ml/ha or thiamethoxam 75 WS 1g /3 lit and repeat after 15 days, if necessary.

Root rot

- Seed treatment with *Trichoderma viride* 4 g/kg or *Pseudomonas fluorescens*
- 10 g/kg
- Basal application of zinc sulphate 25 kg/ha
- Basal application of neem cake @ 150 kg/ha
- Soil application *P. fluorescens* or *T. viride* – 2.5 kg / ha + 50 kg of well
- decomposed FYM or sand at 30 days after sowing.
- Spot drenching of Carbendazim @ 1 gm/ lit

6. D**ISEASES OF COTTON**

1. Fusarium wilt

Causal organism : *Fusarium oxysporum* f.sp. *vasinfectum*

Symptoms: In the affected plants, leaves loose their turgidity, turn yellow and fall off. Symptoms start from the base and proceed upward. . The plant starts wilting and finally dries . The tap root is stunted and lateral roots are limited. On the wood region of roots and stem black streaks are seen. The vascular bundles of affected plants are traversed by the growth of hyphal threads. The mycelium is septate and hyaline. The fungus produces micro and macroconidia and chlamydospores.

Favourable Conditions :

- Soil temperature of 20-30˚C
- Hot and dry periods followed by rains
- Heavy black soils with an alkaline reaction
- Increased doses of nitrogen and phosphatic fertilizers
- Wounds caused by nematode *(Meloidogyne incognita and* grubs of Ash weevil *(Myllocerus pustulatus).*

Disease : Verticillium wilt

Causal organism : *Verticillium dahliae*

Symptoms: The affected plants are severely stunted. Leaves exhibit bronzing of veins followed by interveinal chlorosis and yellowing of leaves. Leaves dry giving a scorched appearance. The characteristic feature is the drying of leaf margin and interveinal areas. Infected stem and roots show pinkish discolouration of the wood.

Favourable Conditions :

 Low temperature of 15-20˚C,

 Low lying and ill-drained soils,

 Heavy soils with alkaline reaction

Heavy doses of nitrogenous fertilizers.

3. Disease : Root rot

Causal organism : *Rhizoctonia solani*

Symptoms: Affected plant wilts suddenly and decay of root system observed. The bark of the root and the lower portion of the stem gets shredded. Large number of sclerotia are found on the affected tissue.

Favourable conditions:

 Dry weather following heavy rains,

 High soil temperature (35-39˚C),

 Cultivation of favourable hosts like vegetables,

 Oil seeds and legumes preceding cotton

Wounds caused by ash weevil grubs and nematodes.

4. Leaf blight

Causal organism : *Alternaria macrospora*

Symptoms: The leaves show brown, round to irregular necrotic spots.

The spots show concentric rings. The spots merge to form bigger patches and the infected leaf withers.

Favourable Conditions: High humidity; Intermittent rains; Moderate temperature of 25-28˚ C.

5. Myrothecium leaf spot

Causal organism : *Myrothecium roridum*

Symptoms: The spots are circular with grey centers and dark brown margin. The center of the spot dries and withers leaving a shot hole.

6. Areolate mildew

Causal organism : *Ramularia areola*

Symptoms: The spots are observed on lower surface of leaves. Lesions are irregular to angular, pale white bound by veinlets. They show frosty white growth consisting of conidiophores and conidia. Leaves became chlorotic and yellow.

Favourable Conditions

Wet humid conditions during winter cotton season; Intermittent rains during Nor th-East monsoon season;Low temperature (20-30˚C) during October-January; Close planting, excessive application of nitrogenous fertilizers;Very early sowing or very late sowing of cotton

7.Angular leaf spot / Black arm

Causal organism : *Xanthomonas axonopodis* pv. *malvacearum*

Symptoms:

Angular leaf spot

Symptoms are observed on the leaves, stem and branches and on bolls. On leaves, angular brown to black water soaked spots are seen and the spots are restricted by veins.

Black vein

The infection spreads to the vein and the affected vein becomes black With bacterial ooze forming an encrustation on veins. This is vein blight stage (black vein).

Black arm

On the surface of stems and branches, elongate black lesions are observed. This causes breaking of the branches which hang on the affected plant. This is black arm stage.

Boll rot.

On the surface of bolls, round to irregular black water soaked, sunken lesions develop. This causes premature opening and shedding of bolls. The lint turns yellow because of bacterial ooze. The bacterium is a Gram negative rod with a single polar flagellum.

Favorable Conditions : Optimum soil temperature of 28˚C; High atmospheric temperature of 30-40˚C;Relative humidity of 85 per cent, early sowing, ;Delayed thinning;Poor tillage, late irrigation;Potassium deficiency in soil ;Rain followed by bright sunshine during the months of October and November are highly favorable.

Disease Management:

Soil drenching with Trifloxystrobin+Tebuconazole – 0.75g/litre .

2. Root rot

Cultural Method

Apply Neem cake @ 150 kg/ha to the soil and treat the seeds with talc based *T. viride* @ 4 g/kg to reduce the root rot incidence.

Biological control

Seed treatment with *T. viride* @ 10 g/kg followed by basal application of zinc sulphate @ 50 kg/ha

Seed treatment with *Bacillus* (BSC 5) @ 10g/kg followed by soil application @ 2.5 kg/ ha in 250kg of compost at the time of sowing. Seed treatment with *Pseudomonas* (PF1) @ 10g/kg and soil application @ 2.5 kg/ha in 250 kg of compost at the time of sowing.

Chemical

Spot drench Carbendazim @ 1 g/lit at the base of affected plants as well as surrounding healthy plants.

2.Wilts

Treat the acid delinted seeds with Carboxin or Carbendazim at 2 g/kg. Remove and burn the infected plant debris in the soil after deep summer ploughing during June-July. Apply increased doses of potash with a balanced dose of nitrogenous and phosphatic fertilizers. Apply heavy doses of farm yard manure or other organic manures @100t/ha. Follow mixed cropping with non-host plants. Grow disease resistant varieties of *G. hirsutum* and *G. barbadense* like Varalakshmi, Vijay Pratap, Jayadhar and Verum. Spot drench with Carbendazim 1g/litre.

Verticilium wilt: Follow crop rotation by growing paddy or lucerne or chrysanthemum for 2-3 years. Spot drench with 0.05g/l benomyl or carbendazim 500mg/l. Grow disease resistant varieties like Sujatha, Suvin and CBS 156 and tolerant variety like MCU 5 WT.

Alternaria leaf spot

Spray any one of the following: Copper Oxychloride 1250g or Mancozeb 1000g or Chlorothalonil

500g/ha or Difenaconazole- 0.05%. **or** Krexoxym methyl – 0.1% Tebuconazole – 1ml/

litre Trifloxystrobin+Tebuconazole – 0.6g/litre 60, 90 and 120 days after sowing.

Bacillus subtilis (BSC 5) – 0.04% on 60, 90 and 120 days after sowing.

Grey Mildew

Spray Carbendazim 250 g/ha or Mancozeb 1000g or Chlorothalonil 500g/ha or Difenaconazole- 0.05% or Krexoxym methyl – 0.1% or Tebuconazole – 1ml/litre 60, 90 and 120 days after sowing

Bacterial leaf blight

Avoid stacking of infected plants Spray Streptomycin sulphate + Tetracycline mixture 100g + Copper oxychloride 1250g/ha.

Repeat spraying at 10 days interval twice or thrice if drizzling continues

Boll rot Spray any one of the following:

Carbendazim 500g or Mancozeb 2000g or Copper oxychloride 2500g/ha along with an insecticide recommended for bollworm from 45th day at fortnightly interval.

7. DISEASES OF SUGARCANE

1. Red rot

Causal organism : *Colletotrichum falcatum*

Symptoms: Symptoms are observed on the leaves and canes. On the midrib, circular to oval spots with red margin and straw coloured center are observed. In the central region, acervuli could be seen black dots. The infected leaves break at the lesions. In the affected canes, the internal tissues become red with cross white patches. The stalks become hollow.

Favourable Conditions: Monoculturing of sugarcane;Successive ratoon cropping; Water logged conditions and injuries caused by insects; Monoculturing of sugarcane; Successive ratoon cropping.; Water logged conditions and injuries caused by insects.

2. Sett rot or Pineapple disease

Causal organism : - ***Ceratocystis paradoxa***

Symptoms: The disease is observed as soon as the setts are planted. The central core of affected tissue turns black. Cavities are formed in the etts and the rotting tissues emit pineapple odour.

Favourable Conditions : Poorly drained fields; Heavy clay soils ;Temperature of 25-30^{o} C ; Prolonged rainfall after planting.

3. Whip smut

Causal organism : ***Ustilago scitaminea***

Symptoms: The affected plants are stunted and the central shoot is converted into a long curved whip like sorus. The sours is covered by a silvery, membrane which soon ruptures exposing a dark mass ofteliospores.

4.Favourable Conditions : Monoculturing of sugarcane; Continuous ratooning and dry weather during tillering stage.

5. Disease : Mosaic

Causal organism : *Sugarcane mosaic potyvirus*

Symptoms: The disease appears prominently on young leaves. Linear chlorotic stripes alternating with dark green areas are seen on the leaves.

At \ later stages yellow stripes appear on leaf sheath and stalk. The virus is a rod. The virus gets transmitted by setts and the aphid, *Raphalosiphum maidis*.

6. Disease : Grassy shoot Disease(GSD)

Causal organism : Candidatus phytoplasma

Symptoms: Large number of lanky tillers are produced from the Affected sett. Leaves become narrow, pale green to white in colour. The internodes get shortened and plants appear bushy due to excessive tillering. The pathogen in transmitted by Aphids-*Melanaphis sacchari and Rhaphalosiphum maidis*

8. Disease : Phanerogamic parasite

Causal organism : *Striga spp.*

Symptoms: It is partial root parasite with chlorophyll bearing leaves. The parasite attaches to the host root by haustoria and suck the mineral nutrients and water. As a result the parasitised cane becomes stunted.

Management:

Red rot:

Selection of setts from healthy nursery programme growing of Recommended resistant and moderately resistant varieties *viz*., Co86249, CoSi95071, CoG 93076, CoC 22, CoSi 6 and CoG 5 Adopt sett treatment With Carbendazim before planting (Carbendazim 50 WP, @ 0.05% or Carbendazim 25 DS @ 0.1% along with 1.0% Urea for 5 minutes) the Irrigation interval in a red rot affected field must be lengthened. Once in 15 days during tillering, growth phases and once in 25 days during

Maturity phase which restricts the spread. Removal of the affected Clumps at an early stage and soil drenching with 0.1 % Carbandazim 50 WP or 0.25 % lime. The trash of red rot affected field after harvest may be uniformly spread And Burnt The red rot affected field must be rotated with rice for one season and Other crops for two seasons.

Smut:

Growing of resistant and moderately resistant varieties viz., Co 86249, CoG

- 93076, CoC 22, CoSi6 and CoG 5
- Sett treatment with fungicides *viz*., Triadimefon @ 0.1% or Carbendazim @ 0.1% for 10 minutes.
- Treating the seed setts with Aerated Steam Therapy (AST) at 50 ºC for 1 hour or in hot water at 50 ºC for 30 minutes or at 52 ºC for 18 minutes Removal of smut whips with gunny bags/polythene bag and burnt Discourage ratooning of the diseased crops having more than 10 per cent infection

Phanerogamic parasite

- Regular weeding and intercultural operation during early stages of parasite growth. Spray Fernoxone (sodium salt of 2, 4-D) at 450g /500 litre of water.

General management

Select healthy setts for planting. In the seed crop, select plants which do not show symptoms of red rot, smut, grassy shoot and ratoon stunting. Setts showing red colour at the cut end and hollows should be rejected and burnt.

Set fire to residues of previous crop to eliminate debris of fungal pathogens.

In fields which had shown high level of red rot disease, follow crop rotation with rice. The setts should be soaked in 0.1% Carbendazim or 0.05% Triademefon for 15 minutes. Treat setts with aerated steam at 50°C for one hour to control primary infection of grassy shoot disease.Clumps infected by grassy shoot, smut and ratoon stunting diseases should be

immediately uprooted and destroyed.Use resistant varieties for the following

diseases: Red rot CO 62198, CO 7704 (Resistant),

8. DISEASES OF OILSEEDS

I . DISEASES OF GROUNDNUT

1. Early leaf spot: *Cercopora arachidicola*

Late leaf spot: *Phaeoisariopsis personata*

Symptoms:

a.Early leaf spot: The sports are circular to irregular and reddish brown to dark brown in colour. Spots appear on the upper surface, encircled by a bright yellow halo. On the lower surface the lesions are light brown in colour.

b. Late leaf spot: Leaves show dark, small, circular spots scattered on the surface and appear in large numbers. The lower surface of the lesion turns to carbonaceous black. Petioles and stem also exhibit black elongated lesions. Spotted leaves shed prematurely

The mycelium is inter and intracellular. Conidiophores are short, olivaceous brown, 1-2 septate and geniculate, arising in clusters.

Favourable Conditions : Prolonged high relative humidity for 3 days Low temperature (20 C) with dew on leaf surface; Heavy doses of nitrogen andphosporus fertilizers ; Deficiency of magesium in soil.

2. Rust :

Causal organism : *Puccinia arachidis*

Symptoms: The leaflets exhibit large number of small powdery pustules on the lower surface. Correspondingly the upper surface shows yellow discolouration which later turns brown. Pustules coalesce and severe infection causes drying and shedding of leaves. Pustules are also seen on petiole and stem. The pustules represent the uredosori.

Favourable Conditions

High relative humidity (above 85 per cent);Heavy rainfall.Low temperature (20-25˚C).

3. Collar rot / Seedling blight / Crown rot

Causal organism : ***Aspergillus niger*** *and* ***A. pulverulentum***

Symptoms: The fungus causes pre-emergence and post-emergence rot and crown rot symptoms.

Post-emergence rot: Young seedlings exhibit circular brown spots on cotyledons. Similar spots appear on the collar region. The affected portion becomes soft and rots. Profuse growth of the fungus is seen on the affected regions.

Crown rot: The adult plants develop large brown lesions on the stem. Leaves droop and plants wilt.

4. Root rot

Causal organism : *Macrophomina phaseolina*

Symptoms: The affected plants exhibit reddish brown discolouration on the stem near soil level. Leaves and branches droop and the whole plant wilts. White mycelial growth is observed on the lesions. The bark of the root becomes shredded and large number of sclerotia are formed in the shredded tissues and also on the wood.

Favourable Conditions : Prolonged rainy season at seedling stage and Low lying areas.

5.Disease : Ring mosaic / Bud necrosis / Bud blight

Causal organism : *Groundnut bud necrosis virus*

Symptoms: The disease is characterized by mottling and ring spotting of leaves, reduction in leaf size and stunting of plants. Leaves are malformed to varying sizes and they become narrow with necrotic lesions. Stem also exhibits streaks and necrosis of bud occurs in advanced stages. The virus is transmitted by the thrips, *Frankliniella schultzi* and *Thrips tabaci*

Disease management

1. Seed treatment: Treat the seeds with any one of the following Thiram @ 4g/kg of seed or Mancozeb @ 4g/kg of seed or Carboxin @ 2g/kg of seed or Carbendazim @ 2g/kg of seed or Talc formulation of *T. viride* @ 4g/kg of seed or *P. fluorescens* @10g/kg of seed.

2. Early leaf Spot and Late leaf Spot:

Spray any one of the following:

Carbendazim 500 g/ha or Mancozeb 1000 g/ha or Chlorothalonil 1000 g/ha . If necessary give the second round 15 days later.

Combined infection of rust and Leaf spot

Spray any one of the following: Spray 10% *Calotropis* leaf extract or Spray Carbendazim 250 g + Mancozeb 1000g/ha or Chlorothalonil 1000g/ha. If necessary give the second round 15 days later.

3.Rust: Spray any one of the following:

Mancozeb 1000g /ha or Chlorothalonil 1000g /ha or Wettable sulphur 2500g /ha or Tridemorph 500 ml/ha or If necessary, repeat the spray 15 days later.

4.Collar rot

- Crop rotation.
- Destruction of plant debris.
- Remove and destroy previous season's infested crop debris in the field

Seed treatment with *Trichoderma viride* / *T.harzianum* @ 4 g/kg of seeds and soil application of *Trichoderma viride* / *T.harzianum* at 2.5kg/ha, preferably with organic amendments such as castor cake or neem cake or mustard cake @ 500 kg/ ha.

5.Root rot:

Soil application of *P. fluorescens* @ 2.5g /ha mixed with 50 kg of well decomposed FYM / sand at 30 DAS.

Spot drench with Carbendazim 1 g / l

6.Groundnut Bud Necrosis:

Adopt a close spacing of 15 x 15 cm. Remove infected plants up to 6 weeks after sowing and spray Monocrotophos 36 WSC 500 ml/ha, 30 days after sowing either alone or in combination with antiviral principles. Antiviral principles from sorghum or coconut leaves.

AVP are extracted as follows: Sorghum or coconut leaves collected, dried, cut into small bits and powdered to one kg of leaf powder two litres of water is added and heated to 60°C for one hour. It is then filtered through muslin cloth and diluted to 10 litres and sprayed. To cover one ha 500 litre of fluid will be required. Two sprays at 10 and 20 days after sowing will be needed

II. DISEASES OF SUNFLOWER

1. Leaf blight

Causal organism : *Alternaria helianthi*

Symptoms: Spots are circular, brown with concentric rings, encircled by yellow halo. Spots coalesce to become bigger and irregular patches. Affected leaf exhibits drying. Spots are also noticed on sepals, petals and stem.

Favourable Conditions : Rainy weather;Cool winter climate;Late sown crops are highly susceptible.

2. Rust

Causal organism : ***Puccinia helianthi***

Symptoms: On the lower surface of leaf, large number of reddish brown pustules are seen either scattered or in groups on leaves at the bottom of the plant. These pustules are powdery in nature and represent the uredosori. Uredospores are echinulate and round to elliptical with a stalk and the fungus is an autoecious rust.

Favorable Conditions : Day temperature of 25.5° to 30.5°C with Relative humidity of 86 to 92 per cent enhances intensity of rust attack.

3. Head rot

Causal organism : *Rhizopus* sp.

Symptoms: Affected heads show water soaked lesions on the lower surface, which turn brown. The head turns soft, pulpy and tissues putrefy. The seeds are converted into black mass. The head is not filled properly and it withers finally.

Favourable Conditions : Prolonged rainy weather at flowering ;Damages caused by insects and caterpillars.

Root rot or charcoal rot :

Causal organism : *Macrophomina phaseolina*

Symptoms: In affected plants, leaves droop and start drying. Bark at the lower portion of stem and root splits into threads and large number of sclerotia are observed on the affected tissue. Pycnidia also develop on the stem.

Sunflower necrosis disease -*Tobacco streak virus* (TSV)

Symptoms: Characterised by the sudden necrosis of part of lamina followed by twisting of leaves and systemic mosaic. Necrosis of lamina of the lamina, petiole, stem floral calyx and corolla. Vector: Thrips

Disease management

1.Seed treatment: Treat the seeds with any one of the following:

T. viride @ 4g/kg of seed,Thiram @ 4g/kg of seed,Carbendazim @ 2g/kg of seed

2. **Alternaria leaf spot and Rust:** Spray Mancozeb 1000g/ha

3.Charcoal rot:

Soil application of *P. fluorescens* or *T. viride* – 2.5 Kg / ha + 50 Kg of well decomposed FYM or sand at 30 days after sowing. Spot drenching with Carbendazim @ 1 gm/ litre.

4.Head rot :

Spray Mancozeb 1000g/ha in case of intermittent rainfall at the head stage, directing the spray to cover the capitulum.Repeat fungicidal application after 10 days if humid weather continues

5.Necrosis virus disease:

Raise sorghum as border crop (One month prior to sunflower sowing).

Imidacloprid seed treatment 2g/kg % Imidacloprid foliar spray at 30 & 45 DAS

III. DISEASES OF GINGELLY

1. Root rot (Charcoal rot)

Causal organism : *Macrophomina phaseolina*

Symptoms: Affected plant exhibits brown discolouration at the stem close to soil. Leaves become yellow, droop and plants die in patches. Bark shredding is noticed in stem and root. The fungus produces dark brown sclerotia. It also forms pycnidia bearing hyaline, single celled, elliptical conidia. **Favourable Conditions :** Day temperature of 30˚C and above; Prolonged drought followed by copious irrigation.

2. Leaf blight

Causal organism : *Alternaria sesame*

Symptoms: Spots are round to irregular, necrotic with concentric rings in The center. Several spots coalesce leading to blight.

3. Powdery mildew

Causal organism : *Erysiphe cichoracearum*

Symptoms: Leaves show white powdery growth on the upper surface. Often the entire lamina is covered by fungal growth. Severe infection leads to malformation of leaves. The white growth consists of hyaline, septate mycelium, conidiophores and chains of conidia.

Favourable Conditions : Dry humid weather; Low relative humidity.

4. Phyllody

Causal organism : Candidatus Phytoplasma

Symptoms: The floral parts are altered into green leafy, phylloid s tructures. Plant exhibits clusters of leaves at the axil and also at the terminal portion which gives a bushy appearance to the plant. The phytoplasma is transmitted by the jassid vector, *Orosius albicinctus.*

DISEASE MANAGEMENT

1.Seed treatment: Treat the seeds with any one of the following *P. fluorescens* @ 10g/kg of seed, *T. viride* @ 4g/kg of seed, Thiram @ 4g/kg of seed, Carbendazim @ 2g/kg of seed

2.Powdery mildew: Apply any one of the following.Sulphur dust 25 kg/ha or Wettable sulphur 25 kg/ha

3.Alternaria blight: Spray Mancozeb 1000g/ha

4.Root rot: Soil application of *P. fluorescens* or *T. viride* – 2.5 Kg / ha + 50 Kg of well decomposed FYM or sand at 30 days after sowing. Spot drench Carbendazim – 1 gm/ litre

5.Phyllody : Remove and destroy infected plants.To control vector, spray Monocrotophos 36 or Dimethoate 30 EC 500 ml/ha combined with intercropping of Sesamum + Redgram (6 : 1)

Current approaches for management of cotton pests and diseases in India

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ABSTRACT

Managing biotic stress in cotton has been dependent on the various pesticide molecules that are becoming available for cotton where farmers took extra-care to see that all the fruiting forms are retained in tact to be harvested fully. This paper discusses the solutions that have arisen out of the country-wide monitoring of insecticide resistance in key pests as well and the use of alternate strategies such as biological control and host-plant resistance.

Introduction

India is one of the two countries of origin of cotton the other being Peru. Fifty years ago India grew cotton over 5.89 million hectares of land with a production of 3.1 million bales. Today, cotton occupies an area of 8.87 M hectares with a total production of 14.5 M bales of cotton (CICR Annual report 2001-2002). With increasing population, the requirement for cotton rose dramatically and in 1999-2000 productivity was 320 kg lint ha^{-1}. Over the last 50 years productivity increased by 221 kg ha^{-1} from an extremely low 88 kg ha^{-1} (Agrl. statistics at a glance, 1999). This phenomenal growth in cotton productivity was attributed largely to hybrid cotton technology (Paroda and Basu, 1990). About 20 major popular hybrids occupy nearly 40 % of the total cotton area and contribute to over 50 % of the total cotton production. With successful exploitation of this technology on a commercial scale, further increases can be brought about through integrated crop management programs of which IPM is a crucial component. This is especially true since there has been no significant expansion in the area under cotton cultivation in recent years and the targets can now be met through good management programs. While India has the largest area in the world under cotton (Table 1), it still ranks amongst the lowest in its productivity.

India is perhaps unique in its cotton cultivation. The four commercialized *Gossypium* species are grown commercially in different regions of the country. *G. hirsutum* and *G. arboreum* are grown in the North Zone comprising the Punjab, Haryana, Rajasthan, and parts of Uttar Pradesh. The Central Zone comprising of Gujarat, Madhya Pradesh, and Maharashtra is home to *G. hirsutum*, *G. arboreum* and *G. herbaceum* while all four species (including *G. barbadense*) are grown in the South Zone (Basu, 1995). Table 2 indicates the expected area under the four species in the years to come. Sixty-five percent of the area under cotton is predominantly rainfed, while the remainder is irrigated. The irrigated cotton belt is largely confined to northern India.

Changes in the cultivars and cultivation practices have effected changes in the dominance of various pest species. Intense efforts to thwart herbivory in cotton crop made it notorious as a pesticide intensive crop in the last few decades, in India as elsewhere in the world. Today, India uses chemicals including pesticides in public health and agriculture to a total of US $640 M of which US $560 M worth pesticides are used in agriculture alone. Of this, insecticides worth US $320 M are used for the control of bollworms and sucking pests and US $222 M of this is apportioned to bollworm control (Ghosh, 2001). In this context, alternate methods of pest management, such as IPM becomes relevant, as there is emphasis on the judicious use of pesticides in combination with other methods of control.

Pest losses in cotton

Insects, mites, pathogens, weeds, nematodes, rodents and birds constitute the pest complex of cotton. Of the biotic stresses, insect pests cause by far, the highest economic losses. Of the 1326 species of insects found on cotton, the sucking pests (jassids and whitefly) and the bollworm complex are designated as the key pests of cotton. Apart from a direct effect in the reduction of yield by these pests, it has been realiszd that their damage contributes to a high trash content in the lint resulting in lower international prices for Indian cotton.

Losses due to bollworms are more or less consistent throughout the sub- continent. However, losses due to sucking pests are variable. During the year 2001-02 heavy losses due to bollworms were reported in Punjab (20%), Haryana (50%) and Rajasthan (70%) (AICCIP annual report, 2001-02). During 1999-2000 and 2000-01 the avoidable losses due to all major pests were 32.3% and 26.2%, respectively. Sucking pests, in two years, caused a loss of 18.1% and 13.5% respectively while bollworms caused loss of 26.57% and 16.23% respectively (CICR Annual Report, 2001). A special mention should be made of the cotton whitefly Bemisia tabaci that has been reported to be a major pest in 16 of the 27 major cotton growing countries of the world, especially during the mid to late cotton growing season. It has also become a serious pest of cotton in recent years in several cotton growing regions of India, especially in the northern parts of India. The problem assumes a serious dimension in relation to the *Cotton Leaf Curl Virus* (CLCuV) being transmitted by the whitefly. Losses caused by CLCuV have seen a reduction in the number of harvestable bolls 15–87% and a loss in boll weight of upto 39% (Singh *et al.*, 1999). Bacterial blight and gray mildew are diseases that affect cotton in rainfed and dryland conditions while root rot and cotton leaf curl, are diseases that affect irrigated cotton in the north zone in India. These diseases limit productivity of lint to the extent of 12-23%. Many of them need critical favorable climatic and host conditions to emerge as a biotic threat for yield destabilization. Diseases in cotton have low yield reducing impact unless they become epidemic. Due to the consistent breeding efforts, we now have inbuilt resistance to bacterial blight, grey mildew and traditional wilts. Loss estimates due to plant parasitic nematodes have been put between 9-15% in India.

Integrated pest management refers to the intelligent selection and use of pest management tactics that results in favorable ecological, sociological and environmental consequences (Rabb, 1972). It has also been defined as one or more management activities carried out by farmers that result in the density of potential pest populations being maintained below levels at which they become pests, without endangering the productivity and profitability of the farming system as a whole, the health of the farm family and its livestock, and the quality of the adjacent and down stream environment (Whiteman *et al*., 1995). IPM recognizes that complete control of a pest is neither required nor desired. It emphasizes the maintenance of pest populations below the economic threshold level (current figures for cotton insect pests has been presented in Table 3) and demands the initiation of pest management tactics before the economic injury level is reached. This concept is coherent with administrators and scientists in India. However its implementation under field situations has not been easy since the average Indian farmer has a low literacy level and fragmented land holdings with multiple crops. Therefore cotton pest management strategies for India have to be designed in such a way so as to ensure that they are in consonance with ground realities of the Indian farming system. Plant protection specialists in various research institutions have to assemble their technologies to fit it into this complex and heterogeneous cropping environment of Indian farms.

Managing biotic stress in cotton was dependent mainly on a plethora of chemical molecules where farmers concern was to ensure the retention of all fruiting forms, intact untill harvest. This paper discusses the imaginative alternate strategies such as adoption of insecticide resistance management strategies, biocontrol-based IPM, host plant resistance, harnessing of low cost methodologies to sustain small growers, maintain a healthy crop to harvest good quality fiber and bring in economic and social benefit. The different approaches have been evolved in such a way to ensure that the cotton grower is able to reduce the cost of cultivation allowing the market price fluctuations which an anticipated in the coming years to be met with more confidence.

Management strategies

Pest monitoring

Monitoring of pests and diseases is necessary for timely action to be initiated. Use of light traps and pheromone traps to monitor insect populations is being recommended. Regular scouting is undertaken by progressive farmers for determining bollworm populations in the egg stage for effective management.

Seed treatment

This is a practice that has been followed primarily for protecting the young seedlings from disease. Historically, organomercurial compounds dominated the seed treatment market. This was gradually replaced with new chemicals such as Thiram, Mancozeb, Carbendazim etc.

Today we have new generation compounds that offer excellent sucking pest control. Jassids, aphids and other sucking pests are better managed with seed treatment allowing a delay in the application of broad spectrum foliar sprays (Russell *et.al*., 1998). Imidaclorprid (Gaucho 70 WS) is a chloronicotinyl molecule used at 7.5 g a.i/ kg of seed and offers protection upto 45 days after sowing against sucking pest such as aphids and jassids. Thiomethoxam (Cruiser 70 WS) and acetamiprid are newer products useful for seed dressing (Leicht, 1993). However, imidacloprid, on account of its high toxicity has been discouraged as a seed-dressing agent for farmer application by the government of India. Approval has been granted for its application by seed companies for seed treatment prior to sale. It has, however, been permitted for use as an early season spray (Confidor®) as and when required. Use of these neonicotinoids is being recognized as a popular technology especially for cotton hybrids as it is cost effective on account of the low seed rate for hybrids. Bt hybrids (MECH 12, 164, 184) seeds are also being treated with imidacloprid. The use of neonicotinoid treated seed is an important component of leaf curl virus management where it has been reported effective in vector management. Seed treatment chemicals like imidacloprid 600 FS, imidacloprid 70 WS, thiomethaxam 70 WS and carbosulfan 25 DS, reduced both the CLCuV and vector incidence for two consecutive years (Singh *et al*., 2002). Seed treatment with carboxin, carbendazim, or carbosulfan protects the cotton crop against fungal soil borne diseases. Mancozeb seed treatment was reported to keep root rot disease to low levels in infected soils (Monga and Raj, 2000). In addition, protection against seed borne diseases is ensured by storing seeds under low moisture conditions and by the use of acid delinted seed.

Host plant resistance

The basis for any sound IPM program is the choice of an appropriate cultivar that fits well into the production system.

The most desirable characteristics of a cotton cultivar or hybrid is that it should possess reasonable pest tolerance, short and early duration, good fiber qualities, coupled with high yield.

Both morphological and biochemical mechanisms in *Gossypium* spp. have been found to mediate resistance against jassids, whiteflies and the bollworms. Morphological characters such as hairiness of leaves, toughness of leaf veins, thickness of leaf lamina, length of hair and angle of insertion are reported to be associated with jassid resistance. The pubescent genes H1 and H2 has been used to provide jassid resistance to cultivars in India. However extreme pubescence has been reported to have an adverse effect on agronomic traits (Uthamasamy, 1995).

Of the cultivated cottons, *G. arboreum* and *G. herbaceum* are resistant to the leaf hopper. Among the wild cottons *G. tomentosum*, *G. armourianum* and *G. raimondii* by virtue of their pubescence are resistant to sucking pests. *Gossypium arboreum* types as compared to *Gossypium hirsutum* types are more resistant to jassids and whiteflies. Morphological attributes such as red leaf, glabrousness, okra leaf and fregobract are known to confer a high degree of tolerance to *Helicoverpa* and whiteflies. Red leaf has an adverse effect on agronomic characteristics especially in environments with high yield potential.

Most of these attributes have been used by breeders to screen for resistant sources and cultivars, such as Kanchana, LK861 and Supriya, have been developed which have considerable tolerance to whitefly. Cotton genotypes, DHY286, Mahalakshmi, MCU15, Krishna, Sujatha have been identified for resistance against jassids. These sources of resistance can be used as parents in crosses. Some exotic hybrids (six *G. hirsutum* x *G. barbadense* interspecific hybrids, five from Israel and one from India, and two intraspecific *G. hirsutum* hybrids (Fateh and LHH144) were tested for their resistance to white flies under field conditions. Table 4 lists the prominent cotton cultivars that have resistance to pests and diseases.

Biochemical features such as levels of gossypol, phenol, tannin, and heliocides of squares and bolls have been found to impact host plant resistance to bollworm significantly. Genetic research has shown that gossypol, anthocyanin, phenolics, and related compounds are amenable to selection and they can be increased to levels effective for useful insect control. While these features have been commercially exploited to a certain extent in the genotypes of the US (Jenkins, 1995), their utilization in the Indian context has been limited. Cultivars or hybrids that show resistance to Helicoverpa armigera, the major cotton bollworm under normal pest pressure do not exhibit the same level of resistance in an outbreak situation. Use of some traits has limitations that relate to the occurrence of different insects in the production system, as a character, which is useful for the control of one pest may be contra-indicated for another.

Effective host plant resistance has been employed against Verticillium wilt in southern India. Three *G. hirsutum* lines, KH-13-146, 15 KW-2 (MB) and 9-KW-2 (MB) have been observed to be resistant to both *R. solani* and *R. beticola*. Molecular approaches to utilize pathogen-derived resistance factors are being employed to develop diagnostic tools for bacterial blight disease in cotton (Chakrabarty, 1999). Newer strategies such as the activation of inducible defense mechanisms of plants by compounds such as ASM (acinbenzolar S-methyl), an activator of broad-spectrum disease resistance, are new tools in crop health management. These are to be evaluated with the Indian varieties and hybrids in developing resistance against grey mildew disease and others where genetic resistance is still elusive.

A national *Gossypium* gene bank of was set up at the Central Institute for Cotton Research (CICR), Nagpur in 1976 and today it boasts 9607 accessions of both cultivated and wild species of cotton which are accessible to both the Government and the private industry for purposes of research that includes resistance breeding. Many tolerant accessions have been identified from within the germplasm repository and a few are listed in Table 5.

Cultural methods

Utilization of cultural methods of pest control has seen limited success. Many of these practices lapsed with the introduction of effective and easy to use pesticides. Utilization of oviposition trap crops such as marigold, in cotton in South India, is a popular cultural practice for improved *H. armigera* management. The use of redgram/cowpea intercrop in cotton production systems has been reported to enhance numbers of beneficial fauna thus aiding crop protection. Grazing of harvested crop stubbles is a recommended practice to prevent carryover of pink bollworm pupae. This is quite often carried out in Indian cotton production systems. Castor is popularly grown around cotton as a trap crop in Andhra Pradesh for *Spodoptera* control. These methods are cheap, sustainable and are readily adopted by farmers. Of the cultural methods of control, cropping practises, close seasons and crop rotation are adopted in cotton cultivation. Although no legal enforcement of the close season is prevalent in cotton production systems of India, in many areas farmers leave cotton fields fallow during the peak summer months of May and June. This close season is of fundamental importance for key pests such as *P. gossypiella* and has been introduced in most cotton growing countries (Matthews, 1994).

Cultural practices have a significant effect in the case of soil borne pathogens. Crop rotation, soil amendments with organic material and mustard cake reduced root rot incidence drastically. Ammonium sulfate and intercropping with moong bean (*Vigna aconitifolia*) have consistently reduced root rot incidence. Soil application of zinc sulfate @ 24 kg/ha was also found suitable in reducing the incidence of root rot (Raj *et al.*, 1999).

Mechanical methods

De-topping in cotton to prevent egg laying by *H. armigera* has been considered as a recommendation. It was found that de-topping of terminal leaves would result in the reduction of eggload in the crop. This practice appears to be feasible only in Central India where genotypes are comparatively short statured to those of North and South India. Thinning of plants to maintain optimum plant populations and mechanical picking and destruction of egg masses of *Spodoptera* are a popular practices in Andhra Pradesh. Handpicking of older larvae of *Helicoverpa* especially during outbreak years, 2-3 days after pesticide application, is a recommended practice to contain resistant *H. armigera* larvae. The use of light traps is popular in some regions of the country (eg. North India) and is especially directed at noctuid moth control. Yellow colored sticky traps for whitefly control form part of the recommended package of practices for whitefly endemic areas in India. The use of pheromone traps was initially envisaged for mass trapping of moths. However, considering limitations such as cost, attraction of the relevant species demonstrated the efficacy of pheromone traps for its purpose, they are now recommended mainly for pest monitoring. They are now reasonably popular for pink bollworm monitoring in North India. Studies at CICR in collaboration with the Bhabha Atomic Research Centre have explored the generation of suitable pheromone blends for monitoring of mixed species bollworm populations and the design of appropriate traps to suit the Indian farmer.

Biological control

Entomopathogens such as *Nuclear Polyhedrosis Virus* (NPV), the egg parasitoid, *Trichogramma minutum*, the larval parasitoids, *Bracon* sp. and *Apanteles* sp, lace-wing, *Chrysoperla carnea*, and coccinellids, *Menochilus* and *Chilomenes* have been used extensively in field trials. Table 6 lists commonly found natural enemies with their peak period of occurrence in the cotton ecosystem. The emphasis in India on biological control has been on the augmentation of natural enemies, involving mass production and release of natural enemies at certain critical periods in the life cycle of the pest when natural enemy populations are at low levels. *Trichogramma* has been extensively used the world over to suppress lepidopteran pests in a number of cropping systems. Effectiveness has been established in India, in the sugarcane, tomato and potato ecosystems (Sithanatham *et al*., 1973, Yadav *et al*., 1985). Chrysopids offer great scope in the suppression of sucking pests in cotton. A mass production technology has been developed at Gujarat Agricultural University, Anand. Over 60 million eggs could be produced in a month, sufficient to occur 100 hectares of irrigated cotton. Of the several pathogens that have been extensively studied, viruses have been found to be the most promising. As many as 35 viruses have been reported from different insects (Pawar and Thombre, 1991).Results of field trials with *Helicoverpa* specific NPV (Ha NPV) on chickpea (Mistry *et.al*., 1984), at Tamil Nadu (Jayaraj, 1988) and Maharashtra (Pawar *et.al*., 1990) have been promising. NPV as sprays against *H. armigera* have been reported effective in cotton (Dhandapani *et.al.*, 1987), sunflower (Rabindra *et.al.*, 1985). Pigeon pea (Pawar and Thombre, 1991) and tomato (Mistry *et.al.*, 1984). *Spodoptera* NPV was found effective in cotton, tobacco and cauliflower (Jayaraj, 1988; Ramakrishnan *et.al*., 1981 and Chaudhary and Ramakrishnan, 1990).

CICR has played a major role in the establishment of small biocontrol factories in Vidarbha region of Maharashtra. These small-scale units are capable of producing *Trichogramma*, *Chrysoperla* and HaNPV. A low cost technology for the mass production of Bt has been introduced. Protocols are also available for mass production of major natural enemies. The basic laboratory host for the multiplication of *Trichogramma* and *Chrysoperla* is *Corcyra cephalonica*, the mass rearing of which is done on cheap local grain. The eggs and larvae thus obtained are put to use in the production of various natural enemies. From a production of 200 000 larval equivalents (LE) per year of HaNPV per year in 1997-98, these enterprises are confident of producing 2.5 million LEs per year per bio-factory unit (Rajendran and Basu, 1999). It must be mentioned here that in India, State Governments offered a heavy subsidy on the production and purchase of HaNPV.

As part of the All India Coordinated Cotton Improvement project (AICCIP), an extensive networking system between ICAR, National Institutes and State Agricultural Universities bio-intensive models of IPM have been tested. These modules lay emphasis on the release of bio-agents with good management practices, which are prevalent or that can be adopted in particular.

Cotton production systems, especially the irrigated areas of North India and Andhra have witnessed rampant misuse of insecticides in the past. This has resulted in the virtually complete elimination of bio-agent populations. It must be emphasized that reduced pesticide use has demonstrated the restoration of bio-agents, with yields being initially low, but once natural enemy populations are restored, higher yields are obtained (Asanov *et al.,* 2001). Globally however the direct impact of the non-chemical control component of IPM has usually led to only modest enhancement of yield, rather slight increases in the importance of beneficial insects and modest reductions in pest damage.

Biocontrol-based management of plant diseases is being adopted today. Several antagonists such as phylloplane and rhizosphere flora have been identified to be potentially useful for bio-control of cotton pathogens. Seed treatment with *Glyocladium virens* and *Bacillus subtilis* to suppress colonies of *Fusarium oxysporum* are recent approaches adopted in India before planting. Several strains of *Trichoderma viride* successfully protected cotton plants against root rot caused by *Rhizoctonia solani*, *Sclerotium rolfsi*, the application of seed treatments with biological products using a talc base is feasible (Mathiavanan *et al*., 2000).

Endopytic bacteria, such as *Agrobacterium sapardae*, *Bacillus pumilus*, *Phyllobacteria rubiacearum*, *Psuedomonas putida* and *Bakholderia solanacearum* show potential for the biocontrol for the vascular wilt pathogen (Chen *et al*., 1995). These bacteria can survive within cottonseeds up to 28 days after inoculation. Soil application of *Trichoderma harzianum* controlled damping off by *R. solani* and gave an excellent crop stand (Monga, 1997). Culture filtrates of *Trichoderma* and *Gliocladium* species reduced root rot pathogens and with suitable organic amendments, these organisms were found to perform better as antagonists of cotton root rot (Monga, 2001). Improved strains of this fungal antagonist with additional copies of the proteinase gene, prb1 (Flores *et al*., 1997) could also provide better ammunition against rhisosphere pathogens such as *R. solani* and *R. beticola*.

Botanicals

Plants are the richest source of renewable active chemicals that can check pest populations. The use of botanicals is another important component of IPM, of which neem is of prime importance. About 67 commercial neem-based formulations are currently available. The active principles in the neem seed and other plant parts are azadirachtin and its analogues, which by virtue of contact and stomach action, possess ovicidal, antifeedant and growth regulatory properties against insects. Neem has been reported to be compatible with parasitoids (Mani, 1994; Regupathy and Mahadevan, 1993) and predators (Schmutterer, 1990; Natarajan, 1990) in the cotton ecosystem. It is certainly possible and advantageous to include neem products in IPM programs (Tadas *et al*., 1994) especially with an estimated 18-million neem trees in India, each with a potential to produce 0.7 tonnes of fruit. Farmers have been made aware of the economics, safety and environmental benefits of neem. This component of IPM was already in practice as an indigenous technology and is a low cost management tool. Refinement in the preparation of sprayable formulations from neem seed has been brought about in many cotton growing regions with farmers being trained to collect neem seeds and process it during the off-season in addition to other techniques. These include the addition of soap as an emulsifier and the addition of neem oil, which reconstitutes the water-extracted azadirachtin to a more effective formulation. Neem suffers the disadvantage of having reduced stability when exposed to sunlight. Research is being directed to improve its stability with the addition of UV protectants to formulated products. Other plant products that are in use include water extracts of *Calotropis, Ipomoea* etc.

Chemicals

The Indian farmer is heavily dependent on insecticides for pest control since these products are ready to use, readily available and provide visible amelioration although they are not cost effective in all cases. A substantial regional difference in pesticide use exists. Andhra Pradesh, Karnataka and Gujarat account for 65% of the total consumption and Andhra Pradesh alone accounts for 34%. The per-hectare pesticide consumption is highest in AP (1023 g), Haryana (889 g), Punjab (834 g) and Tamil Nadu (778 g). During 1997, Andhra Pradesh alone consumed pesticides worth US $85 M (Puri, 1998). Rampant misuse and gross overuse of insecticides have resulted in resistance in almost all insects to major groups of insecticides (Kranthi *et al*., 2002). In the late seventies organophosphates such as monocrotophos, endosulfan were being widely used. With the introduction of pyrethroids and its near-miraculous effect in the initial years on all lepidopteran pests of cotton, farmers grossly misused this molecule. This was especially true of irrigated cotton regions. By the end of 2001, it was found that resistant *H. armigera* were present in all parts of the country (Kranthi *et al*., 2001). It is unlikely that any pyrethroid susceptible *H. armigera* populations can be found in the country. A worrisome development has been the emergence of spurious and substandard formulations of insecticides and botanicals. Pest control failures encouraged farmers to undertake tank mixes of insecticides that worsened the situation because these were not recommended and were highly unscientific. The year 2001-02 witnessed a serious bollworm outbreak in North India. The reasons proposed are many of which the repeated spraying of pyrethroids, lack of availability of newer molecules on time and use of injudicious tank mixes are important.

Insecticide resistance management (IRM)

A novel strategy was devised to provide a practical, robust plant protection package to ensure favorable economic, sociological and ecological consequences. This involved the use of insecticides highly compatible with IPM while taking into cognizance the existence of resistance to insecticides in various insects of the cotton ecosystem. A wide database on the in-season changes in resistance and between years has been generated across North, South and Central India against the major cotton pests (Kranthi *et al*.,2001, 2002). This was established with the setting up of five major insecticide resistance laboratories across the country in a networking project. Details of this are not discussed in this paper. On the basis of the data base insecticide resistance management strategies have been formulated and implemented in parts of Andhra Pradesh, Tamil Nadu, Maharashtra and Punjab through funding by the Indian Council for Agricultural Research, Natural Resources Institute, UK, Department of International Development, UK and ICRISAT, Hyderabad and Punjab and Tamil National Agriculutral Universities. Currently, the Government of India is funding an US $350 000 project for the implementation of IRM strategies in the 26 newest insecticide using cotton-growing districts of India, in the year 2002-03. CICR is coordinating the inputs from government institutes, agricultural universities and the Indian Council of Agricultural Research in expanding this work to the 260 villages, which between them use almost 80% of the insecticides applied on cotton.

The basic concepts of IRM suggest that particular insecticides should be used when resistance to that material is low, that natural enemy populations should be disturbedas little as, that different groups of chemicals are alternated and that sucking pest tolerant genotypes are grown to avoid early season insecticide sprays. Summarised, IRM means cultivation of sucking pest tolerant cultivars, zero insecticides till 60 days after emergence of the crops, adoption of window strategies with no endosulfan beyond 90 days, no organophosphates till 90 days, use of bio-rationals if available between 70-90 days and the use of pyrethroids only after 110 days (CICR, 1999). IRM strategies draw strength from the fact that it is supported by voluminous, meaningful, peer reviewed and published laboratory and field data. Its sustainability is enhanced by the fact that it does not rely on the supply of free inputs to the farmer. The impact of insecticide resistance management can be seen from Table 7.

Insecticide resistance strategies have been adopted in several countries such as USA and Australia since the early nineteen nineties. Strategies suitable to the Indian ecosystem necessarily had to be developed since neither the pest situation nor the crop production practices were common between the countries. Globally, the more rational use of insecticides, through scouting-based systems and proper targeting of appropriate materials in IPM systems, has led to reduction in pesticide costs often exceeding 50%, thereby greatly enhancing cotton production profitability (Russell *et al.*, 1998).

Transgenic Bt cotton

This is a promising seed technology option is now available to the Indian cotton farmer. Cotton genotypes have been successfully transformed with a gene from the soil-borne bacterium, *Bacillus thuringiensis*. The gene is responsible for the production of a protein toxin within the cotton plant that has been found to be effective against wide array lepidopteran insect pests. Monsanto introduced the gene into a cotton genotype in the US in 1993. Commercialised as the "Bollgard technology", it has impacted cotton production in Australia, China, Argentina, and United States during the last 5-6 years with minimal problems of field control failures. India conducted its field trials using transformed Indian genotypes MECH 12, 162 and 184 that contained the Bt gene developed by Monsanto together with the varieties of a leading player in the seed market, Mahyco. The gene was transferred through traditional methods of backcrossing. The Government of India permitted the commercial cultivation of Bt cotton in April 2002. In its first year of cultivation, MECH Bt hybrids occupied an area of approximately 80,000 hectares in Central and South India and is expected to occupy at least 50% of the hybrid cotton area in the country in the next 5-10 years (Mayee and Rao, 2002). The technology ensures the protection of transgenic plants from damage by most lepidopterans thus requiring minimal insecticide sprays. However, MECH BT hybrids are not protected from the attack of *Spodoptera litura* against which the Cry 1Ac toxin incorporated in the current Bt varieties is ineffective. This Bt technology also does not eliminate the requirement for sprays against sucking pests since MECH hybrids are susceptible to sucking pest attack with or without the addition of the Bt toxin. However, new cotton genotypes that are sucking pest resistant in addition to harbouring the Bt gene, are in the pipeline, and will be marketed by seed companies. This technology promises a bright future since it provides genetically engineered seeds that have the capacity to perform with relatively fewer inputs (Ghosh, 2001). From the field experiments conducted in India, cotton productivity was found to be increased by the inclusion of Bt by 23-60% in 1998-99 and 29-88% in 1999-2000 (Table 8). The net profit and the cost benefit ratio obtained in the first year of commercial cultivation have been presented in Table 9. After large-scale field trials, MECH 184 ranked first, while MECH 162 was suitable for rain-fed areas and for drought-prone situations and that MECH 12 had superior fiber quality and higher boll weight suited for areas with assured irrigation.

The government-funded biotechnology networking program aimed at transferring the Bt gene into popular varieties being grown in India is very strong. With the collaboration between at least five premiere research organizations, we now have the Bt gene introduced into LRA 5166, LRA 516, Bikaneri nerma, Sahana, and the G. arboreum genotype, RG 8. Currently, plants that tested positive for Bt presence in southern blots and ELISA are being grown under poly-house, contained, facilities before release. Bt detection kits have been developed by CICR and have been commercialized. One of them, marketed as "Bt Express" has been patented by the ICAR. These kits are being used routinely by seed companies and government research laboratories for the detection of Cry1Ac toxin in their breeding and transformed material. Farmers are using them to check for the quality of supplied transgenic seed.

New molecules for IPM

New molecules are likely to appear in the Indian market in the next two to three years. Some are being tested under the All India Co-ordinated Cotton Improvement Project (AICCIP) while others, like Spinosad and Indoxacarb, are already available in the market. The advantages of the new generation compounds are that, in addition to being effective at low dosages, like pyrethroids, they are reasonably safe to natural enemies. Essentially, they are highly IPM compatible. Several molecules such as chlorphenapyr, IGRs, pymetrozine, avermectins and resistance breaking pyrethroids are in the pipeline. However, two molecules need special mention- since they are commercially available in India.

Spinosad It is effective against lepidopteran insects including *Helicoverpa* through the activation of the neuronal nicotinic acetylcholine receptors, leading to neuro-muscular fatigue and paralysis. Spinosad comprises a mixture of spinosyn A (65-95%) and spinosyn D (5-35%). Structurally it is a macrocyclic lactone, safe to ladybird beetles, *Chrysoperla*, *Geocoris* and *Orius*, spiders, predatory mites and parasitic wasps. Spinosad 48SC is recommended at the rate of 50 g a.i/ha

Indoxacarb It belongs to the oxadiazine group and has contact and stomach action. Like most insecticides, this is a nerve poison, but acts by blocking the sodium pump. It is reported to be effective against pyrethroid resistant *Helicoverpa*. Applied at a low dose of 75 g a.i/ha, indoxacarb has high selectivity compared to conventional synthetic pyrethroids, OPs and carbamates. The only drawback appears to be its current high cost.

New molecules need to be introduced with caution. Generation of base line toxicity data for any new molecule that may shortly be introduced in the market is an important prerequisite to enable the detection of any development of resistance. This is especially important for the cotton ecosystem, which consumes more than 50% of the insecticide used in the country. On the introduction of new molecules and after intensive study under the All India Coordinated Cotton Improvement Trials insecticide resistance management programs for these new materials should be incorporated into IRM programs for cotton. This would help increase the life of the molecule by delaying the development of resistance. Short-term contractual projects are being conducted at the Central Institute for Cotton research to determine the baseline toxicity of some molecules that are in the pipeline for release.

Management of cotton nematodes

Reniform (*Rotylenchus reniformis*), root-knot (*Meloidogyne incognita*), lance (*Hoplolaimus* sp.) and lesion (*Pratylenchus* sp.) nematodes have been reported to be important in cotton. They are responsible for up to 10-12% yield losses in different regions and seasons. Many of them aggravate the damage when present in association with soil-borne pathogens such as *Rhizoctonia*, *Fusarium* and *Pythium*. Low cultural practices cost, have been effective in keeping damage at low levels. Rotations with crops like *Capsicum*, *Tagetes*, *Zinnia* and natural rotations with field crops have had a great impact in reducing nematode populations. Current emphasis of management has been on resistance breeding and biological control. Variety B4 Empire has been found to be highly resistant to root- knot nematodes. Similarly, *Paecilomyces lilacinus*, which parasitises the eggs of the root-knot nematode has shown good promise as a bio-control agent. *Pasteuria penetrans* has been suggested as a potential bio-control agent against root-knot nematode for the last decade.

The future

In the next five years cotton cultivation in India will emerge strengtened by the availability of Bt transgenics varieties and hybrids. Resistance management strategies which are being developed for the transgenic technology, specifically designed for the Indian farming systems will be disseminated. Pesticide consumption may reduce drastically with sustainable, cost effective, pest management programs in cotton. Awareness about new innovative technologies among the farming community will increase. Emphasis will be on parameters such as fiber quality in an endeavour to attract the international market. The cotton farmers and the cotton industry need to be suitably geared-up to meet the challenges of globalisation.

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Table 1. *Area, production and productivity in some of the cotton growing countries of the world.*

Country	Area (000 hectares)	Production (00 M.T.)	Productivity (Lint in kg ha^{-1})
USA	5282	3742	708
Brazil	858	900	1049
Egypt	315	272	864
Uzbekistan	1441	963	668
China	4032	4420	1096
Australia	500	704	1407
India	8148	2384	293
Pakistan	2912	1750	601
Turkey	667	880	1319
Israel	15	23	1586
World Total	31595	19251	609

Table 2. *Species composition – alteration expected (thousands ha).*

Species	Current area		Projected 2006-2007	
	Varieties	Hybrids	Varieties	Hybrids
Hirsutum	3000	3800	2200	4100
Arboreum	1500	< 500	1800	100
Herbaceum	400	Nil	500	Nil
Barbadense	-	200	-	300

Table 3. *Economic threshold levels for cotton insect pests.*

Pest	Economic Threshold Levels
Aphids	10 aphids/ plant or 15-20 % infested plants
Jassids	2 jassids/ leaf
Thrips	10 thrips/leaf or 15-20% infested plants
Whiteflies	8-10 adults or 20 nymphs/ leaf or honey dew on leaves on 50 % of the plants
Spotted bollworm	5-10 % fruiting body damage
Pink bollworm	5-10 % fruiting body damage
American bollworm	5-10 % fruiting body damage

Table 4. *Important varieties resistant to insect pest and disease.*

Variety	Resistant	Area for which recommended
Abhadhita	Bollworms	South zone
LK.861	Whitefly	South zone
Bikaneri narma	Jassids, Bollworms, *Alternaria*	North zone
Eknath	Fusarium wilt	Central zone
Kanchana (LPS.141)	Whitefly	South zone
Kirti (CICR HH.1)	Jassids	Central zone
Mahalakshmi (1301DD)	Jassids, Bollworms, Verticillium wilt	Rainfed areas of Andrah Pradesh
Rohini	Fusarium wilt	Central zone
MCU.5VT	Verticillium wilt	South zone
G.Cot.13	Fusarium wilt	Central zone
Arogya	Bacterial blight	Maharashtra ,TamilNadu
Supriya	Whitefly	

Table 5. *Promising germplasm lines against key pests of cotton.*

Jassid	*Helicoverpa*	Whitefly	*Earias*	*Pectinophora*
Acala	Ambassador	Tx URHU 1-78	Stoneville 731N	LH- 96-4
Acala Monel	Kandaya 19	Tx ORSC-78	Coker 100A	
L-716 SR	Pee Dee 0695	Tx Maroon 2-78	Empire	
320 F-Pakistan	MHR 10		XG 15	
Aboharia	DHY 286			
JBWR-34	EC 44772-20-1			

Table 6. *Some natural enemies in the cotton ecosystem.*

Name	Target pests	Period of occurrence
Orius sp	Aphids immature stages of jassids and whiteflies	July- September
Geocoris sp	Aphids and immature stages of jassids	July - November
Cathecona furscellata	Early instars of *H.armigera*	August- November
Chrysoperla sp	Aphids, jassids, eggs and young larvae of bollworm	June- November
Menochilus and Coccinella sp	Aphids, jassids, eggs and young larvae of bollworm	June - September
Eucelatoria sp	Bollworms	August- October
Apanteles sp	Bollworms	August- October
Campoletis chloridae	Bollworms	September- October
Sisyropa formosa	Bollworms	September - October

Table 7. Outcome for IRM crop management scheme: participating farmers compared with matched control farmers from nearby villages.

	Punjab	Tamil Nadu	Andhra Pradesh	Maharashtra
Number of farmers	40	92	135	2300
Reduction in pesticide use % (No. spray)	-2	46	44	95
Reduction in pesticide use %(a.i./ha)	29	42	69	92
Reduction in plant protection cost %	21	39	55	88
Yield increase (%)	49	17	31	70
Net increase in profitability ($/ha)	40#	93	125	226*
Reduction in health hazard (%)*	48	77	89	92

* Calculated on the basis of human LD 50 dose reductions from the WHO tables for the particular chemicals involved.

Non- participating farmers were operating at a loss.

Table 8. Increase in seed cotton yield in Bt hybrids over local checks (kg ha^{-1}).

Hybrids	Central Zone	South Zone
MECH-184 Bt	544	723
MECH-162 Bt	588	785
MECH-12 Bt	107	751

(Source: Mayee and Rao, 2002)

Table 9. Cost of plant protection and net profit in Bt over local checks (.48 Rs/$ US).

Hybrids	Reduction in cost of plant protection (Rs/ha)	% Reduction	Net profit (Rs/ha)
MECH-184 Bt	1432	50.38	11566
MECH-162 Bt	1432	50.33	10972
MECH-12 Bt	1118	39.29	7041

सत्यमेव जयते

INTEGRATED PEST MANAGEMENT PACKAGE FOR RICE

NATIONAL IPM PROGRAMME

रा व स्वा प्र सं
NIPHM

NCIPM

Government of India
Ministry of Agriculture, Department of Agriculture & Cooperation
Directorate of Plant Protection, Quarantine & Storage
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Cover picture : Healthy crop of Rice

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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.

(Avinash K. Srivastava)

PREFACE

Pests are major biotic constraints to achieve self sufficiency in ensuring food security. Losses due to pest vary range 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 ₹ 260000 million per year. However, negligence of endemic areas can result in complete crop failures. In view of inefficacy of chemical pesticides and environmental problems thereof, 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 components 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 activate appropriate control measures on standing crops.

The existing package and practices was developed way back in 2001-02 by DPPQ & S, Faridabad catering the need of extension personals in extending IPM tactics to farmers. Though these were useful, there is a need to update them in view of changing climate and its impact on pests and their protection measures.

A National Workshop on IPM for harmonization of Package of Practices was organized at the National Centre for Integrated Pest Management, New Delhi, during 25-26th Feb., 2013 with a view to provide technical knowledge to the extension functionaries and farmers in the States. The IPM package has been developed with the technical inputs from the experts from the PI (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 introduced 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

Integral India has the largest area under rice cultivation in the world (44.6 million hectares) and ranks second in production (104.31million tonnes in 2011-12). In India, Rice is grown under different agro ecological conditions viz., water logged, deep water, hills, high humidity, high temperatures, salinity, alkalinity and flood prone areas. The cropping intensity differs from one environment to the other with a maximum of three rice growing seasons in a year in the fertile deltaic regions due to availability of continuous irrigation. The rice crop is prone to stress throughout the crop growth period due to onslaught from different pests such as insects, nematodes, diseases, weeds and rats. Adoption of integrated pest management (IPM) strategies is the best solution to tackle the pest problems. Rice IPM provides a framework for integrating knowledge, skills and information on rice pest management. An IPM practice in rice production initiatives includes regular pest monitoring, research on the optimal use of pesticides, complementary weed control strategies, and alternative cultural and biological controls. In this regard, several efforts have been made to develop, verify, demonstrate and document location specific IPM technologies suited to different ecosystems. Since IPM is a dynamic process, therefore, it needs continuous up gradation of the technology as per the changing pest scenario. To achieve the target of increasing the productivity levels to meet the future demand, it requires adoption of modern and intensive agricultural practices by the farmers. However, concomitant with the practice of intensive agriculture, there is aggravation of biotic constraints like insect pests, diseases and weeds. More than 100 species of insects have been recorded as pest of rice, of which about a dozen are of significance in India. The co-ordinated network trials conducted at different centres in India have indicated that controlling of insect pests alone increase yield by around 1 ton /ha. The diseases of rice accounts for about 10% loss in rice production annually or approximately 2.5 million tons. Even if the average loss caused by rice disease in a year were to be only 5% of the total rice production in the country, it would amount to a great deal, and prevention of such a loss should constitute one of the important methods of augmenting our food security.

2. BIOTIC CONSTRAINTS

2.1. Major Insect Pests: National Significance

1. Yellow stem borer (*Scirpophaga incertulas* Walker)
2. Brown plant hopper (*Nilaparvata lugens* Stal) and White backed plant hopper (*Sogatella furcifera* Horváth)
3. Leaf folder (*Cnaphalocrocis medinalis* Guenée)
4. Gundhi bug (*Leptocorisa acuta* Thunberg)
5. Gall midge (*Orseolia oryzae* Wood-Mason)

2.2. Major Insect Pests: Regional Significance

1. Termite (*Odontotermes obesus* Rambur) - In rainfed upland areas, irrigated rice-wheat system.
2. Swarming caterpillar (*Spodoptera mauritia* Boisduval) - Odisha, West Bengal, Jharkhand, Chhattisgarh and Punjab.

3. Rice Hispa (*Dicladispa armigera* Oliver) - Bihar, West Bengal, Assam, Odisha, Meghalaya, Mizoram, Tripura, Punjab, Himachal Pradesh, Uttar Pradesh and Uttarakhand.
4. Climbing cutworm/Rice Ear Cutting Caterpillar/ Armyworm (*Mythimna separata* Walker) - In coastal rice growing areas, Haryana, Punjab and Uttar Pradesh.
5. Caseworm (*Nymphula depunctalis* Guenée) - In low lying and water logged areas in eastern India.
6. Thrips (*Stenchaetothrips biformis* Bagnall) - In upland rice in Odisha, Andhra Pradesh, Madhya Pradesh, Punjab, Haryana, Assam and Tamil Nadu.
7. Mealy bug (*Brevennia rehi* Lindinger) - In upland rice in Uttar Pradesh, Bihar, West Bengal, Odisha, Madhya Pradesh, Tamil Nadu, Kerala, Pondicherry and Karnataka.
8. Panicle mite (*Steneotarsonemus spinki* Smiley)-Andhra Pradesh, Odisha, West Bengal, Gujarat and Western Uttar Pradesh and Leaf mite (*Oligonychus oryzae* Hirst) –Eastern India and Andhra Pradesh.
9. Root weevil (*Echinochemus oryzae* Marshall) - Haryana, Punjab and Tamil Nadu.
10. White grub (*Holotrichia* spp.) - Hill rice.
11. Black bug (*Scotinophara coaractata* Fabricius) -Andhra Pradesh, Tamil Nadu and Kerala.
12. Blue beetle (*Leptisma pygmaea* Baly) - Kerala, Maharashtra and Tamil Nadu.

2.3. Major Diseases of National Significance

1. Rice blast (*Pyricularia oryzae* Cavara)
2. Bacterial leaf blight (*Xanthomonas campestris* pv *oryzae* (Ishiyama Swings *et al.*))
3. Sheath blight (*Rhizoctonia solani* J.G. Kühn)
4. False smut (*Ustilaginoidea virens* (Cooke) Takah)
5. Brown spot (*Helminthosporium oryzae* Hiroë)

2.4. Major Diseases of Regional Significance

1. Sheath rot (*Sarocladium oryzae* Sawada, W. Gams & D. Hawksw.)
2. Bakanae (*Gibberella fujikuroi* Nirenberg)
3. Stem rot (*Sclerotium oryzae* Catt., R.A. Krause & R.K. Webster)
4. Rice Tungro Virus

2.5. Major Nematodes of National Significance

1. Root knot nematode (*Meloidogyne graminicola* Golden & Birchfield)
2. White tip nematode (*Aphelehchoides besseyi* Christie)

2.6. Major Nematodes of Regional Significance

1. Ufra (*Dilylenchus angustus* Buther) - West Bengal, Assam and Tripura.
2. Rice root nematode (*Hirschmanniella oryzae* van brede de Haan) - Odisha, West Bengal, Bihar and Andhra Pradesh.

3. Cyst nematode (*Heterodera oryzae* Luc & Berdon) - in Kerala only.
4. Root lesion nematode (*Pratylenchus indicus* Das) - Upland and in SRI system, Odisha and Jharkhand.

2.7. Major Weeds of National Significance

1. *Echinochloa crusgalli (L.)* (Beauv)
2. *Cyperus rotundus* (L.)
3. Weedy rice (*Oryzae* spp., wild rice)

2.8. Major Weeds of Regional Significance

1. *Commelina bengalensis* (L.)
2. *Eclipta alba* (L.)
3. *Ischaemum rugosum* (Salisbury)
4. *Eleusine indica* L.(Gaertn)
5. *Amaranthus spinosus* (L.)
6. *Monochria vaginalis* (Burm.f., C.Presl ex Kunth)
7. *Digitaria sanguinalis* (Scop)
8. *Fimbristylis littoralis* (Vahl)
9. *Leersia hexandra* (Sw.)
10. *Leptochloa chinenesis* (L.)
11. *Paspalum* spp.
12. *Brachiaria* spp.
13. *Panicum* spp.
14. *Marsilea quadrifoliata* (L.)
15. *Oxalis latifolia* (Kunth)

2.9. Major Rodents of Regional Significance

1. Smaller bandicoot (*Bandicota bengalensis* Gray)
2. Soft furred field rat (*Millardia meltada* Gray)
3. Indian gerbil (*Tatera indica* Lataste)
4. Field mice (*Mus* spp.)

3. 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.

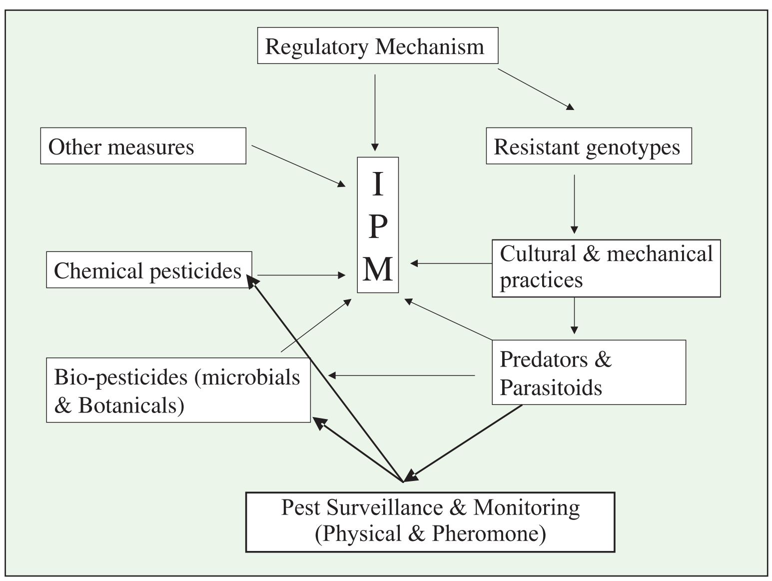


Fig 1. Diagrammatic representation of IPM components.

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

3.1 Pest Monitoring:

a. Survey/Field Scouting

The objective through roving surveys is to monitor the initial development of pests 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 mobilised to observe the insect pest and disease occurrence at the intervals as stipulated hereunder. The plant protection measures are required to be taken only when insect pests and diseases cross Economic Threshold Level (ETL) as per results of field scouting.

1. **Roving survey:** - Undertake roving survey at every 10 km distance at 7-10 days intervals (depending upon pest population). Everyday at least 20 spots should be observed.
2. **Field scouting:** - Field scouting for pests and bio-control fauna by extension agencies and farmers once in 3-5 days should be undertaken to workout ETL.

b. Pest monitoring through pheromones/light traps etc.

Majority of insects population can be monitored by fixing and positioning of pheromones or light traps at appropriate stage of crop. The State Department of Agriculture can initiate this action at strategic locations at village level as per the following details:

1. **Pheromone trap-monitoring** - 5 traps per ha may be used to monitor yellow stem borer and moth population.
2. **Light trap** - Chinsurah light trap or any other light trap can be operated for two hours in the evening to observe photo-tropic insect pests.
3. **Sweep-nets - water pans** - Besides visual observations sweep-nets and water pans may also be used to assess the population of insect pests, and biocontrol agents to determine the type of pesticides to be recommended or used.

3.1.1. Agro Eco System Analysis (AESA)

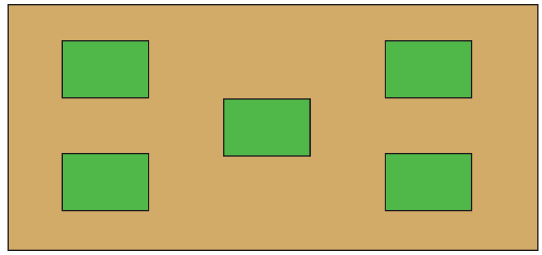
IPM has been evolving over the decades to address the deleterious impacts of synthetic chemical pesticides on environment ultimately affecting the interests of the farmers. In modern IPM (FAO, 2002) emphasis is given to Agro Eco System Analysis (AESA) where farmers take decisions based on larger range 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 transplanting. 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 four hills randomly for recording observations (Total 20 hills/field).



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)**
  - Height of hill
  - Number of tiller per hill
  - Number of leaves
- **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/hill 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 P: D ratios for yellow stem borer are given below.

Sr. No.	Predator	Predator :YSB Ratio
1.	Carabid beetle	5 : 1
2.	Mirid bug	3 : 1
3.	Reduviid bug	6 : 1
4.	Wolf spider	15 : 1
5.	Lynx spider	2 : 1
6.	Jumping spider	8 : 1
7.	Dwarf spider	4 : 1
8.	Long jawed spider	2 : 1
9.	Long horned grass hopper	3 : 1
10.	Ear wig	20 : 1
11.	Wasp	30 : 1
12.	Preying mantid	4 : 1

Model AESA chart

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

Courtsey: NIPHM, Hyderabad

Soil condition :

Weather condition :

No. of insect pests :

No. of natural enemies :

Diseases types and severity :

Weeds types and intensity :

Rodent damage (if any) :

For the success of Integrated Pest Management pest monitoring, prevention (Cultural and genetic) and timely intervention (Biological or chemical) are the key components.

3.1.2. ECONOMIC THRESHOLD LEVEL (ETL) OF MAJOR PESTS OF RICE CROP STAGE WISE

Crop stage	Pest/Disease	Economic Threshold Level (ETLs)
Nursery	Yellow stem borer	1 egg-mass/m^2
	Root-knot nematode	1 nematode/g soil
	BLB: Kresek Phase	2-3 plants/m^2
Early to late tillering	Leaf-folder	2 Fully damaged leaves (FDL) with larva/hill
	Stem borer	2 egg-mass/m^2 or 10% dead heart or 1 moth/m^2 or 25 moths/ trap/week
	Gall midge	1 gall/m^2 or 10% Silver shoot
	Brown planthopper/WBPH	10-15 hoppers/hill
	Rice hispa	2 adults or 2 dead leaf /hill
	Rice caseworm	2 FDL/hill
	Swarming caterpillar	1 damaged tiller/hill or 2 larvae/ m^2
	Foliar blast	3-5 lesions/leaf
	Brown spot	2-3 spots/leaf & 2-3 infected plants/ m^2
	Sheath blight	Lesions of 5-6 mm in length & 2-3 infected plants/m^2
	Sheath-rot	Lesion length 2-3 mm on sheath & 3-5 infected plants/ m^2
	BLB	2-3 infected leaves/m^2
	Tungro	1 Tungro infected plants/m^2 & 2 GLH/hill (in fungus endemic areas)
Panicle initiation to booting	Stem borers	2 egg-mass/m^2 or 1 moth/m2 or 25 moths / trap / week
	Leaf-folders	2 FDL/hill
	BPH/WBPH	15-20 hoppers/hill
	Swarming caterpillar/cut worm	1 damaged tiller/hill or 2 larvae/ m^2
	Neck blast	2-5 neck infected plants/m^2
	Sheath-rot	5 infected plants/m^2
Flowering to milky grain	Gundhi bug	2 bugs/hill
	Rice panicle mite	No ETL[1]

1 If mite appeared in previous season, it requires prophylactic control measures in the current season.

3.2. Cultural Practices

a. Raise pre-crop *kharif* grow *Sesbania* or sunhemp and incorporate 45 days old crop in soil during land preparation wherever possible.

b. Select suitable resistant or moderately resistant variety.

c. Use disease and insect free pure seed.

d. Seed treatment (for diseases) with carbendazim 50% WP @ 2 g/kg seed or *Trichoderma/Pseudomonas* @ 5-10 g/ha of seed for seed or soil borne diseases and carbosulfan 2 g/kg of seed for root nematodes or as per local recommendations. In termites endemic areas, seed treatment with chlorpyriphos 20% EC @ 10000 ml/ha along with 10% solution of gum arabica or imidacloprid 200 SL (20%) @ 0.25 litre/100 kg seed along with 10% solution of gum Arabica in 3.75 litre of water just before sowing.

e. Timely planting/sowing.

f. Pre-sowing irrigation: Many weeds can be controlled by applying pre-sowing irrigation to area where nursery or seedlings are to be transplanted. The emerged weeds can be ploughed under.

g. Raising of healthy nursery.

h. As far as possible rice seedling should be free from weed seedlings at the time of transplanting.

i. Destruction of left over nursery, removal of weeds from field and cleaning of bunds.

j. Normal spacing with 30-36 hills/ m^2 depending on the duration of the variety.

k. 30 cm alley formations at every 2.5 to 3 m distance in plant hopper and sheath blight endemic areas.

l. Balanced use of fertilizers and micro-nutrients as per local recommendations. Proper water management (alternate wetting and drying to avoid water stagnation) in plant hopper, bacterial blight and stem rot endemic areas. Maintain a thin layer of water on soil surface to minimize weed growth.

m. In direct sown rice, the crop should be sown in lines at recommended spacing to facilitate inter-weeding operations. Mechanical methods of weed should be practiced after 2-3 weeks and second time if necessary after 4-6 weeks of sowing.

n. Harvest close to ground level to destroy insect pest present in the internodes/stubbles. This will also expose the insects to birds thus help in natural biocontrol of insect pests.

o. After harvest, the fields should be thoroughly flooded with water and ploughed with discs or rotators to kill hibernating larvae of stem borer present in the stubbles. Summer ploughing of fields also expose larvae and pupae of rice swarming or ear cutting caterpillar (climbing cutworm) hidden in the soil to birds and weather factors.

Important cultural practices reducing insect pests incidence

S. No.	Insect Pest	Cultural Practices
1.	**Caseworm** (*Nymphula depunctalis)*	• Rice fields with wider hill spacing (30 x 20 cm) usually suffers less damage from caseworm. • Early planting may escape the peak caseworm moth activity period. • Draining of fields for 5-7 days kills caseworm larvae. • Use of older seedlings reduces the duration of the susceptible stage of the crop. • Nitrogen fertilizer use at optimal dosages and split applications reduce the rice caseworm's abundance.

S. No.	Insect Pest	Cultural Practices
2.	**Whorl maggot** (*Hydrellia philippina)*	• Adult flies are more attracted to standing water. Therefore, by draining the water at 3-4 days intervals during the first 30 days after transplanting, egg lying is reduced. • Covering the water surface with Azolla and Salvinia molesta prevents rice whorl maggot infestation. • Direct-seeded rice is not as attractive to adults as a transplanted rice crop is. • Fields with higher plant density suffers less damage. • Close planting decreases oviposition and subsequent damage
3.	**Gall midge** *(Orseolia oryzae)*	• Plowing under the ratoon of previous crops can reduce infestation. • Control of grassy weeds and wild rice (alternate hosts) from surrounding areas can reduce gall midge incidence. • Draining of rice fields for 5-7 days affects midge populations. • Planting of early and using early maturing varieties may help to avoid high infestations. • Using only moderate amounts of nitrogen and potassium fertilizers and adopting split applications to reduce population growth rates. • Avoiding staggered planting (complete planting in an area within 3 weeks) to reduce infestation.
4.	**Rice hispa** *(Dicladispa armigera)*	• Clipping and destruction of the top three-fourths of the leaves of highly infested crops with eggs and grubs at the early vegetative stage can suppress populations. • Sustained collection of adults by sweep net and destruction suppress populations and reduces damage. • The removal of rice ratoons and volunteer rice during the crop-free season affects the rice hispa's survival and multiplication of over-wintering populations. • In situations of high hispa incidence, skip nitrogen fertilizer top-dressing. Note that top- dressing after the pest is controlled can enhance recovery.
5.	**Rice leaf folders** *(Cnaphalocrocis medinalis)*	• Early planting may help to avoid greater degrees of leaf damage. • Wider spacing (22.5 x 20 cm and 30 x 20 cm) and low usage of nitrogenous fertilizers decreases leaf damage. • Highly fertilized plots seem to attract females for oviposition. Therefore, it is advisable to avoid over-fertilization. • Egg predators (crickets) inhabit surrounding grass habitats and move to the field at night for predation. Maintenance of non-rice habitats might be worthwhile. • Higher damages will occur in shaded areas. Therefore, remove the causes of shading within the field.
6.	**Yellow stem borer** *(Scirpophaga incertulas)*	• Clipping the tips of seedlings before transplanting greatly reduces the carryover of eggs from the seedbed to the transplanted fields • Rice varieties with short stature and shorter growth duration periods suffer less damage than long growth duration varieties. • Rice – rice with shorter growth duration varieties suffer less damage than long duration varieties. This may be because of stem-borer mortality due to harvests occurring twice in the double cropping system. • Community-wide destruction of diapausing larvae (in stubble) through tillage after harvest, followed by flooding, reduces stem borer populations resulting in low incidence in the next crop.

S. No.	Insect Pest	Cultural Practices
		• Planting or seeding times may be delayed to avoid the peak emergence of moths from the diapausing populations. • Rice seedbeds may be used as a trap crop for moths emerging from diapause.
7.	**Green leafhoppers** *(Nephotettix cincticeps)*	• Reducing the number of rice crops to two per year and synchronized establishment across farms reduces leafhoppers and other insect vectors of rice virus or phytoplasma diseases. • Transplanting older seedlings (>3 weeks) also reduces viral disease susceptibility transmitted by leafhoppers. • Avoid planting at peak activity (shown by historical records) period to avoid infestation. • Early planting within a given planting period, particularly in the dry season, reduces the risk of insect-vector disease. • Nitrogen should be applied at an optimal level to discourage population build-up and influence plant recovery. • Good weed control in the field and on the bunds removes the preferred grassy hosts and promotes crop vigor. • Crop rotation with a non-rice crop during the dry season decreases disease reservoirs. • Upland rice intercropped with soybean reduces the incidence of leafhoppers on rice compared to rice alone.
8.	**Brown planthopper** *(Nilaparvata lugens)*	• High dosages of nitrogenous fertilizers, close spacing, and high relative humidity increases planthopper populations. • Sensible use of fertilizer by splitting nitrogen applications can also reduce chances of plant hopper outbreaks. • Draining rice fields can be effective in reducing initial infestation levels. The field should be drained for 3 - 4 days when heavy infestations occur. • Growing no more than two crops per year and using early-maturing varieties reduces planthopper abundance and damage. • Synchronous planting (planting neighboring fields within 3 weeks) and maintaining a rice-free period may be effective.
9.	**Green stinkbug** *(Nezara viridula)*	• Early-maturing varieties can be used as trap crops to protect the late maturing main crop. However, insecticides need to be applied to the trap crop for the stinkbug's control. • The green-manuring crop, *Sesbania rostrata*, can also be used as a trap crop. • Intercropping of soybean with rice can also be effective. • Adjusting the planting date allows a degree of manipulation of *N. viridula* numbers

3.3. Genetic management

Insect pest and disease resistant/ tolerant varieties mentioned below should be used:

A. Varieties resistant/tolerant to various insect pests and diseases

Insect pests	Resistant/tolerant varieties
Stem borer	Ratna, Sasyasree, Vikas, HKR 46, NDGR 21, Pantdhan 6, VLK 39, Prahlad, Birsadhan 201, Bhudeb Ainesh, Matangini, Radha, Sudha, Amulya, Bhagirathi, Jogan, Mandira, Nalini, Sabita, VL16 and VL 206.

Insect pests	Resistant/tolerant varieties
Gall midge	Bhadrakali, Pavitra, Panchami, Triguna, lndursamba, Shiva, Vasundhara, Mahamaya, Ratnagiri 3, Erra Mallelu, Kavya, Oragallu, Sneha, Bhuban, Shaktiman, Abhaya, Divya, Ruchi, Vibhava, Kshira, Lalat, MDU 3, Pothana, Suraksha, Tara, Rashmi, Karna Mahavir, Neela, Rajendradhan 202, Sarsa, Udaya, Pratap, Daya, Dhanya Lakshmi, Kunti, IR 36, Asha, Samalei, Samariddhi, Pusa, Surekha, Phalguna, Vikram, Shakti, Jyoti, Kakatiya, Kanchan and Birsa Dhan 202.
Brown plant hopper	Vijetha, Chaitanay, Krishnaveni, Pratibha, Vajram, Makom, Pavizham, Mansarovar, CO 42, Jyoti, Chandana, Nagarjuna, Sonasali, Rasmi, Neela, Annanga, Daya, Bhadra, Karthika, Aruna, Remya, Kanakam, Bharathidasan, Remya, Triguna, IET 8116, Rajendra Mahsuri-l, Pant dhan 11, Rajshree, Bhudeb and Hanseshwari .
White backed plant hopper	HKR 120, HKR 126, HKR 228, PR 108, Menher, Pant dhan 10, Pant dhan 11, Mahananda and Hanseshwari.
Green leaf hopper	Vikramarya, Nidhi, IR 24, Radha, Mahananda and Kunti.
Blast	Rasi, Vikas, Krishna Hamsa, Tulasi, IR 64, Aditya, Swarnadhan, Himalaya 1, Himalaya 2, Himalaya 2216, Pant dhan 10, HKR 228 and PNR 519.
BLB	Ajaya, IR 36, IR 64, Swarna, Bhumbleshwari, PR 111, PR 113, PR 114, PR 115, PR 116, PR 118, Rajendra Basmati, Pant dhan 11, Govind, Radha, Kamini, Pant dhan 10, Jayshree, Kanchan and improved sambha masouri.
RTD	Vikramarya, Nidhi, Amulya, Dinesh, Lakshmi and Nalini.
Sheath blight	PR 108, Bhudeb Dinesh, Jogan, Mandira, Nalini, Neeraj and Sabita.

B. Varieties with resistance to more than one pest or disease

S. No.	Variety	Released in	Resistant to*
1.	Udaya	Odisha	BPH, GM, GLH, RTD and RKN
2.	Suraksha	Andhra Pradesh, Odisha, and West Bengal	GM, BPK, WBPH and BL
3.	Vikramarya	Andhra Pradesh	GM, GLH and RTD
4.	Shaktiman	Odisha, and West Bengal	GM, BPH, WBPH and BL
5.	Rasmi	Kerala	GM, BPH and BL
6.	Daya	Odisha	GM, BPH, GLH and BLB
7.	Samalei	Odisha, and Madhya Pradesh	GM, BPH, GLH and BL
8.	Bhuban	Odisha	GM and BLB
9.	Kunti	West Bengal	GM and BL
10.	Lalat	Odisha	GM, BPH, GLH and BL
11.	Sneha	Odisha	GB and RTD

*Abbreviations

GM- Gall midge; BPH- Brown plant hopper; WBPH- White backed plant hopper; GLH- Green leafhopper; BL- Blast; RTD- Rice Tungro Disease; RKN- Root-knot nematode; GB-Gundhi bug; BLB- Bacterial leaf blight.

3.4. Mechanical Practices

- Collection of egg masses and larvae of pest to be placed in bamboo cages for conservation of biocontrol agents.
- Removal and destruction (burn) of diseased/pest infested plant parts.
- Clipping of rice seedlings tips at the time of transplanting to minimize carryover of rice hispa, case worm and stem borer infestation from seed bed to the transplanted fields.
- Use of coir rope in rice crop for dislodging case worm, cut worm and swarming caterpillar and leaf folder larvae etc. on to kerosinized water (1 L of kerosene mixed on 25 kg soil and broadcast in 1ha).

3.5. Biological Control Practices

The details of biological control practices are given below

3.5.1. Augmentation and Conservation

- *Trichogramma japonicum* and *T chilonis* may be released @ 1 lakh/ha on appearance of egg masses / moth of yellow stem borer and leaf folder in the field.
- Natural biocontrol agents such as spiders, drynids, water bugs, mirid bugs, damsel flies, dragonflies, meadow grasshoppers, staphylinid beetles, carabids, coccinellids, *Apanteles, Tetrastichus, Telenomus, Trichogramma, Bracon, Platygaster* etc. should be conserved.
- Collection of egg masses of borers and putting them in a bamboo cage-cum-percher till flowering which will permit the escape of egg parasites and trap and kill the hatching larvae. Besides, these would allow perching of predatory birds.
- Habitat management: Protection of natural habitats within the farm boundary may help in conserving natural enemies of pests. Management of farmland and rice bunds with planting of flowering weeds like marigold, sun hemp increases beneficial natural enemy population and also reduce the incidence of root knot nematodes. Provide refuge like straw bundles having charged with spiders to help in build up spider population and to provide perch for birds

Major parasitoids and predators of insect pests of rice

Natural enemy category	Natural enemy	Pest attacked and feeding potential
I. Parasitoids		
1. Egg parasitoids	*Trichogramma japonicum*	• Egg parasitoid of yellow stem borer (YSB)
	Trichogramma chilonis	• Egg parasitoid of leaf folder, • Case worm, YSB etc.
	Tetrastichus schoenobii	• Egg parasitoid of yellow and white stem borer. • At least 3 stem borer eggs are needed for development of each wasp.
	Telenomus rowani	• Egg parasitoid of yellow and white stem borer. • A female parasitizes 20-40 eggs and lives 2-4 days or longer if nectar or sugar solution is provided. • Both *Tetrastichus* and *Telenomus* may parasitize the same egg mass but not the same egg.
	Gonatocerus spp.	• Egg parasitoid of leaf and plant hoppers. • Parasitize on an average 8 eggs per day.
	Anagrus spp.	• Egg parasitoids of leaf and plant hoppers. • Parasitizes 15 to 30 eggs/day.
	Oligosita spp.	• Egg parasitoid of leaf and plant hoppers. • Consume 2 to 8 eggs per day.
	Copidosomopsis nacoleiae	• Egg parasitoid of leaf folder. • 200-300 wasps are produced from a few eggs.
2. Larval parasitoids	*Amauromorpha accepta*	• Larval parasitoid of yellow and white stem borer. • Adults are medium sized red and black in colour with white band at the abdominal tip.
	Stenobracon nicevillei	• Larval parasitoid of leaf folder. • Adult wasp has orange brown body, black head, 3 pairs of black spots on forewings. • Ovipositor is black and double the length of its body.
	Cotesia flavipes	• Larval parasitoid of stem borer and semi-looper. • Adult wasps are similar to *Cotesia antustibasis* except the antenna is short and yellow brown to red marking at the base of hind legs.
	Elasmus sp.	• Larval parasite of leaf folder. • Wasp emerges from larva or pupa. • Adults are small elongated wasps with pointed abdomen. • Thoracic segment is enlarged and disc shaped. They are black with reddish markings/bands on the abdomen.

Natural enemy category	Natural enemy	Pest attacked and feeding potential
	Haplogonatopus sp *Pseudogonatopus* spp.	• *Haplogonatopus* attack leaf hoppers and *Pseudogonatopus* attack plant hoppers and act as parasites and predators. • Adults of *Pseudogonatopus* are brown or black in colour. • Females are wingless with pincher like front claws.
	Bracon sp.	• Larval parsitoid of yellow stem borer and rice hispa.
3. Larval and pupal parasitoids	*Xanthopimpla flavolineata*	• Larval, pupal parasitoid of stem borer • Adult wasp is medium sized yellow orange in colour with black ovipositor and transparent wings.
	Brachymeria lasus, B. excarinata,	• Larval and pupal parasitoid of Rice skipper, leaf folder and green horned caterpillar. • Adults of *Brachymeria iasus* are black and have a triangular cheek and yellow markings on tip of femur and ventral half of tibia. *Brachymeria excarinata* are black with yellow markings on both ends of hind tibia and no cheek.
	Opius sp.	• Larval pupal parasitoid of whorl maggot larvae. Wasp emerges from whorl maggot pupa. • Adults are small orange brown in colour with long antennae, yellow legs and black ovipositor.
II. Predators		
4. Coccinellid beetles	*Micraspis hirashimai,* Ladybird beetles	• Preying on small hoppers, small larvae and exposed eggs
	Harmonia octamaculata	• Preying on small hoppers, small larvae and exposed eggs
5. Carabid beetle	*Ophionea nigrofasciata,* Ground beetle	• Preying leaf folder larvae and planthoppers
6. Rove beetle	*Paederus fuscipes* Rove beetle	• Preying leaf and planthoppers, eggs, and small moths
7. Spiders	*Pardosa psuedoannulata,* Wolf spider	• Prey stem borer and leaf folder moths, leaf-and plant hoppers, and whorl maggot flies.
	Oxyopes javanus, Lynx spider	• Prey moths of rice pests, adults of whorl maggots, leafhoppers and plant hoppers
	Tetragnatha maxillosa, Long-jawed spider	• Prey stem borer and leaf folder moths, leaf-and plant hoppers
	Argiope catenulata, Orb spider	• Prey moths/adults of rice pests viz. grasshoppers

3.5.2. Pest defender ratio

Pest defender ratio (P: D) 2:1 may be useful to avoid application of pesticides against plant hoppers.

3.5.3. Behavioural Control

Mass trapping of yellow stem borer male moths by installing pheromone traps @ 20 traps/ha with lures containing 10-15 mg pheromone at 20 days after transplanting.

3.6. Chemical Control Measures

The details of the chemical control measures to be adopted against insect pests and diseases are given in Generic IPM module based on vegetative stage. Resort to chemical as the last choice only after the regular pest and when pest population cross ETL.

Generic IPM module based on vegetative stage

CROP STAGE/ PEST VIS-À-VIS IPM PRACTICES

PESTS	PESTICIDES
I. INSECTS	
Nursery	
Gall midge	Carbofuran 3% CG @ 25000-66600 g/ha or carbosulfan 6% G @ 16700 g/ha or carbosulfan 25% EC @ 800-1000 ml/ha.
Stem borer	Cartap hydrochloride 4% granules @ 18750 g/ha or cartap hydrochloride 50% SP @ 1000 g/ha.
Vegetative stage	
Stem borer	Carbofuran 3% CG @ 25000-66600 g/ha or cartap hydrochloride 4% granules @ 18750 g/ha or cartap hydrochloride 50% SP @ 1000 g/ha or monocrotophos 36 % SL @ 625-1250 ml/ha.
Leaf folder	Spray cartap hydrochloride 4% granules @ 18750-25000 g/ha or cartap hydrochloride 50% SP @ 1000 g/ha or monocrotophos 36 % SL @ 625-1250 ml/ha or chlorpyrifos 1.5% DP @ 25000 g/ha.
Brown plant hopper and WBPH	Spray of imidacloprid 70% WG @ 30-35 g/ha or imidacloprid 30.5% m/m SC @ 60-75 ml/ha or ethofenoprox 10% EC @ 500-750 ml/ha or acephate 75% SP @ 666-1000 g/ha or buprofezin 25% SC @800 ml/ha.
Gall midge	Application of carbofuran 3% CG @ 25000-66600 g/ha or fipronil 0.3% GR @16670-25000 g/ha at 20 days after transplanting.
Hispa	Spray quinalphos 25% gel @ 1000 ml/ha or chlorpyrifos 20% EC @ 1250 ml/ha.
Caseworm	Spray carbaryl 10% DP @ 25000 g/ha.
Panicle initiation to booting	
Stem borer	Carbofuran 3% CG @ 25000-66600 g/ha or cartap hydrochloride 4% granules @ 18750-25000 g/ha or cartap hydrochloride 50% SP @ 1000g/ha or monocrotophos 36 % SL @ 625-1250 ml/ha.
Leaf folder	Spray cartap hydrochloride 4% granules @ 18750-25000 g/ha or cartap hydrochloride 50% SP @ 1000 g/ha or monocrotophos 36 % SL @ 625-1250 ml/ha or chlorpyrifos 1.5% DP @ 25000 g/ha.

PESTS	PESTICIDES
Brown plant hopper/White backed plant hopper	Spray of imidacloprid 70% WG @ 30-35 ml/ha or imidacloprid 30.5% m/m SC @ 60-75 ml/ha or ethofenoprox 10% EC @ 500-750 ml/ha or acephate 75% SP @ 666-1000 g/ha or buprofezin 25% SC @ 800 ml/ha.
Flowering	
Brown plant hopper/White backed plant hopper	Spray of imidacloprid 70% WG @ 30-35 ml/ha or imidacloprid 30.5% m/m SC @ 60-75 ml/ha or ethofenoprox 10% EC @ 500-750 ml/ha or acephate 75% SP @ 300-500 g/ha or buprofezin 25% SC @ 800 ml/ha.
II. DISEASES	
Nursery	
Blast	Spray carbendazim 50% WP @ 250-500 g/ha or isoprothiolan 40% EC @ 750 ml/ha or tricyclozole 75% WP @ 300-400 g/ha or tricyclazole 70% WG @ 300 g/ha.
BLB	Spray of streptomycin sulphate 9% + tetracycline hydrochloride 1% SP @ 100-150 ppm.
Vegetative	
Blast	Spray carbendazim 50% WP @ 250-500 g/ha or isoprothiolan 40% EC @ 750 ml/ha or tricyclozole 75% WP @ 300-400 g/ha or tricyclazole 70% WG @ 300 g/ha.
Bacterial leaf blight	Spray streptocycline 100 to 150 ppm solution at early root stage. Second spray, if necessary before grain set. Reduce nitrogen application and apply if needed only small dose of N in more split doses. Chemicals as recommended earlier.
Sheath blight	Apply validamycin 3% L @ 2000 g/ha or hexaconazole 5% EC @ 1000 ml/ha or propiconazole 25% EC @750 ml/ha or propiconazole 10.7% + tricyclazole 34.2% SE @ 500 ml/ha.
Panicle initiation to booting	
Blast	Spray carbendazim 50% WP @ 250-500 g/ha or isoprothiolan 40% EC @ 750 ml/ha or tricyclazole 75% WP @ 300-400 g/ha or tricyclazole 70% WG @ 300 gm/ha.
Bacterial leaf blight	Reduce nitrogen application and apply if needed only small dose of N in more split doses, chemicals as recommended earlier.
Sheath blight	Apply validamycin 3% L @ 2000 ml/ha or hexaconazole 5% EC @ 1000 ml/ha or propiconazole 25% EC @ 750 ml/ha or propiconazole 10.7% + tricyclazole 34.2% SE @ 500 ml/ha.
Flowering	
Blast	Spray ediphenphos 50% EC @ 500-600 ml/ha or isoprothiolan 40% EC @ 750 ml/ha or tricyclazole 75% WP @ 300-400 g/ha. Apply nitrogen in small dose, if needed.
Sheath blight	Apply validamycin 3% L @ 200 g/ha or hexaconazole 5% EC @ 1000 ml/ha or propiconazole 25% EC @750 ml/ha or propiconazole 10.7% + tricyclazole 34.2% SE @ 500 ml/ha.

Weeds

1. Apply cyhalofop-butyl 10% EC @ 0.75-0.80 l/ha @ 18-20 days after sowing in grassy weeds in direct seeded rice followed by one hand weeding given after 4-6 weeks.
2. Apply butachlor 50% EC @ 2.5-4 l/ha or pretilachlor 50% EC @ 1.0-1.5 l/ha or oxadiargyl 80% WP @ 0.125 kg/ha or chlorimuron ethyl 25% WP @ 24 g a.i./ha or metsufluran methyl 20% WG @ 20 gm/l or anilophos 2% G @ 20-25 kg/ha or ethoxysulfuron 15% WDG @ 83.3-100 g/ha or cinmethalin10% EC @ 0.75-1.0 l/ha as pre-emergence within 4-6 days after transplanting.

3. Apply metsulfuron methyl 10% + chlorimuron methyl 10% WP @ 20 g/ha or anilophos 24% + 2, 4-D- ethyl ester 32% EC @ 1-1.5 l/ha at 3-10 days after transplanting.

3.7. Nematode Management Practices

Important nematodes and their management approaches are as under:

1. White tip nematode *(Aphalenchoides besseyi)*

1.1 Sun drying of seeds for 6 hours for 4 days.

1.2 Pre-sowing of nursery bed treatment with carbofuran 3% CG @ 50000 g/ha, if nematode population crosses the ETL.

2. Root knot nematode *(Meloidogyne graminicola)*

2.1 Rotation with the crops like sweet potato, sunflower, cowpea, sesamum, and onion.

2.2 Soil application of carbofuran 3% CG @ 50000 g/ha.

3.8. Rat Management Practices

(Working Index (ETL): Fifteen live burrows per hectare)

1. Rat management need to be adopted on community basis.
2. Employment of indigenous traps preferably one month after transplantation.
3. Application of bromodiolone (0.005% a.i) in baits six weeks after transplantation.
4. The residual live burrows may be treated with second application of bromodiolone (0.005%).
5. The above control operations with rodenticides except Zinc phosphide (as rodents develop bait shyness) may be repeated if the rodent population exceeds working index.

Important:

i) Optimum period for undertaking control operation is six weeks after transplantation.

ii) Zinc phosphide (2.5%) in baits may be applied.

iii) For getting effective control, it is recommended that Zinc Phosphide with ISI mark in 10 g pouches preferably in manufacturers' package should be procured.

4. SAFETY PARAMETERS IN PESTICIDES USAGE

Safety parameters inter alia classification of toxicity as per Insecticides Rules, 1971, WHO classification of hazards, colour of toxicity triangle, First aid measures, symptoms of poisoning and treatment of poisoning, the extension functionaries of the State Department of Agriculture have to make use of this information as under:-

i) Basic precautions which are required to be taken as per classification of toxicity as well as hazard criteria by WHO may be seen as per Annexure – VIII & IX.

ii) The extension functionaries are to educate the farmers on safety use of pesticides with the help of colour toxicity triangle as the farming community can follow the colour and corresponding safety precautions.

iii) The symptoms of poisoning must be known to the extension functionaries to enable them to extend first aid measures to affected persons to the extent possible.

iv) 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 Centres as well as to Private Doctors in the vicinity of spraying of pesticides.

v) 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.

vi) Extension functionaries are to request the doctors to intervene in procurement of antidotes for different pesticides as cited under "Treatment of poisoning".

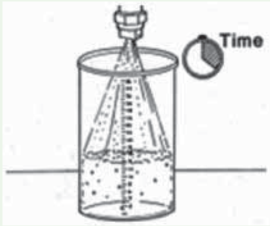
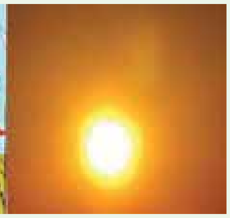
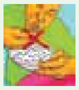
Protocol for Pesticide application techniques, equipments and nozzle specifications

Category A: Stationary, crawling pest/ disease		
Vegetative stage 1. For crawling and soil borne pests 2. For small sucking leaf borne pests	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
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 Reproductive stage (Field Pests)	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
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)

Do's and don't's in IPM

S, No.	Do's	Don'ts
1	Deep ploughing is to be done on bright sunny days during the months of May and June. The field should be kept exposed to sun light at least for 2-3 weeks	Do not plant or irrigate the field after ploughing, at least for 2-3 weeks, to allow desiccation of weed's bulbs and/or rhizomes of perennial weeds
2	Adopt crop rotation	Avoid growing monocrop.
3	Grow only recommended varieties.	Do not grow varieties not suitable for the season or the region
4	Sow early in the season	Avoid late sowing as this may lead to reduced yields and incidence of white grubs and diseases.
5	Always treat the seeds with approved chemicals/bio products for the control of seed borne diseases/pests.	Do not use seeds without seed treatment with biocides/ chemicals.
6	Sow in rows at optimum depths under proper moisture conditions for better establishment.	Do not sow seeds beyond 5-7 cm depth.
7	Apply only recommended herbicides at recommended dose, proper time as appropriate spray solution with standard equipment along with flat fan or flat jet nozzles.	Pre-emergence as well as soil incorporated herbicides should not be applied in dry soils. Do not apply herbicides along with irrigation water or by mixing with soil, sand or urea.
8	Maintain optimum and healthy crop stand which would be capable of competing with weeds at a critical stage of crop weed competition	Crops should not be exposed to moisture deficit stress at their critical growth stages.
9	Use the NPK fertilizers as per the soil test	Avoid imbalanced use of fertilizers.
10	Use micronutrient mixture after sowing based on the test recommendations.	Do not apply any micronutrient mixture after sowing without test
11	Conduct AESA weekly in the morning preferably before 9 a.m. Take decision on management practice based on AESA and P: D ratio only.	Take any management decision considering AESA and P: D ratio
12	Install pheromone traps at appropriate period.	Do not store the pheromone lures at normal room temperature (keep them in refrigerator).
13	Release egg parasitoids only after noticing adult moth catches in the pheromone trap or as pheromone trap or as per field observation	Do not apply chemical pesticides within seven days of release of parasitoids.
14	Apply short persistent pesticides to avoid pesticide residue in the soil and produce.	Do not apply pesticides during preceding 7 days before harvest.
15	Follow the recommended procedure of trap crop technology.	Do not apply long persistent on trap crop, otherwise it may not attract the pests and natural

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

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

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 litre
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}.

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

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:

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

(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 ha^{-1}

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

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

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

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?

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

When concentration expressed is in kg a.t. L^{-1}

Formula:

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

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 :

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

Example: To control stem borer 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:

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

Example : 2000 L of 2 % Methyl Parathion spray is to be prepared. How much commercial 50 % EC is required?

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

Annexure-I

LIST OF RECOMMENDED PESTICIDES FOR RICE (As on 15-10-2013)

Herbicides	Insecticides	Fungicides
Anilophos 2 % G	Acephate 75% SP	Aureofungin 46.15% w/v. SP
Anilofos 30% EC	Acetamiprid 20% SP	Carbendazim 50% WP
Anilofos 18% EC	Aluminum Phosphide 56% 3g tab, 10g pouch	Captan 75% WP
Azimsulfuron 50% DF	Aluminum Phosphide 15%, 12g tablet	Carpropamid 27.8% SC
Anilophos 24% + 2,4-D- ethyl ester 32% EC	Aluminium Phosphide 77.5% GR	Copper Hydroxide 77% WP
Anilophos 24% + 2, 4-D- ethyl ester 32% EC	Azadirachtin 0.15%W/Wmin. Neem seed kernel based EC	Copper oxychloride 50% WP
Bensulfuron Methyl 60% DF	Azadirachtin 0.03% min. Neem oil based EC Containing	Difenoconazole 25% EC
Bispyribac Sodium 10% SC	Azadirachtin 5%W/W min. Neem extract concentrate containing	Ediphenphos 50% EC
Butachlor 50% EC	*Bacillus thuringiensis* var. *galleriae*	Flusilazole 40% EC
Chlorimuron Ethyl 25% WP	*Bacillus thuringiensis* var. *kurstaki*, serotype H-39, 3B, strain Z-52	Hexaconazole 5% EC
Clomazone 50%EC	Buprofezin 25% SC	Hexaconazole 5 % SC
Cyhalofop-butyl 10% EC	Bifenthrin 10% EC	Iprodione 50% WP
2,4-D Ethyl Ester 38 % EC (having 2,4-D acid 34 % w/w)	Bromadiolone 0.25% CB	Isoprothiolan 40% EC
2,4-D Ethyl Ester 4.5 % GR (having 2,4-D acid 4 % w/w)	Bromadiolone 0.005% RB	Kasugamycin 3% SL
Ethoxysulfuron 15% WDG	Carbaryl 10% DP	Kitazin 48% EC
Fenoxaprop-p-ethyl 9.3% w/w EC (9% w/v)	Carbaryl 5% DP	Kresoxim-methyl 44.3% SC
Fenoxaprop-p-ethyl 6.7% w/w EC	Carbaryl 50% WP	Mancozeb 75% WP
Flufenacet 60% DF	Carbaryl 85% WP	Pencycuron 22.9% SC
MCPA, Amine salt 40% WSC	Carbofuran 3% CG	Propiconazole 10.7% + tricyclazole 34.2% SE
Metsufluran methyl 20% WG	Cartap hydrochloride 50% SP	Propiconazole 25% EC
Metsulfuron Methyl 20% WP	Chlorantraniliprole 18.5% SC	Propineb 70% WP
Metsulfuron methyl 10% + Chlorimuron methyl 10% WP	Chlorantraniliprole 0.4% GR	Streptomycin sulphate 9% + tetracycline hydrochloride 1% SP
Oxadiargyl 80% WP	Chlorpyrifos 10% G	Tebuconazole 25.9% m/m EC
Orthosulfamuron 50% WG	Chlorpyrifos 50% EC	Thifluzamide 24% SC
Oxadiargyl 6% EC	Chromafenozide 80% WP	Thiram 75% WS

Herbicides	Insecticides	Fungicides
Oxadiazon 25% EC	Clothianidin 50% WDG	Trichoderma viride 1% WP
Oxyflourfen 0.35% GR	Chlorpyrifos 1.5% DP	Tricyclazole 70% WG
Oxyflourfen 23.5% EC	Chlorpyrifos 20% EC	Tricyclazole 75% WP
Pendimethalin 30% EC	Deltamethrin 11% W/WEC	Validamycin 3% L
Pendimethalin 5 % G	Deltamethrin 1.8% EC	Zineb 75% WP
Pretilachlor 37% EW	Deltamethrin 2.5% WP	Carbendazim 12% + Mancozeb 63% WP
Paraquat dichloride 24% SL	Dichlorvos 76% EC	Iprodione 25% + Carbendazim 25% WP
Pyrazosulfuron Ethyl 10% WP	Dinotefuran 20% SG	Propiconazole 13.9% + Difenoconazole 13.9% EC
Pretilachlor 50% EC	Endosulfan 35% EC	Tebuconazole 50% + Trifloxystrobin 25% WG
Bensulfuron methyl 0.6% + Pretilachlor 6% GR	Endosulfan 4% DP	
Clomazone 20% + 2,4-D EE 30% EC	Ethofenoprox 10% EC	
	Ethiprole 40 + Imidacloprid 40% WG	
	Ethylene Dichloride + CarbonTetrachloride 3:1	
	Fipronil 0.3% GR	
	Fenobucarb (BPMC) 50% EC	
	Fenpropathrin 30% EC	
	Fipronil 5% SC	
	Fipronil 80% WG	
	Flonicamid 50% WG	
	Flubendiamide 20% WG	
	Flubendiamide 39.35% m/m SC	
	Imidacloprid 30.5% m/m SC	
	Imidacloprid 70% WG	
	Imidacloprid 17.8% SL	
	Imidacloprid 0.3% GR	
	Indoxacarb 15.8% EC	
	Lambda-cyhalothrin 4.9% CS	
	Lambda-cyhalothrin 2.5% EC	
	Lambda-cyhalothrin 5% EC	
	Malathion 5% DP	
	Malathion 50% EC	

Herbicides	Insecticides	Fungicides
	Metaldehyde	
	Methyl Bromide 98% W/W	
	Monocrotophos 36 % SL	
	Oxydemeton–methyl 25% EC	
	Phenthoate 50% EC	
	Phorate 10% CG	
	Phosalone 35% EC	
	Phosphamidon 40% SL	
	Quinalphos 5% granule	
	Quinalphos 20% AF	
	Quinalphos 25% EC	
	Quinalphos 1.5% DP	
	Quinalphos 25% Gel	
	Thiacloprid 21.7% SC	
	Thiamethoxam 25% WG	
	Triazophos 20% EC	
	Triazophos 40% EC	
	Chlorpyrifos 50% + Cypermethrin 5% EC	
	Deltamethrin 0.72% W/W+ Buprofezin 5.65% W/W EC	
	Phosphamidon 40% + Imidacloprid 2% SP	
	Acetamiprid 0.4% + Chlorpyriphos 20% EC	

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Annexure-II

Commonly Available Formulations of Pesticides for Agricultural Use

Class	Type	Abbre-viation	Description
Dry	Dust	D	• Ready to use, off shelf available • Low percentage of active ingredients, • Very fine dry inert carrier made from tale, chalk, clay, or ash • Prone to high level of pesticide drift • Granule particles are larger and heavier
	Granule	G	• Granule particles are larger and heavier • Used for soil treatment and broadcasting to manage nematodes, weeds and insect pests
	Wettable	WP	• Finely grounded power
	Powder	W	• Finely grounded power
	Micro encapsulated	M	• Mixed with water for spray application
Liquid	Emulsifiable concentrate	EC	• Particles of active ingredients (liquid or dry) surrounded by a plastic coating
	Concentrate solution	C LC	• Liquid active ingredients, dissolved in petroleum based solvents • Easily absorbed through skin
		ULV	• Diluted with a liquid solvent before being applied
		F L	• Very high percentage of active ingredient • Used before dilution or diluted with small quantities of solvent
Fumi-gants	Pellets liquids		• Finely grounded solid active ingredients suspended in the liquid with inert materials • Solid or liquid that releases/vaporized into toxic gasses

Annexure-III

Pesticides and their Mode of Action

Type of pesticide	Mode of action	How it works
Insecticides and nematicides	Contact	Act through cuticle
	Ingestion	Act upon digestive track
	Systemic	Absorbed and translocated to affected portions
	Fumigants	Penetrates as a into cryptic parts
Herbicide	Contact	Act through cuticle and translocation
	Systemic	Absorbed through soil and translocated to different parts
Fungicide	Superficial protectants	Contact pathogen reproductive propagules
	Systemic	Absorbed through roots from soil, leaf and translocated to different parts

Annexure-IV

Mechanisms of Actions of Major Pesticides

Type of pesticide	Target tissue or organ	Mechanism
Insecticide	Central nervous	Interfere with electron system of nervous system Inhibit acetyl cholinesterase the enzyme responsible for the regulating biological activity
	Cuticle	Inhibit growth and prevent cuticle formulations
	Endocrine system	Disrupts hormonal metabolic system
Herbicide	Seed	Disrupts protein synthesis and inhibits germination
	Leaf, stem,	Prevent photosynthesis
	Leaf, stem, root	Interferes with the mitosis process
	Leaf, stem, root	Affects cell respiration and ATP synthesis
Fungicide	Seed, leaf, stem	Inhibits liquid synthesis affecting cell wall and membrane
	Root	Inhibits synthesis of essential ribosomal proteins Inhibits mitosis, osmoregulation and mitochondrial respiration

Annexure-V

General Guidelines for Management of Resistance

The general guidelines if adopted can prevent development of resistance by various pests in most of the agricultural situations. The general approaches to avoid them are as follows:

Insecticides

- Maintain good plant health,
- Delay the spray of insecticide as far as possible.
- Monitor populations and use economic thresholds
- Use all available tactics for management of a particular arthropod (insect or mite)
- Limit selection pressure throughout the season and remember spraying for one pest may influences another
- Limit use of one chemical molecule at a time and rotate chemical molecule and/or modes of action, and Use appropriate rates

Fungicides

- Avoid growing large areas of highly susceptible varieties in endemic areas. Resistant varieties should be used to reduce reliance on chemical pesticides.
- Make full use of non-fungicidal control measures e.g., dispose of crop debris and control collateral and alternate host, which harbor disease.
- Monitor crops regularly for disease and treat before the infection becomes established.
- Use fungicides only in the unavoidable situations where the risk of disease warrants treatment. Make full use of effective fungicides with different modes of action as alternate sprays. Mixtures of eradicant fungicides with protectants materials offer the most flexibility as well as reducing resistance risk.
- While formulating spray programmes, take into account any earlier use of fungicides groups as seed treatment.
- Do not exceed the maximum recommended numbers of applications to each crop for any particular fungicide group. Avoid repeated applications of very low doses.

Annexure-VI

Pesticides / formulations banned in India (As on 1st Jan, 2014)

A.	**Pesticides Banned for manufacture, import and use.**	
	1.	Aldicarb
	2.	Aldrin
	3.	Benzene Hexachloride
	4.	Calcium Cyanide
	5.	Chlorbenzilate
	6.	Chlordane
	7.	Chlorofenvinphos
	8.	Copper Acetoarsenite
	9.	Dibromochloropropane
	10.	Dieldrin
	11.	Endrin
	12.	Ethyl Mercury Chloride
	13.	Ethyl Parathion
	14.	Ethylene Dibromide
	15.	Heptachlor
	16.	Lindane (Gamma-HCH) (Banned vide Gazette Notification No S.O. 637(E) Dated 25/03/2011)-Banned for Manufecture,Import or Formulate w.e.f. 25th March,2011 and banned for use w.e.f. 25th March,2013.
	17.	Maleic Hydrazide
	18.	Menazon
	19.	Metoxuron
	20.	Nitrofen
	21.	Paraquat Dimethyl Sulphate
	22.	Pentachloro Nitrobenzene
	23.	Pentachlorophenol
	24.	Phenyl Mercury Acetate
	25.	Sodium Methane Arsonate
	26.	TCA (Trichloro acetic acid)
	27.	Tetradifon
	28.	Toxaphene(Camphechlor)
B.	**Pesticide formulations banned for import, manufacture and use**	
	1.	Carbofuron 50% SP
	2.	Methomyl 12.5% L
	3.	Methomyl 24% formulation
	4.	Phosphamidon 85% SL
C.	**Pesticide / Pesticide formulations banned for use but continued to manufacture for export**	
	1.	Captafol 80% Powder
	2.	Nicotin Sulfate
D.	**Pesticides Withdrawn**	
		(Withdrawal may become inoperative as soon as required complete data as per the guidelines is generated and submitted by the Pesticides Industry to the Government and accepted by the Registration Committee. (S.O 915(E) dated 15th Jun,2006)
	1.	Dalapon
	2.	Ferbam
	3.	Formothion
	4.	Nickel Chloride
	5.	Paradichlorobenzene (PDCB)
	6.	Simazine
	7.	Warfarin

Source: www.cibrc.nic.in

Annexure-VII

Pesticides Restricted for Use in the Country (As on 1st Jan, 2014)

S.No.	Name of Pesticides	Details of Restrictions
1.	Aluminium Phosphide	The Pest Control Operations with Aluminium Phosphide may be undertaken only by Govt./Govt. undertakings / Govt. Organizations / pest control operators under the strict supervision of Govt. Experts or experts whose expertise is approved by the Plant Protection Advisor to Govt. of India except 1. Aluminium Phosphide 15 % 12 g tablet and 2. Aluminum Phosphide 6 % tablet.
2.	Captafol	The use of Captafol as foliar spray is banned. Captafol shall be used only as seed dresser. The manufacture of Captafol 80 % powder for dry seed treatment (DS) is banned for use in the country except manufacture for export. (S.O.679 (E) dated 17thJuly, 2001)
3.	Cypermethrin	Cypermethrin 3 % Smoke Generator, is to be used only through Pest Control Operators and not allowed to be used by the General Public.
4.	Dazomet	The use of Dazomet is not permitted on Tea.
5.	Diazinon	Diazinon is banned for use in agriculture except for household use.
6.	Dichloro Diphenyl Trichloroethane (DDT)	The use of DDT for the domestic Public Health Programme is restricted up to 10,000 Metric Tonnes per annum, except in case of any major outbreak of epidemic. M/s Hindustan Insecticides Ltd., the sole manufacturer of DDT in the country may manufacture DDT for export to other countries for use in vector control for public health purpose. The export of DDT to Parties and State non-Parties shall be strictly in accordance with the paragraph 2(b) article 3 of the Stockholm Convention on Persistent Organic Pollutants (POPs).
7.	Fenitrothion	The use of Fenitrothion is banned in Agriculture except for locust control in scheduled desert area and public health.
8.	Fenthion	The use of Fenthion is banned in Agriculture except for locust control, household and public health.
9.	Methoxy Ethyl Mercuric Chloride (MEMC)	The use of MEMC is banned completely except for seed treatment of potato and sugarcane.
10.	Methyl Bromide	Methyl Bromide may be used only by Govt./Govt. undertakings/Govt. Organizations / Pest control operators under the strict supervision of Govt. Experts or Experts whose expertise is approved by the Plant Protection Advisor to Govt. of India.
11.	Methyl Parathion	Methyl Parathion 50 % EC and 2% DP formulations are banned for use on fruits and vegetables.
12.	Monocrotophos	Monocrotophos is banned for use on vegetables.
13.	Sodium Cyanide	The use of Sodium Cyanide shall be restricted for Fumigation of Cotton bales under expert supervision approved by the Plant Protection Advisor to Govt. of India.

Source: www.cibrc.nic.in

Annexure-VIII

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 torn 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. Do not smell the sprayer tank.
9. Avoid spilling of pesticide solution while filling the sprayer tank.
10. Do not eat, drink, smoke or chew while preparing solution.
11. 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- brushes tied with the sprayer and clean with water.
5. Do not use same sprayer for weedicide and insecticide.

F. Precautions for applying pesticides

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


Safe use of Pesticides
कीटनाशकों का सुरक्षित इस्तेमाल
कीटनाशकों को पदार्थों के साथ यहाँ–वहाँ न ले जाएं
ताला चाबी लगा कर रखें
बच्चों की पहुच से दूर रखें
मूल पैंकिंग वाले कीटनाशक ही खरीदे
इस्तेमाल से पहले लेबल और पुस्तिका पढे
सुरक्षात्मक कपड़े पहने।
सुझाई गई मात्रा को सही–सही प्रमाण में इस्तेमाल करे।
लकड़ी या पैडल से पानी को अच्छी तरह मिलाए
कुप्पी का इस्तेमाल करते हुए बिना गिराए भरे।
खाद्य पदार्थों या पानी के संग्रह के लिए कीटनाशक के डिब्बें का इस्तेमाल न करे।
हवा की दिशा में ही छिड़काव करें
नौजल को साफ करने के लिए मुंह से हवा भीतर न डालें
छिड़काव करते समय कुछ खाए–पीएं नहीं तथा न ही धुम्रपान करें
रिसाव वाले स्प्रेयर व डस्टर का प्रयोग न करें
यदि गलती से कपड़े व शरीर पर लग जाए तो दूषित कपड़े व शरीर के हिस्से को अच्छी तरह धो डालें
बच्चों को छिड़काव न करने दें
इस्तेमाल किए जाने वाले स्थान पर खाद्य वस्तु न रखें
खाने–पीने या धुम्रपान करने के पहले हाथ व मुंह को धो लें।
विषैला असर दिखाई देने पर प्राथमिक उपचार व डॉक्टर को बुलाए।
डॉक्टर को डिब्बा व पुस्तिका बताएं
तुरंत विशेष चिकित्सा प्राप्त करें
खाली डिब्बें को तोड़–फोड़ कर नष्ट कर दें तथा गाड़ दे
इस्तेमाल के बाद स्नान करे व कपड़े धो लें
वातावरण को दूषित न होने दें
उपचार किए गए खेतों में चेतावनी सूचना लगा दें
कीटनाशकों की विषाक्तता की श्रेणियों के पहचान-चिह्न
अत्यंत विषैला
POISON
अत्यधिक विषैला
POISON
सामान्य रूप से विषैला
DANGER
थोड़ा से विषैला
CAUTION
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

Annexure-IX

Symptoms of poisoning and the treatment of poisoning for different pesticides

S. No	Name of pesticide	Classification as per Insecticides Rules. 1971	Colour of Toxicity Triangle	WHO classification by hazard	First aid measures	Symptoms of poisoning	Treatment of poisoning
				INSECTICIDES			
				ORGANOPHOSPHATE INSECTICIDES			
1.	Quinalphos	Highly toxic	Yellow	Class II Moderately Hazardous	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) Indigestion – 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.	Nausea, vomiting, restlessness, tremor, apprehension, convulsions, coma, respiratory failure and death Mild – anorexia, headache, dizziness, weakness, anxiety, tremors of tongue and eyelids, miosis, impairment of visual acuity. Moderate- nausea, salivation, lacrimation, abdominal cramp, vomiting, sweating, slow pulse, muscular tremors, miosis. Severe – diarrhea, pinpoint and non-reactive pupils, respiratory difficulty, pulmonary edema, cyanosis, loss of sphincter control, convulsions, coma and heart block.	- Gastric lavage with 2-4 L. tap water. Catharsis with 30 gm (10 oz) sodium sulphate in the cup of water - Barbiturates in appropriate dosages repeated as necessary for restlessness or convulsions. - Watch breathing closely, aspirate oxygen and/or artificial respiration, if needed. - Avoid oils, oil laxatives and epinephrine (Adrenalin) – do not give stimulants. - Give calcium gluconate (19% in 10 ml Ampules) intravenously every four hours. For extreme symptoms of O.P 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 2 mg, 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 (eye wash with isotonic saline). Wear rubber gloves while washing contact areas. In addition to atropine give 2-PAM (2- pyridine aldoxime methiodide) 1g and 0.25 g 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, theophylline, aminophyllin, barbituarates ofrphenothiazines. Do not give atropine to a cyanotic patients. Give artificial respiration first then administer atropine.
2.	Monocrotophos	Extremely toxic	Bright red	Class I b Highly hazardous			
3.	Acephate	Moderately toxic	Blue	Class III Slightly Hazardous			
4.	Chlorpyriphos	Highly toxic	Yellow	Class II Moderately Hazardous			
5.	Ediphenphos	Highly toxic	Yellow	Class I b -Highly hazardous			
6.	Phorate	Extremely toxic	Red	Class Ia- Extremely hazardous			

S. No	Name of pesticide	Classification as per Insecticides Rules. 1971	Colour of Toxicity Triangle	WHO classification by hazard	First aid measures	Symptoms of poisoning	Treatment of poisoning	
				CARBAMATES				
7.	Carbofuran	Extremely toxic	Red	Class I b Highly hazardous Class II Moderately Hazardous Class II Moderately Hazardous Class II Moderately Hazardous		Constriction of pupils, salivation, profuse sweating, lassitude, muscle incoordination, nausea, vomiting, diarrhea, epigastric pain, tightness in chest.	- Atropine injection 1 to 4 mg, Repeat 2 mg when toxic symptoms begin to occur (15-60 minute intervals). Excessive salivation good sign, more atropine needed. - Keep airway open. Aspirate use oxygen, insert endotracheal tube. DO tracheotomy and give artificial respiration as needed. - For ingestion, larvae 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. - Oxygen - Morphine, if needed. Avoid theophyllin and aminophyllin or barbituarates. 2-PAM and other oximes are not harmful and in fact contra indicated for routine usage. Do not give atropine to a cyanotic patient. Give artificial respiration first then administer atropine.	
8.	Carbaryl	Highly toxic	Yellow					
9.	Cartap	Highly toxic	Yellow					
				FUNGICIDES				
10.	Mancozeb	Slightly toxic	Green	Table 5 – Unlikely to present acute hazard in normal use		Headache, palpitation, nausea, vomiting, flushed face, irritation of nose, throat, eyes and skin etc.	No specific antidote, Treatment is essentially symptomatic.	
11.	Hexaconazole	Slightly toxic	Green	Class III Slightly Hazardous				
12.	Propiconazole	Moderately toxic	Blue	Table 5 – Unlikely to present acute hazard in normal use				

S. No	Name of pesticide	Classification as per Insecticides Rules. 1971	Colour of Toxicity Triangle	WHO classification by hazard	First aid measures	Symptoms of poisoning	Treatment of poisoning	
13.	Validamycin	Slightly toxic	Green	Table 5 – Unlikely to present acute hazard in normal use				
14.	Tricyclazole	Highly toxic	Yellow	Class II Moderately Hazardous				
15.	Iprobenphos	Moderately toxic	Blue	Class III Slightly Hazardous				
16.	Thiophanate methyl	Slightly toxic	Green	Table 5 – Unlikely to present acute hazard in normal use				
17.	Carbendazim	-do-	-do-	-do-				
18.	Kasugamycin	-do-	-do-	-do-				
HERBICIDES								
19.	Cyhalofopbutyl	Slightly toxic	Green	Table 5 – Unlikely to present acute hazard in normal use		Headache, palpitation, nausea, vomiting, flushed face, irritation of nose, throat, eyes and skin etc.	No specific antidote, Treatment is essentially symptomatic.	
20.	Butachlor	Moderately toxic	Blue	-do-				
21.	Pretilachlor	Slightly toxic	Green	Table 5 – Unlikely to present acute hazard in normal use				
22.	Chlorymuramethyl	Moderately toxic	Blue	-do-				
OTHER								
23.	Fipronil	Highly toxic	Yellow	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.	
24.	Imidacloprid	-do-	-do-	-do-				

Plate-1:

Symptoms of important diseases of rice

Bakanae

Bacterial leaf blight

Brown spot

Leaf Blast

Nodal Blast

Sheath Blight

False smut on rice panicles

Plate 2:

Important insect pests of rice

YSB Moth

White ear head due to YSB

Leaf folder moth

Folder leaf with larva

BPH adult and nymph (upper) and hopper burn (lower)

Gall midge adult (upper) and its damage i.e. silver shoot

Thrips damage


Gundhi bug adult

Plate 3:

Key parasitoids and predators of rice insect pests

Egg parasitoid emerging from YSB egg mass

Egg parasitoid, *Trichogramma chilonis*

Cocoons of larval parasitoid, *Cotesia flavipes*

Coccinella septumpunctata

Micraspis hirashimai

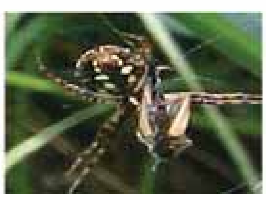
Cheilomenes sexmaculatus

Damselfly
(Agriocnemis femina femina)

Dragonlfly

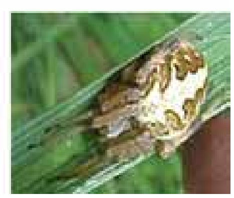
Meadow grasshopper
(Conocephalus longipennis)

Wolf spider with egg sac



Orb spider
(Argiope catenulata)

Oxyopes sp.



Wolf Spider
(*Hogna aspersa*)

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Potato

Diseases

Wart (*Synchytrium endobioticum*):

It is one of the most dreaded diseases of potato. The most favourable conditions for the development of the disease are periodic flooding followed by lack of proper drainage and aeration. The disease is characterised by 'cauliflower-like' warty growths on tubers, stolons and stem bases but not roots. Under wet conditions, it may be seen in the form of greenish-yellow crust on the stems and leaves at or near the soil level. All the tubers on diseased plant do not necessarily develop warts. Diseased tubers may show formation of either one or more tumours. Such tubers sometimes are completely transformed into warty mass. The tumors may turn brown to black with age.

Control: Wart affected tubers used as seed are the chief means of the disease spread. The disease may also spread through seed of wart immune varieties grown in wart infested land, contaminated soil carried on the feet of men, animals or farm implements, and manure containing diseased material.

Control of the disease is possible only by cultivation of immune varieties.

No effective treatments are available and cannot be applied on large field scale. However preventive measures like practicing long crop rotation (5 years or more), using disease free potatoes as seed material and burning of wart affected lumps and potato peelings are effective in checking the spread of the disease.

Soft Rot (*Erwinia. carotovora* subsp *carotovora*):

This disease causes very high losses in storage. Excessive moisture, high temperature excess nitrogen, tuber injuries and poor ventilation during storage are the important factors helping in disease development. Initially a small area of tuber tissue around lenticel or stolon attachment point becomes water soaked and soft. Under low humidity, the initial soft rot lesions become dark and sunken. Under high humidity, the lesion may enlarge and spread to larger area. Tubers in advanced stages of decay are usually invaded by other organisms and the decaying tissue becomes slimy with foul smell and brown liquid ooze. The tuber skin remains intact and sometimes the rotted tubers are swollen due to gas formation. At harvest, many small rotted tubers with intact skin can be seen. The infected seed tubers rot before emergence resulting in gaps. The symptoms appear as water soaked lesions on the stem, leaves and petioles. The affected parts turn black and rot leading to toppling of the stem and leaves.

Control: In the field, avoiding excess irrigation and nitrogen, providing proper and drainage prevents the spread of the disease.

Cultural methods such as adjust planting time to avoid hot weather during plant emergence and harvesting the crop before soil temperature rises above 28° C is recommended. The crop should be harvested only when the tuber skin is fully cured. Care should be taken to avoid injury to tubers and bruised injured tubers are sorted out. Treating the tubers with 3% boric acid for 30 min and drying them under shade minimizes infection in the storage. The treated tubers should be stored in either in well-ventilated cool stores or cold stores.

Charcoal Rot (*Macrophomina phaseolina*):

The diseases infects the tubers in the soil through proliferated lenticels and injuries, Black spots appear around the lenticels and eyes which enlarge into patches extending deep into the tuber flesh. The pathogen infects through lenticels, eyes, stolons and wounds made by larvae of the tuber moth to cause black sunken lesions and later blackening of internal tissues.

Control: Harvesting the crop early before the soil temperature reaches 28°C can check the disease.

Bacterial Wilt or Brown Rot *(Pseudomonas solanacearum):*

Brown rot or bacterial wilt is a destructive disease of the potato. It causes losses in two ways: (i) premature wilting and death of the plants leading to total loss of yield, and (ii) rotting of the tubers in transit or storage.

The earliest symptom is slight wilting of the top, which is soon followed, by total wilting. In advanced stage, if the base of the stem of the affected plants is cut transversely and squeezed, the bacterial mass is seen to ooze out as a dull white slimy mass on the cut surface.

Two types of symptoms are produced in tubers, viz. vascular rot and pitted lesions. In vascular rot, the vascular tissues look like a water soaked circle, which subsequently may turn brown.

The lesions on tuber are produced due to infection through lenticels (skin pores). Initially water soaked spots develop which enlarge forming pitted lesions.

Control: The infected seed tubers including apparently healthy seed tubers from diseased crop are important in spread and carry over of the disease. Hence, disease free seed tubers obtained from disease free areas should be used for planting. Splitting of the tubers at the time of the planting should be avoided as splitting spreads the disease even to health tubers. Application of stable bleaching powder (12kg/ha) mixed with fertilizer in furrows while planting reduces wilt incidence by 80%. Practicing crop rotation for 2-3 years with crops like maize, finger millet, cereals, garlic, lupin, and onion cabbage can reduce the disease inoculum.

Black Scurf and Stem Canker *(Rhizoctonia solani):*

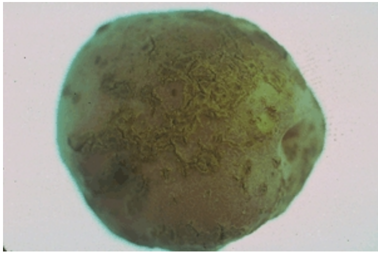
The disease commonly affects the tubers, sprouts, stems and stolons. The most common symptom is black scurf comprising of dark brown to black irregular lumps sticking on the surface of tubers. These irregular lumps are closely adhered to the tuber surface and do not wash off easily. Other symptoms on the tuber include skin cracks, crater like depressions, pitting, stem-end necrosis and shape deformity.

The disease often causes sprout injury both in storage and in fields after planting. The affected sprouts show discoloration of tissue. The heavily infected sprouts cannot emerge from soil leading to gappy germination.

The emerging sprouts when infected later develop cankers causing girdling of stem bases. Such affected plants show upward rolling of leaves with pinkish or purplish margin. Often small green or reddish aerial tubers are also formed in the axils. The infection also spreads to roots and developing stolons resulting in rotting of cortical tissues. Such infected roots later shed away hence infected plants have poor root system. Infected stolons give rise to deformed tubers.

Control: Combination of tuber disinfection and improved cultural practices successfully checks the incidence and severity of black scurf. In the hills tuber treatment with an organomercurial compound & soil application of PCNB @ 30kg/ha is most effective. In the North India plains, treatment of the diseased seed with Thiabendazole, TBZ + 8 Hydroxyquinoline, acetic acid +zinc Sulphate, Carbendazim and Boric Acid effectively controls the disease. The progeny tubers of such treated seeds are usually free from black scurf. A continuous use of treated seed for 2-3 crop seasons is found to completely check the disease. Crop rotation with maize or 'dhaincha' (*Sesbania aegyptiaca*) for green manure also checks the disease build up.

Common Scab (*Streptomyces spp.*):



The disease does not cause yield losses but disfigures the tubers, thereby reducing the market value and increasing peeling losses. The disease mainly affects potato tubers causing any of the following symptoms viz., mere abrasion of skin (russetting); corky lesions around lenticels which may be star shaped or irregularly circular; irregular concentric corky rings around lenticels; raised rough corky pustules and 3-4 mm deep pits surrounded by hard corky tissues. In case of severe attack, dark brown lesions may develop on roots and stolons.

Control: The pathogen is difficult to control because of long survival both on seed tubers and in soils. However using disease free seed tubers could minimize the disease incidence. Before planting the seed tubers are treated with organomercurial compounds (0.015%for 20 minutes) or Boric Acid (3% for 30 minutes) and dries in shade. The same treatment is repeated before the storage of the tubers. Maintaining high moisture in ridge atleast for a few weeks during the initial tuber formation phase crates adverse conditions for the development of the disease. Following crop rotations with wheat, pea, oats, barley, lupin, soybean, sorghum and bajra checks the disease development.

Dry Rot (*Fusarium spp.*):

The dry rot is an important disease of storage. The skin of the dry rot infected tubers first becomes brown then turns darker and develops wrinkles. These wrinkles are often arranged in irregular concentric circles. In the later stage of infection, a hole may be observed in the center of the concentric ring with whitish or pinkish growth of fungal mycelium. On cutting these affected tubers, whitish or brownish tissues are seen with one or more cavities. Eventually the infected tubers loose water and become dry, hard and shriveled.

Control: Use only clean and healthy seed tubers for planting and tuber washing followed by drying under shade substantially reduces the infection. Dipping the tubers in organomercurial compounds (0.2%) for 30 minutes is effective. Tuber damage and injury must be avoided during harvest and storage. Tubers should be stored in cold stores in plains. In country stores, tubers must be examined periodically and rotting tubers sorted out. If possible, splitting of seed during planting should be avoided. Otherwise seed pieces may be treated with Mancozeb (1kg in 450 litres water) for 10 minutes and dried for 24-48 hrs before planting.

Late Blight (*Phytophthora infestans*):

The disease affects all plant parts, viz., leaves, stems and tubers. It appears on leaves as small pale green spots, which enlarge into large water soaked lesions. A white mildew (cottony growth) ring forms around the dead areas on the lower side of leaves. In dry weather, water soaked areas turn necrotic brown. On stems, light brown elongated lesions are formed which may encircle the stem. Tubers develop reddish brown, shallow to deep, dry rot lesions. The affected tuber flesh becomes 'caramalised' with a sugary texture. Frequently metallic tinge develops on the margins of the affected tissue.

Tubers carrying the pathogen are the real carriers and serve as the source of the disease in the subsequent season. Infected seed tubers grow into healthy plants but under favourable conditions for the disease (10-12^{o}C and RH > 80%) development, the disease infects the stem and lower leaves.

Control: Seed potatoes should be checked thoroughly before storage. All blighted tubers must be removed and buried deep in the soil. Ridges should be made high enough to cover all daughter tubers and reduce chance of their infection upon exposure. If the weather conditions (temperature 10-20^{o}C, RH>80%) are favourable for the disease development irrigation should be stopped immediately. If essential only light irrigation is given. When the disease affects 75% crop foliage, the haulms should be cut, removed from the field, and buried deep.

Protective sprays with a contact fungicide, viz., Mancozeb (0.2%) before appearance of the disease is effective. Subsequent sprays if necessary should be repeated at 8 to 10 days interval. In case of severe blight attack, one or two sprays of Metalaxyl (0.25 %) are given to check the further spread of the disease. Mancozeb is applied at an interval of 15 days after the Metalaxyl application.

Early blight (*Alternarial solani*):

The disease mainly infects leaves and tubers. Initially the symptoms occur on the lower and older leaves in the form of small (1-2 mm) circular to oval brown spots. These lesions have the tendency to become large and angular at later stage. Mature lesions on foliage look dry and papery, and often have the concentric rings, looking like bulls eye. The symptoms on the tuber comprise of brown, circular to irregular and depressed lesions with underneath flesh turning dry, brown and corky. Lesions tend to enlarge during storage and affected tubers later become shriveled.

Control: Use of disease free seed tubers for raising the crop. The crop must be given balanced doses of fertilizers, especially nitrogen. Spraying the crop with urea (1.0%) at 45 days after sowing and giving subsequent sprays 8-10 days after the first spray helps the crop to easily escape the severe onslaught of early blight disease.

In the hilly regions, spraying of Copper Oxychloride (0.30%) and Bordeaux mixture (1.0%), is recommended for control of early blight disease. Solanaceous crops, which act as the collateral hosts for the disease organism, hence their cultivation nearby potato fields, must be avoided.

Potato Leafroll Virus (PLRV):

The PLRV invokes primary or secondary types of symptoms in plants depending upon the age of infection. The primary symptoms develop during the crop growth. These symptoms are confined to top young leaves, which usually stand upright, roll and turn slightly pale. The secondary symptoms of PLRV develop when plants are grown from infected seed tubers. Such symptoms are rather prominent in older leaves. Infected plants have characteristic pale, stunted and upright appearance with rolling of lower leaves that turn yellow, brittle and are leathery in texture.

Control: The disease is managed by using virus-free seed potatoes. Multiplying virus-free seed in aphid free areas. Population of aphid vectors is controlled by application of suitable contact/systemic insecticides.

Potato Mosaics

Potato mosaics mostly invoke inter-veinal and veinal chlorosis, mild mottling and slight crinkling of leaves. Top necrosis occurs in immune varieties while others express light yellowing of the leaf margins or shiny yellow mottle of the entire leaf lamina. The potato plant is also affected by a severe

Integrated Pest Management in Brinjal

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Technical Bulletin

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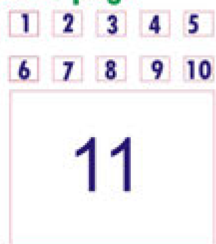
Front Cover page



1. BFSB larvae inside fruit
2. Adult of BFSB
3. Clipping of infested shoot
4. Hadda beetle
5. Flowers infested with red mites
6. Nymphs & adults of whiteflies
7. Jassids
8. Spider feeding on BFSB larvae
9. Damping off of seedling
10. Wilted plants
11. A woman clipping off the infested twigs & fruits in brinjal field

Back cover page

Installation of Traps in the brinjal field

Farmers' Training Programme at Narayana, Akhnoor

Funded and Prepared under the project ICAR-Horticulture Technology Mini Mission-I, entitled **"Development and promotion of IPM module in temperate vegetable crops of Jammu (HTMM1-2.37)"**

Integrated Pest Management in Brinjal

SHANKAR, U. , KUMAR, D. AND GUPTA, S.

Introduction

Vegetables are considered as 'protective supplement food' as they contain large quantities of minerals, vitamins and essentials amino acids required for normal functioning of human metabolic processes. Thus, vegetables constitute an essential component of a balanced diet and play a vital role in the maintenance of good health.

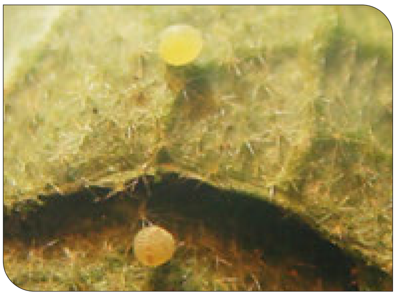
Brinjal, *Solanum melongena* L., is a common, popular and extensively grown vegetable crop in the subtropics and tropics. Insect pest infestation is one of the major bottlenecks in increasing the yield potential in brinjal crop. The crop is susceptible to the attack of various insect pests and diseases in different stages with varying degree of damage which causes considerable losses by reducing potential yield and quality of the produce. In view of the lucrative returns from brinjal, farmers with limited land holdings and resources are forced to follow monoculture and intensive cultivation, which also exacerbates the survival of various insect pests and pathogens from one season to another. In such conditions, the role of Integrated Pest Management in brinjal cannot be overlooked. The efficient management of these insect pests and diseases is possible only through adequate knowledge of different stages of insects, nature of damage and symptoms caused by pathogens, survival and dissemination of the pathogen as well as effect of environmental condition on insect pests and disease development.

During the recent years, important insect pests and diseases of brinjal from Jammu have been recorded and described in this bulletin for an easy identification, decision making and timely management by the farmers to avoid the losses caused by the pests.

INSECT PESTS OF BRINJAL

1. Shoot and Fruit Borers, *Leucinodes orbonalis* (Lepidoptera: Pyralidae)

Brinjal shoot and fruit borer (BSFB) inflicts a serious damage to the fruit causing drastic reduction in the marketable quality fruit yield. The damage starts soon after transplanting the crop and continues till harvest of the fruits. The adults are small moths having brown to black spots on the wings. The adult female lays eggs on the ventral surface of the leaves, flower buds and on young fruits. After hatching within the week, small pinkish larva initially bores into the terminal shoots resulting in withering and drying of the shoot and at later stage, it damages the young fruits by making holes and feeds inside which makes the fruits unfit for consumption and marketing. One larva is responsible to damage at least 4-6 fruits. Often the entry hole encourages the secondary bacterial infection and rotting of fruits. As its larvae are concealed within the twigs as well as in fruits it is very difficult to control.


Eggs


Larva opened our from shoot


Larva inside the shoot


Larvae inside the fruit


Larva and pupae


Adult moth of BSFB


Clipping of affected shoot


Pheromone and water traps


Clipping of shoots and fruits

Management

- Monoculture or continuous cropping of brinjal on the same piece of land should be avoided.
- As soon as the insect is detected, the affected twigs should be clipped/removed along with the insect and destroyed. Fruits showing any boring symptoms should also be picked and destroyed.
- The moths can be mass trapped by installation of pheromone traps @ 100 per ha at 10 m spacing.
- Apply ash dust and avoid the excessive dose of nitrogenous fertilizers in brinjal crops to reduce the infestation of BSFB.
- Long and oblong varieties with bunchy fruiting/ flowering behavior are less susceptible to BSFB.
- Spraying the crops alternatively with profenophos 50 EC @ 2ml /litre of water at 15 days interval and cypermethrin (0.5 ml/litre of water) starting from 20 days after transplanting to control the pest.
- Before spraying, all the affected twigs and fruits should be clipped off or removed from the field.

2. Leaf Roller, *Eublemma olivacea* (Lepidoptera:Noctuidae)

The neonate larvae start folding the leaves from tip downwards. Caterpillars roll leaves and feed on chlorophyll while remaining inside the folds. The folded leaves wither and dry up. Full grown larvae are stout purple brown in colour and ornamented with yellow spots and hairs.


Leaf Roller larva


Adult

Management

- Collection and destruction of infested leaves along with insects in the initial stage help to minimize the infestation.
- Spraying of carbaryl (0.1%) or malathion (0.1%) just after clipping of damaged leaves.

3.Brinjal stem borer, *Euzophera perticella* (Lepidoptera: Phycitidae)

Pale white coloured larvae attack the stem and often kill the young plants. The growth is

Stem borer larva inside stam

stunted, plants wither and fruit yield is adversely affected in case of older plants. Moths have greyish brown forewings with transverse lines and white hind wings. The larvae are creamy white with few hairs.

Management

- Avoid rationing in endemic area.
- Removal and destruction of the affected plants help in reducing the infestation.
- Apply carbofuran 25 kg a.i/ha or neem cake @ 250 mg/ha as spot application around the root zone.

4. Brinjal Fruit borer, *Helicoverpa armigera* (Lepidoptera: Noctuidae)

Helicoverpa larvae damages the flowers, buds and fruits at several places in Jammu province. Their presence can be detected by using pheromone traps. It can also be used for mass destruction of male *Helicoverpa* moths. Their activity persists on brinjal from March to September months. They are responsible for causing serious damage in brinjal fruits, also.

Larva feeding on flower

Female moth laying eggs

Management

- Spray Ha NPV @ 250 LE per ha a t evening hours mixed with adjuvant such as APSA 80 gave promising effect.
- Pheromone traps are beneficial to detect early infestation of the pest.
- Release of bioagents *Trichigramma brasiliense* and *T. chilonis* @ 2.5 lacs parasitized eggs per ha (in the form of Tricho-cards).
- Needs based application of cypermethrin @ 0.5 to 1 ml per lit of water with the appearance of insect pests in the field.

5. Brinjal leaf defoliators, *Spodoptera litura* (Lepidoptera: Noctuidae)

Spodoptera larvae are very common defoliator of leaves of brinjal plants. They are voracious feeders and completely defoliate the leaves of plants. Adult female lays eggs on leaves in batches. The egg masses are covered with scales. Initially young larvae with black spots on thoracic region feed gregariously.

Feeding on bud

Feeding on leaf

Adult *Spodoptera* moth

Management

- Mass trapping can be done by using pheromone traps. *Splt* NPV mixed with adjuvant can be sprayed in the afternoon @ 300 LE/ha.
- *Spodoptera* can be controlled by spraying endosulfan 35 EC @ 2ml per litre or cypermethrin 25 EC @ 0.5 to 1 ml per lit of water.
- Foliar spray of bioagent or chemicals should be done after removal of egg mass by clipping.

A farmer is watching the trap catches

6. Hadda Beetle, *Epilachana vigintioctopunctata and E. Dodecastigma* (Coleoptera: Coccinelidae)

The yellowish coloured grubs and adults feed voraciously by scrapping the leaves and tender parts of the plant. As a result, the leaves are completely skeletonized leaving only a network of veins. It often causes serious damage when they appear in large numbers.

Eggs

Grubs

Adult

Management

- Collection and destruction of infested leaves along with the grubs, adult and eggs reduces the pest incidence.
- Spraying the crop with malathion 50 EC (2ml/litre of water) or carbaryl 50 WP (2 g/litre of water) effectively controls the hadda beetle incidence.

7. Jassids, *Amrasca biguttula biguttula* (Hemiptera:Cicadellidae)

Both nymphs and adults suck the sap from the lower surface of the leaves. The infested leaf curl upward along the margins, which may turn yellowish and show, burnt up patches. They also transmit mycoplasma disease like little leaf and virus disease like mosaic. Fruit setting is adversely affected by the infestation.

Jassids

Cup like curling symptoms

Management

- Seed treatment with thiamethoxam 70 WS @ 3g/kg seed at the time of sowing.
- Foliar spray of imidacloprid (0.006 %) during the vegetative stage of the crop.

8.Whiteflies, *Bemesia tabaci* (Hemiptera:Aleyrodidae)

Whiteflies directly suck the saps from the leaves and lower the vigour of crops, more importantly it causes damage by transmitting the leaf curl diseases in plants. Infested palnts show the symptoms like vein and leaf yellowing, mosaic of leaves , leaf curling and plant stunting.

Whitefly eggs and nymphs

Adults

Management

- Use the tolerant varieties like Hisar anmol and Kashi vishesh.
- Seed treatment with imidacloprid 70 WS @ 3 g per kg to protect the crop from whiteflies attack.
- Use of nylon agro-net in nursery.
- Removal of weed hosts to reduce the damage.
- Spraying of imidacloprid 17.8 SL @ 0.3 ml per lit of water after transplantation.

9. Red Spidermite, *Tetranychus cinnabarinus* and *Paratetranychus indicus* (Acari: Tetranychidae)

The red spider mite infests brinjal particularly in low humid dry condition. Different stages of mites are found in colonies covered by white-silky webs on lower surface of leaves. Nymphs and adults suck cell sap and white patches appear on leaves. Affected leaves become mottled, turn brown and fall down.


Red spider mites


Mites webbing on buds & leaves

Management

- During egg stage and the resting stages, most acaricides are ineffective. At high temperatures, it may be necessary to apply these at an interval of two days.
- Acaricides like dicofol (0.05%) and wettable sulphur (0.3%) gives effective control of mites. Avoid use of synthetic pyrethroids for borer control.
- Collection and burning of severely infested plant parts reduces further multiplication of mites.
- Proper irrigation and clean cultivation are essential to reduce the damage caused by mites.

10. Mealy Bug, *Planococcus solenopsis* (Homoptera: Pseudococcidae)

P. solenopsis has been recorded for the first time in Jammu causing damage in different parts. Nymphs and adults of mealy bugs suck sap from the leaves, tender shoots, and the fruits. Leaves show characteristic curling symptoms similar to that of a virus. A heavy black sooty mould may develop on the honeydew like droplets secreted by mealy bugs. Flower development and fruit set are adversely affected. Infested fruits are entirely covered with the mealy bug. The infestation may lead to fruit drop or the fruits remain on the shoots in a dried and shriveled condition.


Mealybugs on leaves


On fruit

Management

- Unlike the adults, the crawlers are free from waxy coating and therefore the crawler stage is the most effective for spraying pesticides. Crops should be monitored to spot the early infestation.

11. Lace wing Bug, *Urentius hystricellus* (Hemiptera: Tingidae)

This pest has been reported first time from Jammu and is a specific pest of brinjal mostly attacking in the summer and rainy season. Both the nymphs and dark brown bugs with lace like wings suck the sap from leaves, which turn whitish and are found covered with insect excreta. The affected leaves eventually dry up.

Lace wing eggs and nymphs

Adult Bug

Management

- Proper crop rotation and spraying with imidacloprid 17.8 SL @ 0.3 ml per lit of water help in the reduction of the pest population.

Diseases of brinjal

A. Fungal diseases

1. Damping off

Causal organism (Species of *Pythium*, *Phytophthora*, *Fusarium*, and *Rhizoctonia solani*)

It is an important disease of brinjal and also other vegetable crops like bell pepper, chilli, cabbage, cauliflower, broccoli, onion etc. for which nursery is raised for transplanting. In case of pre-emergence damping off failure of seedling emergence from the soil results in patchy appearance of seedling stand in the nursery in early stages of growth whereas in case of post-emergence damping off topping over of infected seedlings at any time after their emergence from the soil resulting in mortality of the seedlings.

Damping off

Management

- Change the nursery site every year
- Either treat the soil with transparent polyethylene (25μm) sheet for 45 days during summer months or treat the soil with formalin (5%) at least 21 days before sowing or apply bio-agents like *Trichoderma harzianum* / *T. viride* (40g/m^2).
- Treat the seed with Captan or Thiram (0.3%).
- After seedling emergence from the soil, drench the bed with the mixture of mancozeb

(0.25%) and carbendazim (0.1%) and repeated at 10 days interval. Give light but frequent irrigation.

2. Phomopsis blight and fruit rot

Causal organism: *Phomopsis vexans*

In nursery bed it causes damping off. After transplanting circular grey spots with light coloured centers appear on leaves. Affected leaves turn yellow and fall down prematurely. The disease also appears on the stem in the form of elongated blackish brown lesions. Pale sunken spots with black picnidia develop on the fruits and may progress to cover the entire fruit surface. The pathogen is seed born and it also survives in the infected plant debris. Warm (25° C) and wet weather conditions favour infection and subsequent disease development.


Phomopsis blight and fruit rot

Management

- Collection & burning of the old plants as soon as the crop is over.
- Use disease free seeds and treat the seeds with carbendazim (0.2 %)
- Spray the crop with mancozeb ((0.25 %) or carbendazim (0.1 %) or combination of mancozeb ((0.2 % & carbendazim (0.05 %) or copper oxychloride 0.3 % and repeat at 10-14 days interval.

B. Wilt Complex

This disease is becoming a limiting factor in successful cultivation of brinjal. There are many pathogens associated with this disease include *Verticillium* sp., *Fusarium solani, Sclerotium rolfsii* and *Macrophomina phaseolina*. In Jammu province wilt disease causes severe problems in commercial brinjal cultivation. The characteristic symptoms of the disease are wilting and yellowing of the foliage followed by collapse of entire plants.

1. Fungal wilt, *Verticillium sp.*

The pathogen is soil-borne and the primary inoculum usually comes from the soil. Its characteristic symptoms are found on stem and roots of young as well as on mature plants. The infected plants become stunted in growth and do not flower and set fruit. If the infection takes place after the flowering or fruit setting, the flowers and fruits are deformed and finally drop off.


Fungal wilt

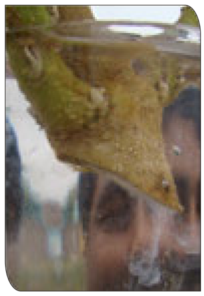
Management

- Soil solarization and crop rotation are recommended as control measures.
- Use of resistant varieties like Pusa purple long (PPL), Black beauty and K 2282.

2. Bacterial wilt, *Ralstonia solanacearum*

The symptoms of bacterial wilt on susceptible plants are yellowing, curling and wilting of leaf; and dying of the plant. The bacterium has a wide host range and can also survive in moist soil for longer periods in the absence of plant debris. The disease usually develops when the average temperature is above 20 °C and more severe wilting is seen at higher temperature of 30 °C or more along with high soil moisture. Disease is further aggravated if soil is infested with root knot nematodes.

Bacterial wilt



Ooze test

Management

- Follow at least three year crop rotation with non- solanaceous crops.
- Solarize the field soil before planting for at least 45 days.
- Apply bleaching powder (15 kg/ha) before transplanting.
- Use resistant varieties/hybrids if available.
- Apply carbofuron @ 1.25 kg per canal at the time of field preparation and immediately irrigate the field.

C. Little leaf of brinjal

Causal organism: *Phytoplasma* spp.

The diseased is characterized by smalling of leaves and shortening of node and internodes, which gives the plant a bushy appearance. The fruiting is very rare. In nature, the phytoplasma perenate on the weed host like *Dhatura* spp. and *Vinica rosea* and several others. The disease is transmitted through leaf hopper vector, *Hishimonas phycitis*.

Little leaf of brinjal

Management

- Destruction of weeds like *Dhatura* and *Vinica rosea* from in and around the field.
- Dipping of seedling in tetracycline (0.05 %) before transplanting followed by soil

application of carbofuron @ 1.25 kg per canal also keeps the disease under check.

D. Cucumber Mosaic virus

There are several viruses which infest the brinjal plants under natural conditions and produce the cucumber mosaic symptoms on leaves. Perhaps the whiteflies and jassids are the important source of virus vector for mosaic disease in brinjal plants. The leaves of infected plants are deformed, small and leathery. Plants infected by the virus in early stages show the stunted growth. Another important viral disease is caused by potato Virus Y and transmitted by aphids.

Cucumber mosaic symptoms

Management

- Proper management of vectors like whiteflies, jassids and aphids.
- Rouging and destruction of infected plants and eradication of weed hosts around the fields.
- Use of resistant varieties.
- Spraying imidacloprid 0.5 ml per lit of water twice after 15 days interval on 20 days transplanted plants.

Natural enemies of Brinjal pests

Natural enemy fauna or farmers friend insects also play a vital role in regulating the insect pests of brinjal. They can be preserved and encouraged by planting some border row of flowering plants and reducing the pesticide pressure. It would be beneficial to use eco-friendly pesticides in less quantity at evening hours. Various types of coccinellid beetles, big-eyed bug, green lace wing larva, rove beetles, minute pirate bug (nymphs and adults) and spiders are the general predators abundantly found in brinjal eco-system to control small and sucking pests. Besides this, several parasitoids are also recorded in brinjal crop ecosystem which suppresses the immature stages of insect pests on crops.

Xanthopimpla sp.

Ichneumonid wasp

Brachymeria wasp

Ichneumonid wasp

Minute pirate bug

Nymph feeding on aphids

Eocanthecona bug

Green lace wing larva

Green lace wing adult

Spider feeding on BFSB larvae

Long legged fly

Big eyed bug

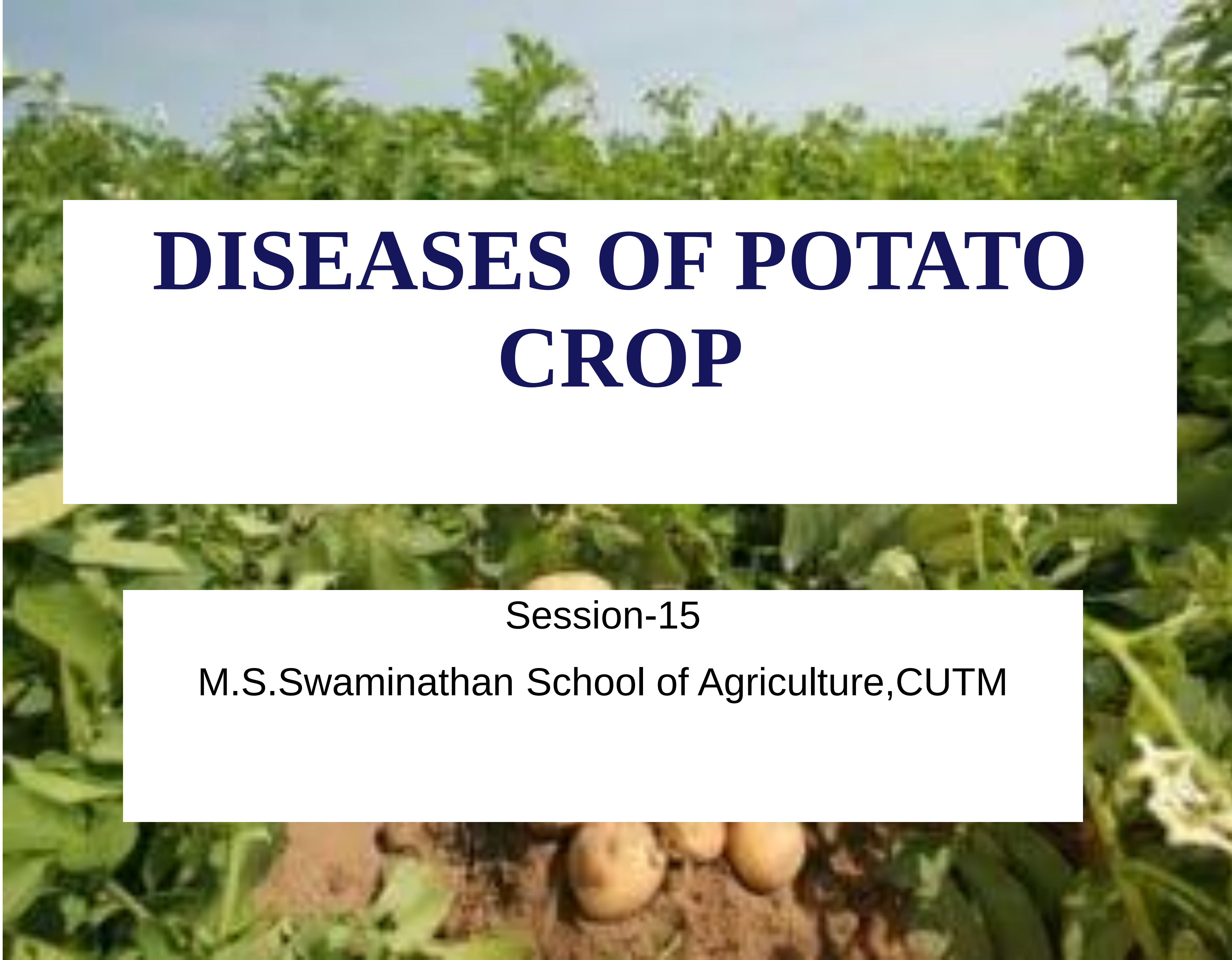
Rove beetle & coccinella

Coccinella tarnsversalis

Coccinella spp.

Prepared Under HTMM-I, 2.37 ICAR Project

Farmers' Training Programme at Narayana, Akhnoor



DISEASES OF POTATO CROP

Session-15

M.S.Swaminathan School of Agriculture,CUTM

LATE BLIGHT OF POTATO

INTRODUCTION

- Usually infection starts in **6 weeks old plants.**
- First reported from Andes mountains of South America.
- It cause famine in 1845 in Ireland of Europe.
- In India, the disease was first reported in Darjeeling district in India (1880)

SYMPTOMS

- Initially starts as water soaked ,light brown lesions on the leaf blade. In favourable climatic condition disease spread to leaflet and petiole.
- Characteristic lesions are roundish with concentric marking in margin. The lesion generally appear in leaf margin.
- The lesions are dirty brown colour in beginning ,later stage turn black.
- Downy growth of the pathogen on subsequent lower surface.
- Progressive defoliation and collapse of plants under favourable conditions.
- Water soaked stripes appear on stem which becomes necrotic.
- Purplish brown spots appear on skin of tubers.
- On cutting, the affected tubers show rusty brown necrosis spreading from surface to the centre.
- Decay of plant parts under favourable weather which emits foul smell.

Cont...

CAUSAL ORGANISIM

Phytopthora infestans

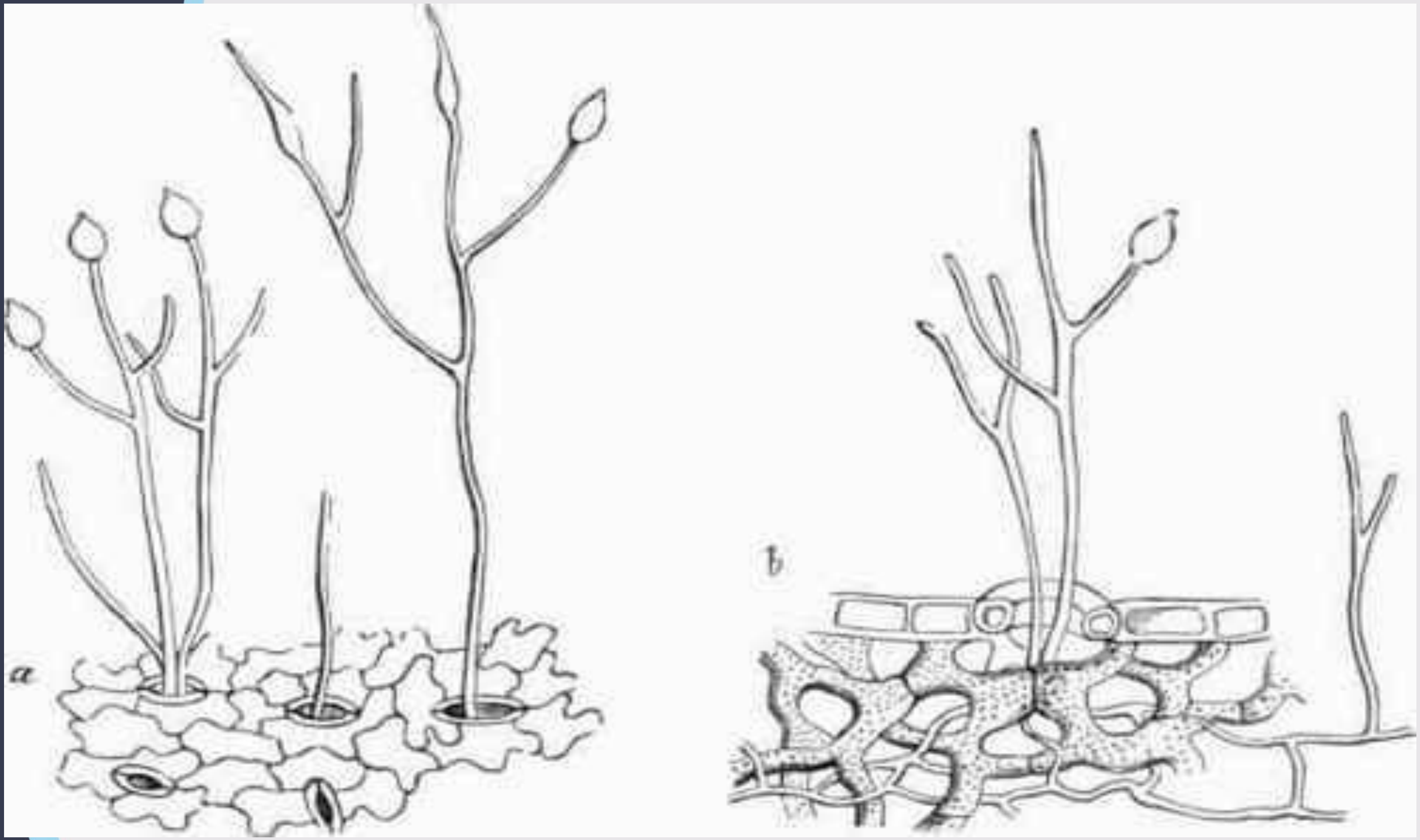
- Fungus both inter– and intra-cellularly present in host and spreads by feely branching,hyaline,coenocytic hyphae.
- Sporangiophores emerge in cluster through the stomata and bear a hyaline,thin walled,lemon shaped,papillate sporangia.
- The sporangia spread though wind which germinate through germ tube and cause further infection.
- As disease advances it produce the thick walled oospore from which sporangia produce which contain biciliate sporangiospore.

DISEASE CYCLE

- P.I: Infected potato tubers or oospores.
- Collateral host: Tomato (*Lycopersicon esculentum), Pepper and egg plant.*
- S.I: Sporangia dispersed by wind or water.

PHYTOPTHORA INFECTION IN LEAF AND TUBER

SPORANGIOPHORES AND SPORANGIA



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FAVOURABLE CONDITIONS

- Cool moist conditions
- RH: >90% and with suitable temperature (12-13$_{0}$ C) and optimum soil moisture (15-20% saturation).

MANAGEMENT

- Regulatory measures
- Select healthy tubers for planting
- Delayed harvesting
- High ridging to about 10-15cm height reduces tuber infection.
- Grow resistant varieties such as **Kufri Jyothi, Kufri Badshah, Kufri Jeevan, Kufri Sherpa, etc.**
- Resistant sources: *Solanum demissum and S. phureja*
- ***Prophylactic measures***
- Metalaxyl (0.1%) or Mancozeb (0.25%) or chlorothalonil (0.2%) or BM (1%) can be applied at 7 to 10 days intervals in the hills and 10 to 15 days intervals in plains.

EARLY BLIGHT

SYMPTOMS

- It is prevalent both in hills and plains.
- The disease appears first on old leaves and subsequently spreads to the top young leaves.
- Brown to black necrotic spots angular, oval or circular in shape characterised by concentric rings appear on the affected leaves.
- Unlike late blight, these spots are dry and brittle and smaller in size usually not exceeding 1 cm in diameter.
- Several spots coalesce and affect the entire leaf.
- Sometimes the necrotic tissue drops out leaving shot holes in the leaves.

ETIOLOGY

- The pathogen responsible for this disease is *Alternaria solani.*
- Hyphae are light brown or olivaceous which become dark coloured with age.
- The hyphae are branched,septate and inter and intra cellular.
- The conidiophores of the pathogen emerge through stomata from the spots and bear conidia.
- The conidia are long beaked which is often half the long of the whole conidium muriform with 5– 10 transverse septa along witha few longitudinal septa.
- The lower part of the conidium is brown while the neck is colorless.
- Conidia germinate within 35–45 minutes at 28–300C.

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ALTERNARIA LEAF SOPT

ALTERNARIA SOLANI CONIDIA

Centurion

CONT..

FAVOURABLE CONDITIONS

- It occurs in high intensities in are as where dry warm weather alternates with the intermittent rains.
- It is serious in late planted crop in Bihar,UP and Punjab.
- Reduction in plant vigour.

MODE OF SURVIVAL AND SPREAD

- The conidia and the mycelium in the soil or in the debris of the affected plants can remain viable for more than 17 months.
- The conidia are disseminated by wind (for long distances) ,water and insects.

MANAGEMENT

- As the pathogen is soil–borne , crop rotation should be followed for 2–3 years withn on solanaceous crops.
- Disease free seed tubers should be used for planting.
- Dead haulms should also be raked band burnt after harvesting.
- Fungicides like DithaneM–45 @ 0.2%, Blitox–50 @ 0.25%, Captan @ 0.2% etc have also been recommended for disease control.
- Use of resistant varieties is effective. Moderately resistant varieties are Kufri Naveen (for hills), K. Sindhuri and K. Jeevan(for planes). Hybrid 66–528/8 (*Solanum tuberosum x S. andigena) is a source of high resistance to early blight.*

BLACK SCRUF

Symptom

- Black speck,black speck scab, russet scab on tubers.
- At the time of sprouting dark brown colour appear on the eyes.
- Affected Xylem tissue causes to wilting of plants. Infected tuber contains russeting of the skin.
- Hard dry rot with browning on internal tissue.
- Spongy mass appear on the infected tuber. Seed tubers are source of spread.
- Moderately cool, wet weather and temp 23 °C are the favourable for the development of disease.

Causal Organism - Rhizoctonia *solani*

Sub-division: Deuteromycotina

BLACK SCRUF OF POTATO

Disease cycle

- **Primary infection –** Sclerotia present in soil
- **Secondary infection -** Water

Management

- Disease free seed tubers alone should be planted.
- If there is a slight infection of black scurf that can be controlled by treating seed tubers wi mercuric chloride solution for 1.5 hr with acidulated mercuric chloride solution for 5 min.
- Treating the soil with pentachloroni trobenzene at the rate of 70 kg/ ha lowers the incidence of the disease, but it is too expensive and cumbersome.
- Well sporulated tubers may be planted shallow to control disease. The disease severity is reduced in the land is left fallow for 2 years.

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VIRAL DISEASE OF POTATO

SEVERE MOSAIC AND MILD MOSAIC

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Mild mosaic/Interveinal mosaic – (Potato virus X) PV X

SYMPTOMS

- Often referred as latent potato mosaic
- Light yellow mottling with slight crinkling on potato plants
- Interveinal necrosis of top foliage
- Stunting of diseases plants.

PATHOGEN

Contain ssRNA come under potex virus group.

Virus particle is flexuous , filamentus measuring about 450-540×13 nm.

SPREAD

- Spreads mechanically through rubbing of leaves, contact of infected plants, seed cutting knives, farm implements.
- Root clubbing of healthy and diseased plants in field

MANAGEMENT

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MILD MOSAIC

SEVERE MOSAIC – POTATO VIRUS Y (PV Y)

- Also called **potato leaf drop streak.**

SYMPTOMS

- Chlorotic streaks on leaves which become necrotic
- Necrosis of leaf veins and leaf drop streak
- Interveinal necrosis and stem/petiole necrosis
- Plant remain stunted in growth
- Rugosity and twisting of the leaves occurs in combination with PV X and PV Y

PATHOGEN

- Contain ssRNA come under potyvirus group.
- The particle of virus are elogated,flexuous,helicaly constructed rod,measureing about 730-740×11-15 nm.

SURVIVAL AND SPREAD

- Infected tubers
- Spread by aphids, *Myzus persicae and Aphis gossypii*

MANAGEMENT

- Disease free seed tubers for planting

SEVERE MOSAIC

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LEAF ROLL OF POTATO

SYMPTOMS

- Upward rolling of leaves, which have a stiff leathery texture
- Plants stunted and have a stiff upright growth
- Phloem necrosis of tubers in some varieties

PATHOGENS: Potato leaf roll virus(PLRV) ,Family-Luteoviridae and contain ss RNA**.**

SPREAD

- Infected seed tubers or by **aphids**

MANAGEMENT

- Disease free seed tubers for planting.
- Aphid control.

LEAF ROLL OF POTATO

PHLOEM NECROSIS

Onion

Diseases

Damping-off (***Fusarium oxysporum* f.sp.cepae; *Pythium sp.; Sclerotium rolfsii and S. cepivorum and Colletotrichum sp.***):

The disease is more prevalent during kharif season and causes about 60-75% damage. High soil, moisture and moderate temperature along with high humidity especially in the rainy season leads to the development of the disease. Two types of symptoms are observed-

Pre-emergence damping-off: The pre-emergence damping off results in seed and seedling rot before these emerge out of the soil.

Post-emergence damping-off: The pathogen attacks the collar region of seedlings on the surface of soil. The collar portion rots and ultimately the seedlings collapse and die.

Control: Healthy seed should be selected for sowing. The seed should be treated with Thiram @ 2g/kg of seed before sowing. Continuous raising of nursery in the same plot should be avoided. The topsoil of nursery should be treated with Thiram @ 5g/m^2 area of the soil and nursery should be drenched with the same chemical @ 2g/litre of water at fortnightly interval. Soil solarization by spreading 250 gauge polythene sheet over the bed for 30 days before sowing and application of bio-control agent *Trichoderma viride* in soil @ 1.2kg/ha is also found effective to control damping-off to considerable extent.

Purple Blotch (***Alternaria porri***):

It is an important disease prevalent in all the onion growing areas. Hot and humid climate with temperature ranging from 21-30°C and relative humidity (80-90%) favour the development of the disease. It is more common in kharif season. The symptoms occur on leaves and flower stalks as small, sunken, whitish flecks with purple coloured centres. The lesions may girdle leaves/stalk and cause their drooping. The infected plants fail to develop bulbs .The intensity of disease varies from season to season.

Control: Use of healthy seeds for planting and crop rotation of 2-3 years with non-related crops checks the disease. Spraying Mancozeb (0.25%) or Chlorothalonil (0.2%) or Iprodione (0.25%) after one month from transplanting at fortnightly interval reduces the disease incidence. The sticker triton/sandovit should also be mixed in spray solution.

Stemphylium Blight (***Stemphylium vesicarium***):

The Stemphyliium blight is a serious problem in Northern parts of the country especially in the seed crop. This disease is very common on onion leaves and flower stalks. Infection occur on radial leaves of transplanted seedlings at 3- 4 leaf stage during late March and early April. The symptoms appear as small yellowish to orange flecks or streaks in the middle of the leaves, which soon develop into elongated spindle shaped spots surrounded by pinkish margin. The disease appearing on the inflorescence stalk causes severe damage to the seed crop.

Control: Field sanitation and collecting and burning of crop residues minimizes the spread of infection. Spraying Mancozeb (0.25%) along with Monocrotophos (0.05%) with sticker triton on appearance of disease at fortnightly interval controls the disease.

Basal Rot (*Fusarium oxysporum f.sp. cepae*):

The disease incidence is more in the area where onion crop is grown continuously. A moderate temperature of 22-28°C favours disease development. Initially yellowing of leaves and stunted growth of plant is observed and later on, the leaves dry from tip downwards. In early stage of infection, the roots of the plants become pink in colour and rotting take place later. In advanced stage, the bulb starts decaying from lower ends and ultimately whole plant die.

Control: Since the pathogen is soil borne, it is difficult to control disease. Mixed cropping and crop rotation reduce the incidence of disease. Soil solarization by spreading polythene sheet of 250 guage in summer season for 30 days reduces the infectious propagules, which in turn reduces the disease. Seed treatment with Thiram (2 g/kg of seed) and soil application of Carbendazim, Thiophanate Methyl (Topsin-M) or Benomyl @ 0.1% is effective in the controlling the disease. Seedling dip in Carbendazim (0.1%) or with antagonist viz*. Pseudomonas cepacis,* and *Trichoderma viride* significantly reduces the basal rot in onion crop.

Downy Mildew (*Perenospora destructor*):

The disease is caused by and reported from northern hilly track and plains particularly in high humid locations. The disease is worst in damp conditions and late planting of the crop, application of higher doses of fertilizers and numerous irrigation increased disease severity. Symptoms appear on the surface of leaves or flower stalk as violet growth of fungus, which later becomes pale greenish yellow and finally the leaves or seed stalks collapse.

Control: For managing the disease effectively, onion bulbs meant for seed crop should be exposed to sun for 12 days to destroy the fungus. Spraying with Zineb (0.2%), Karathane (0.1%) or Tridemorph (0.1%) also gives good control of the disease.

Onion Smut (*Urocystis cepulae*):

The disease occurs in areas where temperature remains below 30°C. Since the fungus remains in soil, disease appears on the cotyledon of the young plant soon after it emerges. Smut appears as elongated dark, slightly thickened areas near the base of seedlings. The black lesions appear near the base of the scales on planting. The affected leaves bend downwards abnormally. On older plants, numerous raised blisters occur near the base of the leaves. The lesions on plant at all stages often expose a black powdery mass of spores.

Control: Treating the seeds with Captan or Thiram (2.5g/kg of seed) before sowing controls the disease. Seed bed treatment with Methyl Bromide (1 kg/25 m^2.) is effective in controlling the disease.

Onion Smudge *(Colletotrichum circinans)*:

It occurs on white onion varieties and reduces the market value of the bulbs. The disease is characterized by small dark green to black spots, which appear on the outer scales.

Control: Thorough curing of the bulb after harvesting and storing the bulbs in well-ventilated rooms can control the disease

Black Mould (***Aspergillus niger)***:

The disease is common in onions stored in hot climates where the temperature ranges between 30- 45^{0}C. It is characterized by the black powdery mass of spores that appear on the exterior of the scales. The black spore masses are also seen on inner scales. It reduces the market value of the bulbs.

Control: For effective control of die disease, left for drying in the field for two days. These bulbs should be further dried in shade for 10-15 days before storage. Care should be taken to avoid injury to the bulbs during post harvest handling. The crops should be sprayed with Carbendazim (0.2%) 10-15 days before harvesting.

Bacterial Brown Rot (***Pseudomonas aeruginosa***):

It is very serious disease of onions in storage. The infection occurs through the wounds. The rot begins at the neck of the bulbs which later gives foul smell through the neck when squeezed.

Control: Proper curing and rapid drying of the bulbs after harvesting is essential for controlling the disease. Affected bulbs should be discarded before storage. If rains occur during maturity, spraying of Streptocycline (0.02%) is recommended.

Onion Yellow Dwarf:

This is a viral disease caused by onion yellow dwarf virus. It is transmitted mechanically as well as by insect vectors. The symptoms of the disease are severe stunting of the plants, dwarfing and twisting of the flower stalk. The affected leaves and stems change their normal green colour to various shades of yellow and leaves tend to flatten and crinkle and as a result bend over.

Control: Removal and destruction of the diseased plants checks the spread of the disease. Healthy bulbs should be used for seed production. Spraying of Malathion (0.1%) or Metasystox (0.1%) to control the vectors checks further spread of the disease.

Anthracnose (*Colletotrichum gloeosporiodes or Colletotrichum circinans)*:

The symptoms appear initially on the leaves as water soaked pale yellow spots, which spreads lengthwise covering entire leaf blade. The affected leaves shrivel and droop down.

Control: Since the pathogen survives on crop debris, sanitation and destruction of infected crop debris helps in reducing the disease. Mancozeb (0.25%), Carbendazim (0.1%) or Thiophanate Methyl (0.1%) as foliar spray is effective against the disease.

White rot (*Sclerotium rolfsii*):

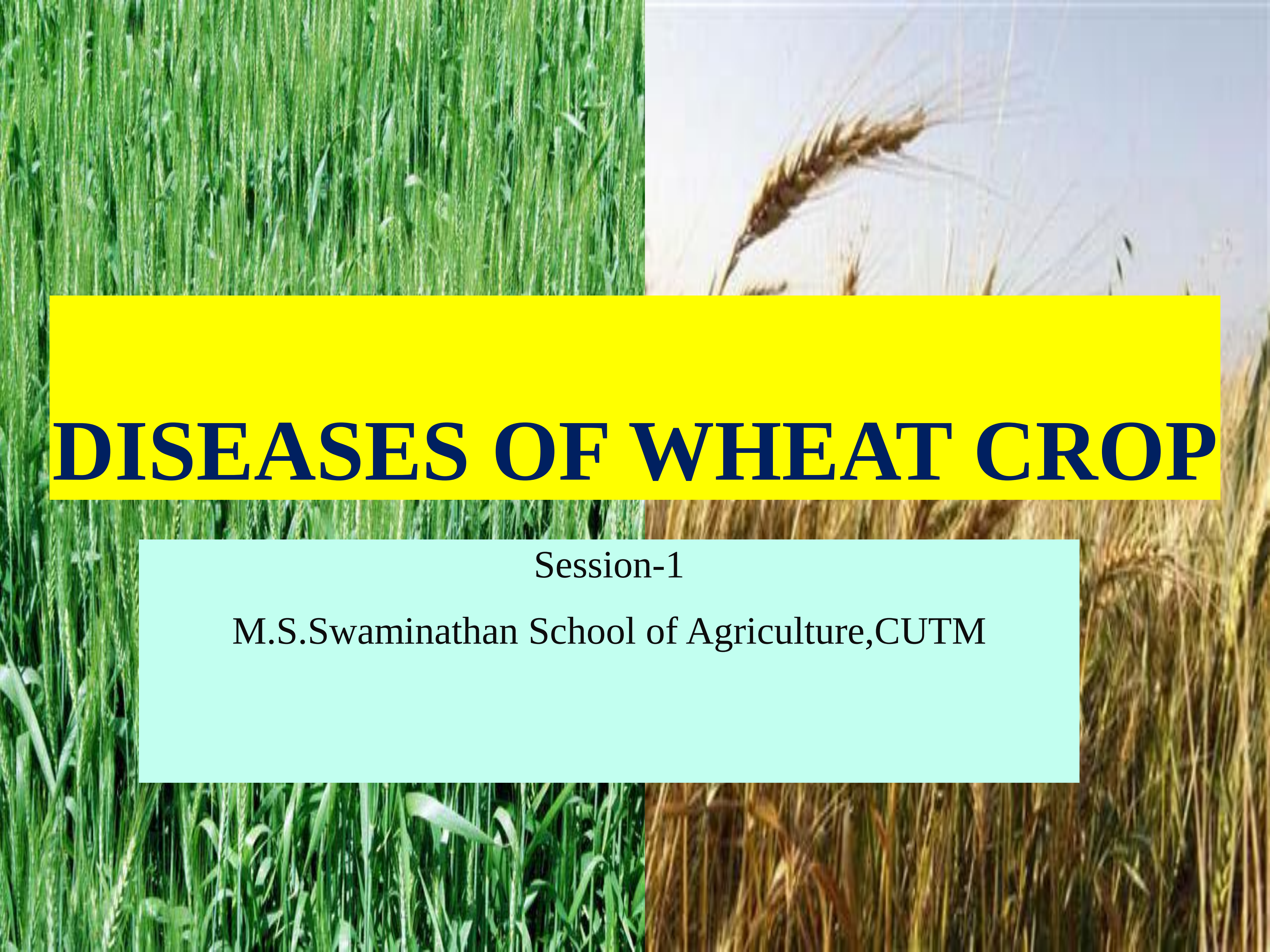
The initial symptom of the disease is yellowing and dieback of leaf tips. Scales, stem plate and roots get destroyed. The bulbs become soft and water soaked. White fluffy or cottony growths of mycelium with abundant black sclerotia resembling mustard grain are seen on the infected bulbs.

Control: Repeated cultivation of onions on the same piece of land should be avoided. Crop rotation with cereal crops is recommended. Seed treatment with Thiram (4 g/kg of seed) and drenching of soil with Mancozeb (0.25%) are effective in controlling the disease. Application of bio-control agents like *Trichoderma viride* to the soil reduces the disease inoculum.

Neck rot (*Botrytis allii*):

The infection usually takes place in the field and symptoms become evident in storage. It is more severe when moist conditions prevail just before and during harvest and while onions are cured in the field. Excessive nitrogen and untimely irrigation increases the incidence of this disease, which is more severe in mild than in pungent onions. The fungus causes softening of the scales which appear water soaked. Under moist conditions, a grayish fungal mat develops on the surface of the scales.

Control: For effective control of die disease, left for drying in the field for two days. These bulbs should be further dried in shade for 10-15 days before storage. Care should be taken to avoid injury to the bulbs during post harvest handling. The crops should be sprayed with Carbendazim (0.2%) 10-15 days before harvesting



DISEASES OF WHEAT CROP

Session-1

M.S.Swaminathan School of Agriculture,CUTM

MAJOR DISEASES OF WHEAT

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FUNGAL DISEASE	
BLACK OR STEM RUST	*Puccinia graminis tritici*
LEAF, BROWN OR ORANGE RUST	*Puccinia recondita*
YELLOW OR STRIPE RUST	*Puccinia striformis*
LOOSE SMUT	*Ustilago nuda tritici*
KARNAL BUNT	*Neovossia indica* *(formerly Tilletia indica)*
LEAF BLIGHT	*Alternaria triticina*
POWDERY MILDEW	*Erysiphe graminis var. tritici*
EAR COCKLE OF WHEAT	*Anguina tritici (Nematode)*

BLACK OR STEM RUST OF WHEAT

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Economic importance

- The most important and destructive disease throughout the world where ever wheat is grown.
- The rust epidemics of 1946-47 in M.P, Maharashtra, Rajasthan and U.P destroyed over two million tonnes of grain.
- In India though black stem rust is prevalent in all parts of the country.
- It normally appears in epidemic form only in central, southern and eastern parts of the country where high temperatures prevailed during crop season.

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SYMPTOMS

- The initial symptom of rust infection appear as flecking on leaves, leaf sheaths, culms and floral structures and soon develop as oblong, reddish brown uredo-pustules, frequently merging into one another, finally bursting to expose a mass of brown uredospores.
- When large number of uredosori burst affected parts will have a brownish appearance even from a distance.
- Later in the season, teleutosori are produced. Teleutosori are conspicuous, linear or oblong, dark brown to black and often merging with one another, to cause linear patches of black lesions, which account for the name black rust.
- The affected part of plant dry up prematurely and in sever infection plant produce small spikes and shrivelled grains, or no grain at all.

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BLACK OR STEM RUST OF WHEAT

PYCNIA IN UPPER SURFACE(2) AND AECIA LOWER SURFACE(1)

1

2

ETIOLOGY

Causal organism- *Puccinia graminis tritici*

[subdivision-Basidiomycotina

The pathogen is a

-Biotrophic (obligate) parasite(only grow upon living host)

-Heteroecious(required two host for complet life cycle)

-Macrocyclic(5-type of rust spore present)

-Polymorphic species

ETIOLOGY

The pathogen has the following stages-

- Stage 0 : Pycnia(spermagonia) and pycniospores(spermatia).
- Stage I : Aecia and aeciospores.
- Stage II : Uredia and uredospores.
- Stage III : Telia and teleutospores.
- Stage IV : Basidia and basidiospores.
- Black stem rust is **heteroecious full cycle rust. It requires more than one host species to** complete its life cycle.
- The uredial and telial stages occur on wheat, barley and some grasses and the pycnial and aecial stages on the species of ***Berberis (Barbery) and Mahonia, the alternate hosts.***

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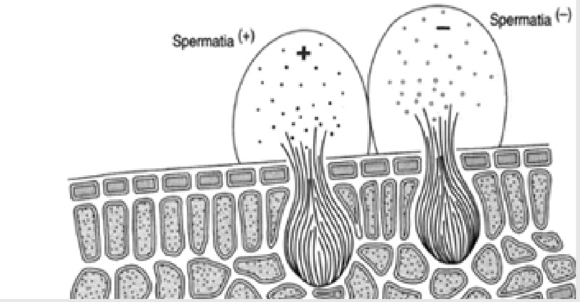
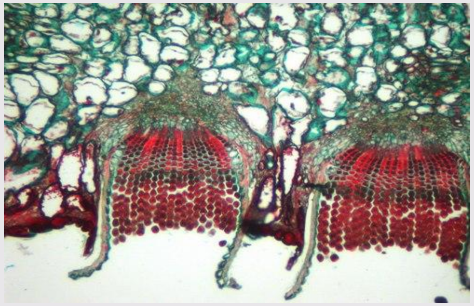
SPORE PRODUCED BY WHEAT RUST

PYCNIOSPORE OR SPERMATIA AND AECIOSPORE PRODUCED IN BARBERY



Spermatia



Aeciospores

UREDOSPORE ,TELIOSPORE AND PROMYCELLIUM CONTAIN BASIDIOSPORE PRODUCED IN WHEAT

Uredospores

Teliospores

Basidiospore

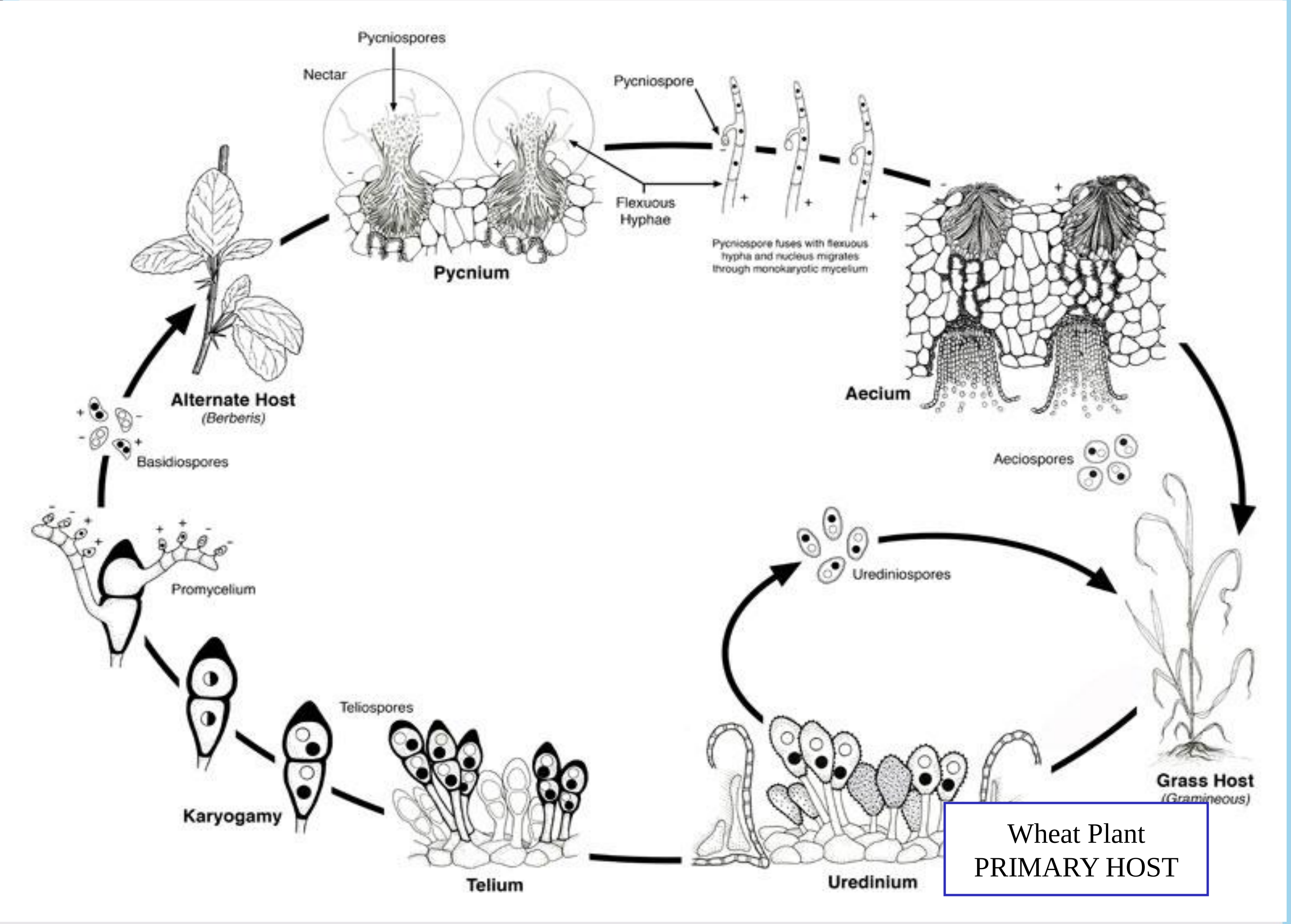
DISEASE CYCLE

In USA, Europe and Australia Primary infection is mainly through **barberry, i.e.,** ***Berberis vulgaris which act as the alternate host in which aeciospore produced which infect wheat and disease cycle continue.***

INDIAN CONDITION

- ***The barbery*** plants in India are not known to play any role in the perpetuation of the fungus.
- It stuided that source of inoculum for black rust comes from **wheat crops and certain grasses growing in cool areas particularly in the foot hills Of** Himalayas in the North, the Nilgiris and Pulney hills in the South appear to be great.
- ***It is believed that the fungus over summers on*** the wheat plants and grasses in the hilly areas and spreads to the plains in the main wheat crop season.
- In the central Nepal, the wheat crop sown in August and harvested in December, January becomes infected by *P. graminis tritici from October. This may be a* source of inoculum for the main crop sown in the plains, which becomes infected from February each year.

DISEASE CYCLE



FAVOURABLE CONDITIONS

- Hot days (25-30$_0$C),mild nights (15-20ºC) and wet leaves from rain or dew. In this condition large number of teliosporesare produced.

DISEASE MANAGEMENT

- Eradication of self sown wheat plants and weed hosts.
- Adjust time of sowing.
- Grow resistant varieties like Kalyanasona, Sonalika, Choti Lerma, Lerma Rojo, Safed lerma, NP 700 & 800.
- Avoid late sowing
- Balanced application of nitrogenous fertilizers
- Application of sulphure 15 kg/ha in 15 days interval.
- Seed dressing with Plantavax@0.1% followed by two sprays with the same chemical.
- Spray twice or thrice with Zineb@0.25% or Mancozeb@0.25% or Plantavax@0.1% , at 15 days interval.

LEAF, BROWN OR ORANGE RUST

SYMPTOMS

- The first symptom of the disease is the appearance of minute, round, **orange sori,** irregularly distributed on the leaves, **rarely on the leaf sheath and stem.**
- **The sori turn** brown with maturity.
- As the disease advances, the telial stage may be found in the same pustule.
- The telia are small, oval to linear, black and covered by the epidermis.
- The telia are also found on the leaf sheath.
- Severe rusting of leaves causes reduction in yield.

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Causal organism: *Puccinia recondita, is heteroecious rust*

Subdivision-Basidiomycotina

- *Primary host:**Wheat***
- Secondary host:***Thalictrum***

FAVOURABLE CONDITIONS

- Free moisture
- Temperature between 20-300C.

DISEASE CYCLE

Primary infection :Uredospore

Alternate host, species of *Thalictrum*

ORANGE RUST

MANAGEMENT

- Grow resistant varieties like Sonalika, NP 700 & 800, Lerma Rojo and Safed Lerma.
- RH-124, an Indofil product is very specific to brown rust (or) spray dithiocarbamates like zineb@0.25% or Mancozeb@0.25%
- Seed dressing with Plantavax@0.1% followed by two sprays with the same chemical

YELLOW OR STRIPE RUST

SYMPTOMS

- The uredosori appear as bright yellow pustules mainly on the leaves, in severe infections they may be seen on leaf sheaths,stem also.
- The sori are elongated and are arranged in linear rows between the veins of the leaf and hence it is referred as stripe rust.
- The sori are mostly sub-epidermal and are remained covered by the epidermal layer and break only at the time of crop maturity.
- The teleutosori appear late in the season and are also arranged in linear rows,sori are compact, elongated, and black which remain subepidermal.

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YELLOW OR STRIPE RUST

STRIPE RUST SYMPTOM ON LEAF SURFACE OF WHEAT

Causal organism: *Puccinia striformis*

Disease cycle

- Some weeds like *Agropyron semicostatum, Bromus catharaticus, Bromus japonicus and Hordeum murinum also serve as primary source of inoculum.*
- *Secondary infection is by wind borne* uredospores.

Favourable conditions

- Optimum temperature ideal for the disease development is 8 - 130C.
- No infection occurs above 230Cand below 20Cand Heavy Rainfall

Management

- Grow resistant varieties like Lerma Rojo, Safed Lerma, Sonalika and Choti Lerma.
- Spray plantavax@0.1%.
- Removal and destruction of weed hosts.

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LOOSE SMUT

SYMPTOMS

- The symptoms are evident only at the time of emergence of the ears from boot leaf.
- All the spikelets in a ears transform into a mass of **black powdery spores.**
- **The infected ears** emerges earlier than healthy ones.
- Usually all spikelets are affected, having been transformed into a mass of black powdery spores.
- The spores are easily blown by wind leaving the bare rachis.

LOOSE SMUT SYMPTOM

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Causal organism:**Ustilago nuda tritici

[subdivision-Basidiomycotina

- Chlamydospores**(TELIOSPORES)** of the fungus are pale, olive brown, spherical to oval in shape, about 5-9µ in diameter and echinulate on the surface.

DISEASE CYCLE

- It is **internally and externally seed borne and is systemic.**
- **The fungus is carried over in** the seed as dormant mycelium.
- Secondary spread occurs through wind borne smut spores.

FAVOURABLE CONDITIONS:

- 20-21°C temperature and high RH (60-80%) during flowering stage favour the disease development.
- Flowers of cultivars with loose spikelets are more susceptible than those with compact spikelets.

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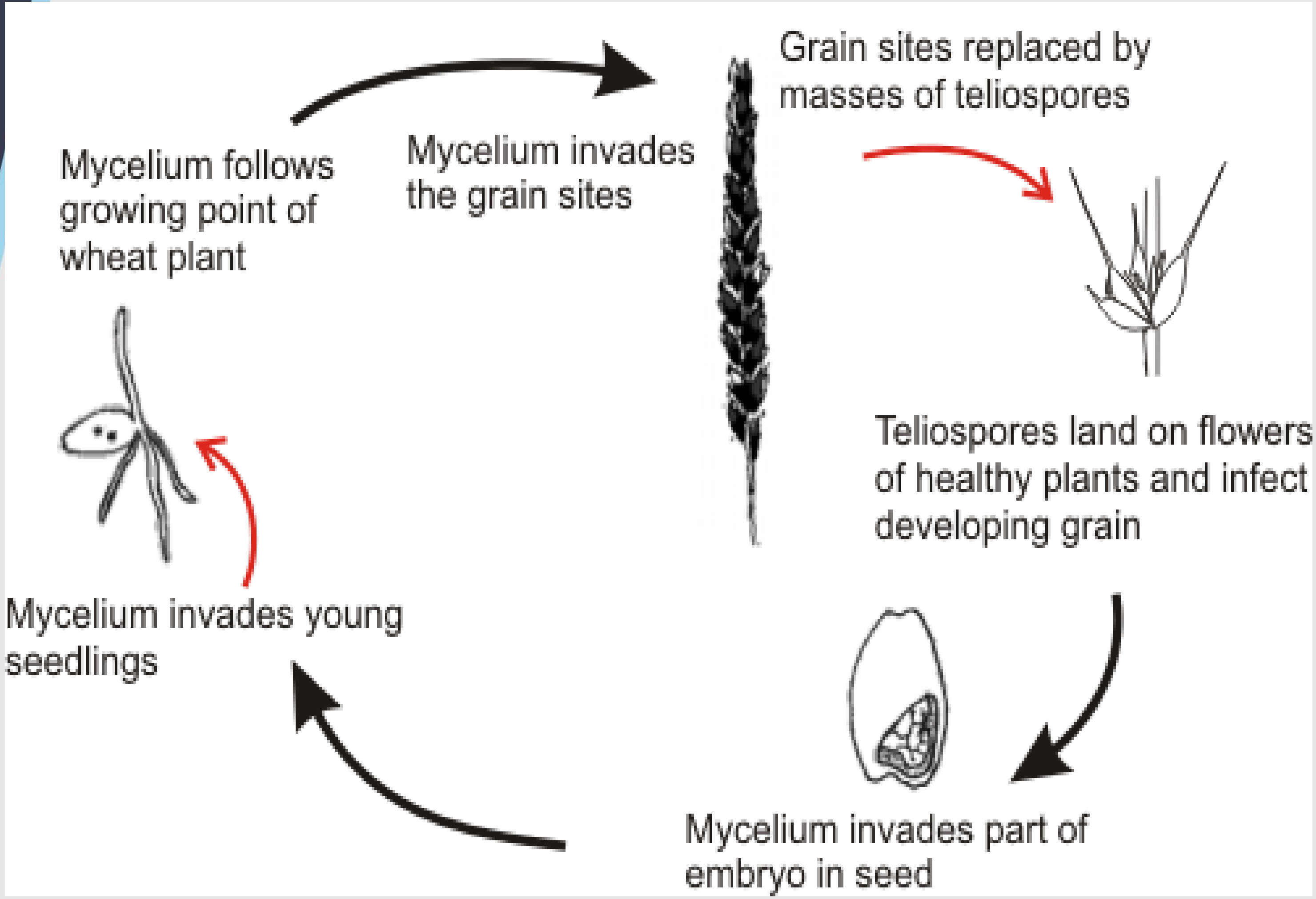
DISEASE CYCLE OF LOOSE SMUT OF WHEAT



MANAGEMENT

- Grow resistant varieties kalyanasona, PV 18, WG 307 and HD 450.
- ***Hot water treatment (Jensen, 1908): Soak the seed in cold water for 4 hours and then*** immerse the seed in hot water at a temperature of 520C for about 10 minutes.
- Dry the seed in shade before sowing.
- ***Solar seed treatment (Luthra and Sattar, 1934): Soak the seed in water for 4 hours (8*** AM to 12 Noon) and expose the seed to the hot sun for 4 to 5 hours (from 12 Noon to 5 PM) on cement or rocky surface.
- Seed treatment with systemic chemicals like vitavax@0.2% or Benlate@0.2% .
- Use certified seed.

KARNAL BUNT

The disease was first reported in India from Karnal (Haryana) by **Mitra in 1931.**

SYMPTOMS

- The infection is usually confined to a **few grains in the spike with irregular arrangement.**
- In some cases the infection may spread to only a part of the grains.
- In severe cases, the grain is reduced to black shiny sac of teliospores.
- As the grains mature the outer glumes spread and the inner glumes expand, exposing the bunted grains.
- The bunt balls are first enclosed by the pericarp but when it bursts the masses of bunt spores are exposed.
- The bunt affected plants emits a foul smell which is mainly due to the presence of **Trimethyl amine.**

KARNAL BUNT SYMPTOM

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SYMPTOM AND PATHOGEN OF BUNT DISEASE

BUNTED GRAINS **TELIOSPORE** **ALLANTOID SPORIDIA**

Causal Organism:*Neovossia indica*

subdivision-Basidiomycotina

- Teliospores are smooth walled measuring 22-49µ in diameter and require a long resting period.
- Teliospores germinate and produce a large number (60-120) of needle shaped primary sporidia on a short stout basidium.
- Later, sickle shaped (allantoid) secondary sporidia are produced which help in the dispersal of karnal bunt.

DISEASE CYCLE

Primary infection:By teliospores

Secondary infection:By sporidia

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FAVOURABLE CONDITIONS

- Moderate temperatures (19-230C), high humidity (>70%) and cloudiness or rainfall during anthesis favours disease development in susceptible host varieties.

MANAGEMENT

- Grow tolerant varieties, viz., WL 1562, HD 2281, etc.
- Use resistant sources like wild species of *Aegilops and Triticum, HD 2329, HD 29 and HD 20 for breeding* programme.
- Follow strict quarantine measures.
- Use disease free seed for sowing.
- Judicious application of nitrogenous fertilizers.
- Adjust date of sowing.
- Intercropping with Gram or Lentil.

LEAF BLIGHT

SYMPTOMS

- Reddish brown oval spots appear on young seedlings with bright yellow margin.
- In severe cases, several spots coalesce to cause drying of leaves.
- The young leaves are not usually infected.
- Heavily infected fields display a burnt appearance even from a distance.
- In some varieties reduction in grain yield is as high as 90% if the infection takes place at or before the boot leaf stage.

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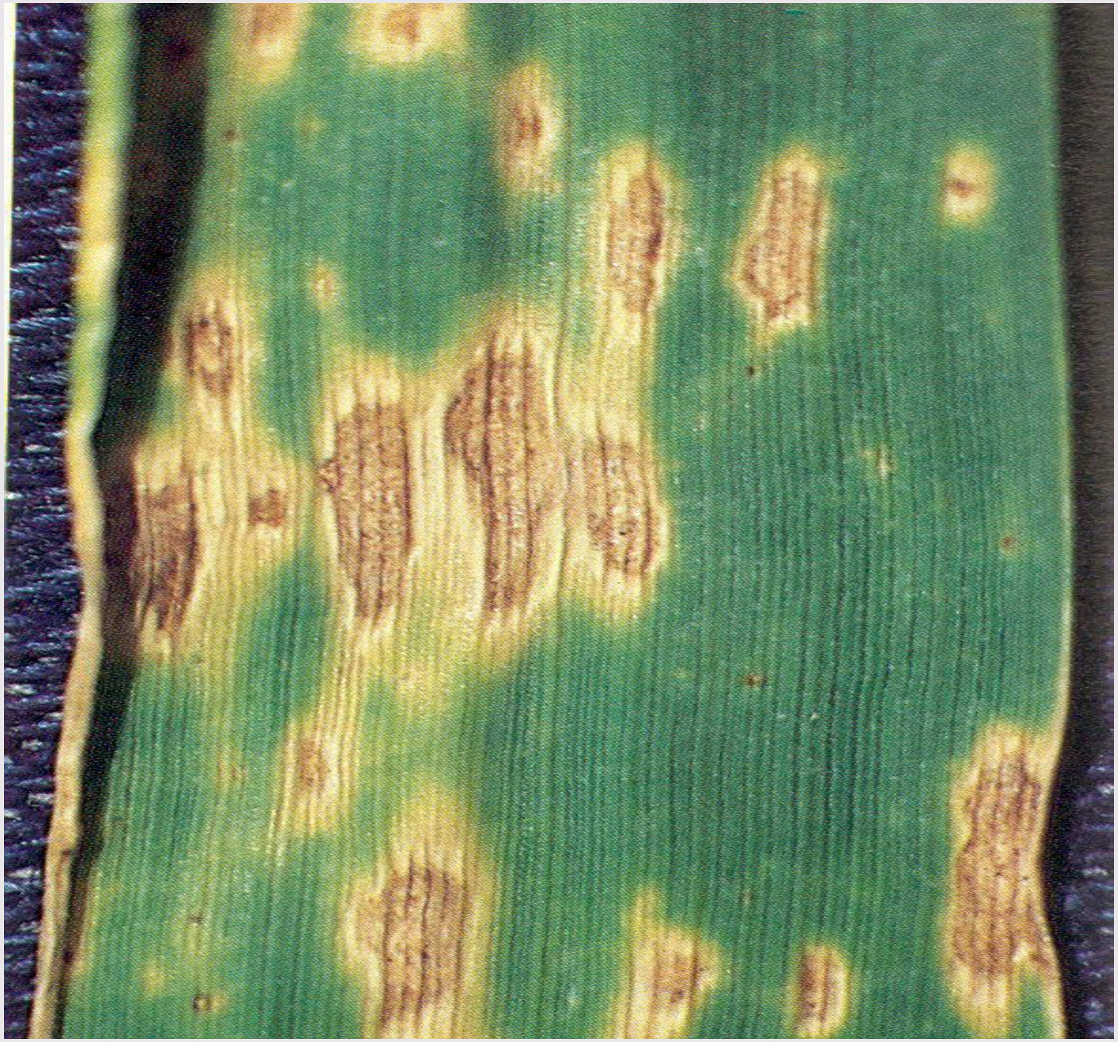
LEAF BLIGHT SYMPTOM



Causal organism: *Alternaria triticina*

Subdivision-Deuteromycotina

DISEASE CYCLE

- Primary spread is by externally and internally seed-borne conidia.
- Secondary infection is mainly through wind-borne conidia.

Favourable conditions

- Temperature of 25 0C and high relative humidity favours the disease.

Management

- Soak the seeds in water for 4 hrs followed by 10 min. dip in hot water at 520C.
- Grow resistant varieties like Co.25, Sonalika, Arnautka, E6160 and K7340.
- Spray the crop with Mancozeb@0.25% or Zineb@0.25%.

POWDERY MILDEW OF WHEAT

SYMPTOMS

- Grayish white powdery growth appears on the leaf sheath, stem and floral part.
- Powdery growth later become black leasions and cause drying of leaves and other parts.
- The affected leaves die off prematurely.
- The cleistothecia remain on wheat debris.

SYMPTOMS OF POWDERY MILDEW OF WHEAT

CONIDIA AND CLEISTOTHECIA OF *ERYSIPHE GRAMINIS VAR.TRITICII*

CONIDIA IN CHAINS

CLEISTOTHECIA

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Causal organism: *Erysiphe graminis var. tritici..*

Favourable condition

Temperature of 20-21 ^{0}C is ideal for the disease development.

Diseasecycle

- Fungus remains in infected plant debris as dormant mycelium and asci.
- Primary spread is by the ascospores and secondary spread through air borne conidia.

DISEASE MANAGEMENT

- Spray dust sulphur @ 40Kg/ha.
- Seed dressing and soil drenching with 0.01% calexin was also found effective.
- One spray of propiconazol (Tilt) 25EC @1.5ml/lit. On disease appearance is highly effective.
- Grow resistant varieties like C591, E750, UP1109 and VL421 etc.

EAR COCKLE OF WHEAT

The ear cockle disease of wheat occurs in most of the wheat-growing parts of the world. In India, the disease commonly occurs in U.P., Punjab and Western part of Bihar, and is popularly known as "sehun" disease

Symptoms

- Symptoms appear on leaves, stems, and heads (floral organs).
- The affected plants look dwarfed with twisted and crinkled leaves.
- Infected heads are shorter, broader, remain green for longer period, and contain hard, dark-brown or black cockles (also called galls) replacing grains in the ear partially or completely.
- The cockles remain filled with nematode larvae.
- When they are soaked in water and then macerated, one can see larvae coming out from them.

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EAR INFECTION

Fig :- Healthy v/s Diseased Earheads

GRAIN INFECTION

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Causal Organism :*Anguina tritici*

- The second-stage larva infect host.
- Second-stage larvae, which remain inside the cockle (gall) to carry on the life-cycle.

Disease Cycle

Primary infection: By infected seed.

Secondary infection:By second stage larve.

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Management

- Affected plants should be uprooted and burnt.
- Healthy seeds should be selected and sown.
- Healthy seeds and cockles (galls) can be better separated by immersing in water or normal salt solution (brine). The cockles come up on the surface and can be collected and destroyed.
- Early sown crops usually escape infection hence early sowing should be preferred.
- Nematicides such as D-D Mixture (20-40 gallons/acre), Nemaphos proved to be most effective.
- Varieties like Sonara 63, NP 908, and 227 are preferable against this disease as they show certain degree of resistance.

Tomato

Diseases

Damping Off (*Pythium aphanidermatum*):
This is one of the worst diseases of tomato occurring in the nursery. Damping off of tomato occurs in two stages, i.e. the pre-emergence and the post-emergence phase. In the pre-emergence the phase the seedlings are killed just before they reach the soil surface. The young radical and the plumule are killed and there is complete rotting of the seedlings. The post-emergence phase is characterized by the infection of the young, juvenile tissues of the collar at the ground level. The infected tissues become soft and water soaked. The seedlings topple over or collapse.
Control: Seed treatment with fungal culture Trichoderma viride (4 g/kg of seed) or Thiram (3 g/kg of seed) is the only preventive measure to control the pre-emergence damping off. Soil drenching of the affected seedlings with Dithane M45 (3 g/litre of water) helps to reduce the disease incidence.

Early Blight (*Alternaria solani*):
This is a common disease of tomato occurring on the foliage at any stage of the growth. The fungus

attacks the foliage causing characteristic leaf spots and blight. Early blight is first observed on the plants as small, black lesions mostly on the older foliage. Spots enlarge, and by the time they are one-fourth inch in diameter or larger, concentric rings in a bull's eye pattern can be seen in the center of the diseased area. Tissue surrounding the spots may turn yellow. If high temperature and humidity occur at this time, much of the foliage is killed. Lesions on the stems are similar to those on leaves, sometimes girdling the plant if they occur near the soil line. Transplants showing infection by the late blight fungus often die when set in the field. The fungus also infects the fruit, generally through the calyx or stem attachment. Lesions attain considerable size, usually involving nearly the entire fruit; concentric rings are also present on the fruit.
Control: Removal and destruction of the affected plant parts. Practicing crop rotation helps to minimize the disease incidence. Spraying the crop with Difolatan (0.2%), Dithane M-45 (0.2%) or Bavistin (0.1%) is recommended for effective disease control.

Buck Eye Rot (*Phytophthora parasitica*):

Fruit rot or buckeye rot is a serious disease in all the tomato growing areas. The disease causing the fruits to rot initially affects the fruits near the ground level. The pathogen does not affect the foliage and thus the disease is distinct from late blight. The disease appears as a greyish green or brown water soaked spot that usually occurs where the fruit touches the soil. As the spot enlarges, the surface of lesion assumes a pattern of concentric rings of narrow, dark brown and wide, light brown bands. When young green fruits are infected, they usually become mummified.
Control: In order to minimize infection, good drainage conditions should be maintained in the field. Staking plants and removing foliage and fruits upto a height 15-30 cm from ground level helps to control this disease. Spraying with Difolaton (0.3%) 4 times at an interval of 10 days effectively controls the disease.

Late Blight *(Phtophthora infestans):*

Late blight occurs when humid conditions coincide with mild temperatures for prolonged periods. If conditions are ideal for disease development, disease development is rapid causing severe economic losses. Lesions produced on the leaves are at first irregular, rather large, greenish-black and water-soaked. These areas enlarge rapidly, becoming brown, and under humid conditions, develop a white moldy growth near the margins of the diseased area on the lower surface of the leaves or on stems. The disease spreads rapidly under humid conditions, destroying quickly large areas of tissue. Lesions produced on the leaves are at first irregular, rather large, greenish-black and water-soaked. These areas enlarge rapidly, becoming brown, and under humid conditions, develop a white moldy growth near the margins of the diseased area on the lower surface of the leaves or on stems. The disease spreads rapidly under humid conditions, destroying quickly large areas of tissue.

Fruit lesions occur as large, green to dark brown lesions, mostly on the upper half of the fruit, but they may also occur on other parts. White moldy growth may also appear on fruits under humid conditions. The disease attacks the fruits a well as the leaves of the plant. Symptoms on the fruits usually begin on the shoulders of the fruit because spores land on fruit from above.

Control: Control practices include rotating fields so as not to follow potato or tomato; avoiding planting tomatoes near potatoes; using disease-free seeds and transplants.

Adopting certain prophylactic measures can also control the disease. Firstly, the seed material should be obtained from a disease free area. Before planting the seeds should be treated with Thiram (2-3 g/kg of seed). The plants must be sprayed with Captafol (2 g/litre of water) or Dithane M 45 (2 g/kg of seed) at 15 days interval, starting from 30 days after transplanting.

Fusarium Wilt (*Fusarium oxysporum f. sp. lycopersici*):

This is one of the worst diseases of tomato occurring mostly in the nurseries. The first symptoms of the disease are clearing of the veinlets and chlorosis of the leaves. The younger leaves may die in succession and the entire may wilt and die in a course of few days. Soon the petiole and the leaves droop and wilt. In young plants, symptom consists of clearing of veinlet and dropping of petioles. In field, yellowing of the lower leaves first and affected leaflets wilt and die. The symptoms continue in subsequent leaves. At later stage, browning of vascular system occurs. Plants become stunted and die.

Control: The nursery should be regularly inspected for wilt infected plants. The affected plants should be removed and destroyed. Prior to planting the beds should be drenched with Carbendazim (0.1%) and the seeds should be treated with the Thiram (2.5 kg/ha). Crop rotation with a non-host crop such as cereals helps to reduce the disease inoculum.

Septoria Leaf Spot *(Septoria lycopersici):*

The plant may be attacked at any stage of its growth. The disease is characterized by numerous, small, grey, circular leaf spots having dark border.

Control: Removal and destruction of the affected plant parts. Seed treatment with Thiram or Dithane M-45 (2 g/kg seed) is useful in checking seed borne infection. In the field spraying with Dithane Z-78 (0.2%) effectively controls the disease.

Powdery Mildew *(Leveillula taurica):*

The disease occurs severely during dry seasons. A white powdery coating of the fungal growth appears on the leaf surface. Infected leaves may be dwarfed, stiff, and narrow. The fungus progressively attacks new leaves, spreading over leaf stems, twigs, and even the fruit. Terminal growth of the affected shoot is stunted or killed. The fruit yield is reduced and the affected fruit are smaller in size.

Control: Spraying with Karathane (0.1%) or Wettable Sulphur (3 g/ litre of water) twice at an interval of 10 days helps to control the disease.

Bacterial Wilt *(Pseudomonas solanacearum):*

This is one of the most serious diseases of tomato crop. Relatively high soil moisture and soil temperature favour disease development. Characteristic symptoms of bacterial wilt are the rapid and complete wilting of normal grown up plants. Lower leaves may drop before wilting. Pathogen is mostly confined to vascular region; in advantage cases, it may invade the cortex and pith and cause yellow-brown discolouration of tissues. Infected plant parts when cut and immersed in clear water, a white streak of bacterial ooze is seen coming out from cut ends.

Control: Crop rotations, viz., cowpea-maize-cabbage, okra-cowpea-maize, maize- cowpea-maize and finger millet-egg plant are reported effective in reducing bacterial wilt of tomato.

Control: Seedling treatment with Streptocycline (1 g/40 litres of water) for 30 min protects the seedlings in the initial stages of growth.

Bacterial Leaf Spot (*Xanthomonas campestris pv. vesicatoria):*

Moist weather and splattering rains are conducive to disease development. Most outbreaks of the disease can be traced back to heavy rainstorms that occur in the area. Infected leaves show small, brown, water soaked, circular spots surrounded with yellowish halo. On older plants the leaflet infection is mostly on older leaves and may cause serious defoliation. The most striking symptoms are on the green fruit. Small, water-soaked spots first appear which later become raised and enlarge until they are one-eighth to one-fourth inch in diameter. Centers of these lesions become irregular, light brown and slightly sunken with a rough, scabby surface. Ripe fruits are not susceptible to the disease. Surface of the seed becomes contaminated with the bacteria, remaining on the seed surface for some time. The organism survives in alternatehosts, on volunteer tomato plants and on infected plant debris.

Control: Bacterial spot is difficult to control once it appears inthe field. Disease-free seed and seedlings should always be used and the crop should be rotated with non-host crops so as to avoid last years crop residue. Seed treatment with mercuric chloride (1:1000) is also recommended for control of disease. Spraying with a combination of copper and organic fungicides in a regular preventative spray program at 5 to 10 day intervals or Spraying with Agrimycin-100 (100 ppm) thrice at 10 days intervals effectively controls the disease.

Bacterial Canker *(Clavibacter michiganensis pv. michiganensis):*

Temporary and later on permanent wilting of leaflets of affected plants is observed the disease in the field. Light streaks appear at the juncture of petiole and stem extending down the internode and up the petiole. At a later stage canker like opening may appear in stem, petiole and midrib. When the stem of diseased plants is cut longitudinally, a creamy white, yellow or brown line follows the phloem. The disease appears on the green fruit as water soaked spots with a white halo. Halo is the distinguishing character of bacterial leaf spot of tomato.

Control: Hot water treatment of seeds at 50°C for 25 minutes is effective. Seed treatment with mercuric chloride (1:1000) is also recommended for control of disease. Crop rotation with non-host crop helps in reducing the disease incidence. Soaking of seed in solution of Streptocycline (1g/40 litres of water) for 30 min protects the seedlings in the initial stages of growth.

Tomato Mosaic Virus *(TMV)*

The disease is characterized by light and day green mottling on the leaves often accompanied by wilting of young leaves in sunny days when plants first become infected. The leaflets of affected leaves are usually distorted, puckered and smaller than normal. Sometimes the leaflets become indented resulting in "fern leaf" symptoms. The affected plant appears stunted, pale green and spindly. The virus is spread by contact with clothes, hand of working labour, touching of infected plants with healthy ones, plant debris and implements.

Control: Seeds from disease free healthy plants should be selected for sowing. Soaking of the seeds in a solution of Trisodium Phosphate (90 g/litre of water) a day before sowing helps to reduce the disease incidence. The seeds should be thoroughly rinsed and dried in shade. In the nursery all the infected plants should be removed carefully and destroyed. Seedlings with infected with the viral disease should not be used for transplanting. Crop rotation with crops other than tobacco, potato, chilli, capsicum, brinjal, etc. should be undertaken.

Tomato Leaf Curl Virus *(TLCV):*

This disease is transmitted by whitefly (*Bemisia tabaci*). It is one of the most devastating diseases of tomato. Leaf curl disease is characterized by severe stunting of the plants with downward rolling and crinkling of the leaves. The newly emerging leaves exhibit slight yellow colouration and later they also show curling symptoms. Older leaves become leathery and brittle. The nodes and internodes are significantly reduced in size. The infected plants look pale and produce more lateral branches giving a bushy appearance. The infected plants remain stunted.

Control: The affected plants should be removed and destroyed. Alternate or collateral hosts harboring the virus causing this disease is removed at the time of weeding or earthing up operations to minimize the spread of the disease. Checking the white fly population can reduce the disease incidence. Soil application of granular insecticide like Furadan (1 kg a.i./ha) at the time of sowing seeds in the nursery bed checks whitefly population. Another dose of Furadan (1.5 kg a.i./ha) is given one week after transplanting. 2-3 foliar sprays with Dimethoate (0.05%) or Monocrotophos (0.05%) at 10 days intervals controls the white fly population.

The disease spread can be minimized by cultural practices like use of border or barrier cropping. Barrier crops like maize, jowar, bajra are good to protect the crop from TLCV infection. Five or six rows of these crops all around the main tomato plot should be sown at least 50-60 days before transplanting of tomato. These crops check incoming viruliferous whiteflies from entering into tomato crop.

TLCV incidence can be reduced drastically by the use of polythene mulching in the soil just before transplanting of tomato. Polythene sheets of white, blue, grey and black colours are effective. Combined application of polythene mulching and Furadan application in the soil is recommended.

Tomato Spotted Wilt Virus *(TSWV):*

The spotted wilt virus is transmitted through thrips (*Thrips tabaci*, *Frankliniella schultzi* and *F. occidentalis*). This disease is similar to streak in that it causes streaking of the leaves, stems and fruits. Numerous small, dark, circular spots appear on younger leaves. Leaves may have a bronzed appearance and later turn dark brown and wither. Fruits show numerous spots about one-half inch in diameter withconcentric, circular markings. On ripe fruit, these markings are alternate bands of red and yellow.

Control: The affected plants should be removed and destroyed. Alternate or collateral hosts harboring the virus causing this disease is removed at the time of weeding or earthing up operations to minimize the spread of the disease. Checking the population of thrips can reduce the disease incidence. 2-3 foliar sprays with Dimethoate (0.05%) or Monocrotophos (0.05%) at 10 days intervals controls the thrips population.

Tomato Bunch Top Virus *(TBTV):*

The infected plants show extensive abnormal growth with apical proliferation. The new leaves arising from the axillary buds give closely crowded bunchy appearance. The leaflet margins curl towards the tips and the surface show puckered conditions. Necrosis of leaves and stems are also characteristic symptoms. The diseased plants bear very few flowers and 1-2 very small fruit.

Control: The affected plants should be removed and destroyed. Alternate or collateral hosts harboring the virus causing this disease is removed at the time of weeding or earthing up operations to minimize the spread of the disease.

Tomato Big Bud *(TBB):*

The disease infects all the plant parts. The big bud of tomato is transmitted by leaf hopper (*Orosius argenatatus*). The first indication of infection appears at the tips of the actively growing shoots. The youngest fruit truss, instead of becoming recurved as in normal plants, assumes an upright position. The buds on the truss also point in a vertical direction, the calyx segments remain united almost to the tips, and the whole calyx enlarges to a form like a bladder with a toothed opening at the top. On pruned plants in the field, the growing points fail to develop normally.

After a short time, the axillary buds grow out, forming shoots affected in the same way as the main shoot. Simultaneously, there is a gradual thickening of the stems of the affected parts due to the formation of an abnormal tissue, In cases where the growth of the terminal buds completely ceases, the thickening of the stems may become very marked.

The disease appears initially on young developing. The affected leaves become yellow-green and roll along their margins. The size of the leaves reduces as the disease advances.

Fruit that is well developed but still green at the time of infection becomes hard and tough and colours extremely slowly or not at all.

Control: Removal and destruction of the affected plant parts is the only control measure.

Anthracnose *(Colletotrichum phomoides):*

At first, infected fruit show small, slightly sunken, water soaked spots. These spots enlarge, become darker in color, depressed and have concentric rings. Masses of the pink fruiting fungus can be seen on the surface of the lesions in moist weather. Under warm and humid conditions, the fungus penetrates the fruit, completely destroying it. The fungus persists on infected plant refuse in the soil. Fruit may be infected when green and small, but do not show any marked lesions until they begin to ripen. Fruit becomes more susceptible as they approach maturity.

Control: Control of this disease involves the use of well-drained soil, crop rotation and a preventative fungicide program is recommended.

9. DISEASE MANAGEMENT IN COTTON

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In 2023, cotton diseases led to an approximate yield loss of 13% in North Carolina. Diseases are more severe in inhospitable environments, such as fields with too much or too little water or fertilizer; air pollutants; unfavorable temperatures; insect infestations; or chemical injury from pesticide applications or carryover. Management of diseases in cotton should focus on prevention through cultural practices that promote good soil conditions and inoculum suppression.

SEED AND SEEDLING DISEASES

Seedling diseases are among the major diseases in North Carolina, causing an estimated average annual yield loss of 2.5%. Seedling diseases are caused by several soilborne fungi; however, cultural and environmental factors that delay seed germination and seedling growth lead to more severe disease.

Fungi Causing Seedling Diseases

The most prevalent of these in North Carolina are *Fusarium* spp, *Phoma exigua (Ascochyta)*, *Pythium* spp., and *Rhizoctonia solani*. Among these, *Pythium* spp. and *R. solani* are the most common fungi associated with seedling diseases. These fungican infect seeds before or at germination, and seedlings before or after emergence. Multiple fungi can be found infecting the same seeds and seedlings.

Symptoms of seedling diseases include seed decay, necrosis of the new root or hypocotyl, decay of the seedling before emergence, and partial or complete girdling of emerged seedling stems. Seed and seedling diseases are characterized by soft, watery rots. Damaged seedlings that emerge are pale, stunted, slower growing, and may die within a few days. Examination of infected seedlings may reveal dark lesions on the stem and root. The taproot is often destroyed, and only shallow-growing lateral roots remain to support the plant. The "sore shin" phase of seedling disease is characterized by reddish-brown, sunken lesions at or below ground level. These lesions enlarge, girdle the stem, and cause it to shrivel. Seedling diseases do not usually kill the entire seedling population, but may result in uneven, slow-growing stands with skips in the rows. In some years, replanting is necessary. Poor stand establishment causes problems with the management of other pests and may reduce yields.

The most common fungi associated with seedling diseases in North Carolina are *Pythium* spp. and *Rhizoctonia solani*. Often both fungi can be found on the same seedling. The fungi may cause seed decay, seedling root rot, or both. *Pythium* spp. and *Fusarium* spp. usually attack the seed and below-ground parts of young seedlings, while *R. solani* usually causes sore shin. *Rhizoctonia solani* and *P. exigua* may attack seedlings from the time they emerge until they are about 6 inches tall. After this stage, the stem becomes woody, and subsequent infection rarely occurs unless the stem is injured.

***Fusarium* spp.** Various species of the fungal genus *Fusarium* are typically found on diseased cotton seedlings. *Fusarium* spp. usually attack the seed and below-ground parts of young seedlings. Seed-applied fungicides are generally effective in managing it.

Phoma exigua (Ascochyta gossypii). This fungus can cause post-emergence damping-off up until cotton plants are 6 inches tall. This disease is characterized by premature dying of cotyledons, which turn brown and shrivel. *P. exigua* is often observed when night temperatures fall between 50°F to 60°F and are accompanied by foggy or misty conditions (see also Plant Pathology Cotton Information Note No. 2). Fungicide effectiveness against *P. exigua* has not been evaluated.

Pythium spp. Several species in the genus *Pythium* can cause seedling disease in cotton as well as several other crops. Like *Fusarium*, *Pythium* spp. usually attack the seed and below-ground parts of young seedlings *Pythium* spp. are classified as water molds, producing spores that move actively in soil water. In general, *Pythium* is commonly the culprit if the soil has remained saturated for several days or is poorly drained. Fungicides such as mefenoxam (Ridomil Gold) or etridiazole (ETMT, Terrazol) are usually effective in reducing *Pythium* spp. seedling disease.

Rhizoctonia solani. This fungus typically causes sore shin and is more common on sandy, well-drained soils. Like Phoma, Rhizoctonia may attack seedlings from the time they emerge until they are about 6 inches tall. Plants injured by sand blasting are particularly susceptible to this pathogen. Fungicides such as PCNB (Terrachlor), iprodione (Rovral), azoxystrobin (Quadris), or pyraclostrobin (Headline) are generally effective against *Rhizoctonia solani*.

Boll Rot. Boll rot is generally the most prevalent problem in North Carolina cotton, and occurs when excessive insect damage or excessively wet conditions exist. Boll rot typically starts with small brown lesions that expand until the entire boll becomes blackened and dry. Chapter 11, “Managing Insects on Cotton,” and chapter 2, “The Cotton Plant,” explain how to reduce insect damage and lower humidity in the canopy by preventing rank growth to reduce boll rot problems.

Foliar Diseases: Leaf Spots. Leaf-spot diseases are typically of minor importance, appearing when plants are under nutritional stress or periods of high moisture. Leaf spots may be minimized by using the proper amounts of fertilizer and adequate drainage, and by reducing rank vine growth, which can promote excessively high humidity in the crop canopy. Several pathogens cause leaf spots on cotton, including Ascochyta blight (*Phoma exigua*), Alternaria leaf spot (*Alternaria* spp.), Cercospora leaf spot (*Cercospora* spp.), Stemphylium leaf spot (*Stemphylium solani*), and Target spot (*Corynespora cassiicola*). Cotton leaves often develop small, brown, circular lesions that enlarge to approximately 1/2 inch. Old lesions can develop gray centers which may fall out. Sometimes lesions are not a disease, but rather phytotoxicity symptoms caused by a variety of crop protection chemicals. Differentiating between causal agents of leaf spots is difficult, and often requires the aid of the North Carolina State University Plant Disease and Insect Clinic. Leaf-spot diseases are typically of minor importance, appearing when plants are under nutritional stress or periods of high moisture.

Emerging Foliar Diseases. Since 2018, damages from areolate mildew (also known as false mildew) caused by *Ramularia gossypii* have been observed in North Carolina. Since 2012, target spot caused by *Corynespora cassicola* has also become more common in North Carolina cotton fields. In the last few years, both diseases have led to increasing yield losses in the state. Frequent scouting and disease reporting is important to monitor foliar disease development in the field.

Bacterial Blight. Bacterial blight, also known as angular leaf spot, is caused by the bacterium *Xanthomonas compestris* pv. *malvacearum*. Bacterial blight initially appears as angular leaf spots with a red or brown border, and spots may spread along the major leaf veins. Premature defoliation may occur and bolls may become infected, causing a boll rot that results in discolored lint and rotted seed. This disease is promoted by high amounts of rainfall and humidity in conjunction with warm temperatures. There are no corrective measures to reduce disease after a field is infested. Planting high-quality, acid-delinted seed, planting bacterial-blight-resistant varieties (where available), proper plant spacing to reduce humidity in the canopy, applications of plant growth regulators to prevent rank growth, and destruction of crop debris after harvest will reduce incidence of bacterial blight under conducive environmental conditions for disease development.

Cotton Stem Canker. Cotton stem canker is caused by the fungus *Phoma exigua* (often referred to as *Ascochyta*). This disease typically develops in cool, wet weather. Management options for this disease are limited; rotation has little impact on this disease due to the wide host-range, including other field crops and weed species present in North Carolina. Fungicides currently labeled for foliar application on cotton in the Southeast may not provide adequate control of this disease.

SEEDLING AND FOLIAR DISEASE MANAGEMENT

A control program for cotton diseases is based on preventive rather than remedial treatments. A combination of cultural practices and chemical controls is required for cotton disease management to make conditions more favorable for young cotton and less favorable for disease-causing organisms. Poor-quality seed with low germination potential should be avoided. Cotton plants are less susceptible to seed and seedling disease when they are about 6 inches tall. After this stage, the stem becomes woody, and subsequent infection rarely occurs unless the stem is injured. For additional information on seedling diseases, see content.ces.ncsu.edu/cotton-seedling-diseases. Even after disease management strategies are practiced, foliar diseases may occur during the blooming period when environmental conditions are favorable for disease. Foliar fungicides may be used in these cases; for available treatments, see the *North Carolina Agricultural Chemical Manual* (content.ces.ncsu.edu/north-carolina-agricultural-chemicals-manual).

Crop Debris Destruction and Tillage. Despite soil property benefits, the recent trend to low- or no-till cotton has resulted in an increased frequency and severity of seedling diseases. The inoculum of pathogens from previous crops overwinters in crop debris, and reduced tillage preserves the debris adjacent to emerging seedlings whereby pathogens have little distance to infest susceptible tissues. The lack of a raised bed, inadequate seed bed preparation, and additional crop residue associated with reduced tillage, all contribute to delays in emergence and stand establishment. Early cutting and shredding of stalks aid in the control of several cotton diseases by reducing the amount of inoculum that carries over from year to year. The use of an in-furrow fungicide or seed treatment should be considered in reduced-tillage situations.

Rotation. Rotating cotton with other non-host crops helps prevent buildup of several seedling and leaf spot cotton diseases. The longer a rotation, the more effective it is at reducing disease; however, even a rotation of at least 2 years is more beneficial than continuous cropping.

Plant Health Promotion. It is important to prepare a good seedbed to control seedling diseases. Raised beds give some control of seedling disease, especially in cotton planted early, by improving soil drainage. Avoid planting when soil temperatures are below 65°F. Below this temperature, germination is slow, and the seed and seedlings are more vulnerable to infection. Proper fertilization and liming promote early growth, which gets the seedling to a resistant stage sooner. Avoid improper use of herbicides, as this may lead to injury that will expose seedling to fungal infections.

Seed Treatment. All cotton seeds offered for sale in North Carolina are base-treated with fungicides and insecticides. Systemic fungicides provide temporary protection from certain types of preemergence and postemergence damping-off. In most years, seed treatment fungicides are sufficient for controlling seedling disease, unless the quality of the seed is low or weather conditions are unfavorable for germination.

Several seed treatments are available for cotton nematode control. These products often work best on low populations of soil nematodes, and determining the level of nematode pressure in a given field is important for selecting the proper seed treatment. Chemicals available include Avicta Complete Cotton from Syngenta, which also has the insecticide Cruiser for thrips control and additional fungicide treatments on the seed, and Aeris with Poncho, Votivo, or Trilex Advanced, which has an option to add Gaucho Grande for thrips control and additional fungicides if desired by the producer. Avicta complete pack has abamectin (a nematicide), and Aeris has thiodicarb (Larvin), which acts as a nematicide. Acceleron is another brand offered by Bayer that can provide some control of diseases, thrips, and nematodes, depending on the version requested. A plethora of chemistries are also offered through downstream seed-treaters.

In-furrow Fungicides. Seedling diseases are more likely to occur when planting and environmental conditions are favorable for disease. Seedling diseases tend to be more severe under cool, wet conditions, in reduced-tillage situations, compacted soil, and when beds are absent. Assess the risk of disease development based on the factors occurring in a field and consider an in-furrow treatment when the threshold (200 points) is exceeded (Table 9-1A).

Table 9-1A. Point System for Determining the Need for In-Furrow Fungicides*

Factor	When Does It Matter	Points*
Soil temperature	Less than 65°F	75
5-day forecast	Colder and wetter	50
Seed quality	Cold germination less than 59°F	75
Field history	Severe disease	100
Tillage	Minimum tillage	50
Row preparation	Beds absent	75
Seeding rate	Less than 3 to 4 per ft of row	100
Poorly drained soil	Consistently saturated	50
TOTAL		—

If the total exceeds 200, consider using an in-furrow fungicide.
* This point system is only a guide as to the probability of cotton seed benefitting from an application of an in-furrow fungicide.

Foliar Fungicides. Foliar fungicides may be beneficial for controlling foliar diseases such as target spot or areolate mildew (Table 9-1B) when disease management strategies are not fully practiced, disease pressure is high, and environmental conditions are favorable for disease (excessive warm, wet conditions). Start scouting for foliar diseases in the first week of bloom by checking the lower canopy of at least 10 cotton plants in 10 different locations in a field. If symptoms are not seen, scout again within 2 weeks. If excessive foliar disease symptoms are observed and extensive wet conditions are predicted, a foliar fungicide may be used. If not scouting, a fungicide spray may be optimal during the third week of bloom. For fields that are beyond the sixth week of bloom—full cutout with fairly mature bolls and within about four weeks from defoliation—a fungicide application may not be warranted.

Fungicides must be used carefully to protect against human injury and harm to the environment. When possible, use different modes of action (FRAC) when repeated applications of pesticides are necessary for controlling disease. Follow label-use directions, and obey all federal, state, and local pesticide laws and regulations.

Table 9-1B. Condensed List of Foliar Fungicides for Target Spot and Areolate Mildew

FRAC	Fungicide	Active Ingredient	Rate
11	Quadris	Azoxystrobin	7 fl oz/a
11	Headlinea	Pyraclostrobin	6 fl oz/a
3	Topguard	Flutriafol	14 fl oz/a
3	Proline	Prothioconazole	5 fl oz/a
7,11	Priaxor	Fluxypyroxad & Pyraclostrobin	4 fl oz/a
Row preparation	Beds absent		75
Seeding rate	Less than 3 to 4 per ft of row		100
Poorly drained soil	Consistently saturated		50

For more information, contact your local Cooperative Extension agent.

Table 9-3. Variety Resistances for Common Diseases of Cotton

Variety	Root-Knot Nematode	Fusarium Wilt	Verticillium Wilt	Bacterial Blight
ST 5020GLTP	MR [1]	MR	MR	R
ST 49494GLT	MR	MR	MR	S
ST 5115GLT	MR	MR	MR	R
ST 4946GLB2	R	R	MR	S
ST 6448GLB2	MR	MR	MR	R
NG 4601 B2XF	MR	MR	MR	S
NG 3406 B2XF	R	R	MR	S
NG 3522 B2XF	N/A	N/A	MR	S
NG 1511 B2RF	R	R	MR	S
AM UA48	R	R	R	R
DP 1725 B2XF	N/A	R	S	S
DP 1747NR B2XF	R	MR	N/A	S
DP 1646 B2XF	N/A	MR	MR	MR
DP 1558NR B2RF	R	S	R	S
DP 1522 B2XF	N/A	MR	MR	S
DP 1252 B2RF	N/A	S	MR	S
DP 1050 B2RF	N/A	MR	MR	S
3109 B2XF	N/A	N/A	MR	N/A
3445 B2XF	N/A	N/A	HT	HT
3544 B2XF	N/A	N/A	HT	HT
3635 B2XF	N/A	HT	N/A	N/A
3226 B2XF	N/A	N/A	LT	S
PHY 220 W3FE	N/A	N/A	HT	N/A
PHY 427 WRF	R	N/A	N/A	N/A
PHY 490 W3FE	N/A	N/A	N/A	R
PHY 575 WRF	N/A	N/A	N/A	R
PHY 805 RF	N/A	MT	N/A	N/A
PHY 811 RF	N/A	HT	N/A	N/A
PHY 841 RF	N/A	HT	N/A	N/A

[1] Resistance level of a variety to a given disease denoted by R = resistant, MR = moderately resistant, S = susceptible, HT = high tolerance, MT = moderate tolerance, LT = low tolerance, or N/A = resistance information not available.