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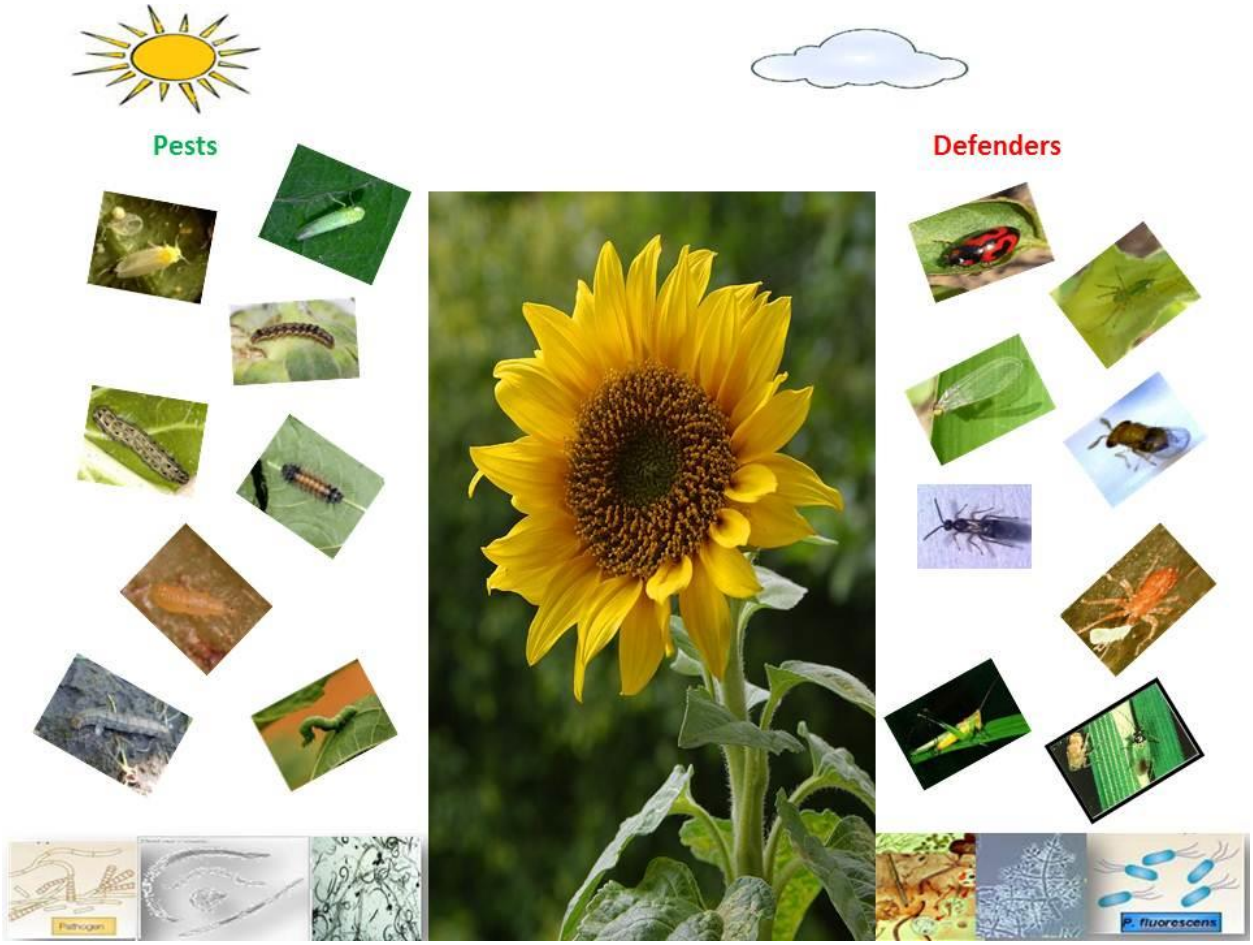
AESA BASED IPM PACKAGE
Sunflower



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Ministry of Agriculture
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The AESA based IPM – Sunflower (*Helianthus annuus* L.), was compiled by the NIPHM working group under the Chairmanship of Dr. Satyagopal Korlapati, IAS, DG, NIPHM, and guidance of Shri. Utpal Kumar Singh, IAS, JS (PP). The package was developed taking into account the advice of experts listed below on various occasions before finalization.

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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 K 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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XV. Pesticide application techniques

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AESA BASED IPM FOR SUNFLOWER

Sunflower- Plant description:

Sunflower (*Helianthus annuus* L., Family: Compositae) is one of the four most important annual crops in the world grown for oil along with soybean, rapseed and groundnut. It is an important additional to the list of edible oilseed crops in India in the last four decades. The genus *Helianthus* is named from the Greek *Helio* meaning sun, and *anthos* meaning flower. The Spanish name for sunflower, 'girasol' and the French name 'tournesol', literally means 'turn with the sun', a trait exhibited by sunflower until anthesis, after which the capitula face east. The genus associates the characteristic heliotropism exhibited during the flower period and *Helianthus annus* was so named by Linnaeus, who encountered sunflowers living only for one season. Cultivated sunflower is an erect, tall, usually unbrached and coarse annual of varying size with conspicuously large inflorescence. Quantitative characteristics such as plant height, head diameter, achene size and days to flowering and maturity vary greatly depending on the environment in which plants grow (Robinson, 1978).

The primary uses of sunflower are for human consumption. The consumption of oil from the seed and use of non-oilseed sunflower are the predominant uses of sunflower products worldwide. There is growing interest for non-oilseed sunflower as snack food in the developed economies. Sunflower also yields natural red food colorant derived from purple-hulled sunflower, flour and protein isolates for food products, pectin and sunflower oil as an energy source in fuels. During 2010-11, sunflower was cultivated in 0.897 million hectares with a production of 0.625 million tonnes and productivity of 696kg/hac. Karnataka accounts for 46% of sunflower area but the productivity is lowest among all the states cultivating sunflower. Among traditional sunflower growing states, Tamil Nadu (1486 kg/hac) has the highest productivity (AICRP Sunflower, 2013)

I. PESTS

A. Pests of National Significance

1. Insect Pests

1.1 Tobacco caterpillar: *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae)

1.2 Head borer: *Helicoverpa armigera* Hübner (Lepidoptera: Noctuidae)

1.3 Jassids: *Amrasca biguttula* Ishida (Homoptera: Cicadellidae)

1.4 Thrips: *Scirtothrips dorsalis* Hood (Thripidae: Thysanoptera)

1.5 Green semilooper: *Thysanoplusia orichalcea* Fabricius (Lepidoptera: Noctuidae)

1.6 Cabbage semilooper: *Trichoplusia ni* (Hubner) (Lepidoptera: Noctuidae)

1.7 Bihar hairy caterpillar: *Spilosoma obliqua* Walker (Lepidoptera: Arctiidae)

1.8 Cutworm: *Agrotis ipsilon* Rott (Lepidoptera: Noctuidae)

1.9 Termite: *Odontotermes obesus* (Rambur) & *Microtermes obeli* Hol (Isoptera: Termitidae)

2. Diseases

2.1 *Alternaria* leaf spot: *Alternaria helianthi* (Hansf.) Tubaki & Nishi

2.2 Sunflower Necrosis disease: *Tobacco Streak Virus*

2.3 Downy mildew: *Plasmopara halstedii* Farl. Berl. & De Toni

2.4 Rust: *Puccinia helianthi* Schwein

2.5 *Sclerotium* wilt: *Sclerotium rolfsii* Sacc

2.6 Charcoal rot: *Macrophomina phaseolina* (Tassi) Goid

2.7 Sclerotinia wilt and rot: *Sclerotinia sclerotiorum* (Lib.) de Bary

B. Pests of Regional Significance

1. Insect Pests

1.1 Whitefly: *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae)

1.2 Armyworm: *Spodoptera exigua* (Hubner) (Lepidoptera: Noctuidae)

2. Diseases

2.1 Head rot: *Rhizopus arrhizus* Fischer

2.2 Powdery mildew: *Erysiphe cichoracearum* f.sp. *helianthi* DC ex Meret and *Sphaerotheca fuliginea* (Schlecht.ex Fr) Pollacci

1. Weeds

3.1 Grassy weeds

3.1.1 Rabbit/crow foot grass: *Dactyloctenium aegyptium* Willd (Poaceae)

3.1.2 Goose grass: *Eleusine indica* L. Gaertner (Poaceae)

3.1.3 Crabgrass: *Digiteria sanguinalis* L.Scop (Poaceae)
3.1.4 Burmuda Grass: *Cynodon dactylon* (L) Pers (Poaceae)
3.1.5 Cannery grass: *Phalaris minor* Retz. (Poaceae)
3.1.6 Barnyard grass: *Echinochloa colona* (L.) Link, *E. crusgalli* (L.) Honda (Poaceae)
3.1.7 Viper grass: *Dinebra retroflexa* (Vahl) Panz (Poaceae)
3.1.8 Sweet signal grass: *Brachiaria eruciformis* (Sm.) Griseb (Poaceae)

3.2 Broad leaf

3.2.1 False amaranth: *Digera arvensis* Forssk (Amaranthaceae)
3.2.2 Pigweed: *Amaranthus viridis* Hook. F. (Amaranthaceae)
3.2.3 Swine cress: *Coronopus didymus* L. Sm. (Brassicaceae)
3.2.4. Black nightshade: *Solanum nigrum* L. (Solanaceae)
3.2.5 Common purselane: *Portulaca oleracea* L. (Portulacaceae)
3.2.6 Carrot grass: *Parthenium hysterophorus* L. (Asteraceae)
3.2.7 Tropical spiderwort: *Commelina benghalensis* L. (Commelinaceae)
3.2.8 Stonebreaker: *Phyllanthus niruri* L. Phyllanthaceae
3.2.9 Silver cockscomb: *Celosia argentea* L. Amaranthaceae
3.2.10 Devil's horsewhip: *Achyranthes aspera* L. Amaranthaceae

3.3 Sedges

3.3.1 Purple nutsedge: *Cyperus rotundus* L (Cypraceae)
3.3.2 Rice flatsedge: *Cyperus iria* L (Cyperaceae)
3.3.3 Yellow nutsedge: *Cyperus esculentus* L (Cyperaceae)

5. Vertebrates

5.1. Birds: Parakeets

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 observe 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 and weather factors
- Farmers past experience

Principles AESA based IPM:

Grow a healthy crop

- Select a variety resistant/tolerant to major pests
- Select healthy seeds/seedlings//planting material
- Treat the seeds/ seedlings//planting material with recommended pesticides especially biopesticides
- Follow proper spacing (60cm(row) x 30cm(plant))
- Thinning at 15-18 DAS to maintain one seedling per hill is critical to reduce intra-plant competition, pest and disease management.
- Soil health improvement (mulching and green manuring wherever application)
- Adequate NPK+ blanced nutrition with on secondary nutrient S and micronutrients B and secondary as per soli test basis is critical for realising higher seed and oil yield of sunflower. 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 adequate nutrients for best results. The phosphatic fertilizers need not be applied each and every season as the residual phosphate of the previous season will be available for the current season also. Use of phosphate solubilising bacteria (PSB) @ 0.4kg/acre is useful. Also dual inoculation of *Azospirillum* and *Azotobactor* would reduce up to 50% N requirement under rainfed conditions.
- Clean cultivation: weed free crop and surrounding areas will help in reducing pest and disease incidence and severity.
- Proper irrigation
- Crop rotation with at least 3-7 non-sunflower crops preferably including legumes.
- Deep ploughing in summer

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

Farmers should

- Monitor the field situation regularly (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 and early instar larvae in gregarious stage, remove infested plants with SND 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.

Understand and conserve defenders

- Know defenders/natural enemies to understand their role through regular observations of the agro-ecosystem
- Use of chemical pesticides as per the need as a last resort to protect the crop

Insect zoo

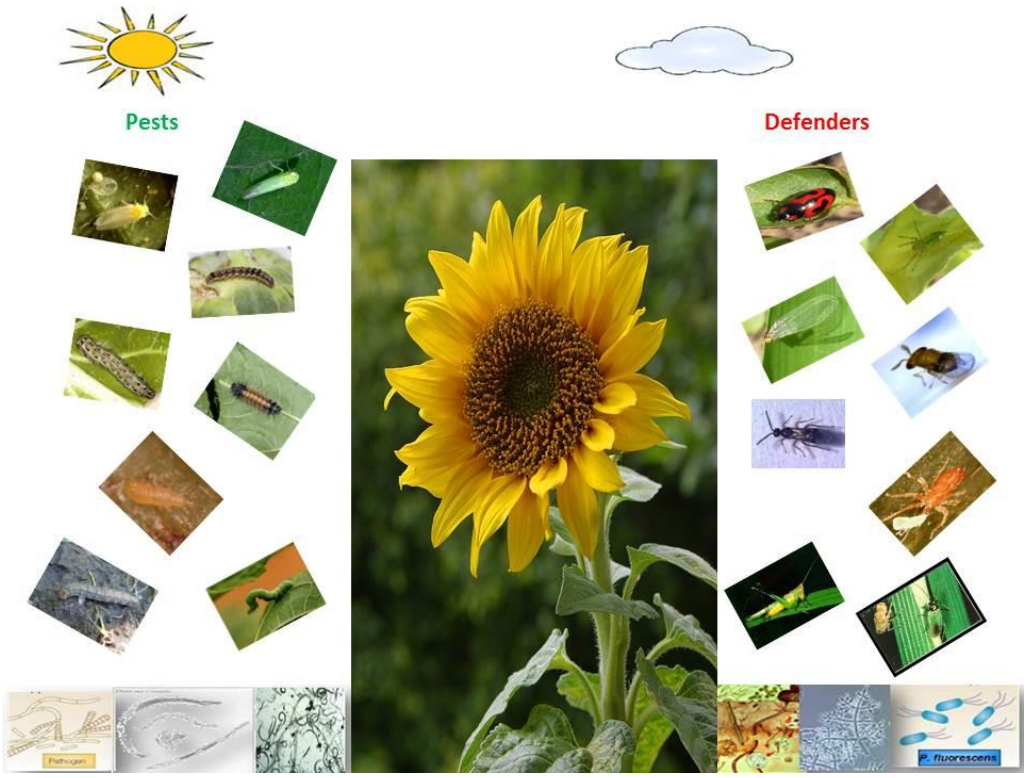
In field various types of insects are present. Some are beneficial and some may be harmful. Predators which feed on pests are not easy to observe in crop field. Insect zoo concept can be helpful to enhance farmers' skill to identify beneficial and harmful insects. In this method, predators are collected in plastic containers 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 Pest: Defender ratio (P:D ratio) can vary depending on the feeding potential of natural enemy as well as the type of pest. The natural enemies of Sunflower insect 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.
    - Weeds: Observe weeds in the field and their intensity.
    - Water: Observe the situation of the field/soil moisture.
    - Weather: Observe the weather condition and forecasts.

- 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, soil moisture 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

- Keep records of what has happened
- Help us making an analysis and draw conclusions

Data to be recorded

- **Check plant growth (weekly):** 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 build up?
- What are the 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 limitations of the ETL is that it is based on parameters that are changing all the time, and many are often not known. The damage or losses caused by a certain density of insects cannot be predicted precisely implied. In ETL, the role of natural enemies in decreasing pest population. 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 experience and economic and social situation before they can make the right crop management decisions. In AESA based IPM emphasis is given to natural enemies, plant compensation ability, abiotic factors and P: D ratio.

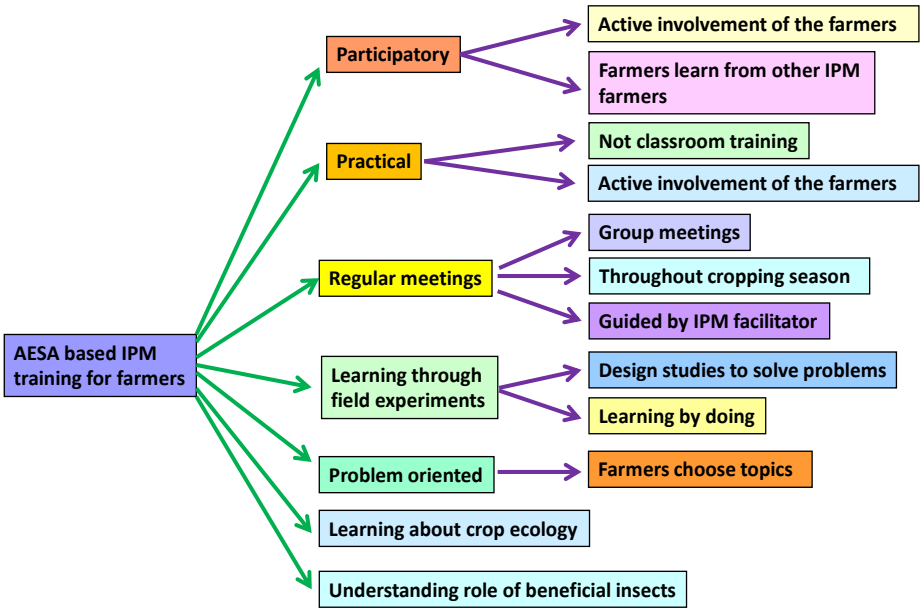
AESA and farmer field school (FFS)

AESA is a season-long training activity that takes place in the farmer field. It is season-long so that it covers 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 build up
- 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 (four in the corners, at least 5 feet inside of the field borders, and one in the centre). Select five random plants at each spot for recording counts of insects as per procedure finalized for individual insects.

For insect pests

Whitefly: Count and record the number of both nymphs and adults on five randomly selected leaves per plant.
Thrips: Count and record the number of nymphs and adults of thrips present on five terminal leaves per plant (tapping method also can be used to count thrips).
***Spodoptera*:** Count the number of young and grown up larvae on each plant and record.
Capitula/ *Helicoverpa*: Total number, damaged due to *Helicoverpa* and number of larvae on individual plants should be counted and recorded.
Cut worm: Count and record the number of grubs and adults present in ear head

For diseases:

Whenever scouting, be aware that symptoms caused by different biotic factors such as fungal, bacterial, viral pathogens or abiotic factors such as weather, fertilizers, nutrient deficiencies, pesticides and 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). 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 pseudo/stem damaged/infested/infected due to rot should 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 the number of leaves (leaf area diameter)/plant infected due to disease and incidence should be recorded.

Stem and capitulum sampling: Carefully examine the stems and capitulum of plants for signs of fungal material diseases or lesions. The stems and capitulum should be split or taken apart and examined for discoloration caused by fungi and bacteria. Count the number of stems and capitulum infected due to disease and incidence should be recorded.

C. Surveillance through pheromone traps: Pheromone traps for two insects viz., *Helicoverpa armigera* and *Spodoptera litura* @ 4/acre have to be installed. Install the traps for each species separated by a distance of >75 feet in the vicinity of the selected fixed field. Fix the traps to the supporting pole at a height of one foot above the plant canopy. Change of lures should be made once a month. During each week of surveillance, the number of moths/trap should be counted and entered.
Procedure for observation: Total number of moths of *Helicoverpa armigera* and *Spodoptera litura* / trap/week should be recorded year round. The trapped moths should be destroyed and removed after each recording.

D. Yellow/ blue pan water trap

Set up yellow pan water trap/sticky traps 15 cm above the canopy for monitoring whitefly and blue sticky trap for thrips @ 4-5 traps/acre. Locally available empty tins can be painted yellow/ coated with grease/Vaseline/castor oil on outer surface may also be used.

E. 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).

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. Ecological engineering for pest management is based on informed ecological knowledge rather than high technology approaches such as synthetic pesticides and genetically engineered crops (Gurr et al. 2004).

Ecological Engineering for Pest Management – Below Ground:

There is a growing realization that the soil borne, seed and seedling borne diseases can be managed with microbial interventions, besides choosing appropriate plant varieties. The following activities increase the beneficial microbial population and enhance soil fertility.

- 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 of beneficial microbes and insects.
- Application of balanced dose of nutrients using biofertilizers based on soil test report.
- Application of biofertilizers with special focus on mycorrhiza and plant growth promoting rhizobia (PGPR)
- Application of *Trichoderma harzianum/ viride* and *Pseudomonas fluorescens* for treatment of seed/seedling/planting materials in the nurseries and field 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).

Ecological Engineering for Pest Management – Above Ground:

Natural enemies play a very significant role in control of foliar insect pests. Natural enemy diversity contributes significantly to management of insect pests both below and above ground.

Natural enemies may require:

1. Food in the form of pollen and nectar.
2. Shelter, overwintering sites and moderate microclimate, etc.
3. Alternate hosts when primary hosts are not present.

In order to attract natural enemies following activities should be practiced:

- 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 such as *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.

- Reduce tillage intensity so that hibernating natural enemies can be saved.
- Select and plant appropriate companion plants which could be trap crops and pest repellent crops. The trap crops and pest repellent crops will also recruit natural enemies as their flowers provide nectar and the plants provide suitable microclimate.

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

Plants suitable for Ecological Engineering for Pest Management

Attractant plants

Cowpea

Carrot

Marigold

Buckwheat

French bean

Alfaalfa

Mustard

Cosmos

Anise

Caraway

Dill

Parsley

White Clover

Tansy

Yarrow

Repellent plants

***Ocimum* sp**

Peppermint/Spearmint

Barrier plant

Rye grass

Border plants

Maize

Sorghum

Crop rotation plants

***Sesbania* sp.**

***Crotalaria* sp.**

***Gaillardia* sp.**

Castor

Desmodium

Potato

Trap plants

Tomato

Marigold

Pearl millets

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

IV. Resistant/tolerant varieties

Pest	Tolerant/ Resistant Variety
Resistant Hybrids to Powdery mildew	KBSH-53

***For detailed information and further updates nearest KVK/State department/SAU / ICAR Institute may be contacted**

V. CROP STAGE WISE IPM

Management	Activity
Pre-sowing*	
	Common cultural practices: • Deep ploughing during summer exposes the pests and weeds to high temperature and reduces their load present in the soil. • Crop rotation of 3-4 years reduces soil borne diseases • Adopt timely sowing should be done. • Keeping field bunds and crop free of weeds to avoid high pest load as it favours the pest build up on the main crop.
Nutrients	• Incorporate 3-4 t/acre of well decomposed FYM or compost or crop residues treated with *Trichoderma* 2-3 week prior to sowing. • Do not leave FYM or compost exposed to sunlight as nutrients may be lost. • Apply adequate and balanced nutrients along with organics as per soil test basis.
Weeds	• At the time of field preparation, adopt stale seed bed technique i.e. pre sowing irrigation followed by shallow tillage to minimize the weeds menace in field. Adopt integrated weed management to reduce weed competition.
Soil borne diseases (Downy mildew, Charcoal rot, *Sclerotium* wilt, *Alternaria* leaf spot, Rust) and Sunflower necrosis virus	**Cultural control:** • Uproot and burn infected plants early enough to avoid spread of the disease. • Effective weed control. • Maintain good fertility levels. • Place the seeds at a depth of 3 cm along the furrows in which the fertilizer mixture is placed and cover with soil. Put two seeds per hole at the rate of 1.6-2.8Kg/acre based on irrigated and rainfed land.

Thrips	**<u>Cultural control:</u>** • Mixed cropping of sunflower with cotton • Growing of sorghum/pearl millet/maize 10 days before sowing of main crop 5-7 rows as a barrier against thrips
Termite	**<u>Cultural control:</u>** • Destroying queen by digging it out from the termitorium in red soil areas. • Field sanitation and use of fully decomposed FYM mixed with wood ash will reduce termite activity
Sowing/Seedling*	
	<u>Common cultural practices:</u> • Application of balanced dose of NPK fertilizers • Use healthy, clean, quality, certified and weed free seeds. • Timely sowing with recommended spacing • Use tolerant/resistant varieties • Sow trap crops like marigold at@50 plants/acre **<u>Common mechanical practices:</u>** • Collection and destruction of plant debris • Use of pheromone traps @4-5 traps/acre • Set up of light traps @1trap/acre • Set up yellow sticky traps @4-5traps/acre coated with grease/sticky oily materials. • Collect and destroy egg masses, larvae and damaged leaves in early stage
Nutrient management	• For efficient use of applied fertilizers, adopt fertilizer cum seed drill. • Seed treatment should be done with *Azotobactor /Azospirillum* and PSB @ 250 g /acre and VAM inoculum @ 1Kg /acre as soil application. • Fertilizers should be applied on soil test basis. Generally, it is recommended to apply NPK @ 25, 20 and 16 Kg /acre. • Apply 50% of N and full dose of P &K preferably in the form of band placement at the time of sowing. • Apply Sulphur @10-15 Kg/ acre through gypsum or Single Super Phosphate (SSP). • Prefer SSP as source of Phosphorous as it also supply Sulphur to the crop. • In boron deficient soils, apply boron @ 400 g / acre (4.5 Kg borax per acre) in alternate years. • In saline soils, sow sunflower on ridges and apply additional N @ 8 Kg/ acre. • Spray boron @0.2% as directed spray to capitulum at ray floret

	opening stage.
Weed management	• Line sowing should be done to facilitate inter-culture operations. • Plant population should be maintained to its optimum right from beginning to minimize the weeds competition. • Adopt crop rotation and follow Inter cropping with recommended short duration cereals/ millets/pulse/oil seed crops e.g. black gram, finger millet, soybean, groundnut etc. to suppress weeds between rows.
Cutworm	**Cutural control:** • Sowing sunflower seeds on ridges (6-8 cm height), in cutworm endemic areas **Biological control:** • Release of *Trichogramma chilonus*@ 20000/acre.
Jassids	**Cultural control:** • Close spacing reduces pest infestation particularly if the rainfall is heavy. • Apply adequate amount of nitrogen • Mixed cropping of sunflower with cotton • Intercropping sunflower with groundnut in the ratio(1:4) **Mechanical control:** • See the common mechanical practices **Biological control:** • Conserve coccinellids like *Brumus suturalis, Chilochorus nigritus, Coccinella septumpunctata, Menochllus sexmaculata, Scemnus nubillus* • Predatory lygaeid *Geocoris tricolor* and *Anthocoris* sp., • Several mantids like *Eumantissa giglio, Cariagrion coromandeliorum, Ichneura* sp.*, Dolichopus* sp. *and Therevia* sp. • Release predators viz., *Chrysoperla zastrowi* sillemi **Chemical control:** • Seed treatment with imidacloprid 48% FS @ 5-9ml/Kg seed and imidacloprid 70% WS @ 7ml/ Kg seed. • Spray imidacloprid 17.8% SL @40ml/acre diluted in 200 lit of water.
Thrips	• As mentioned above in the pre-sowing stage.

White fly**	**Cultural control:** • Intercropping sunflower with groundnut in the ratio of 1:4 **Mechanical control:** • Use of synthetic pyretheroids decreases the intensity of Whitefly. **Biological control:** • Spray neem product (5% Neem oil before egg laying) or 5 Kg/acre neem kernel extract with any sticky material **Chemical control:** • Seed treatment with imidacloprid 48% FS@5-9ml/Kg seed and imidacloprid 70% WS 7ml/ Kg seed. • Spraying of imidacloprid 17.8% SL @ 40ml/acre diluted in 200 l of water. or • Spraying of malathion 50% EC @400 ml/acre diluted in 200-400 l of water.
Tobacco caterpillar	**Cultural control:** • Intercropping sunflower with pigeonpea **Mechanical control:** • See the common mechanical practices **Biological control:** • Conserve natural enemies such as the egg parasitoid, *Trichogramma evanescens minutum*, larval parasitoids, *Aponteles prodeniae*, *Cotesia* sp., *Peribaea* sp. predatory stink bug, *Cantheconidia furcellata* and pupal parasitoids, *Tetrastichus ayyari, Metopius* sp. and *Trichospilus pupivora* are important. • Several general predators like spiders, *chrysoperla*, predatory bugs, insectivorous birds etc • Spray 5% neem seed kernel extract @5Kg/acre preferably in the evening. • Spray SLNPV @ 100LE/acre for parasitizing the larvae. (SLNPV @ 100 LE/acre with 0.2% kernel is more effective) • Apply *Bacilus thuringiensis* and *Radius cereus* for the management of this pest in the field • Spray *Cierodedrum inerme* dust (25%) and plant extracts (10%) **Chemical control:** • Spray dichlorvos 76% EC @ 250ml/acre diluted in 200- 400 l of water.
Sunflower	**Cultural control:**

necrosis disease	• Clean cultivation by removing the weeds specially *Parthenium, Cammelina* etc both inside and neighbouring plots • Follow optimum plant population in the field • Rouging of infected plants before flowering. Grow 3-5 rows of sorghum as border crop.
Downy mildew	**Cultural control:** • Use downy mildew resistant hybrids LSH-1 and LSH-3 for endemic pockets of Maharastra. Most of the recently released hybrids viz., BSH-1, KBSH-1, MSFH-17, DSH-1, SPIC-105 are resistant to downy mildew. • Remove volunteer sunflower plants, *Parthenium* weed around around the field and clean cultivation. • Shollow sowing (3 cm) is desirable to avoid downy mildew. • Pre sowing irrigation followed by one irrigation at 10 or more days after sowing reduces disease • Rouging of mildew infected seedlings during thinning, removal and destruction of infected plants. • Crop rotation in sunflower with groundnut/ sorghum/ pigeonpea for six-years. **Chemical control:** • Seed treatment with metalaxyl-M 31.8% ES & metalaxyl 35% WS @ 2g/Kg and 6g/Kg seed has been found to give effective control.
Charcoal rot	**Cultural control:** • Avoid moisture stress and high temperature
***Alternaria* leaf spot**	**Cultural control:** • Early planting during *kharif* escapes from the leaf spot • Occurrence and severity of the disease depend on the season and planting dates. • Mid-September planting of sunflower remains free from most of the major diseases including *Alternaria*. • Intercropping of sunflower with groundnut in the ratio of 6:2 reduces leaf spot. • Spacing of 60 x 30cm or 45 x 30cm is optimum in reducing the buildup of leaf spot
Sclerotium wilt	**Cultural control:** • Avoid moisture stress.
***Sclerotinia* wilt and rot**	**Cultural control:** • Soil amendment with farm yard manure @ 5 tonnes/acre • Avoid moisture stress during high summer and water logging conditions **Biological control:** • Seed treatment with *Trichoderma. viride* 6g/Kg seed. • Addition of *Trichoderma harzianum* in soil at 10g/kg and soil amendments like castor cake, neem cake, oat straw reduces

	disease incidence
Note: Apply *Trichoderma viride/harzianum* and *Pseudomonas fluorescens* for treatment of seeds/seedlings/planting materials in the nurseries and field 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 stage	
	<u>Common cultural practices:</u> • Avoid water stagnation in the field/ moisture stress • Removal and destruction of crop residues, volunteer sunflower plants reduce the disease severity • Maintain one seedling per hill by thinning at 10-15 days after germination. **<u>Common mechanical practices:</u>** • Optimum plant population has to be maintained • Apart from hand-pick and destruction of young larvae of *Agrotis* spp . feeding gregariously on foliage. • Set up light trap @1 trap/acre to attract and kill adults. • Set up pheromone traps @4-5 traps/acre • Install bird perches @ 20/acre
Nutrient	• In dry lands, top dress of rest of nitrogen around 30 days after sowing depending on rainfall and soil moisture preferably at the time of inter-culture. • For the irrigated crop, apply remaining nitrogen in two equal splits, first at 30 days after sowing and second at 30 days thereafter. • Depending on specific deficiencies and based on soil test values, take up micronutrient correction.
Weed	• Very shallow tillage after one week of sowing with spike tooth harrow/coil spring harrow/rotary hoe before germination of sunflower seeds. • Two hoeing or hand tool weeding at 20-25 days and 35-40 days after sowing . • Mulches like straw hay, black polyethylene etc. can be used in between the rows to suppress the weed growth .provided intercrops not grown.
Jassids	• As mentioned above in the sowing stage.
Thrips	• As mentioned above in the pre-sowing stage.
Tobacco caterpillar	**<u>Cultural control:</u>** • Hand collection and destruction of egg masses and skeletonized leaves along with first and second instar gregarious larvae. • As mentioned above in the seedling stage.
Green semilooper	**<u>Mechanical control:</u>** • See the common mechanical practices **<u>Biological control:</u>**

	• Conserve natural enemies such as egg parasitoids like *Trichogramma* spp, larval parasitoids like *Cotesia* spp, *Apanteles ruficrus*, *A.africanus*, *Euplecturs ceylonensis*, *Campoletis chloridae*, *Exorista xanthaspis*, *Copidosoma ftoridanum*, *Disophrys lurea* and *Enicospilus* sp. • General predators like lady bird beetles, *chrysoperla*, mantids and spiders • A few birds also predate such as ashy wren warbler, tailor bird, green leaf warbler black drongo and house sparrow **Chemical control:** • Spraying of dichlorvos 76% EC @250ml/acre diluted in 200- 400 l of water.
Cabbage semilooper	**Biological control:** • Spray 5% neem seed and kernel extract @5Kg/acre preferably in the evening.
Bihar hairy caterpillar	**Cultural control** • Use of well rotten manures. • Intercropping with pigeon pea at a row ratio of 2:1 is effective in reducing the insect attack. • Hand collection and destruction of egg masses and skeletonized leaves along with first and second instar gregarious larvae. **Biological control:** • Conserve parasite such as *Champs obtusus* and *Meteorus clichomerictis* • Spray 5% neem seed kernel extract @ 5Kg/acre preferably in the evening. **Chemical control:** • Spray cypermethrin 10% EC @260-300ml/acre diluted in 200 – 260 l of water.
Capitulum borer	**Cultural control:** • Sow 3- 4 lines of maize around the sunflower crop to monitor the moth. • Intercropping with pigeonpea, groundnut, finger millet and soybean. **Mechanical control:** • See the common mechanical practices **Biological control:** • Release predators like Coccinellids, *Chrysoperla zastrowi* sillemi @ 1 larva/ head, *Menochilus sexmaculata* • Release parasitoides like *Trichogramma* spp. @ (20,000/acre), *Bracon* spp., *Campoletis* spp. • Spray HaNPV 100 LE + Bt @0.2Kg/acre for effective control. • Spray HaNPV 100 LE/acre + 0.4 Kg Jaggery + 80ml Sandovit (or) Teepal; mixing and spray in the evening hours only. • Spray 5% neem oil or 5% neem seed kernel extract @5Kg/acre • Natural enemies as well as honey bees.

	• Spray *Clerodendrum inerme* dust (25%) and plant extract (10%)
White fly**	• As mentioned above in the sowing stage.
Downy mildew	• As mentioned above in the sowing stage
***Alternaria* leaf spot**	• As mentioned above in the sowing stage
Rust	**Cultural control:** • Avoid high nitrogen rates and high plant populations.
Sunflower Necrosis	• As mentioned above in the sowing stage
Sclerotinia wilt and rot	• As mentioned above in the sowing stage
Charcoal rot	• As mentioned above in the sowing stage
Powdery mildew**	**Cultural control:** • Wild species of sunflower i.e., *Hellanthus debilis, H.californicus, H. ciliaris, H.decapetalus L., H.lacinatus* and *H. rigidus* show resistance to powdery mildew **Mechanical control:** • See the common mechanical practices
Flowering/Seed formation stage	
Nutrient Management	• Spray of boron (0.2%) to capitulum at ray floret opening stage. Incorporate crop residues in soil immediately after harvest.
Weed management	• Remove left over weeds to prevent weed seed spread in field. • .
Tobacco caterpillar	• As mentioned above in the sowing stage.
Bihar hairy caterpillar	• As mentioned above in the vegetative stage
Capitulum/Head borer	• As mentioned above in the vegetative stage
***Alternaria* leaf spot**	• As mentioned above in the sowing stage
Rust	• As mentioned above in the vegetative stage
Head rot**	**Cultural control:** • Avoid injury to flower head due to mechanical operations
Birds**	**Cultural control:** • Grow sunflower in large continuous area to minimise localised damage. **Mechanical control:** • Apart from employing labour for bird scaring, use polypropelene metallic shining reflective bird scaring ribbon (Agni strip) with red/yellow on one side and silver white on other side of 10-15 meter length at 4 to 8 meters distance (20-24/acre)
Storage	
Store grain insect pests and seed mycoflora	• Moisture content of seeds should not exceed 6.5% and relative humidity of storage containers should not exceed 70% to minimise losses due to insect pests and fungi during storage.

Note: The pesticide dosages and spray fluid volumes are based on high volume spray.

** Pests of regional significance

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

Nutrients	Fig.
Nitrogen: Little new growth, yellow leaves: this being more pronounced in older leaves. Earlier fall leaf drop. New shoots may be red to red-brown.	
Phosphorous: Overall dark green with purple, blue or reddish cast to leaves particularly on underside, veins and stems and some plants respond to lack of P with yellowing. Foliage may be sparse, small and distorted becoming mottled and bronzy with maturity. Excess foliage with no flowers can also indicate lack of P.	
Potassium: Sickly looking plants, undersized flowers and seeds, leaves showing marginal and interveinal yellowing. Yellowing starts on older leaves and progresses upwards. Leaves may crinkle, turn brown and roll upwards. Blossoms may be distorted and small. Plant has little resistance to heat, cold and disease problems.	
Sulphur: Plants showing paling/yellowing of leaves. Yellowing spreads from the base to the apex. Growth of plants is reduced. The size of capitulum is severely restricted. Inflorescence may remain covered within the bracts. Maturity of flowers is delayed.	

Boron: Under severe deficiency at about 3 weeks growth, young and middle leaves of plants develop small chlorotic patches. Cotyledons of these plants become massive and the shoot apex becomes globose and deformed. Later, chlorotic patches become more pronounced and develop orange coloured necrotic areas in young leaves. Shoot apex may turn necrotic and cease to grow. Young leaves show severe curling and distortion. This leads to appearance of side branches bearing small leaves. Eventually all the young leaves turn necrotic. For remedy, give directed spray of 0.2% Borax (2g/l of water) to capitulum at ray floret opening stage.	
Calcium: Young leaves are small and distorted with curled back leaf tips. Shoots may be stunted and show some dieback, reduced roots and shoot development. Small distorted leaves near branch tips, and terminal buds blacken and fail to continue to develop and reduces the seed formation.	
Zinc: Light yellow stripes along with veins of leaf blade. Under acute condition-vein chlorosis and cessation of growth of terminal bud. Older leaves may show slight chlorosis. Apply foliar spray of ZnSO4@0.5%.	
Iron: Yellowing of young leaves; interveinal chlorosis. Apply foliar spray of FeSO4@0.5%.	

VIII. COMMON WEEDS

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

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

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

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

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

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

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

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

9. Carrot grass: *Parthenium hysterophorus* L. Asteraceae

10.Common purselane: *Portulaca oleracea* L. Portualacaceae

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

12.Cannery grass: *Phalaris minor* Retz. (Poaceae)

13.Barnyard grass: *Echinochloa colona* (L.) Link, *E. crusgalli* (L.) Honda (Poaceae)

14. Viper grass: *Dinebra retroflexa* (Vahl) Panz (Poaceae)

15.Sweet signal grass: *Brachiaria eruciformis* (Sm.) Griseb (Poaceae)

16.Tropical spiderwort: *Commelina benghalensis* L. (Commelinaceae)

17.Stonebreaker: *Phyllanthus niruri* L. Phyllanthaceae

18. Silver cockscomb: *Celosia argentea* L. Amaranthaceae

19. Devil's horsewhip: *Achyranthes aspera* L. Amaranthaceae

20. Rice flatsedge: *Cyperus iria* L (Cyperaceae)

21.Yellow nutsedge: *Cyperus esculentus* L (Cyperaceae)

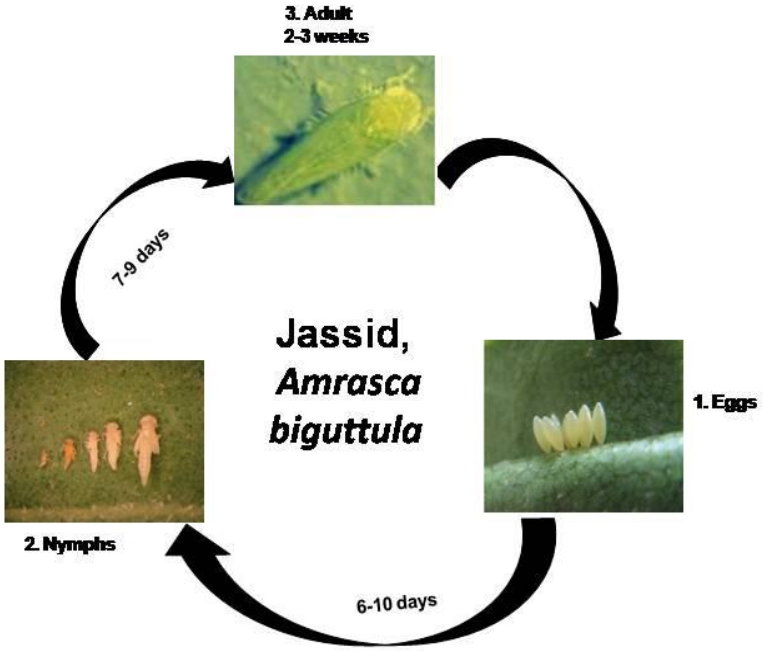
IX. DESCRIPTION OF INSECT PESTS

1. Sunflower Jassids:

Biology: Adults are greenish yellow, wedge shaped with a pair of black spots on vertex and a black spot on each of the forewings. Nymphs pale greenish almost translucent and walk diagonally.

- **Egg:** The female lays eggs inside the leaf veins in the paranchymatous tissues. On an average, each female will lay 10 to 15 eggs. The incubation period varies from 4 to 11 days.
- **Nymph:** Nymphs are greenish yellow. The nymphal period occupies about 7days in summer and 21 days in winter.
- **Adult:** Adults are greenish yellow, wedge shaped with a pair of black spots on vertex and a black spot on each of the forewings. Adults survive for about 5 weeks in summer and 7 weeks in winter.

Life cycle:



1.http://zaraimedia.com/wp-content/uploads/2013/08/jassid5.jpg
2,3.G:\Sunflower\Sunflower Jassid UAS Raichur.htm

Damage symptoms:

- The incidence starts from seedling stage and prevails right through entire crop growth period.
- Both nymphs and adults suck the cell sap from under surface of leaves and cause stunted growth of plant , yellowing, cupped and crinkled leaves, burnt appearance of leaf margins or entire leaf called 'hopper burn' are symptoms of damage.

Damage symptom

G:\Sunflower\Sunflower Jassid UAS Raichur.htm

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

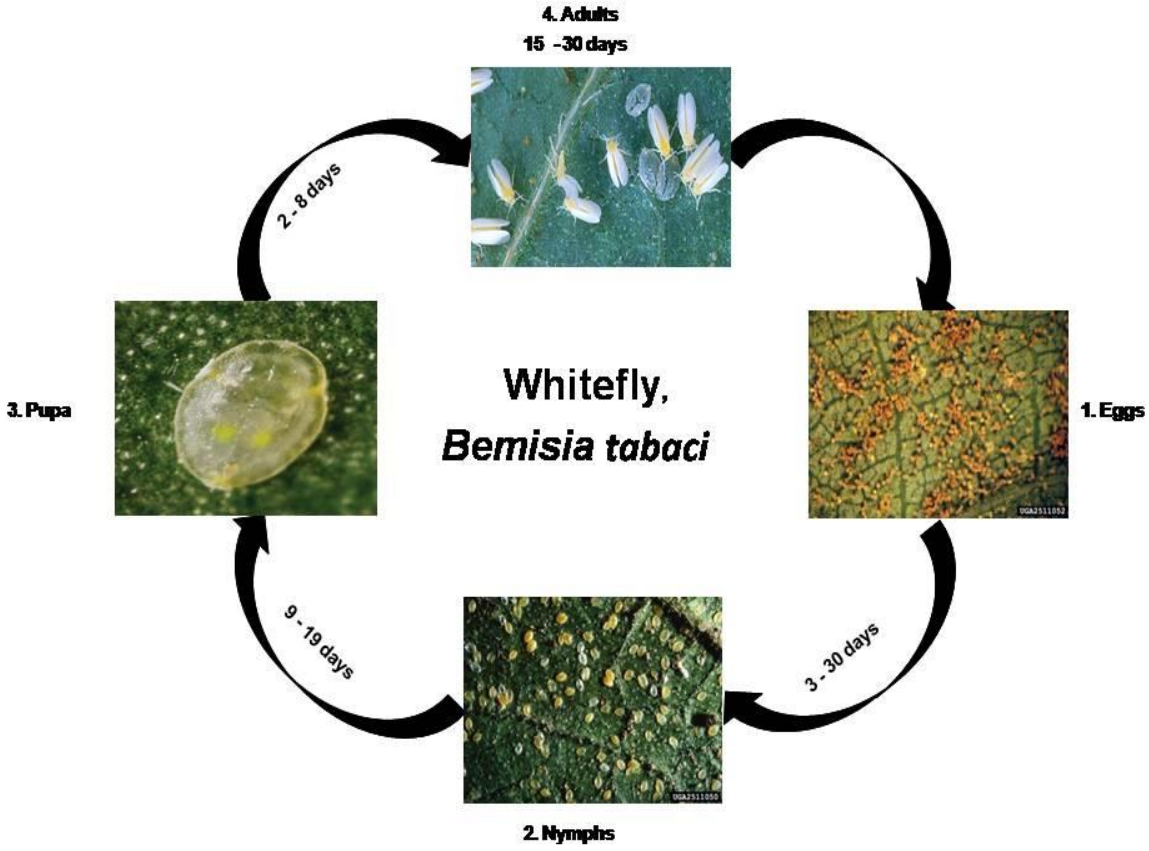
2.Sunflower Whitefly:

Biology:

Nymphs are oval, scale like and remain attached to the leaf surface. Adults are tiny, moth like with yellowish body and wings coated with milky white waxy powder.

- **Egg:** Pear shaped, light yellowish Stalked
- **Nymph:** On hatching Oval, scale-like, greenish white
- **Adult:** White, tiny, scale-like adult

Life cycle:



1. http://animal.memozee.com/Arch03/1132935290.jpg
2. http://www.forestryimages.org/images/192x128/2511050.jpg
3 http://www.fera.defra.gov.uk/plants/publications/documents/factsheets/bemisia.pdf
4. http://www.entomology.umn.edu/cues/inter/inmine/Whitefg.html

Damage symptoms:

- Nymphs and adults suck sap and excrete honeydew.
- A secondary infection develops when a black sooty mould fungus grows on the sticky honeydew.

- There are no visible damage symptoms with low numbers of whiteflies.
- Under very heavy infestations, plants lose vigour and damage is manifested under severe moisture stress, causing leaf wilting and failure to set seed.

Damage symptom

http://uasr.agropedia.in/content/sunflower-whitefly

Favourable conditions:

- Warm weather conditions are favourable for multiplication.

Natural enemies of whitefly:

Parasitoids: *Encarsia formosa, Chrysocharis pentheus*, *Eretmocerus* spp.

Predators: Mirid bug, green lacewing, lady beetle, big-eyed bugs

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

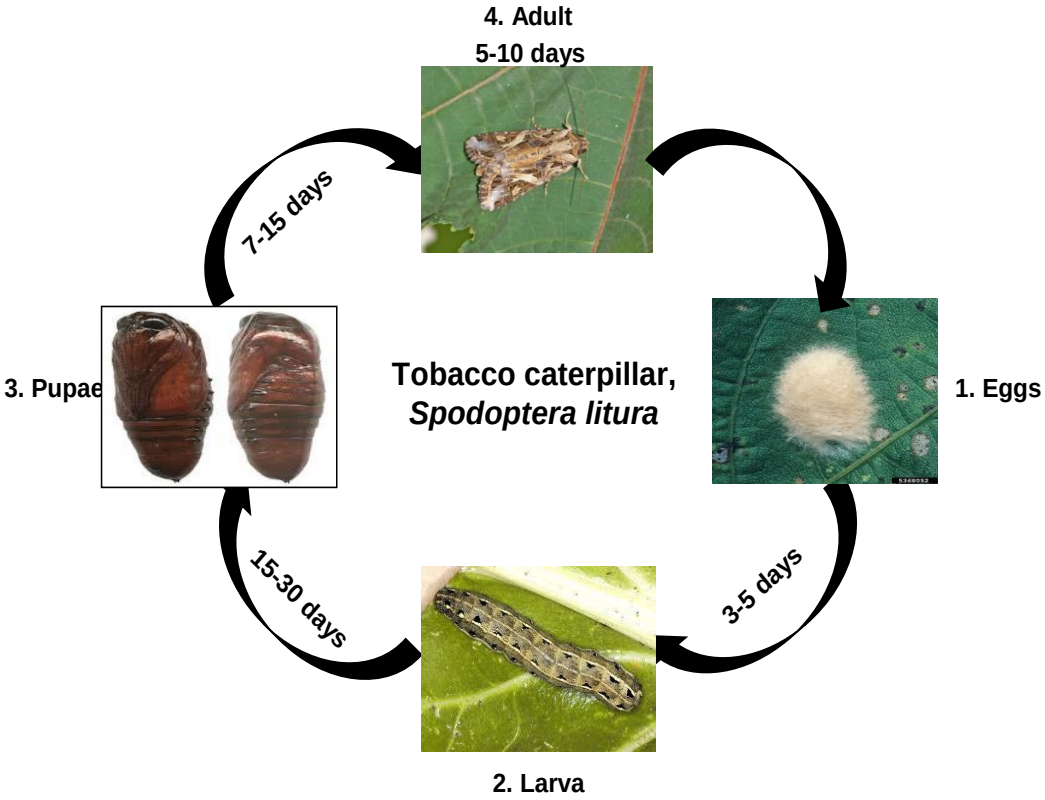
3.Sunflower Tobacco caterpillar:

Biology:

It is found throughout the tropical and subtropical parts of the world, wide spread in India. Besides tobacco, it feeds on sunflower, cotton, castor, groundnut, tomato, cabbage and various other cruciferous crops.

- **Egg:** Female moth lays eggs in a mass on the under surface of leaves and covers them with brown hairs. The female lays 500 to 600 eggs which will hatch in 4-5 days.
- **Larva:** Grown up larva is stout, cylindrical, pale greenish brown with dark markings. Some have transverse and Longitudinal grey and yellow bands and others have rows of dark spots. It feeds during night time**.** On an average, larval_ period lasts for 2-3 weeks**.**
- **Pupa:** Pupation occurs in soil in an earthen cocoon at 5 cm depth or Leaf debris and adults emerge in 6-7 days
- **Adult:** The moth is stout, dark with wavy white markings on the forewings and white hind wings, margin having a brown colour. The total life cycle is completed in 30 to 40 days

Life cycle:



1. http://commons.wikimedia.org/wiki/File:Spodoptera_litura_egg_mass.jpg
2. http://lepidoptera.butterflyhouse.com.au/lynf/lynf.html
3. http://www.ccs-hk.org/DM/butterfly/Noctuid/Spodoptera-litura.html
4. http://www.nbaii.res.in/insectpests/images/Spodoptera-litura11.jpg

Damage symptoms:

- Initially, the neonate larvae feed gregariously on a single leaf on underside of leaves giving "mesh" like appearance to leaves.
- The full grown larva will feed voraciously on leaf leaving petiole and stalk during night time.
- It is reported to cause severe damage to the crop by damaging leaves, flower buds and capitulum whenever there is sever outbreak.

Damage symptom

http://uasr.agropedia.in/content/sunflower-tobacco-caterpillar

http://www.agritech.tnau.ac.in/crop_protection/crop_prot_crop_insect_oil_sunflower.html

Favourable conditions:

- Warm weather conditions and rainy conditions are favourable for multiplication.

Natural enemies of tobacco caterpillar:

Parasitoids: *Trichogramma* spp., *Tetrastichus* spp., *Telenomus* spp., *Chelonus* spp., *Bracon* spp., *Ichneumon* spp., *Carcelia* 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 management refer to page number----------

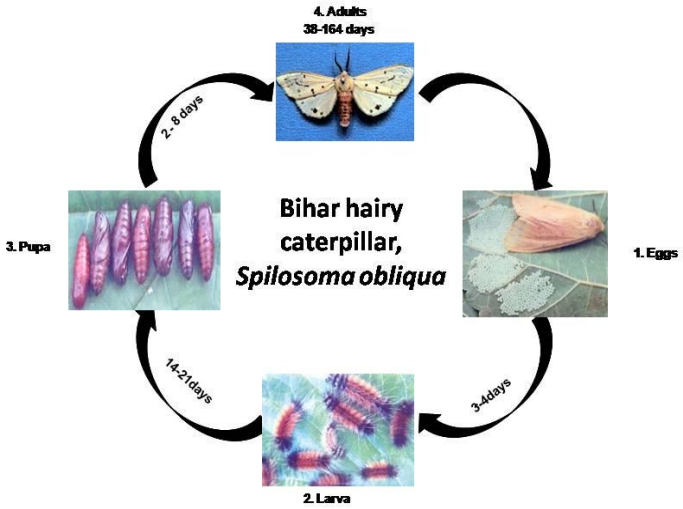
4.Bihar hairy caterpillar:

Biology:

This pest occurs during October to December and of late it is also occurring from July. In recent years, it has become an important pest on sunflower also.

- **Egg:** Female moth lays eggs in masses on lower surface of leaf which hatch within 3-4 days.
- **Larva**: Larvae are hairy, gregarious in early instars (up to 14 days after egg-hatch), later disperse, fully grown larva are of 5 cm long. The larvae are pale yellow coloured with dark yellow hair over the body. Larval period varies from 14 -21 days
- **Pupa**: Pupation takes place at 10-20 cm depth in soil
- **Adult:** Adult moth has reddish black spots on both the pinkish wings. The life cycle of the pest occupies 38 days at 30 °C.

Life cycle:



1,2. http://uasr.agropedia.in/content/sunflower-bihar-hairy-caterpillar
3,4. https://www.google.co.in/search?q=Bihar+hairy+caterpillar+in+sunflower

Damage symptoms:

- Young larvae feed gregariously mostly on the under surface of the leaves.
- Caterpillars feed on leaves and in severe infestation the whole crop is defoliated.
- Drying up of infected leaves is the main symptom

Damage symptom

http://www.agritech.tnau.ac.in/crop_protection/crop_prot_crop_insect_oil_sunflower.html.

Natural enemies of bihar hairy caterpillar:

Predators: *Chrysoperla*, Coccinellids

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

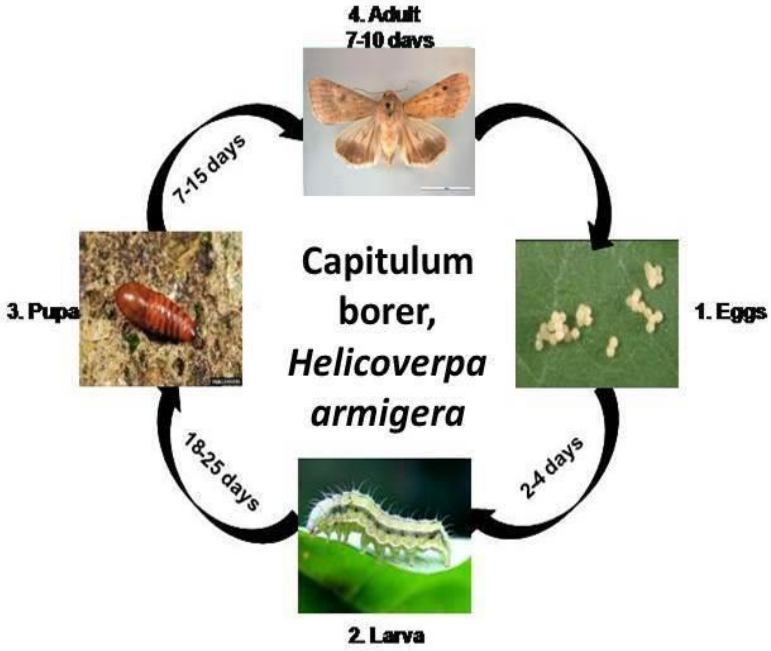
5.Capitulum borer:

It is polyphagous, infesting gram, lablab, safflower, sunflower, chillies, groundnut, tobacco, cotton etc.

Biology:

- **Egg:** Eggs of *H.armigera* are nearly spherical, with a flattened base, giving dome shaped appearance, the apical area surrounding the micropyle is smooth, the rest of the surface sculptured in the form of longitudinal ribs; at first yellow-white, glistening, changing to dark brown before hatching. The diameter of the egg ranges from 0.40 to 0.55 mm. The incubation period of the egg is longer in cold weather and shorter in hot weather, it ranges from 2 to 5 days
- **Larva:** The newly hatched larva is translucent and yellowish white in colour, with faint yellowish orange longitudinal lines. The head, thoracic and anal shields and legs are brown and the setae dark brown in colour. The full grown larva is about 35-42 mm long, the general body colour is externally variable, and the pattern may be in shades of green, straw yellow, and pinkish to reddish brown or even black with one broken stripe along each side of the body and one line on the dorsal side. The larval period vary from season to season, place to place and crop to crop.
- **Pupa:** Pupation occurs in earthen cocoons in the soil which is 14 to 18 mm long, smooth with mahogany brown colour with two tapering parallel spines at the posterior tip. Pupal period varies due to weather conditions and ranges from 5 to 8 days.
- **Adult:** Each female moth can lay on an average of 700-1000 eggs. The female moth is a stout bodied with wing span of 40 mm whereas, male is smaller with wing span of 35 mm. The moth has v-shaped speck on the light brownish forewings and dark borders on the hind wings. Tufts of hairs are present on the tip of the abdomen in female.

Life cycle:



1. http://www7.inra.fr/hyppz/RAVAGEUR/6helarm.htm
2. http://www.infonet-biovision.org/default/ct/120/crops
3. http://www.invasive.org/browse/subinfo.cfm?sub=9408
4. http://en.wikipedia.org/wiki/Helicoverpa_armigera

Damage symptoms:

- Young larva feeds on the leaves for some time and then attacks flower head. Internal tissues are eaten severely and completely hollowed out. While feeding the caterpillar thrust its head inside leaving the rest of the body outside.
- Bore with round holes.
- Feed leaves, shoots and buds.
- The activity of *Helicoverpa* starts on sunflower, summer vegetables and maize and continues their generation by Aug-Sept months synchronizing with main crop.

Natural enemies of captiulum borer:

Parasitoids: *Trichogramma* spp,*Tetrastichus* spp, *Chelonus* spp, *Telenomus* spp, *Bracon* spp, *Ichneumon* spp, *Carcelia* spp,*Campoletis* spp, *Senometopia illota*

Predators: Lacewing, lady beetle, spider, fire ant**,** dragon fly, robber fly, reduviid bug, praying mantis**,** black drongo, wasp, common mynah

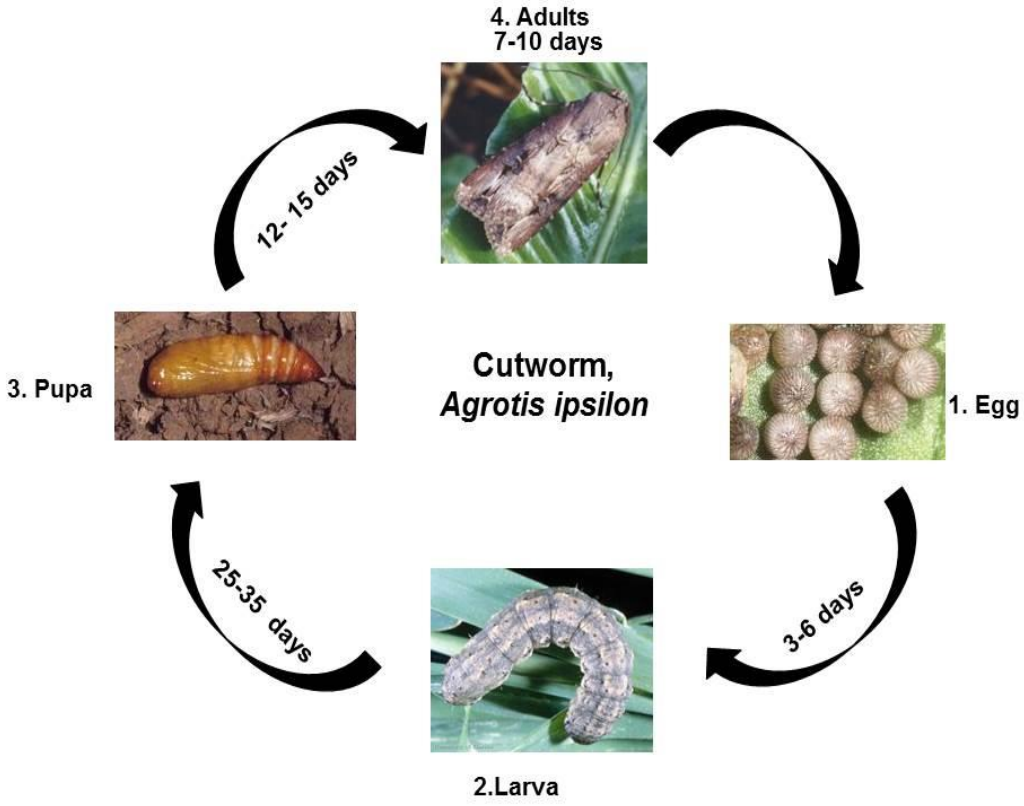
*For management refer to page number----------

6.Sunflower Cutworm:

Biology:

- **Egg:** Eggs are cream coloured, globular, laid in batches, on leaves, stems of weeds or crop plants, on Litter; upto1800 eggs/female, hatch in 2-9 days**.**
- **Larva:** Larvae are brownish above with a broad pale grey band mid line, black stripe laterally, sides greyish green, head capsule black with two white spots, 45 mm length when full grown; feed on foliage at night, hide in soil and debris during day.
- **Pupa:** Pupation take place in soil and the pupa is dark brown in colour
- **Adult**: The adult is a large moth (40-50 mm wing span) with grey forewings and dark brownish black markings, pearly hind wings with a dark fringe. To complete one life cycle, it takes around 30 days.

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.
- When numerous, cutworms can destroy as much as 75% of a crop.

Natural enemies of cutworm:

Parasitoids: *Cotesia* spp, *Meterorus* spp, *Campoletis* spp

Predators: Ground beetle

*****For the management refer page number.....

7.Green semilooper:

Biology:

- **Egg:** Female moth lays greenish white eggs singly on the under surface of leaf concentrating more on mid canopy.
- **Larva:** Larva is green in colour with a thin white lateral line and two white Lines on the back, active and form loop in motion; swollen at posterior end and tapers anteriorly**.**
- **Pupa:** Pupation takes place in white transparent silken cocoons in leaf litter or crop debris.
- **Adult:** Adult is a dark brownish moth with golden coloured triangle on forewings with a tuft of hair on thoracic region. Total life cycle takes 30 days.

Damage symptoms:

- Early instars feed on chlorophyll, tender leaves with transparent leaf spots, later feed from leaf margin and defoliate leaving midribs in case of severe incidence.

Life cycle:

Natural enemies of green semilooper:

Parasitoids: *Trichogramma* spp, *Cotesia* spp, *Apanteles ruficrus*, *A.africanus*, *Euplecturs ceylonensis, Campoletis chloridae, Exorista xanthaspis, Copidosoma ftoridanum, Disophrys lurea* and *Enicospilus* sp.
Predators: lady bird beetles, chrysoperla, mantids and spiders

*For the management refer page number.....

8.Cabbage semilooper:

Biology:
Egg: The female moth lays greenish white, spherical sculptured eggs singly on the under surface of sunflower leaf.
Larva: The larva is slender, attenuated anteriorly and full grown larvae measures 38 mm. Larva is green with wavy white lines and broader lateral white stripe.
Pupa: It pupates in a thin transparent cocoon on the under surface of leaves.
Adult: The moth is stout, brown in colour with light wavy markings and a more slender white mark on fore wings**.** Total life cycle takes about one month.
Life cycle:

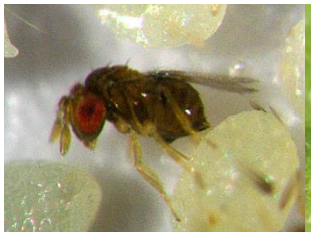
Damage symptoms:

- Initially, early instars feed on chlorophyll and tender leaves.
- In case of severe incidence, gown up larvae feed from leaf margin and defoliate the entire plant leaving midribs.

Natural Enemies of Sunflower Insect Pests

Parasitoids

Egg parasitoids



1. *Trichogramma* 2. *Tetrastichus* spp. 3. *Telenomus* spp

Egg-larval parasitoid

4. *Chelonus* spp.

Larval parasitoids




5. *Bracon* spp. 6. *Ichneumon* sp 7. *Carcelia* spp. 8. *Campoletis* spp

Nymphal/larval and adult parasitoids


9. *Encarsia formosa* 10*. Eretmocerus* spp.

1. http://www.nbaii.res.in/Featured_insects/Trichogrammatids.php
2. http://www.pbase.com/image/135529248
3. http://baba-insects.blogspot.in/2012/02/telenomus.html
4. http://www.nbaii.res.in/Featured%20insects/chelonus.htm
5. http://www.nbaii.res.in/Featured%20insects/Bracon%20brevicornis.htm
6. http://www.organicgardeninfo.com/ichneumon-wasp.html
7. http://72.44.83.99/forum/viewthread.php?thread_id=40633&pid=178398
8. http://www.nbaii.res.in/Featured%20insects/Campoletis.htm
9. http://www.buglogical.com/whitefly-control/encarsia-formosa/
10. http://www.dongbufarmceres.com/main/mboard.asp?strBoardID=c_product01_en

Predators

1. Lacewing

2. Ladybird beetle

3. Reduviid bug

4. Spider

5. Robber fly

6. Fire ant

7. Black drongo

8. Common mynah

9. Big-eyed bug

10. Earwig

11. Ground beetle

12. Pentatomid bug

13. Preying mantid

14. *Geocoris* spp.

15. 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.britishbugs.org.uk/heteroptera/Miridae/blepharidopterus_angulatus.html

X. DESCRIPTION OF DISEASES

1.*Alternaria* leaf spot:

Damage symptoms:

- Circular to oval, dark brown to black spots appear on the leaves. Later, the spots enlarge into round to irregular spots with concentric rings and coalesce causing blighting and withering of leaves. These are surrounded by chlorotic zone with grey white necrotic center.
- The spot appear first on the lower leaves and as the plant grows the spots subsequently appears on middle and upper leaves. Stem lesions begin as dark flecks which enlarge to form long, narrow lesions which may also coalesce to a larger blackened area resulting in stem breakage.
- In severe cases, the lesions appear on petioles, ray florets and head as brown round spots about 1cm diameter with a slight depression in the centre. Sometimes rotting of flower heads also occurs. *A. alternata* also causes Leaf spots in rabi season.

Survival and spread:

- The fungus overwinters as mycelium on infected plant residues and in dry conditions survives for 20 weeks in soil.
- The fungus is seed borne with 22.9% seed transmissible nature.

Favourable conditions:

- The disease is favoured by 25-27° C temperature and 12 hrs of wet foliage.
- The disease spreads rapidly in rainy season. Hot weather and frequent rains during the milk and wax stages of plant development favour infection.

Leaf spot on the leaf & flower head

http://uasr.agropedia.in/sites/default/files/A.%20Leaf%20spot.jpg

http://www7.inra.fr/hyp3/images/6030014.jpg

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

2.Rust:

Damage symptoms:

- Initially, small reddish brown circular uredial pustules, covered with rusty coloured dust appear on the lower leaves.
- Under severe conditions, the pustules are produced on younger leaves and spread over the entire vegetative surface covering stems, petioles, floral bracts and petals with pustules on stem being linear rather than round.
- Uredia often coalesce to cover large areas on the affected plant parts. The leaves become dry and towards maturity stage of crop, the uredosori are replaced by 'Lelia and the black rust appears.
- On susceptible cultivars, pustules are often surrounded by chinrotic halos and adjacent pustules may merge. In case of highly resistant varieties, uredia are not formed and only small chlorotic or necrotic flecks develop at the point of infection.

Survival and spread:

- The fungus mainly survives through teliospores (thick walled, resting spores) on leaves left in the field or on the soil surface.
- The disease spreads by wind-borne uredospores from infected crop.

Favourable conditions:

- Temperature ranging from 25.5 to 30.5° C with relative humidity of 86-92°c favours high intensity of rust

Rust on the leaf & flower head

http://upload.wikimedia.org/wikipedia/commons/3/34/Puccinia_helianthi.jpg
http://www.forestryimages.org/images/768x512/5358438.jpg

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

3.Powdery mildew:

Damage symptoms:

- White to grey powdery patches appear on upper surface of older leaves which are still green.
- Occassionally the symptoms appear on stem and bracts. White to grey areas enlarge, coalesce and cover most plant parts. As the season progresses, the mildewed leaves take on a dusty, powdery appearance. T
- This powder is easily rubbed off. Small black dots, cleistothecia become visible as black

pinpoints over the white mildew areas late in the season.

- Severely infected areas lose luster, curls, become permanently yellow and may dry up. Normally the lower leaves are more heavily infected than the upper leaves.

Survival and spread:

- The primary sources of inoculum are oospores present in the soil.
- Secondary infection by air-borne conidia

Favourable conditions:

- The disease is more under dry condition by the end of the winter months.

Powdery mildew infection on leaves

http://oilseeds.agropedia.in/sites/default/files/Sunflower%20Powdery%20Mildew%20(1).JPG
http://oilseeds.agropedia.in/sites/default/files/Sunflower%20Powdery%20Mildew%20(3).JPG

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

4.*Sclerotium* wilt:

Damage symptoms:

- Initial symptoms of the disease are noticed 40 days after sowing. Stem is usually infected at or near the soil line.
- A brownish lesion develops at the base of the stem and eventually girdles the plant. A white fan-like mycelial growth forms over the infected tissues and often radiates over the soil surface.
- Sickly appearance of plants can be spotted from a distance and a row effect can be observed in heavily infected soil.
- Later the entire plant withers and dies. The lesion grows up the stem, destroying the cortical tissue and leaving the fibrous vascular strands as the tissues dry out.
- White cottony mycelium and mustard seed type sclerotial bodies are conspicuous on the affected stem near soil level. This also causes collar rot in the seedling stage.

Survival and spread:

- The fungus survives as sclerotia or mycelium in infected plant residue and soil

Favourable conditions:

- Aerobic conditions, high temperatures and high humidity favour the germination of sclerotia and mycelial growth.

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

5.Sunflower Necrosis disease

Damage symptoms:

- The disease is observed at all growth stages of the crop, from seedling to maturity. Initially small, irregular necrotic patches appear on leaf lamina, more near to the mid rib.
- As the necrosis advances, it results into twisting of the leaf. Later, it extends from one side of the lamina to the petiole and stem in the form of black streaks and finally terminates at shoot of the plant leading to paralytic symptoms.
- Infected plants generally exhibit mosaic, mottling and necrosis of tissues of leaf lamina which later spreads to all other aerial parts of the plant.
- The early-infected plants become stunted, weak and die before flowering. Necrosis at bud formation stage makes the capitulum to trend and twist.
- Most destructive symptoms of the disease include sudden necrosis, twisting and systemic infection of floral parts like calyx, bracts and capitulum.
- Black or brown streaks on petiole, stem, underneath of flower head followed by twisting and splitting is usually noticed in a typically necrosis affected plant.
- In late infected plants, flower heads become malformed resulting into complete failure of seed setting or with partial filling of deformed /chaffy grains.

Survival and spread:

- Virus spreads through transmission by thrips *Frankliniella schultzii.*
- Weed hosts serve as natural virus reservoirs.
- Long and continuous dry spell increases the disease incidence.

Sunflower necrosis virus infected plants

http://1.bp.blogspot.com/-quxOg3Pfb7c/TduSvyUlUwI/AAAAAAAAAZ4/O4bURBmt-5w/s1600/8++NECROSIS+VIRUS.jpg
http://jpkc.jluhp.edu.cn/zwkx/zwbl/improve/tools/BSPP/ndr/jul2001/2001-26-1.jpg

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

6.Head rot:

Damage symptoms:

- Initial symptom appears as brown irregular water soaked spots on the back of ripening head usually adjacent to flower stalks.
- Spots gradually enlarge and become soft and pulpy and get covered with superficial white mycelium, which later becomes black due to formation of sporangia. In cases of severe infection, the rot spreads to flower stalk and the sunflower head drops off.
- Generally, some seeds of the rotted heads shed and those, which remain in the head, taste bitter. Susceptibility of the flower head is increased as its age advances. Maximum rotting is noticed at the soft dough stage. Injury to the flower head is necessary for infection.
- Larvae of *Heliothis armigera* have been reported to predispose heads to infection. *Rhizopus* enters the head through wounds caused by hail, birds and insects. The susceptibility of heads increases from the bud stage up to the full bloom and ripening stages.
- Oil from *Rhizopus* head rot infected seed has very much higher free fatty acid content. Disease development is most rapid in warm humid weather. In severe cases, the seeds

are transformed into a black powdery mass. The spores of the fungus are carried away by the wind and infect the new host.

Survival and spread:

- The fungus survives as a saprophyte in host debris and other crop residues.
- The disease is spread by wind-blown spores.

Favourable conditions:

- Prolonged rainy weather at flowering.
- Damages caused by insects and caterpillars.

Infected sunflower heads

http://www.forestryimages.org/images/768x512/5361537.jpg
http://www.ianrpubs.unl.edu/epublic/live/g1677/build/graphics/g1677-1.jpg

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

7.Downy mildew:

Damage symptoms:

The fungus causes different types of symptoms as damping off of seedlings, systemic infection, Local foliar lesions and root galls.

Damping off

- Damping off of the seedlings occurs particularly under cool and moist conditions. Seedlings are killed before or soon after emergence, resulting in reduced plant stand under field conditions. Affected plants dry and become wind-blown.
- The symptoms appear as yellowing of the first pair of true leaves. Under conditions of cool temperature and high humidity, whitish growth of downy mildew consisting of fungal mycelia and spores may appear on the cotyledonary leaves of young seedlings.
- As the plant grows, the fungus spreads to younger tissue, the chlorotic area expands and chlorosis appears on leaves and also on stem.

Systemic infection

- The affected plants are severely stunted and upper leaves are entirely chlorotic. At

flowering stage, when healthy plants are 1.5 to 1.8 m tall, the height of severely infected plants may vary from 0.1 to 1.0m.

- Due to systemic infection, the fungal mycelium may be present in all plant tissues except meristems. Affected plants bear abnormally thick, downward curled leaves showing prominent yellow and green epipwilous mottling.
- White downy growth of the fungus develops on lower surface of the leaves and covers large areas. The stem becomes brittle and flower heads of the affected plant remain sterile, stiff and face upwards and seeds are not produced or rarely the seeds are formed on such heads.
- Systemically infected plants exhibit severe inhibition of the stem elongation and loss of phototropic and negative responses. Scopoletin, a fluorescent compound present naturally in small amounts in sunflower was found to be considerably increased in infected tissue
- In affected plants, water permeability of the surface layers are adversely affected, reducing the water retention capacity. This sharply increases the transpiration rate and respiration with decrease in level of carbohydrates and accumulation of potassium and phosphorus in leaves of infected sunflower plants.

Local foliar lesions

- Greenish yellow small angular spots appear on leaves. The spots may enlarge and coalesce to infect a larger part of the leaf.
- Plants are susceptible to such infection for a longer period than to systemic infection. The fungal growth becomes visible at the lower surface of the diseased area and persists for some time under humid conditions.

Root galls

- Gall symptoms occur independently of systemic infection. The galls are formed at the base of plants on primary roots that took discoloured, scurfy and hypertrophied with reduced development of secondary roots. Such plants are less vigorous and subject to lodging.

Survival and spread:

- The pathogen survives through oospores in this residue of the preceding sunflower crop in soil or through oospores on pericarp any testa of seeds in systemically infected plant.
- Seed borne infection usually results in by percentage of systemically infected plants.

Favourable conditions:

- Cool weather with 16-18 temperature, cloudy weather with winds and drizzle or high relative humidity favours infection and disease development.

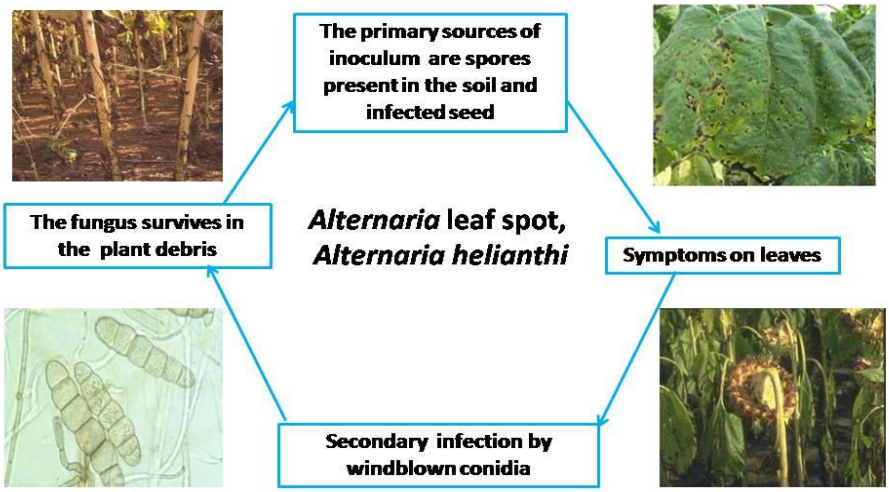
Downy mildew infection under leaf surface

http://www.forestryimages.org/images/768x512/0725009.jpg
http://web2.mendelu.cz/af_291_projekty2/vseo/files/9/1857.jpg

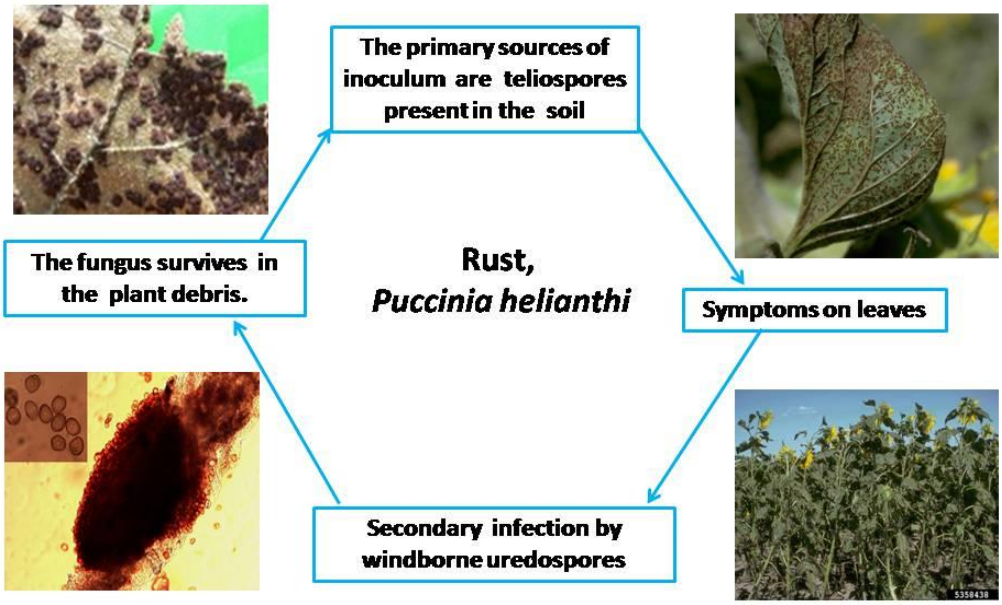
*For management refer to page number----------

Disease cycles:

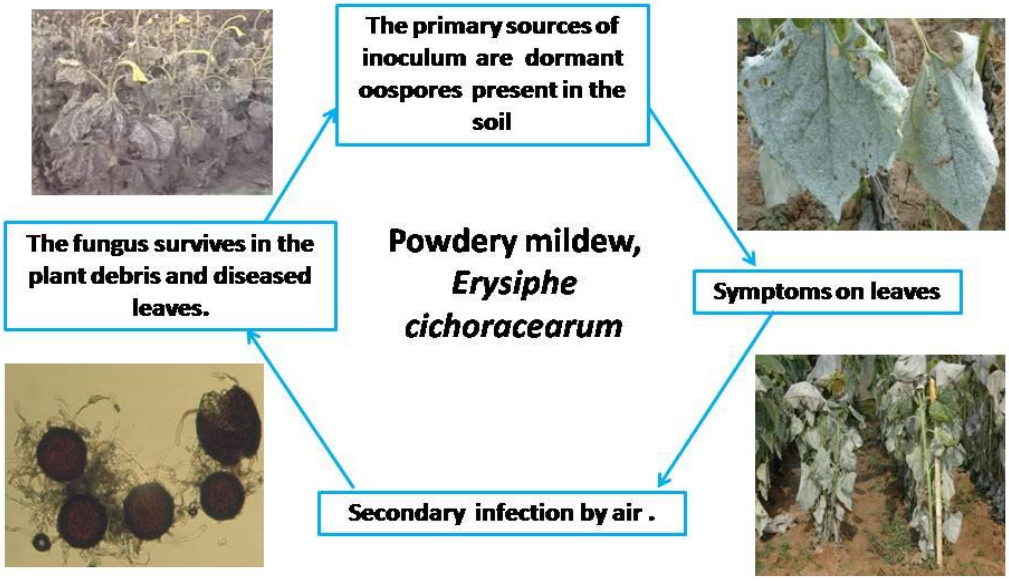
1. *Alternaria* leaf spot:



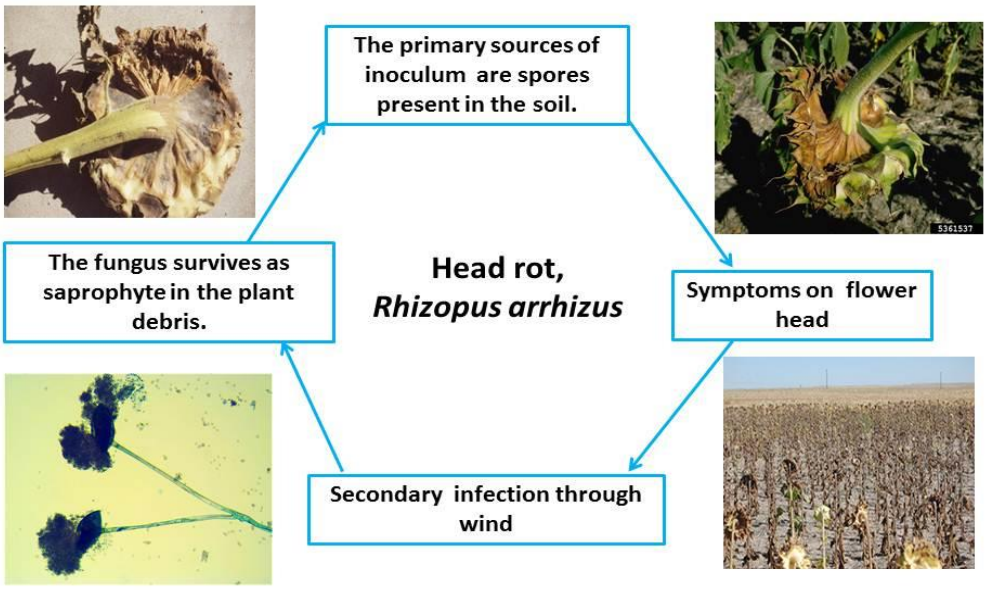
2. **Rust:**



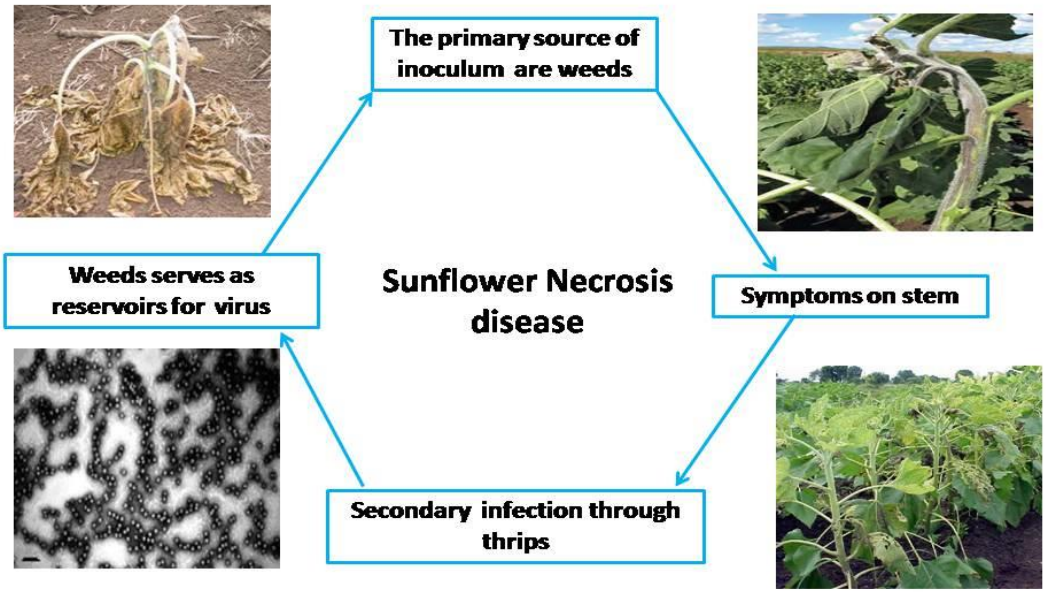
3. **Powdery mildew:**



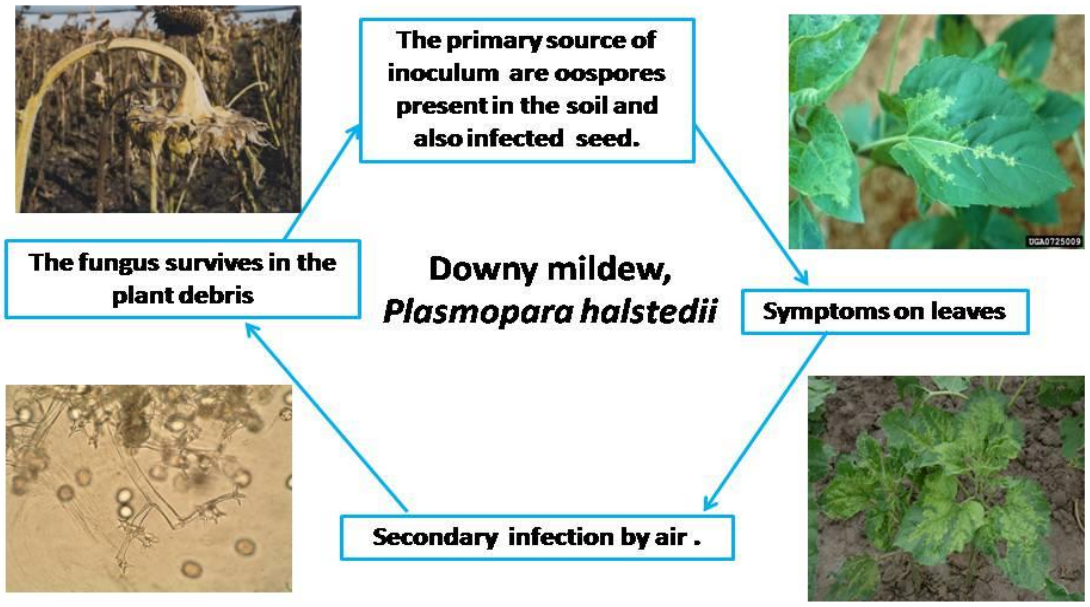
4. Head rot:



5. **Sunflower necrosis disease:**



6. **Downy mildew:**



XI. SAFETY MEASURES

A. At the time of harvest:

Losses in the field occur at the time of harvesting due to untimely harvest, poor agricultural operations, careless handling, birds, rodents, bad weather conditions like heavy rainfall, hailstorm, etc. During harvesting, proper care should be taken to avoid quantitative and qualitative losses. Following care should be taken during harvesting:

Sunflower should be harvested when the plant attains physiological maturity i.e. when the back of the head turns from green to lemon yellow colour and the bottom leaves starts drying and withering. At physiological maturity, the seed attains maximum weight and oil concentration and harvesting at this stage, results in highest seed and oil yield. 10 percent of heads should turn brown and florets attached to the tip of the seeds drop off naturally. Delay in harvesting causes reduction in seed yield due to lodging of plants and more damage due to birds, rodents and termite attack. Harvesting should be done by adopting proper method. Chemical defoliation or, dessication using DIQUAT, magnesium chlorate or, dipyridyl phosphate should be used to accelerate drying of standing crops. Mechanical thresher should be used to separate seed from flower which is labour saving and economical. Avoid harvesting during adverse weather conditions i.e. rains and overcast weather.

B. Post-harvest storage:

Harvest timely to reduce losses. Adopt proper method of harvesting. Adopt modern mechanical methods to avoid the losses in threshing and winnowing. Use improved techniques of processing. Adopt the grading to get better price. Use good packaging materials for storage and transportation. Use proper techniques in storage. Moisture content of the seed should be less than 9.5 percent for storage. Adopt proper pest control measures during storage. Adopt timely and proper handling while loading and unloading. Avoid use of hooks during handling.

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/planting as this may lead to reduced yields and incidence of white grubs and diseases.
5	Always treat the seeds with approved chemicals/biopesticides 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.
14	Apply HaNPV or SINPV at recommended dose when a large number of egg masses and early instar larvae are noticed. Apply NPV only in the evening hours after 5 pm.	Do not apply NPV on late instar larva and during day time.
15	Apply short persistent pesticides to avoid pesticide residue in the soil and produce.	Do not apply pesticides during preceding 7 days before harvest.
16	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 1971 Colour of toxicity triangle	WHO classification of hazard	Symptoms of poisoning	First aid measures and treatment of poisoning	Safety interval (days)
INSECTICIDES					
1.	Imidacloprid Highly toxic 		Harmful if swallowed, absorbed through skin or inhaled. Avoid breathing vapor or spray mist. Causes moderate eye irritation.	**First aid measures:** **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.	
2.	Malathion Moderately toxic 	Class III slightly hazardous	-do-	-do-	3 days
3.	Dichlorvos Extremely toxic 	Class I b highly hazardous	Moderate nausea, salivation, lacrimation, abdominal cramp, vomiting, sweating, slow pulse, muscular tremors, miosis	**First aid measures:** Rush to the nearest physician. **Treatment of poisoning:** Speed is imperative. Atropine injection-1-4 mg. repeat 2 mg when symptoms begin to recur (15-16 min interval) excessive salivation- good sign, more atropine needed	--
4	Cypermethrin	Highly toxic	Headache, palpitation, nausea,	**Treatment of poisoning:** No specific	14 days

		Class II Moderately hazardous 	vomiting, flushed face, irritation of nose,throat, eyes and skin, allergic manifestation etc.	antidote. Treatment is essentially symptomatic.	
Fungicides					
5	Metalaxyl MZ	Moderately toxic Class III slightly hazardous 	Headache, palpitation, nausea, vomiting, flushed face, irritation of nose, throat, eyes and skin etc.	**Treatment of poisoning:** No specific antidote. Treatment is essentially symptomatic	60 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; **Do not** 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.

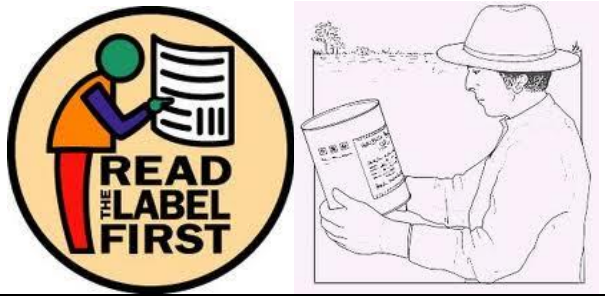
XV. PESTICIDE APPLICATION TECHNIQUES

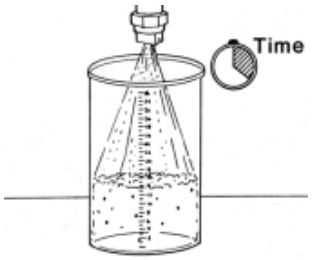
<table>
<tr><td colspan="4">Equipment</td></tr>
<tr><td colspan="4">Category A: Stationary, crawling pest/disease</td></tr>
<tr><td rowspan="2">Vegetative stage
i) for crawling and soil borne pests

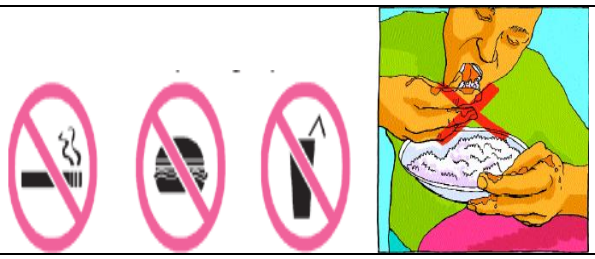
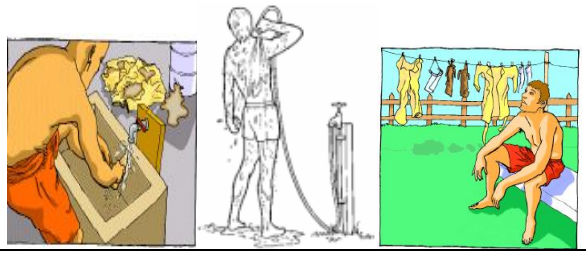
ii) for small sucking leaf borne pests</td><td rowspan="2">Insecticides and fungicides</td><td rowspan="2">• Lever operated knapsack sprayer (Droplets of big size)
• Hollow cone nozzle @ 35 to 40 psi
• Lever operating speed = 15 to 20 strokes/min
or
• Motorized knapsack sprayer or mist blower (Droplets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

Reproductive stage *(Field Pests)*		• 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 proper bath with soap after completing spraying	
9.	Do not blow the nozzle with mouth for any blockages. Clean with water and a soft brush.	

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