सत्यमेव जयते

AESA BASED IPM PACKAGE

AESA BASED IPM - Sorghum

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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 and pesticide residues. There is a growing awareness world over on the need for promoting environmentally sustainable agriculture practices.

Integrated Pest Management (IPM) is a globally accepted strategy for promoting sustainable agriculture. During last century, IPM relied substantially on economic threshold level and chemical pesticides driven approaches. However, since the late 1990s there is conscious shift to more ecologically sustainable Agro-Eco System Analysis (AESA) based IPM strategies. The AESA based IPM focuses 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 of pests 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 ecologically 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 the AESA based IPM packages will be relied upon by various stakeholders relating to Central and State government functionaries involved in extension and Scientists of SAUs and ICAR institutions in their endeavour to promote environmentally sustainable agriculture practices.

A Srivastava

Date: 6.3.2014

(Avinash K. Srivastava)

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FOREWORD

IPM is a holistic approach of crop protection based on the integration of multiple strategies viz., cultural, physical, mechanical, biological, botanicals and chemical. Over the years IPM underwent several changes, shifting its focus from damage boundary, economic injury to economic threshold. Currently most stake holders rely upon economic threshold levels (ETL) and tend to apply chemical pesticides at the first instance in the event of a pest attack, though Government of India has advocated need based and judicious application of chemicals. This approach is likely to cause adverse effects on agro-ecosystems and increase the cost of agricultural production due to problems of pest resurgence, insecticide resistance and sustainability.

During the late 90s FAO started advocating Agro-Ecosystem Analysis (AESA) based IPM. Experience in different countries have since shown that AESA, which takes into account ecological principles and relies on the balance that is maintained by biotic factors in an ecosystem has also resulted in reduction in cost of production and increase in yields. AESA based IPM also takes into account the need for active participation of farmers and promotes experiential learning and discovery based decision making by farmers. AESA based IPM in conjunction with ecological engineering for pest management promotes bio-intensive strategies as against current chemical intensive approaches, while retaining the option to apply chemical pesticides judiciously as a measure of last resort.

The resource persons of NIPHM and DPPQ&S have made sincere efforts in revising IPM packages for different crops by incorporating agro-ecosystem analysis, ecological engineering, pesticide application techniques and other IPM options with the active cooperation of crop based plant protection scientists working in State Agricultural Universities and ICAR institutions. I hope this IPM package will serve as a ready reference for extension functionaries of Central/ State Governments, NGOs and progressive farmers in adopting sustainable plant protection strategies by minimizing the dependence on chemical pesticides.

(Utpal Kumar Singh)

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PREFACE

Need for environmentally sustainable agricultural practices is recognised worldwide in view of the wide spread ecological imbalances caused by highly intensive agricultural systems. In order to address the adverse impacts of chemical pesticides on agro-ecosystems, Integrated Pest Management has evolved further from ETL based approach to Agro-ecosystem Analysis based Integrated Pest Management (IPM).

In AESA based IPM the whole agro-ecosystem, plant health at different stages, built-in-compensation abilities of the plant, pest and defender population dynamics, soil conditions, climatic factors and farmers' past experience are considered. In AESA, informed decisions are taken by farmers after field observation, AESA chart preparation followed by group discussion and decision making. Insect zoo is created to enable the farmer understand predation of pests by Natural Enemies. AESA based PHM also results in reduction of chemical pesticide usage and conserves the agro-ecosystems.

Ecological Engineering for Pest Management, a new paradigm, is gaining acceptance as a strategy for promoting Biointensive Integrated Pest Management. Ecological Engineering for Pest Management relies on cultural practices to effect habitat manipulation and enhance biological control. The strategies focus on pest management both below ground and above ground. There is a growing need to integrate AESA based IPM and principles of ecological engineering for pest management.

There is a rising public concern about the potential adverse effects of chemical pesticides on the human health, environment and biodiversity. The intensity of these negative externalities, though cannot be eliminated altogether, can be minimized through development, dissemination and promotion of sustainable biointensive approaches.

Directorate of Plant Protection Quarantine and Storage (DPPQS), has developed IPM package of practices during 2001 and 2002. These packages are currently providing guidance to the Extension Officers in transferring IPM strategies to farmers. These IPM package of practices, have been revised incorporating the principles of AESA based IPM in detail and also the concept of Ecological Engineering for Pest Management. It is hoped that the suggested practices, which aim at enhancing biodiversity, biointensive strategies for pest management and promotion of plant health, will enable the farmers to take informed decisions based on experiential learning and it will also result in use of chemical pesticides only as a last resort & in a safe and judicious manner.

(K. SATYAGOPAL)

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AESA BASED IPM PACKAGE FOR SORGHUM

Sorghum plant description:

Sorghum is a genus of grasses with about 30 species, one of which is raised for grain and many of which are used as fodder plants, either cultivated or as part of pasture. The plants are cultivated in warm climates worldwide. They are native to the tropics and subtropics of the Old World and one species is endemic to Mexico; a number have been introduced into other parts of the world. Sorghum is in the subfamily Panicoideae and the tribe of Andropogoneae (the tribe of big bluestem and sugar cane).

One species, *Sorghum bicolor*, native to Africa with many cultivated forms now, is an important crop worldwide, used for food (as grain and in sorghum syrup or "sorghum molasses"), fodder, the production of alcoholic beverages, and biofuels. Most varieties are drought- and heat-tolerant, and are especially important in arid regions, where the grain is one of the staples for poor and rural people. These varieties form important components of pastures in many tropical regions*. Sorghum bicolor* is an important food crop in Africa, Central America, and South Asia and is the "fifth most important cereal crop grown in the world".

Some species of sorghum can contain levels of hydrogen cyanide, hordenine and nitrates lethal to grazing animals in the early stages of the plant's growth. When stressed by drought or heat, plants can also contain toxic levels of cyanide and/or nitrates at later stages in growth.

Sorghum grain ranks 5th in cereals for global production. Sorghum is a genus with many species and subspecies, and there are several types of sorghum, including grain sorghums, grass sorghums (for pasture and hay), sweet sorghums (for syrups), and Broomcorn.

I. PESTS

A. Pests of National Significance

1. Insect pests

1.1 Shoot fly: *Atherigona soccata* (Rondani) (Diptera: Muscidae)
1.2 Stem Borer: *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae)
1.3 Midge: *Stenodiplosis sorghicola* (Coquillett) (Diptera: Cecidomyiidae)
1.4 White grub: *Holotrichia consanguinea* (Hope) (Coleoptera:Scarabaeidae)

2. Diseases

2.1 Grain mold: *Fusarium* sp.,*Phoma*sp. (Saccardo) *Curvularia* sp.
2.2 Charcoal rot: *Macrophomina phaseolina* (Tassi, Goid)

3. Weeds

3.1 Broad leaf

3.1.1 Cock'scomb: *Celosia argentea* L. (Amaranthaceae)
3.1.2 Common purselane: *Portulaca oleracea*L.(Portulacaceae)
3.1.3 False amaranth: *Digera arvensis* (Forssk) (Amaranthaceae)
3.1.4 Horsepurslane: *Trianthema portulacastrum* L. (Aizoaceae)
3.1.5 Pigweed: *Amaranthus* viridis (Hook. F.)(Amaranthaceae)
3.1.6 Swinecress: *Coronopus didymus* L. Sm. (Brassicaceae)
3.1.7 Black nightshade: *Solanum nigrum* L. (Solanaceae)
3.1.8 Sessilisjoywood: *Alternanthera sessilis* L DC (Amaranthaceae)
3.1.9 Punarnava: *Boerhavia diffusa* L. (Nyctagnaceae)
3.1.10 Tropical spiderwort: *Commelina benghalensis* L (Commelinaceae)
3.1.11 Whitetop Weed: *Parthenium hysterophorus* L (Asteraceae)
3.1.12 Bullhead: *Tribulus terrestris* L (Zygophyllaceae)
3.1.13 Coat button: *Tridax procumbens*L(Asteraceae)

3.2 Grasses

3.2.1 Rabbit/crow foot grass: *Dactyloctenium aegyptium* (Willd) (Poaceae)
3.2.2 Goosegrass: *Eleusine indica* L. (Gaertner) (Poaceae)
3.2.3 Barnyard grass: *Echinochloa crusgalli*L. (Scop) (Poaceae)
3.2.4 Crabgrass: *Digiteria sanguinalis* L. (Scop) (Poaceae)
3.2.5 Burmuda Grass: *Cynodon dactylon* (Poaceae)
3.2.6 Johnson grass: *Sorghum halepense* L Pers (Poaceae)
3.2.7Gamba grass: *Brachiaria ramose* L (Poaceae)
3.2.8 Finger grass: *Chloris barbata* Sw (Poaceae)

3.3 Sedges

3.3.1 Purplenutsedge: *Cyperus rotundus* L (Cypraceae)
3.3.2 Flat sedge: *Cyperus iria* L. (Cypraceae)

3.4. Parasitic weeds

3.4.1 Witchweed: *Striga asiatica* L. (Kuntze) (Orobanchaceae)

4. Nematode

4.1 Lesion Nematode: *Pratylenchus* spp. (Tylenchida: Pratylenchidae)
4.2 Cyst nematode: *Heterodorasorghii*

5. Vertebrates

5.1 Rodent: *Springhare* sp. (Rodentia)
5.2 Parrot: *Psittacines* sp. (Psittaciformes)
5.3 Crow: *Corvus* spp. (Passeriformes: Corvidae)

B. Pests of Regional Significance

1. Insect and mite Pests

1.1 Armyworm: *Mythimna separate* (Walker) (Lepidoptera: Noctuidae) Karnataka, Maharashtra
1.2 Cutworms: *Agrotisipsilon* (Ochsenheimer) (Lepidoptera: Noctuidae)
1.3 Grasshopper: *Hieroglyphus* sp (Krauss) (Orthoptera: Acrididae) Karnataka, Rajasthan, Tamil Nadu, Madhya Pradesh, Uttar Pradesh, Haryana, Delhi
1.4 Pyrilla: *Pyrilla perpurilla* (Linnaeus) (Hemiptera: Lophopidae) Maharashtra, Madhya Pradesh
1.5 Shoot bug: *Peregrinus maidis* (Ashmead) (Hemiptera: Delphacidae) Andhra Pradesh, Madhya Pradesh, Karnataka, South India, Tamil Nadu, Bihar, Maharashtra
1.6 Earhead caterpillars: *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) *Eublemma* spp,(Lepidoptera: Noctuidae) *Crytoblabes* spp. (Lepidoptera: Pyralidae) Gujarat, Andhra Pradesh, Tamil Nadu, Haryana, Madhya Pradesh, Delhi, Maharashtra
1.7 Earhead bug: *Calocoris angustatus* (Hemiptera: Miridae) Karnataka, Andhra Pradesh, Tamil Nadu, Uttar Pradesh
1.8 Sugar cane aphid: *Rhophalosiphum maidis* Koch (Hemiptera: Aphididae) Andhra Pradesh, Delhi, Gujarat, Maharashtra
1.9 Spider mite: *Oligonychus indicus* Hirst (Trombidiformes: Tetranychidae) Karnataka, Punjab, Maharashtra, Tamil Nadu

2. Diseases

2.1 Downy mildew: *Peronosclerospora sorghi* (Weston & Uppal, C.G. Shaw) Rajasthan, Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Haryana
2.2 Anthracnose: *Colletotrichum graminicola* (D.J. Politis)
2.3 Loose smut: *Sporisorium cruenta* (de Bary)
2.4 Ergot: *Claviceps sorghi* (B.G.P. Kulk)Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra
2.5 Grain smut: *Sporisorium sorghi* (Ehrenb ex. Link)
2.6 Red leaf spot : *Helminthosporium turcicum* Madhya Pradesh, Bihar, Maharashtra
2.7 Rust : *Puccinia purpurea* (Cooke) Karnataka, Madhya Pradesh, Tamil Nadu, Uttar Pradesh, Maharashtra, Andhra Pradesh, Bihar, Central Provinces

3.4.2

4.2

5.2

II. AGRO-ECOSYSTEM ANALYSIS (AESA) BASED INTEGRATED PEST MANAGEMENT (IPM)

A. AESA

The 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. The economic threshold level (ETL) was the basis for several decades but in modern IPM (FAO 2002) emphasis is given to 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. soil, rain, sunshine hours, wind etc.) 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.

Decision making in pest management requires a thorough analysis of the agro-ecosystem. Farmer has to learn how to monitor the crop, how to analyze the field situation and how to make proper decisions for their crop management. This process is called the AESA. Participants of AESA will have to make a drawing on a large piece of paper (60 x 80 cm), to include all their observations. The advantage of using a drawing is that it requires the participants/farmers to observe closely and intensively. It is a focal point for the analysis and for the discussions that follow, and the drawing can be kept as a record.

AESA is an approach, which can be gainfully employed by extension functionaries and farmers to analyze the field situations with regards to pests, defenders, soil conditions, plant health and the influence of climatic factors and their relationship for growing a healthy crop.The basic components of AESA are

- Plant health at different stages
- Built-in compensation abilities of plants
- Pest and defender population dynamics
- Soil conditions
- Climatic factors
- Farmers past experience

Principles of AESA based IPM:

Grow a healthy crop

- Select a variety resistant/tolerant to major pests
- Select healthy seeds/seedlings/planting material
- Treat the seed with recommended pesticides especially biopesticides
- Follow proper spacing
- Soil health improvement (mulching and green manuring wherever applicable)
- Nutrient management especially organic manures and biofertilizers based on the soil test results. If the dosage of nitrogenous fertilizers is too high the crop becomes too succulent and therefore susceptible to insects and diseases. If the dosage is too low, the crop growth is retarded. So, the farmers should apply an adequate for best results. The phosphatic fertilizers should not be applied each and every season as the residual phosphate of the previous season will be available for the current season also.
- Proper irrigation

- Crop rotation

Observe the field regularly (climatic factors, soil and biotic factors)

Farmers should

- Monitor the field situation at least once a week (soil, water, plants, pests, natural enemies, weather factors etc.)
- Make decisions based on the field situation and P: D ratio
- Take direct action when needed (e.g. collect egg masses, remove infested plants etc.)

Plant Compensation ability

Compensation is defined as the replacement of plant biomass lost to herbivores and has been associated with increased photosynthetic rates and mobilization of stored resources from source organs to sinks (e.g., from roots and remaining leaves to new leaves) during active vegetative growth period. Plant tolerance to herbivory can arise from the interaction of a variety of plant traits and external environmental factors.A set of 12 cytoplasmic male-sterile and maintainer lines, 12 restorer lines and their F1 hybridswere evaluated for resistance to sorghum shoot fly *Atherigona soccata* Rondani, spotted stem borer *Chilo partellus* (Swinhoe) and sugarcane aphid *Melanaphis sacchari* (Zehntner)under field conditions. There were significant differences among the genotypes tested. Atotal of 50% of male-sterile lines, 41.7% maintainers, 58.3% restorers and 35.4% of the hybrids tested showed moderate to high level of resistance to the three pests(H.C. Sharma *et al*, 2006).The studies were conducted for the inheritance of resistance to sorghum midge and compensation in grain weight and volume in panicles of sorghum hybrids and their parents under uniform infestation(H.C. Sharma *et al,*2002).The yields of individual stems of grain Sorghum in different categories of tillering and of injury by the stem borers *Busseola fusca* (Fuller) and *Chilo partellus* (Swinhoe) were obtained from nine plantings. In each of three seasons, tillering was stimulated by Insect damage, although the number of productive tillers did not differ significantly between insect-damaged and undamaged plants. Under sub-optimal climatic conditions the yield potential of undamaged plants decreased in relation to tillering potential, tillers being more adversely affected than main culms, and single stems being less affected than tillering plants. In damaged plants tillers and juvenile panicles contributed more to the total plant yield than in undamaged plant. Compensation of the

main culms for loss of tillers through 'dead heart' and *vice versa* was dependent on the number of tillers produced (J.B.J. Van Rensburg*et al*, 1991). The level of resistance to *Chilo partellus* was evaluated in 49 commercially available grain sorghum hybrids using artificial infestation in each of two field trials. The assessment of leaf feeding damage on a scale of one to nine indicated levels ranging from susceptibility to intermediate resistance. Hybrid performance in relation to reduction in peduncle length was inconsistent for all seasons. Pronounced differences in yield loss were observed between hybrids within each trial (9–67%) as well as in yields of the same hybrids for all seasons. This was described to tolerance to damage and the ability of the plant to compensate for damage by means of tiller formation (J. Van Den Berg*et al*, 1995). The relationship between percentage seed set on grain sorghum (*Sorghum bicolor*) panicles damaged by sorghum midge, *Contarinia sorghicola* (Coquillett), and percentage compensation (percentage increase in weight) of undamaged seed was examined in 11 experiments covering a wide range of environmental variation and incorporating various sorghum midge susceptible and resistant genotypes (B. A. Franzmann*et al*, 1993)

Understand and conserve defenders

- Know defenders/natural enemies to understand their role through regular observations of the agro-ecosystem
- Avoid the use of chemical pesticides especially with broad-spectrum activity

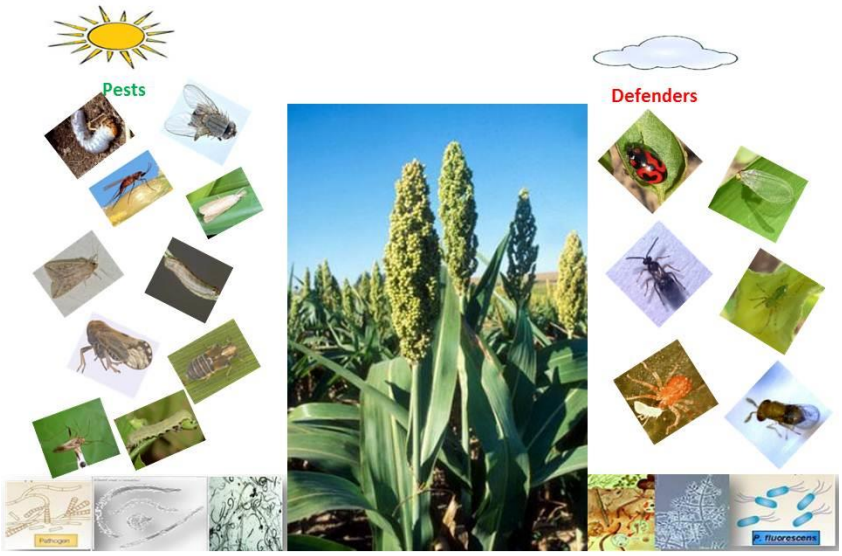
Insect zoo

In field various types of insects are present. Some are beneficial and some may be harmful. Generally farmers are not aware about it. Predators (friends of the farmers) which feed on pests are not easy to observe in crop field. Insect zoo concept can be helpful to enhance farmers' skill to identify beneficial and harmful insects. In this method, unfamiliar/unknown predators are collected in plastic containers with brush from the field and brought to a place for study. Each predator is placed inside a plastic bottle together with parts of the plant and some known insect pests. Insects in the bottle are observed for certain time and determined whether the test insect is a pest (feeds on plant) or a predator (feeds on other insects).

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 Sorghum pests can be divided into 3 categories 1. parasitoids; 2. predators; and 3. pathogens.

Model agro-ecosystem analysis chart

Date:
Village:
Farmer:



Decision taken based on the analysis of field situation

Soil conditions :
Weather conditions :
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.

Decision making

Farmers become experts in crop management

Farmers have to make timely decisions about the management of their crops. AESA farmers have learned to make these decisions based on observations and analysis viz. abiotic and biotic factors of the crop ecosystem. The past experience of the farmers should also be considered for decision making. However, as field conditions continue to change and new technologies become available, farmers need to continue improving their skills and knowledge.

- Farmers are capable of improving farming practices by experimentation
- Farmers can share their knowledge with other farmers

AESA methodology

- Go to the field in groups (about 5 farmers per group). Walk across the field and choose 20 plants/acre randomly. Observe keenly each of these plants and record your observations:

    - Plant: Observe the plant height, number of branches, crop stage, deficiency symptoms etc.
    - Pests: Observe and count pests at different places on the plant.
    - Defenders (natural enemies): Observe and count parasitoids and predators.
    - Diseases: Observe leaves and stems and identify any visible disease symptoms and severity.
    - Rats: Count number of plants affected by rats.
    - Weeds: Observe weeds in the field and their intensity.
    - Water: Observe the water situation of the field.
    - Weather: Observe the weather condition.

- 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).
- 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.

Data recording

Farmers should record data in a notebook and drawing on a chart

- Keeping records of what has happened help us making an analysis and draw conclusions

Data to be recorded

- **Plant growth (weekly):** Height of plant; Number of leaves
- **Crop situation (e.g. for AESA):** Plant health; Pests, diseases, weeds; Natural enemies; Soil condition; Irrigation; Weather conditions
- **Input costs:** Seeds; Fertilizer; Pesticides; Labour
- **Harvest:** Yield (Kg/acre); Price of produce (Rs./Kg)

Some questions that can be used during the discussion

- Summarize the present situation of the field?
- What crop management aspect is most important at this moment?
- Is there a big change in crop situation compared to last visit? What kind of change?
- Is there any serious pest or disease outbreak?
- What is the situation of the beneficial insects?
- Is there a balance in the field between pests and defenders?
- Were you able to identify all pests and diseases?
- Do you think the crop is healthy?
- What management practices are needed at this moment?
- When will it be done? Who will do it? Make sure that responsibilities for all activities are being discussed.
- Are you expecting any problems to emerge during the coming week such as congenial weather conditions for pest buildup?
- What problems? How can we avoid it? How can we be prepared?
- Summarize the actions to be taken.


Advantages of AESA over ETL

One of the problems of the ETL is that it is based on parameters that are changing all the time, and that are often not known. The damage or losses caused by a certain density of insects cannot be predicted at all. In ETL the due recognition of the role of natural enemies in decreasing pest population is ignored. Farmers cannot base their decisions on just a simple count of pests. They will have to consider many other aspects of the crop (crop ecology, growth stage, natural enemies, weather condition, etc.) and their own economic and social situation before they can make the right crop management decisions. In ETL based IPM, natural enemies, plant compensation ability and abiotic factors are not considered. In AESA based IPM emphasis is given to natural enemies, plant compensation ability, abiotic factors and P: D ratio.

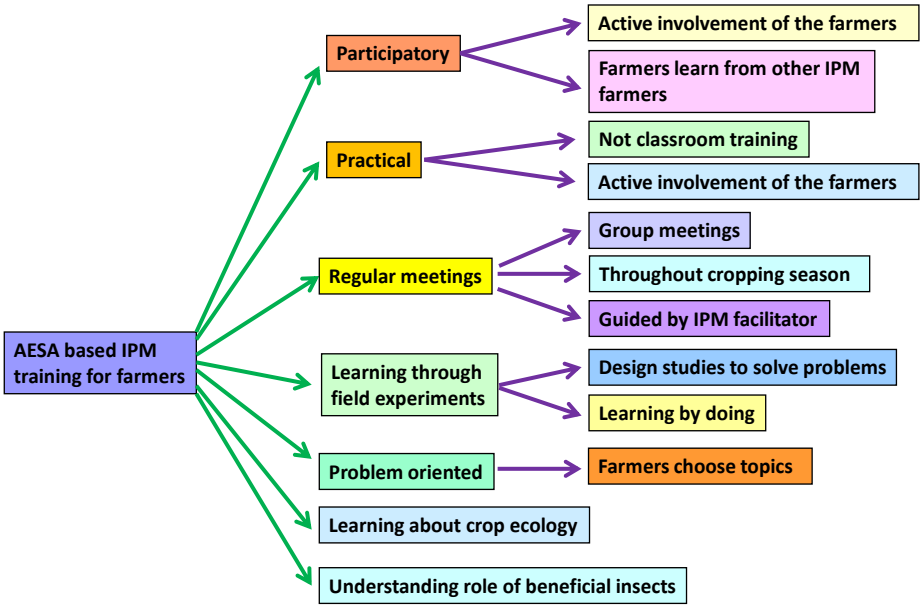
AESA and farmer field school (FFS)

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 learn 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



B. Field scouting

AESA requires skill. So only the trained farmers can undertake this exercise. However, other farmers also can do field scouting in their own fields at regular intervals to monitor the major pest situation.

Surveillance on pest occurrence in the field should commence soon after crop establishment and at weekly intervals thereafter. In each field, select five spots randomly. Select

five random plants at each spot for recording counts of insects as per procedure finalized for individual insects.

For insect pest

Shoot fly, stem borer and pink borer: Count and record the number of both larva and adults on five randomly selected leaves per plant count and record the no.of shoot fly and stemborer damages

Midge, shoot fly, shoot bug, plant lice, pyrilla and grasshopper: Count and record the number of nymphs and adults present per plant

Ear head bug: Count and record the number of nymphs and adults present in ear head on five plants.

White grub, army worm, cut worm: Count and record the number of grubs and adults present in ear head

Ear head caterpillar: count and record the number of larva present in five ear head.

For Diseases:

Whenever scouting, be aware that symptoms of plant disease problems may be caused by any biotic factors such as fungal, bacterial, viral pathogens or abiotic factors such as weather, fertilizers, nutrient deficiencies, pesticides and abiotic soil problems. In many cases, the cause of the symptom is not obvious. Close examination, and laboratory culture and analysis are required for proper diagnosis of the causal agent of disease. Generally fungal diseases cause the obvious symptoms with irregular growth, pattern & colour (except viruses), however abiotic problems cause regular, uniform symptoms. Pathogen presence (signs) on the symptoms can also be observed like fungal growth, bacterial ooze etc. Specific and characteristic symptoms of the important plant diseases are given in description of diseases section.

Root sampling

Always check plants that appear unhealthy. If there are no obvious symptoms on plants, examine plants randomly and look for lesions or rots on roots and stems. Observe the signs of the causal organism (fungal growth Or ooze). Always check plants that appear unhealthy. It is often necessary to wash the roots with water to examine them properly. If the roots are well developed, cut into them to examine the roots for internal infections (discolouration & signs). Count the total number of pseudostem damaged/infested/infected due to rotshould be counted and incidence should be recorded.

Leaf sampling

Examine all leaves on each plant for lesions and determine the amount area of leaf infection. Leaf diseases cause most damage during the seedling and flowering stages of plant growth. Observe for the symptoms and signs on the infected plant parts. Count thenumber of leaves (leaf area diameter)/plant infected due to disease and incidence should be recorded.

Stem and head sampling

Carefully examine the stems, heads and pods of plants for signs of fungal material diseases or lesions. The stems, pods and heads should be split or taken apart and examined for discoloration caused by fungi and bacteria. Count then number of plant, pod infected due to disease and incidence should be recorded.

C. Surveillance through pheromone traps: Use Pheromone traps for monitoring lepidopteron pests. Install pheromone traps at distance of 50 meter @ 4-5traps per acre for each insect pest. Use specific lure for each insect pest species and change it after every 20 days. Trapped moths should be removed daily.

D. Light traps

Set up light traps @ 1 trap/acre 15 cm above the crop canopy for monitoring and mass trapping insects. Light traps with exit option for natural enemies of smaller size should be installed and operate around the dusk time (6 pm to 10 pm).

E. Nematode extraction

Collect 100 to 300 cm^3 (200-300 g) representative 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 60 mesh sieve to collect cysts into first bucket; discard residue in second bucket. 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.

III. ECOLOGICAL ENGINEERING FOR PEST MANAGEMENT

Ecological engineering for pest management has recently emerged as a paradigm for considering pest management approaches that rely on the use of cultural techniques to effect habitat manipulation and to enhance biological control. The cultural practices are informed by ecological knowledge rather than on high technology approaches such as synthetic pesticides and genetically engineered crops (Gurr et al. 2004a, b).

Natural enemies may require

1. Food in the form of pollen and nectar for adult natural enemies.
2. Shelters such as overwintering sites, moderate microclimate, etc.
3. Alternate host when primary host are not present.

Ecological engineering for pest management – Above ground:

- Raise the flowering plants / compatible cash crops along the field border by arranging shorter plants towards main crop and taller plants towards the border to attract natural enemies as well as to avoid immigrating pest population
- Grow flowering plants on the internal bunds inside the field

- Not to uproot weed plants those are growing naturally like *Tridax procumbens, Ageratum* sp. *Alternanthera* sp. etc which act as nectar source for natural enemies,
- Not to apply broad spectrum chemical pesticides, when the P: D ratio is favourable. The plant compensation ability should also be considered before applying chemical pesticides.

Ecological engineering for pest management – Below ground:

- Crop rotations with leguminous plants which enhance nitrogen content.
- Keep soils covered year-round with living vegetation and/or crop residue.
- Add organic matter in the form of farm yard manure (FYM), vermicompost, crop residue which enhance below ground biodiversity.
- Reduce tillage intensity so that hibernating natural enemies can be saved.
- Apply balanced dose of nutrients using biofertilizers.
- Apply Mychorrhiza and plant growth promoting rhizobacteria (PGPR)
- Apply *Trichoderma viride/ harzianum* and *Pseudomonas fluorescens* as seeds/ seedlings/ planting material treatment and soil application (if commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).

Due to enhancement of biodiversity by the flowering plants, parasitoids and predators (natural enemies) number also will increase due to availability of nectar, pollen, fruits, insects, etc. The major predators are a wide variety of spiders, lady bird beetles, long horned grasshoppers, *Chrysoperla,* earwigs,etc

Ecological Engineering Plants

Attractant plants

Sunflower

Coriander

Carrot

Jatropha

Buckwheat

Chrysanthemum

Alfalfa

Mustard

Parsely

***Coreopsis* spp.**

Cosmos

Dandelion

Anise

Caraway

Dill

Marigold

Repellent plants

***Ocimum* sp**

Peppermint

Border plants

Maize

Bajra

Intercrops

Maize

Groundnut

The flowering plants suggested under Ecological Engineering for pest management strategy are known as attractant plants to the natural enemies of the selected pests. The information is based on published research literature. However, the actual selection of flowering plants could be based on availability, agro-climatic conditions and soil types.

Biodiversity of natural enemies observed in Ecological Engineering field at NIPHM

Biodiversity of natural enemies: Parasitoids

Biodiversity of natural enemies: Predators

Biodiversity of natural enemies: Spiders

A. Resistant/ tolerant varieties

Pest/disease	Tolerant/ resistant variety
Moderately resistant to shoot fly and stem borer. Resistant to downy mildew	Sorghum Coimbatore 30
Resistant to shoot fly	IS-2205,IS- 3962,I-5469, IS-1054,S-386,SPV-102.
Resistant to Striga weed	Gobiye, Abshir and Birhan

***For detailed information and further updates nearest KVK, state departments,SAU / ICAR Institute may be contacted**

IV.CROP STAGE WISE IPM

Management	Activity
Pre-sowing*	
	<u>Common cultural practices:</u> • Deep summer ploughing • Use resistant/tolerant varieties • Follow crop rotation with non-host crops • Destroy the alternate host plants • Sow the ecological engineering plants • Sow sorghum/maize/bajra in 4 rows all around the main crop as guard/barrier crop • Soil solarization to prevent soil borne pathogens. • Timely sowing should be done. • Field sanitation, rogueing • Destroy the alternate host plants • Apply manures and fertilizers as per soil test recommendations • Adoption of crop rotation **<u>Common mechanical practices:</u>** • Uproot and burn infected plants parts early to avoid spread of the disease. • Collection and destruction of larvae.
Nutrients	• Apply FYM @ 5 t/ acre and incorporate in the soil 2 to 3 weeks before sowing.
Weeds	• Remove existing weeds at the time of sowing.

	• Weed species: *Cyperus iria, Digera arvensis, Convolvulus arvensis, Trianthema* sp.*,Tridax procumbens, Euphorbia hirta, Phyllanthus niruri* are controlled by 2,4-D dimethyl amine salt 58% SL 612 ml in 200-240 l of water/acre and 2,4-D ethyl ester 38 % EC (having 2,4-D acid 34 % w/w**)** 400 ml in 170 l of water/acre.
Soil borne pathogens, resting stages of insects	**Cultural control:** • Effective weed control. • Trimming of bunds • Early planting minimizes shoot fly, midge and ear head bug damage. • Planting sunhemp as trap crop to control the pest. **Biological control**: • Application of neem cake@ 80 Kg/ acre for nematode control. • Controlling adult beetles feeding on neem. • Acacia like trees on field bunds by shaking trees and destroying the beetles.
Sorghum loose Smut**	**Cultural control:** • Collect smutted ear-heads in cloth bags and destroy by dipping in boiling water or bury in soil. • Avoid ratooning. **Chemical control:** • Spray thiram 75% WS @ 10-12 g/acre in 400 ml of water.
Grain smut**	**Cultural control:** • Collect smutted ear-heads in cloth bags and destroy by dipping in boiling water. • Avoid ratooning **Chemical control:** • Seed treatment with sulphur 80% WP 1.2-1.6g/Kg seed in 400 ml of water.
Sowing*	
	Common cultural practices: • Use healthy, certified and weed free seeds. • Follow proper spacing • Crop rotation with pulses or oilseed crops. **Common mechanical practices:** • After harvest, plough to remove and destroy the stubbles. • Collection and destruction of white grub.
Nutrients	• Apply NPK fertilizers as per soil test recommendations as far as possible. If soil test recommendations are not available, adopt a blanket recommendation of 30 N, 18 P_2O_5, and 18 K_2Kg/acre. • Application of bio-fertilizers: When *Azospirillum* is used apply only 75% of recommended N for irrigated sorghum. • Mix 12.5 Kg of micronutrient mixture formulated with enough sand to make a total quantity of 50 Kg. • Basal application of 10 Kg ZnSO4/acre-1 for the deficient soils or 5 Kg Zn SO4 acre -1 + FYM for the Zn deficient

	soils • Basal application of FeSO4, 20 Kg/acre along with 5 t/acre FYM for iron deficient soils.
Weeds	• Weed Species: *Cyperus iria, Digera arvensis, Convolvulus arvensis, Trianthema* sp.*,Tridax procumbens, Euphorbia hirta, Phyllanthus niruri* are controlled by2,4-D dimethyl amine salt 58% SL 612 mlin200-240 l of water/acre and 2,4-D ethyl ester 38 % EC (having 2,4-D acid 34 % w/w**)**400 ml in 170 l of water/acre.
Shoot fly	**Cultural control:** • Early sowing to avoid the active period of shoot fly population. • Planting date in *kharif* 7-10 days onset of monsoon and in rabi end of September to 1st week of October is ideal to escape the shoot fly • High seed rate 1.6 – 2.0 Kg/acre. • Tall variety with yellow glossy stem less attacked. **Mechanical control:** • Removal of the seedlings with dead hearts. • Set up the low cost fish meal traps @4/acre till the crop is 30 days old. **Chemical control:** • Seed treatment with imidacloprid 48% FS @12ml/Kg seeds • Seed treatment with imidacloprid 70% WS@ 10g/Kg seeds • Spraying carbaryl 50%WP@ 600g/acre in 200-400 l of water. • Soil application carbofuran 3% CG @13320g/acre. • Spraying oxydemeton-methyl 25% EC @400ml/acre in 200-400 l of water. • Soil application phorate 10% CG @ 7500g/acre. • Spraying quinalphos 25%EC @ 600ml/acre in 200-400 l of water. • Seed treatment with thiamethoxam 30% FS @ 10 ml/Kgseeds.
Sorghum white grub	**Mechanical control:** • See the common mechanical practices **Chemical control:** • Apply phorate 10% @ CG 10 Kg/acre.
Sorghum downy mildew**	**Cultural control:** • Grow moderately resistant varieties. **Chemical control:** • Seed treatment with metalaxyl 35% WS @ 6-7 g/Kg seed.

	• Seed treatment with metalaxyl-M 31.8% ES @ 2.0 ml/ Kg seed.
Note: Apply *Trichoderma* spp*./ harzianum* and *Pseudomonas fluorescens* as seeds/ seedling/ planting material treatment and soil application (if commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).	
Vegetative	
	<u>Common cultural practices:</u> • Collect and destroy crop debris • Collect and destroy disease infected and insect damaged plant parts • Provide irrigation at critical stages of the crop • Avoid water logging • Avoid water stress during flowering stage • Judicious use of fertilizers • Enhance parasitic activity by avoiding chemical spray, when 1-2 larval parasitoids are observed **<u>Common mechanical practices:</u>** • Collection and destruction of eggs and early stage larvae • Handpick the older larvae during early stages • The infested shoots and seed capsules may be collected and destroyed • Handpick the gregarious caterpillars and the cocoons which are found on stem and destroy them in kerosene mixed water. • Use yellow sticky traps @ 4-5 trap/acre • Use light trap @ 1/acre and operate between 6 pm and 10 pm • Install pheromone traps @ 4-5/acre for monitoring adult moths activity (replace the lures with fresh lures after every 2-3 weeks) • Erecting of bird perches @ 20/acre for encouraging predatory birds such as King crow, common mynah etc. • Set up bonfire during evening hours at 7-8 pm **<u>Common biological practices:</u>** • Conserve natural enemies through ecological engineering • Augmentative release of natural enemies
Nutrients	• Apply N @ 50:25:25 % at 0, 15 and 30 DAS and full dose of P2O5 and K2O basally before sowing and if basal application is not possible the same could be top dressed within 24 hours.
Weeds	• Apply 2,4-D @ 400g/acre on 20-25 DAS on the plants surface, using Backpack/Knapsack/Rocker sprayer fitted with a flat fan nozzle using 80 l of water/acre (or) if herbicides are not used, hand weeding twice on 10-15 DAS and 30-35 DAS.
Stem borer	• Follow common cultural, mechanical and biological practices **<u>Cultural control:</u>** • Select and grow varieties resistant to spotted stem borer. Sow the lablab or cowpea or pigeon pea as an intercrop (Sorghum: Lablab 4:1) reduces the damage by stem borers. **<u>Biological control:</u>**

	• Egg parasitoids: *Trichogramma chilonis* @ 30,000/acre/ week **<u>Chemical control:</u>** • Spray carbaryl 50%WP @ 800g in 200-400 l of water/acre. • Application of carbofuran 3%CG @ 3320gm/acre. • Apply quinalphos 5% G 6000 @ g/acre.
Sorghum downy mildew	• As mentioned above in the sowing stage
Flowering	
Midge	• Follow common cultural, mechanical and biological practices **<u>Cultural control</u>:** • Removal of Johnson grassy weed **<u>Biological control:</u>** • Neem seed kernel extract 5% • Azadirachtin 1% • Parasitoids: *Aprostocetus* sp. **<u>Chemical control:</u>** • Spray quinalphos 1.5% DP @ 10640 g/acre; phosalone 4% DP @ 10000g/acre; phosalone 35% EC @ 457.2 ml in 200-400 l of water/acre; malathion 50% EC @ 400ml in 200-400 l of water/acre.; malathion 5% DP@ 8000 g/acre; dimethoate 30% EC @ 660 ml in 200-400 l of water/acre; carbaryl 5% DP @ 8000 g/acre.
Sorghum ear head caterpillar**	• Follow common cultural, mechanical and biological practices **<u>Biological control:</u>** • Two applications of NPV at 10 days interval at 1.5 $X10^{12}$ POB along with crude sugar 2.5 Kg + cotton seed kernel powder 250 g.
Sorghum earhead bug**	• Follow common cultural, mechanical and biological practices **<u>Biological control:</u>** • Neem seed kernel extract 5% • Azadirachtin 1% **<u>Chemical control:</u>** • Quinalphos 1.5% DP 10kg/acre.
Sorghum grain mould	• Follow common cultural, mechanical and biological practices
Sorghum charcoal rot	• Follow common cultural, mechanical and biological practices **<u>Cultural control:</u>** • Plant varieties with good stalk strength • Plant in fertile soil. • Avoid high plant populations unless irrigating. • Rotate with cotton.
Sorghum anthracnose**	• Follow common cultural, mechanical and biological practices **<u>Cultural control:</u>**

	• Eliminate other susceptible plants such as Johnson grass. • Rotate crops. • In poorly rotated fields, plough under infested residue where erosion is not a problem. **<u>Chemical control:</u>** • Treat the seeds with thiram at 4 g/Kg.
Sorghum rust**	• Follow common cultural, mechanical and biological practices **<u>Cultural control:</u>** • Remove the alternate host *Oxalis comiculata.*
Sorghum ergot**	• Follow common cultural, mechanical and biological practices •
Sorghum loose smut**	• Same as mentioned in the above pre-sowing stage
Grain smut**	• Same as mentioned in the above pre-sowing stage
Birds**	**<u>Mechanical control:</u>** • Use bird scarer • Use reflecto-ribbon surrounding sorghum field **<u>Botanical control:</u>** • Apply NSKE5% on panicle to save the damage from birds

V. RODENT PEST MANAGEMENT

<u>Rodent management practices:</u>

- Plough the fields to demolish the rodent habitat and maintain weed free fields to reduce alternate source of food and habitat
- Practice burrow smoking by ANGRAU/ NIPHM burrow fumigator with natural smoking materials for 2-3 min. for each burrow.

VI. INSECTICIDE RESISTANCE AND ITS MANAGEMENT

Insecticide resistance: Resistance to insecticides may be defined as 'a heritable change in the sensitivity of a pest population that is reflected in the repeated failure of a product to achieve the expected level of control when used according to the label recommendation for that pest species' (IRAC). Cross-resistance occurs when resistance to one insecticide confers resistance to another insecticide, even where the insect has not been exposed to the latter product.

Causes of resistance development: The causes and rate at which insecticide resistance develops depend on several factors, including the initial frequency of resistance alleles present in the population, how rapidly the insects reproduce, the insects' level of resistance, the migration and host range of the insects, the insecticide's persistence and specificity, and the rate, timing and number of applications of insecticide made. For instance, insect pests that survive in large populations and breed quickly are at greater advantage of evolving insecticide, especially when insecticides are misused or over-used.

General strategy for insecticide resistance management: The best strategy to avoid insecticide resistance is prevention and including insecticide resistance management tactics as part of a larger integrated pest management (IPM) approach.

1) **Monitor pests:** Monitor insect population development in fields to determine if and when control measures are warranted. Monitor and consider natural enemies when making control decisions. After treatment, continue monitoring to assess pest populations and their control.
2) **Focus on AESA.** Insecticides should be used only as a last resort when all other non-chemical management options are exhausted and P: D ratio is above 2: 1. Apply biopesticides/chemical insecticides judiciously after observing unfavourable P: D ratio and when the pests are in most vulnerable life stage. Use application rates and intervals as per label claim.
3) **Ecological engineering for pest management:** Flowering plants that attract natural enemies as well as plants that repel pests can be grown as border/intercrop.
4) **Take an integrated approach to managing pests.** Use as many different control measures as possible viz., cultural, mechanical, physical, biological etc. Select insecticides with care and consider the impact on future pest populations and the environment. Avoid broad-spectrum insecticides when a narrow-spectrum or more specific insecticide will work. More preference should be given to green labeled insecticides.
5) **Mix and apply carefully.** While applying insecticides care should be taken for proper application of insecticides in terms of dose, volume, timing, coverage, application techniques as per label claim.
6) **Alternate different insecticide classes.** Avoid the repeated use of the same insecticide, insecticides in the same chemical class, or insecticides in different classes with same mode of action and rotate/alternate insecticide classes and modes of action.
7) **Preserve susceptible genes.** Preserve susceptible individuals within the target population by providing unsprayed areas within treated fields, adjacent "refuge" fields, or habitat attractions within a treated field that facilitate immigration. These susceptible individuals may outcompete and interbreed with resistant individuals, diluting the resistant genes and therefore the impact of resistance.

VII. NUTRIENT DEFICIENCIES

Nitrogen: Little new growth, yellow leaves, this being more pronounced in older leaves and leaf drop. Plants stunted, spindly pale yellow or deep yellow color near the tips and margins progresses toward the base heads small seed numbers reduced
Correction measure: Apply 8-10 Kg N / acre as top dressing or foliar spray of urea @ 2-3 percent.

Phosphorous: Small root systems; grain filling inhibited. Growth stunted, spindly, dark green leaves with dark red coloration. Leaf sheaths bend upward with red coloration leaf. Leave appear to be erect and leathery. Roots turn dark brown purple or black.
Correction measure: foliar spray of 2% DAP2-3 sprays at an interval of 15 days.

Potassium: Deficiency first seen on older leaves. Irregular necrotic patterns intermingled with red pigmentation. Streaked patterns on the interveinal tissue symptoms at tips and margins move towards the base.
Correction measure: foliar spray of KCl @ 1%.

Sulphur: Deficiency appears first on younger leaves. New growth is pale yellow.
Correction measure: foliar spray of CaSO4 @ 2%

VIII. COMMON WEEDS

1. Crabgrass: *Digiteria sanguinalis* (L.) Scop. (Poaceae)

3. Barnyard grass: *Echinoclo acrusgalli* (L.) Beauv.

3. Goosegrass: *Eleusine indica*(L.) Gaertner (Poaceae)

4. Bermuda grass*: Cynodon dactylon* (L.) Pers. (Poaceae)

5. Rabbit/Crow foot grass: *Dactyloctenium aegyptium L. Willd.* (Poaceae)

6. Horse purslane: *Trianthema portulacastrum L.* (Aizoaceae)

6.Swine cress: ***Coronopus Didymus* (L.) Sm. Brassicaceae**

8. Coat buttons: *Tridax procumbens* L. (Asteraceae)

9. Pigweed: *Amaranthus viridis Hook. F.* (Amaranthaceae)

10. False amaranth: *Digera arvensis* Forssk. (Amaranthaceae)

11.Black nightshade: *Solanum nigrum* L. (Solanaceae)

12.Common purselane: *Portulaca oleracea* L. (Portualacaceae)

13. Purple nutsedge: *Cyperus rotundus* L. (Cyperaceae)

14. Flat sedge: *Cyperus iria* L. (Cyperaceae)

Witch weed: *Striga asiatica* L. Kuntze (Orobanchaceae)

IX. DESCRIPTION OF PESTS

1) Shoot fly:

Biology:

Egg: Eggs are cigarette shape, white coloured laid generally singly parallel to the midrib on the under surface of the 3rd to 5th leaf. Under high shoot-fly pressure, there may be several eggs on the same leaf. Sometimes, as many as 25 eggs may be laid on the same seedling. They hatch in 2-5 days.

Maggot: Yellow in colour migrate to the dorsal surface of the leaf, enter the space between the leaf sheath and the axis and make a clean cut at the base of the leaf. The larval period lasts for 6 - 10 days.

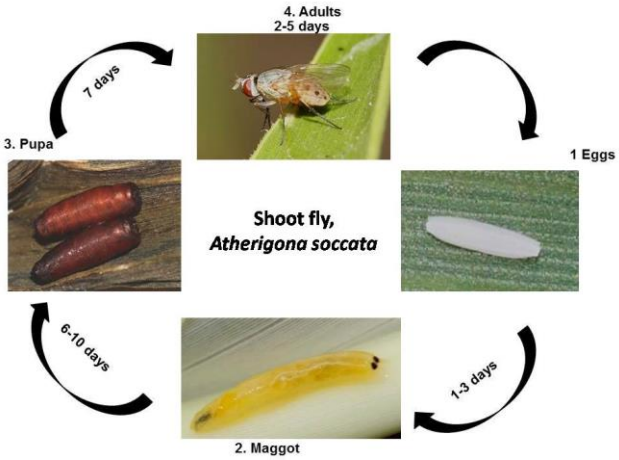
Pupa: Pupation takes place inside the stem and the adults emerge in about a week.

Adult: The adults are dark brown and similar to domestic housefly, but nearly half the size with the males smaller than the females. The adults usually live for 10 to 20 days.

Favourable conditions:

- The late sown crops generally suffer greater shoot fly damage because of high humidity and moderate temperature.
- Infestation is normally high in the post rainy season crop, which is sown in September-October temperature above 35^{o}C and below 18^{o}C reduces shoot fly survival.

Life cycle:



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2http://www.nbaii.res.in/insectpests/images/Atherigona-soccata2.jpg
3 www.nbaii.res.in/insectpests/images/Atherigona-soccata3.jpg
4 http://www.nbaii.res.in/insectpests/images/Atherigona-soccata4.jpg

Damage symptoms:

- Damage by at the seedling stage (5 to 30 days after seedling emergence) will lead to the typical dead heart symptoms.
- The larva migrates to the upper side of the leaf, and moves along the leaf whorl until it reaches the growing point where the larvae cut the growing point. As a result the central leaf dries up forming a dead heart, which can be pulled out easily and produces a rotting smell.
- Normally the damage occurs 1 to 4 weeks after seedling emergence. Seedlings of 5 to 30 days old are generally susceptible to shoot fly damage.
- Older plants (>30 days after seedling emergence) are not usually damaged by *A. soccata* however, under conditions of high humidity during the rainy season, infestation may occur.
- Under these conditions the infested plants do not produce the typical dead heart symptoms. In this instance, the damaged leaf becomes thin and papery, wrapping around the other leaves. The plants may fail to grow normally.
- Late infestations may also damage the panicle in the formative stage, resulting in rotting or drying up of a portion of the panicle affected by shoot fly damage.
- The damage plants produce side tillers
- Infestation is especially high when sorghum planting is staggered due to erractic rainfall.

1 Damage symptoms –deadheart

1http://www.takingroots.in/sites/default/files/Sorghum_Shoot_Fly_02.jpg

Natural enemies of shootfly:

Parasitoids : *Trichogrammatoidea simmonalsi, Trichogramma chilonis, Neotrichoporoides nyemitawus*

Predators: Spiders, Coccinellids, lace wings etc.

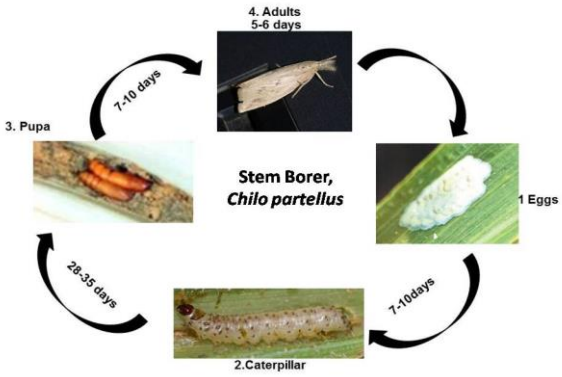
*****For the management refer page no.....

2. Sorghum stem borer:

Biology:

Egg: The eggs are laid on the underside of a leaf near the midrib in 3-5 rows, in groups of 10-100. They are flattened, oval, and about 0.8 mm long. Hatching takes place after 7-10 days.
Larva: The young caterpillars produce characteristic leaf windowing. Sometimes the early stages mine in the leaves, causing yellow streaks. After a few days they bore down inside the tunnel. They also may move down outside the stem and then bore into it just above an internode. In older plants the caterpillars sometimes live in the developed heads. In general appearance the larvae look like *Busseola fusca* larvae (= Maize Stalk Borer). They are creamy pink with groups of dark spots along the back. The head capsule is brown. When mature they are about 25 mm long. The caterpillars can be distinguished from *B. fusca* and from *Sesamia calamistis* (= Pink Stalk Borer) by the hooks on its prolegs. In *C. partellus* these hooks are arranged in a complete circle. In *B. fusca* and *S. calamistis* they are arranged in a crescent. The larval period takes 28-35 days.
Pupa: Pupation takes place in a small chamber in the stem. The pupal period takes 7 10 days.
Adult: Adult moths have a wingspan of 20-30 mm. Males are smaller and darker than females. The forewings of males are pale brown. The forewings of the females are much paler and the hind wings are almost white.

Life cycle:



1 http://www.infonet-biovision.org/default/ct/92/pests
2http://www.nbaii.res.in/insectpests/images/Chilo-partellus6.jpg
3http://push-pull.net/striga/stem borer.html
4http://www.nbaii.res.in/insectpests/images/Chilo-partellus15.jpg

Damage symptoms:

- Damage occurs as a series of small holes in lines (pin holes) in younger leaves and/or patches of transparent leaf epidermis (window panes) in older leaves.
- Holes in stem caused by larvae tunnelling into the stem can result in broken stems or drying and eventual death of the growing point (deadheart).

1. Dead plant **2 Leaf damage at early stage**

1http://ethiopia.ipm-info.org/insect_pests_ethiopia/Chilo_partellus.htm
2.http://keys.lucidcentral.org/keys/v3/eafrinet/maize_pests/key/maize_pests/Media/Html/Chilo_partellus_(Swinhoe_1885)_-_Spotted_Stemborer.htm

Natural enemies of stem borer:

Parasitoid: *Cotesia sesamiae, Cotesia chilonis*

Predators: *Chrysoperla zastrowi sillemi*, ladybird beetle, reduviid bug, spider, fire ant, robber fly, black drongo (King crow), common mynah, big-eyed bug (*Geocoris* sp), earwig, ground beetle, pentatomid bug (*Eocanthecona furcellata*), preying mantis, *Dicyphus hesperus* etc.

*****For the management refer page no.....

3. Sorghum midge:

Biology:

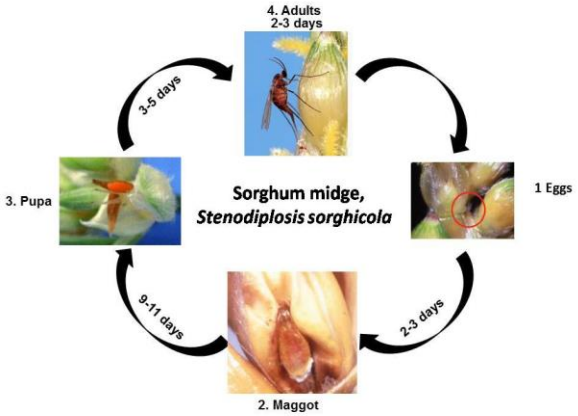
Eggs: Each white, cylindrical egg, 0.3 by 0.6 mm, is attached to the host spikelet by a slender, tapering stalk.

Maggot: The newly hatched larva is colorless. As it feeds on the developing grain, it gradually becomes pale pink to a deeper pink, then orange, and finally a darker orange or red-orange. The full-grown larva, 1.5 to 2.0 mm long, is slightly flattened and spindle-shaped, tapering to a point at the head.

Pupa: At first, the pupa is uniformly dark orange, but after a few hours the head, antennae, legs and thorax darken until they become black. Only the abdomen retains the orange color.

Adult - The sorghum midge is an orange fly, the male measuring approximately 1.3 mm in length and the female 1.6 mm.

Life cycle:



1&2 http://hal.archives-ouvertes.fr/docs/00/52/09/81/PDF/Stenodiplosis-vercambreVF20100924.pdf
3http://www.cabi.org/cpc/bigimage.aspx?imageURL=portfolio/compendia/Normal/contpup1.img&captiondesc=Pupa&captioncap=Pupa%20in%20sorghum%20seed%20head.%20Before%20adult%20emergence%20the%20pupa%20wriggles%20its%20way%20to%20the%20tip%20of%20the%20spikelet.&captioncopy=H.C.%20Sharma/A.B.%20Chitnis/ICRISAT
4 http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/sorghum-midge

Damage symptoms:

- Maggot feed on the developing ovary inside the glumes: this results in empty or chaffy spikelets as shrivelled grains fail to develop.
- During the grain filling or milk stage, if damaged spikelets are pressed between the finger and thumb or between a pair of forceps, they produce a red ooze: the body contents of the midge larva or pupa.
- In the mature crop, damaged spikelets become empty or chaffy, and the sorghum panicles present a blasted appearance.
- Damaged panicles have small, transparent midge pupal cases attached to the tip of the damaged spikelets.

1 Damaged grains **2 Infested panicles**

1 http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/sorghum-midge
2 http://www.cabi.org/cpc/bigimage.aspx?imageURL=portfolio/compendia/Normal/contdam.img&captiondesc=Symptoms&captioncap=Infested%20spikelets.&captioncopy=Keith%20M.%20Harris

Natural enemies of sorghum midge:

Parasitoids: *Aprostocetus* spp.

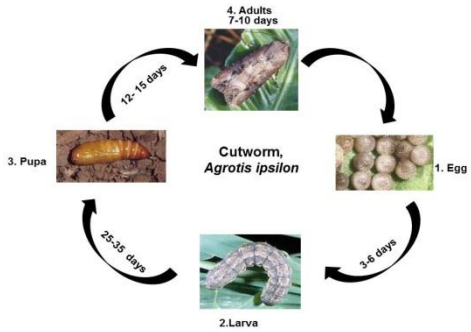
*****For the management refer page no.....

4. Cutworm:

Biology:

Egg: The egg is white in color initially, but turns brown with age. It measures 0.43 to 0.50 mm high and 0.51 to 0.58 mm wide and is nearly spherical in shape, with a slightly flattened base. The egg bears 35 to 40 ribs that radiate from the apex; the ribs are alternately long and short. The eggs normally are deposited in clusters on foliage. Females may deposit 1200 to 1900 eggs. Duration of the egg stage is three to six days.
Larva: There are five to nine instars, with a total of six to seven instars most common. the larva is rather uniformly colored on the dorsal and lateral surfaces, ranging from light gray or gray-brown to nearly black. The head is brownish with numerous dark spots. Larvae usually remain on the plant until the fourth instar, when they become photo-negative and hide in the soil during the daylight hours. In these latter instars they also tend to sever plants at the soil surface, pulling the plant tissue belowground. Larvae tend to be cannibalistic.
Pupa: The pupa is 17 to 22 mm long and 5 to 6 mm wide and dark brown. Duration of the pupal stage is normally 12 to 20 days. Pupation occurs belowground at a depth of 3 to 12 cm.
Adult: The adult is fairly large in size, with a wingspan of 40 to 55 mm. The forewing, especially the proximal two-thirds, is uniformly dark brown. The distal area is marked with a lighter irregular band, and a small but distinct black dash extends distally from the bean-shaped wing spot. The hind wings are whitish to gray, and the veins marked with darker scales.

Life cycle:



1,3&4https://extension.umd.edu/news/photos/cutworm
2 http://entnemdept.ufl.edu/creatures/veg/black_cutworm.htm

Damage symptoms:

- Cutworms usually feed at night or during overcast days. Newly hatched larvae feed on weeds, and/or young maize plants if present, leaving small irregular holes in the leaves. Such early feeding is of little significance to plants.
- Larger larvae may completely cut through stalks, which can cause plants to wilt and die. Severe stand reductions can result. They sometimes drag cut plants under soil clods or into small holes in the soil to continue their feeding during the daylight hours.
- In other crops like potatoes and root vegetables, damage can take the form of unsightly holes in the subterranean tubers, which may allow the penetration of secondary fungi.
- When numerous, cutworms can destroy as much as 75% of a crop.

Damage symptoms

1 http://ppp.missouri.edu/pestmonitoring/bcw/images/black-cutworm-JAK270.jpg

Natural enemies of cutworm

Parasitoids: *Cotesia* spp., *Meterorus* spp., *Campoletis* spp.
Predators: *Chrysoperla zastrowi sillemi*, ladybird beetle, reduviid bug, spider, fire ant, robber fly, black drongo (King crow), common mynah, big-eyed bug (*Geocoris* sp), earwig, ground beetle, pentatomid bug (*Eocanthecona furcellata*), preying mantis etc.

*****For the management refer page no.....

5. White grub:

Biology:

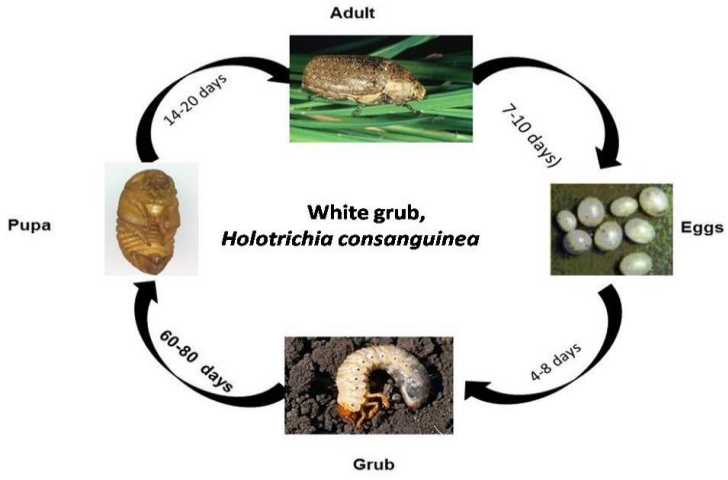
Egg: A female lays on an average of 27 eggs in the soil, which are pear like white enclosed in earthen cells.

Grub: Fleshy 'C' shaped, whitish yellow in colour found close to the base of the clump.

Pupa: Pupae are tan to brown, and occur deeper in the soil in earthen chambers.

Adult: Adult beetles are a rusty-red color just after emerging from the pupal stage, but turn nearly black.

Life cycle:



https://www.google.co.in/search?q=white+grub+life+cycle&espv=210&es_sm=93&source=lnms&tbm=isch&sa

Damage symptoms:

- Yellowing and wilting of leaves.
- Drying of entire crown.
- Affected stem come off easily when pulled.
- Cause extensive damage to roots and base of shoot.

Natural enemies of white grub:

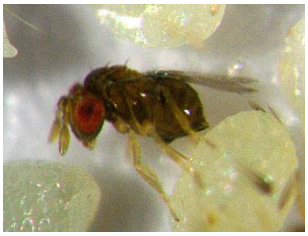
Parasitoids:*Typhia* (parasitic wasp)
Predators: Ground beetle, red ant etc.

*For management refer to page number----------

Natural Enemies of Sorghum Insect Pests

Parasitoids

Egg parasitoids



1.*Tricogramma* spp.

Egg-larval parasitoid

2. *Chelonus* spp.

Larval parasitoids

3.*Cotesia sesamiae*

4.*Cotesia chilonis*

5. *Aprostocetus* spp.

6.*Campoletis* spp.

Nymphal/larval and adult parasitoids

7. *Cotesia* spp

8. *Meterorus* spp

9.*Campoletis* spp

1. http://www.nbaii.res.in/Featured_insects/Trichogrammatids.php
2. http://www.nbaii.res.in/Featured%20insects/chelonus.htm
3. http://www.sharkeylab.org/cotesia/display_morph.cgi?Species=sesamiae&part=lateralHabitus&Author=Cameron
4. http://www.nbaii.res.in/Introductions/images/apanteles-chilonis.jpg
5. http://www.nbaii.res.in/Featured_insects/images/aprostocetus-gala3.jpg
6. http://www.nbaii.res.in/Featured%20insects/Campoletis.htm
7. http://www.nbaii.res.in/Featured_insects/images/cotesia-flavipes7.jpg
8. http://micropics.org.uk/Braconidae/Meteorus/1/meteorus%201.htm
9. http://www.nbaii.res.in/Featured_insects/images/campoletis-chlorideae4.jpg

Predators

Predators

1. *Chrysoperla*

2. Coccinellid

3. Reduviid bug

4. Spider

5. Robber fly

6. Red ant

7. Black drongo

8. Common mynah

9. Big-eyed bug

10. Earwig

11. Ground beetle

12. Pentatomid bug (*Eocanthecona furcellata*)

13. Preying mantis

14. *Geocoris* spp.

15. Predatory mite

16. Predatory thrips


17. *Oligota* spp.


18. *Orius* spp.


19. Hover fly


20. Mirid bug

5. http://www.warpedphotosblog.com/robber-fly-and-prey
6.http://www.couriermail.com.au/news/queensland/queensland-launched-a-war-against-the-fire-ant-invasion-but-12-years-later-they8217re-still-on-the-march/story-fnihsrf2-1226686256021
7. http://nagpurbirds.org/blackdrongo/picture/1639
8. http://nickdobbs65.wordpress.com/tag/herbie-the-love-bug/
9. http://bugguide.net/node/view/598529
10. http://www.flickr.com/photos/johnhallmen/2901162091/
11.http://www.mattcolephotography.co.uk/Galleries/insects/Bugs%20&%20Beetles/slides/ Ground%20Beetle%20-%20Pterostichus%20madidus.html
12. http://www.ndsu.nodak.edu/ndsu/rider/Pentatomoidea/Genus_Asopinae/ Eocanthecona.htm
13. http://spirit-animals.com/praying-mantis/
14. http://nathistoc.bio.uci.edu/hemipt/Dicyphus.htm
15. http://www.dragonfli.co.uk/natural-pest-control/natural-enemies
16. http://biocontrol.ucr.edu/hoddle/persea_mite.html
17. http://www.fugleognatur.dk/forum/show_message.asp?MessageID=560188&ForumID=33
18. http://en.wikipedia.org/wiki/File:Orius_insidiosus_from_USDA_2_(cropped).jpg
20. http://www.britishbugs.org.uk/heteroptera/Miridae/blepharidopterus_angulatus.html

X. DESCRIPTION OF DISEASES

1. Sorghum grain mould:

Damage symptom:

If rains occur during the flowering and grain filling stages, severe grain moulding occurs. The most frequently occurring genera are *Fusarium, Curvularia, Alternaria, Aspergillus* and *Phoma. Fusarium semitectum* and *F.moniliforme* develop a fluffy white or pinkish coloration. *C. lunata* colours the grain black. Symptom varies depending upon the organism involved and the degree of infection.

Survival and spread:

- The fungi mainly spread through air-borne conidia.
- The fungi survive as parasites as well as saprophytes in the infected plant debris.

Favourable conditions:

- Wet weather following the flowering favors grain mould development.
- The longer the wet period the greater the mould development.
- Compact ear heads are highly susceptible.

Damage symptom

http://plantpath.caes.uga.edu/extension/plants/fieldcrops/sorghumheadmold.html

*****For the management refer page no.....

2. Sorghum charcoal rot:

Damage symptom:

Charcoal rot is a major disease in the dry sorghum growing regions.The disease is particularly destructive on high yielding, sorghum that mature during hot and dry weather if the vigorously growing crop is subjected to moisture stress during the pre-flowering period.Infected stalks show an internal shredding at and above the ground line. The shredding can be observed by splitting the stalk and molting the deteriorated soft pith tissue leaving the tougher vascular strands

Survival and spread:

- Survival of microsclerotia is several years in dry soil but only a few weeks in wet, saturated soils.

Favourable conditions:

- Charcoal rot is caused by *Macrophomi naphaseolina*, a disease that appears in hot and dry weather.
- When soil temperatures are 80-95°F (27-35°C) for 2 to 3 weeks.

Damage symptoms

http://www.soilcropandmore.info/crops/sorghum/sorghum5.jpeg
http://extension.missouri.edu/p/G4356

*****For the management refer page no.....

3.Sorghum downy mildew:

Damage symptom:

The fungus causes systemic downy mildew of sorghum. It invades the growing points of young plants, either through oospore or conidial infection. As the leaves unfold they exhibit green or yellow colouration. Abundant downy white growth is produced on the lower surface of the leaves, which consists of sporangiophores and sporangia. Normally three or four leaves develop

the chlorotic downy growth. Subsequent leaves show progressively more of a complete bleaching of the leaf tissue in streaks or stripes. As the infected bleached leaves mature they become necrotic and the interveinal tissues disintegrate, releasing the resting spores (oospores) and leaving the vascular bundles loosely connected to give the typical shredded leaf symptom.

Transmission:

- The primary infection is by means of oospores present in the soil which germinate and initiate the systemic infection.
- Secondary spread is by air-borne sporangia

Favourable conditions:

- Maximum sporulation takes place at 100 per cent relative humidity.
- Optimum temperature for sporulation is 21-23˚C during night.
- Light drizzling accompanied by cool weather is highly favourable.

Damage symptoms

http://tnau.ac.in/eagri/eagri50/PATH272/lecture02/001.html
http://cropdisease.cropsci.illinois.edu/corn/sorghumdownymildew.html
*****For the management refer page no.....

4. Sorghum anthracnose:

Damage symptom:

The fungus causes both leaf spot (anthracnose) and stalk rot (redrot). The disease appears as small red coloured spots on both surfaces of the leaf. The centre of the spot is white in colour encircled by red, purple or brown margin. Numerous small black dots like acervuli are seen on the white surface of the lesions. Red rot can be characterized externally by the development of circular cankers, particularly in the inflorescence. Infected stem when split open shows discoloration, which may be continuous over a large area or more generally discontinuous giving the stem a marbeled appearance.

Survival and spread:

- The disease spread by means of seed-borne and air-borne conidia and also through the infected plant debris.

Favourable conditions:

- Continuous rain.
- Temperature of 28-30˚C.
- High humidity.


Damage symptom

http://tnau.ac.in/eagri/eagri50/PATH272/lecture02/004.html
http://plantpath.caes.uga.edu/extension/plants/fieldcrops/images/image002.jpg

*****For the management refer page no.....

5.Loose smut:

Damage symptom:

The affected plants can be detected before the ears come out. They are shorter than the healthy plants with thinner stalks and marked tillering. The ears come out much earlier than the healthy. The glumes are hypertrophied and the earhead gives a loose appearance than healthy. The sorus is covered by a thin membrane which ruptures very early, exposing the spores even as the head emerges from the sheath.

Transmission:

- The pathogen is externally seed borne.

Favourable conditions:

- Optimum environmental conditions for maximum infection include: temperatures between 20 and 25°C and slightly acidic soils favour the disease developments.

Damage symptom

http://tnau.ac.in/eagri/eagri50/PATH272/lecture02/006.html
http://www.infonet-biovision.org/res/res/files/1162.280x185.clip.jpeg

*****For the management refer page no.....

6. Rust:

Damage symptom:

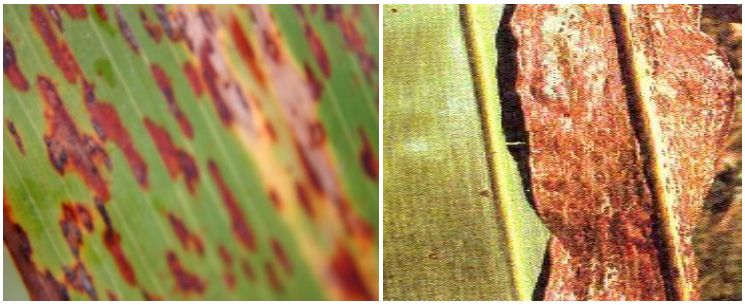
The fungus affects the crop at all stages of growth. The first symptoms are small flecks on the lower leaves (purple, tan or red depending upon the cultivar). Pustules (uredosori) appear on both surfaces of leaf as purplish spots which rupture to release reddish powdery masses of uredospores. Teliopores develop later sometimes in the old uredosori or in telisori, which are darker and longer than the uredosori. The pustules may also occur on the leaf sheaths and on the stalks of inflorescence.

Survival and spread:

- The uredospores survive for a short time in soil and infected debris. Presence of alternate host helps in perpetuation of the fungus.

Favourable conditions:

- Low temperature of 10 to 12˚C favours teliospore germination.
- A spell of rainy weather favours the onset of the disease.



Damage symptom

http://agropedia.iitk.ac.in/sites/default/files/Rust%20affected%20leaf.JPG
http://planecreeksustainablefarmers.com/wp-content/uploads/2011/04/Figure-6.jpg

***For the management refer page no.....

7. Ergot:

Damage symptom:

The disease is confined to individual spikelets. The first symptom is the secretion of honey dew from infected florets. Under favourable conditions, long, straight or curved, cream to light brown, hard sclerotia develop. Often the honey dew is colonised by *Crerebella sorghivulgaris* which gives the head a blackened appearance.

Survival and spread:

- The primary source of infection is through the germination of sclerotia which release ascospores that infect the ovary.
- The secondary spread takes place through air and insect-borne conidia. Rain splashes also help in spreading the disease.

Favourable conditions:

- A period of high rainfall and high humidity during flowering season.
- Cool night temperature and cloudy weather aggravate the disease.

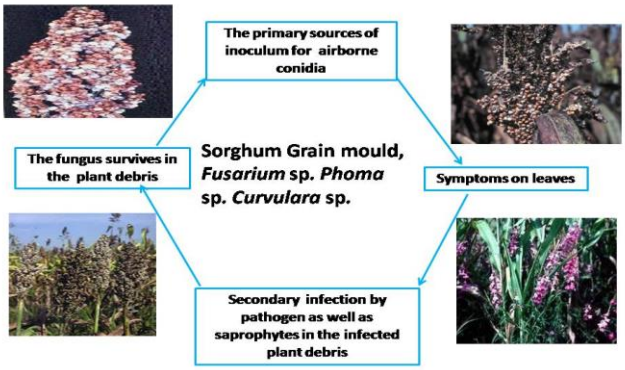
Damage symptom

http://www.daff.qld.gov.au/__data/assets/image/0007/65914/Sorghum-ergot-250_rdax_90.jpg
http://www.daff.qld.gov.au/__data/assets/image/0011/54479/sorghum-ergot_rdax_90.jpg

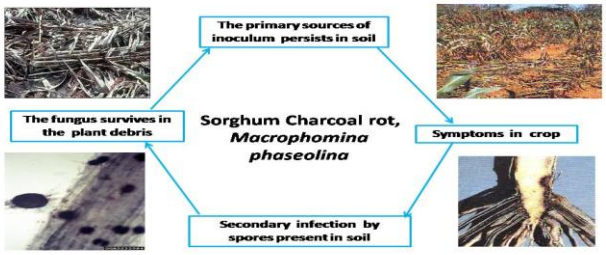
***For the management refer page no.....

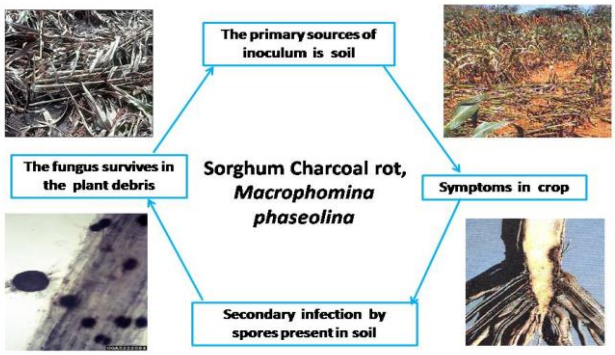
Disease cycles:

1. Sorghum grain mould:

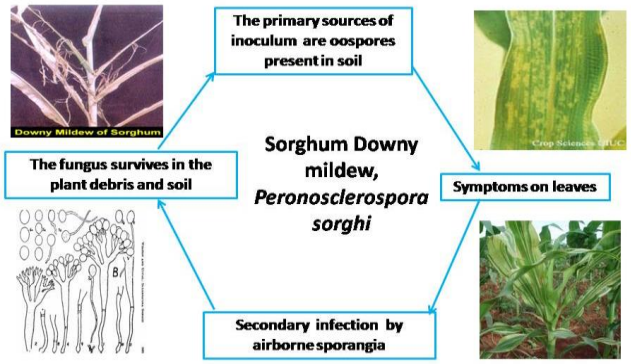


2. Sorghum charcoal rot:

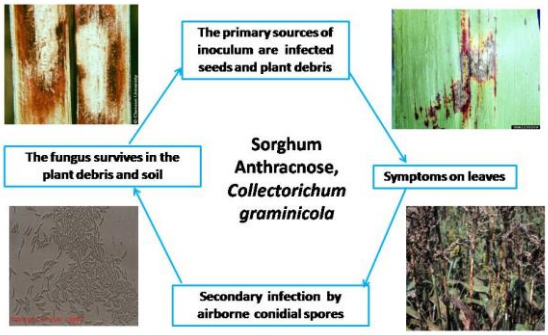




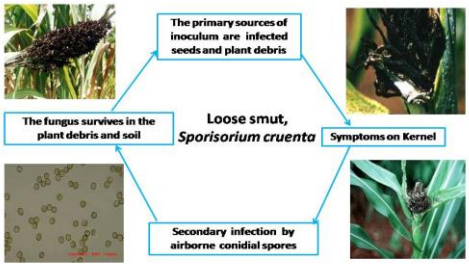
3.Sorghum downy mildew:



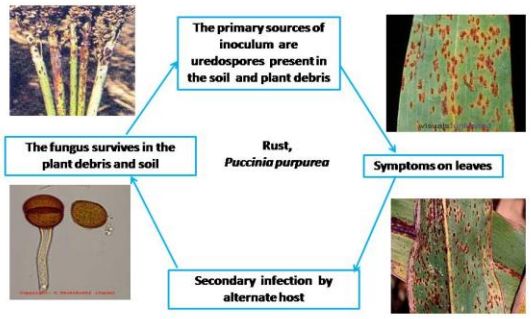
4. Sorghum anthracnose:



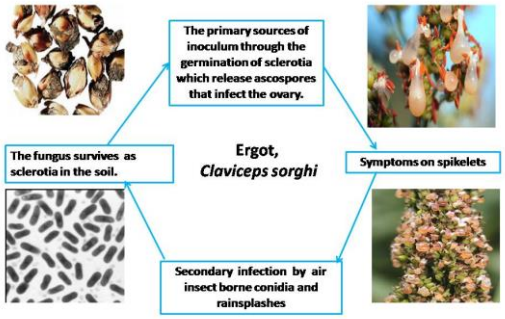
5. Loose smut:



6. Rust:



7. Ergot:



XI. SAFETY MEASURES

A. <u>At the time of harvest:</u>

Harvesting should be done by adopting proper method. Jowar grown for grain should be harvested when it attains physiological maturity. Dry earheads promptly as moisture content influence keeping quality. Avoid pest infestation during drying and threshing etc. Grain sorghum kernels are highly exposed to the elements of nature (like wheat). Consequently, it is highly susceptible to pre-harvest losses from birds, insects, molds, and unfavorable weather. Unlike wheat or corn, milo does not normally dry in the field to a moisture level that is suitable for direct marketing (14.0%) or safe storage (13.5% or lower) until after a killing frost or the application of a desiccant chemical. Consequently, artificial drying is usually required unless dry weather prevails for several days after the crop reaches physiological maturity (moisture content of ~30%). Like corn and wheat, milo can be harvested at moderately high grain moistures (between 18 to 22%) if sufficient drying capacity is available

<u>B. Post-harvest storage:</u>

The grain should be cleaned and dried to bring the moisture content below 9 per cent. Dry the sorghum grains sufficiently (below 9 percent) prior to packing and storing. sorghum seeds should be dried in diffused sunlight in sun. Pack the sorghum in jute bags free from infestation and obnoxious smell. Avoid harvesting during adverse weather conditions i.e. rains and overcast weather. Use strong and free from infestation packaging material for storage and

transport. Use proper scientific technique in storage. Use pest control measures (fumigation) before storage. Provide aeration to stored grain and stir grain bulk occasionally. Seed should not be exposed to direct sunlight. Seed should be inspected at fortnightly interval. Use proper techniques while handling (loading & unloading), good and fast transport to avoid losses during transport.

XII. DO'S AND DON'TS 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 monocroping.
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 pesticides for the control of seed borne diseases /pests.	Do not use seeds without seed treatment with biopesticides /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-emergent 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 NPK fertilizers as per the soil test recommendation.	Avoid imbalanced use of fertilizers.
10	Use micronutrient mixture after sowing based test recommendations.	Do not apply any micronutrient mixture after sowing without test recommendations.
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.	Do not take any management decision without 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 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.
15	Spray pesticides thoroughly to treat the undersurface of the leaves, particularly for mitesetc.	Do not spray pesticides only on the upper surface of leaves.
16	Apply short persistent pesticides to avoid pesticide residue in the soil and produce.	Do not apply pesticides during preceding 7 days before harvest.
17	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 enemies.

XIII. SAFETY PARAMETERS IN PESTICIDE USAGE

S. No.	Pesticide Classification as per insecticide rules Colour of toxicity triangle	WHO classification of hazard	Symptoms poisoning	First Aid measures Treatment of poisoning	Waiting period from last application to harvest (days)
Insecticides					
1	Carbofuran Extremely toxic	Class I b highly hazardous	Constriction of pupils, salivation, profuse sweating, muscle incordination, nausea, vomiting,diarrhea, epigastric pain, tightness in chest	Treatment of poisoning: Atropine injection-1-4 mg. repeat 2 mg when symptoms begin to recur (15-16 min interval) excessive salivation- good sign, more atropine needed	-
2	Phorate Extremely toxic Do 	Class Ia- Extremely hazardous	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,	First Aid measures: 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	-

			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.	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 Treatment of poisoning - 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 aldoximemethiodide) 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, barbituaratesofrphenothiazines. Do not give atropine to a cyanotic patients. Give artificial respiration first then administer atropine	
3	Quinalphos Highly toxic 	Class II Moderately Hazardous	do	do	-
4	Dimethoate Highly toxic 	Class II Moderately hazardous	Mild-anorexia, headache, dizziness, weakness, anxiety, tremors of tongue and eyelids, miosis, impairment of visual acuity	Treatment of poisoning -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.	
5	Imidacloprid Highly toxic		Harmful if swallowed, absorbed through skin or inhaled. Avoid breathing vapor or spray mist. Causes moderate eye irritation.	**First Aid measures:** Have person sip a glass of water if able to swallow. Do not induce vomiting unless told to do so by a doctor, do not give anything by mouth to an unconscious person **Treatment of poisoning:** No specific	3 days

				antidote. Treatment is essentially symptomatic.	
6	Oxydemeton-methyl Highly toxic 	Class Ib Moderately Hazardous	Severe – diarrhoea, pinpoint and non - reactive pupils, respiratory difficulty, pulmonary edema, cyanosis, loss of sphincter control, convulsions, coma and heart block.	**First Aid measures:**Atrophine sulphate **Treatment of poisoning:** 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 – pyridine aldoximemethiodide). 1 g and 0.25g for infants intravenously at slow rate over a period of 5 minutes and administer again periodically as indicated. More than one injection may be required. Avoid morphine, theophylline, aminophylln, barbiturates Phenothiaznines	7 days
7	Thiamethoxam			**First Aid measures:** Have person sip a glass of water if able to swallow. Do not induce vomiting unless told to do so by a poison control center or doctor. Do not give anything by mouth to an unconscious **Treatment of poisoning:** No specific antidote. Treatment is essentially symptomatic.	5 days

XIV. BASIC PRECAUTIONS IN PESTICIDES USAGE

A. Purchase

1. Purchase only just required quantity e.g. 100, 250, 500, 1000 g/ml for single application in specified area.
2. **Do not** purchase leaking containers, loose, unsealed or torn bags;**Do not**purchase pesticides without proper/approved labels.
3. While purchasing insist for invoice/bill/cash memo

B. Storage

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

C. Handling

1. Never carry/ transport pesticides along with food materials.
2. Avoid carrying bulk pesticides (dust/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 polythene bags as hand gloves, handkerchiefs or piece of clean cloth as mask and a cap or towel to cover the head (Do not use polythene bag contaminated with pesticides).
5. Read the label on the container before preparing spray solution.
6. Prepare the spray solution as per requirement
7. **Do not** mix granules with water;eat, drink, smoke or chew while preparing solution.
8. Concentrated pesticides must not fall on hands etc. while opening sealed container. Do not smell pesticides.
9. Avoid spilling of pesticides while filling the sprayer tank.
10. The operator should protect his bare feet and hands with polythene bags

E. Equipment

1. Select right kind of equipment.
2. Do not use leaky and defective equipment
3. Select right kind of nozzles
4. Don’t blow/clean clogged nozzle with mouth. Use old tooth brush 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;**Do not**apply just before the rains and after the rains;**Do not**apply against the windy direction.

3. Emulsifiable concentrate formulations should not be used for spraying with battery operated ULV sprayer.
4. Wash the sprayer and buckets etc. with soap water after spraying
5. Containers buckets etc. used for mixing pesticides should not be used for domestic purpose
6. Avoid entry of animals and workers in the field immediately after spraying
7. Avoid tank mixing of different pesticides

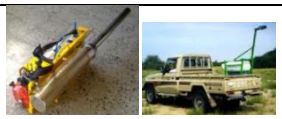
G. Disposal

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 buried deep into soil away from water source.
3. Never reuse empty pesticides container for any other purpose.

XV. PESTICIDE APPLICATION TECHNIQUES

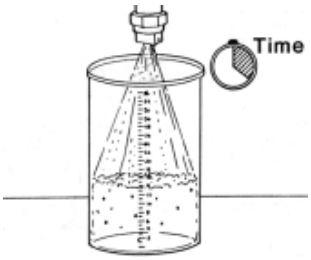
<table>
<tr><td colspan="4">Equipment</td></tr>
<tr><td colspan="4">Category A: Stationary, crawling pest/disease</td></tr>
<tr><td rowspan="2">Vegetative stage
i) for crawling and soil borne pests

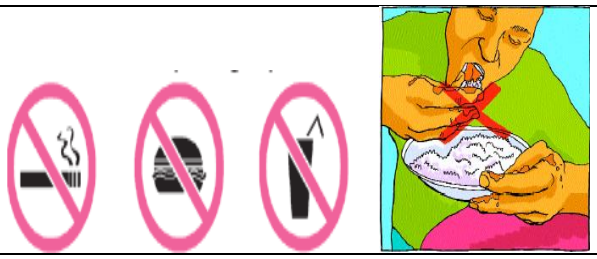
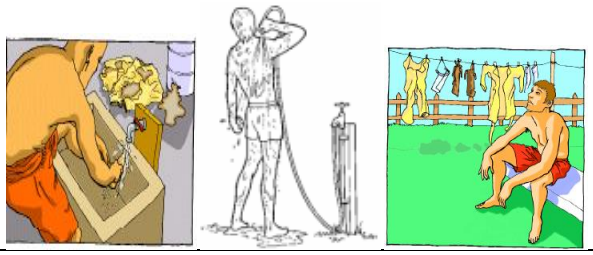
ii) for small sucking leaf borne pests</td><td rowspan="2">Insecticides and fungicides</td><td rowspan="2">• Lever operated knapsack sprayer (Droplets of big size)
• Hollow cone nozzle @ 35 to 40 psi
• Lever operating speed = 15 to 20 strokes/min
or
• Motorized knapsack sprayer or mist blower (Droplets of small size)
• Airblast nozzle
• Operating speed: 2/3rd throttle</td><td> 
  </td></tr>
<tr><td>Reproductive stage</td><td>Insecticides and fungicides</td><td>• Lever operated knapsack sprayer (Droplets of big size)
• Hollow cone nozzle @ 35 to 40 psi
• Lever operating speed = 15 to 20 strokes/min</td><td>  </td></tr>
<tr><td colspan="4">Category B: Field flying pest/airborne pest</td></tr>
<tr><td>Vegetative stage</td><td>Insecticides and</td><td>• Motorized knapsack</td><td>  </td></tr>
</table>

Reproductive stage *(Field Pests)*	fungicides	sprayer or mist blower (Droplets of small size) • Airblast nozzle • Operating speed: 2/3rd throttle ***Or*** • Battery operated low volume sprayer (Droplets of small size) Spinning disc nozzle	
Mosquito/ locust and spatial application *(migratory* Pests)	Insecticides and fungicides	• Fogging machine and ENV (Exhaust nozzle vehicle) (Droplets of very small size) • Hot tube nozzle	
Category C: Weeds			
Post-emergence application	Weedicide	• Lever operated knapsack sprayer (Droplets of big size) • Flat fan or floodjet nozzle @ 15 to 20 psi • Lever operating speed = 7 to 10 strokes/min	
Pre-emergence application	Weedicide	• Trolley mounted low volume sprayer (Droplets of small size) • Battery operated low volume sprayer (Droplets of small size)	

XVI. 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 properbath with soap after completing spraying	
9.	Do not blow the nozzle with mouth for any blockages. Clean with water and a soft brush.	

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