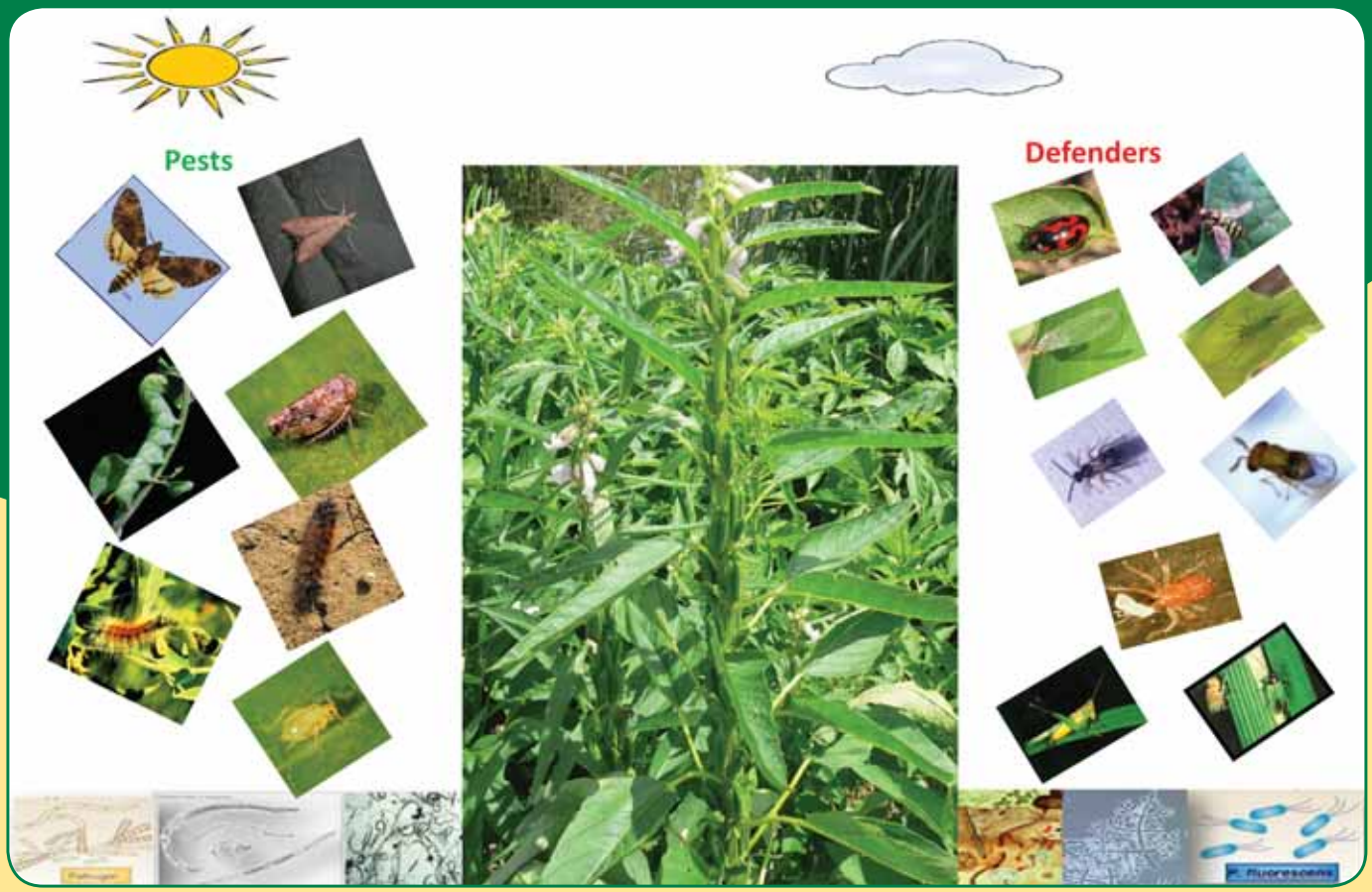
AESA BASED IPM PACKAGE

AESA based IPM – Sesame



Directorate of Plant Protection Quarantine and Storage
N. H. IV, Faridabad, Haryana

National Institute of Plant Health Management
Rajendranagar, Hyderabad, Telangana

Department of Agriculture and Cooperation
Ministry of Agriculture
Government of India

Important Natural Enemies of Sesame Insect Pests

Parasitoids

***Trichogramma* spp.**

***Bracon* spp.**

***Campoplex* spp.**

***Ichneumon* spp.**

***Cremastus* spp.**

Pteromalus fasciatus

Predators

Lacewing

Ladybird beetle

Reduviid bug

Spider

Red ant

Pentatomid bug
(Eocanthecona furcellata)

The AESA based IPM-Sesame, 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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Front cover picture Model AESA chart for Sesame

Back cover picture Sesame field

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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.

Date : 6.3.2014

(Avinash K. Srivastava)

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FOREWORD

IPM as a holistic approach of crop protection based on the integration of multiple strategies viz., cultural, physical, mechanical, biological, botanical 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, through 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 sine show 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 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, through 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)

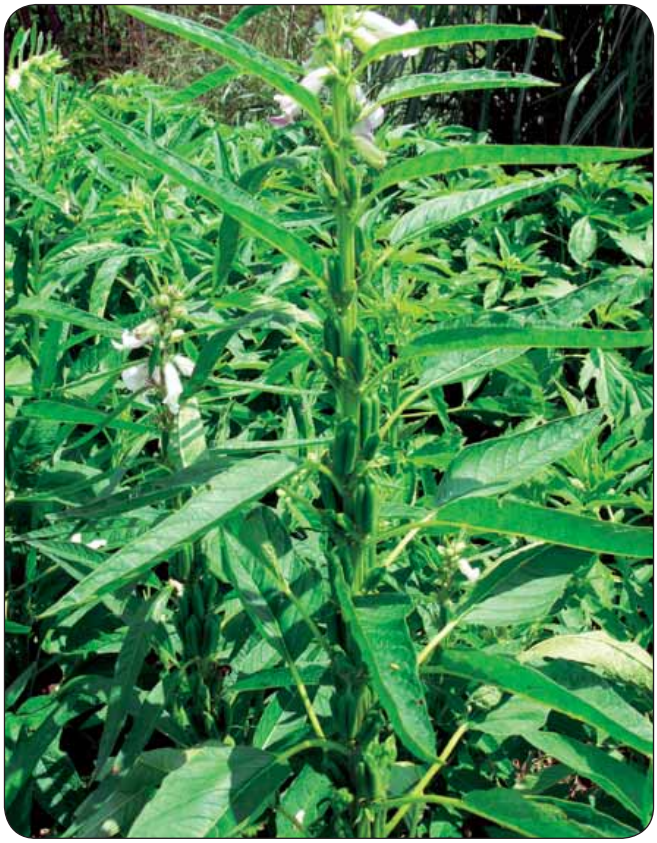
CONTENTS

AESA BASED IPM PACKAGE FOR SESAME

Sesame plant description:

Sesame (*Sesamum indicum* L.; Family: Pedaliaceae) is a flowering plant in the genus Sesamum. Numerous wild relatives occur in Africa and a smaller number in India. It is widely naturalized in tropical regions around the world and is cultivated for its edible seeds, which grow in pods. Sesame seed is one of the oldest oil seed crops known, domesticated well over 3000 years ago. Sesame is drought-tolerant and is able to grow where other crops fail. Sesame has one of the highest oil contents of any seed. With a rich nutty flavour, it is a common ingredient in cuisines across the world. Like other nuts and foods, it can trigger allergic reactions in some people. The world harvested about 3.84 million metric tonnes of sesame seeds in 2010. The largest producer of sesame seeds in 2010 was Burma. The world's largest exporter of sesame seeds was India, and Japan the largest importer.

It is an annual plant growing 50 to 100 cm (1.6 to 3.3 ft) tall, with opposite leaves 4 to 14 cm (1.6 to 5.5 in) long with an entire margin; they are broad lanceolate, to 5 cm (2 in) broad, at the base of the plant, narrowing to just 1 cm (0.4 in) broad on the flowering stem. The flowers are yellow, tubular, 3 to 5 cm (1.2 to 2.0 in) long, with a four-lobed mouth. The flowers may vary in colour with some being white, blue or purple. Sesame fruit is a capsule, normally pubescent, rectangular in section and typically grooved with a short triangular beak. The length of the fruit capsule varies from 2 to 8 cm, its width varies between 0.5 to 2 cm, and the number of loculi from 4 to 12. The fruit naturally splits open (dehisces) to release the seeds by splitting along the septa from top to bottom or by means of two apical pores, depending on the varietal cultivar. The degree of dehiscence is of importance in breeding for mechanised harvesting as is the insertion height of the first capsule.



I. PESTS

A. Pests of National Significance

1. Insect pests

1.1 Leaf webber or roller and capsule borer: *Antigastra catalaunalis* Duponchel (Lepidoptera: Crambidae)

1.2 Gall fly: *Asphondylia sesame* Felt (Diptera: Cecidomyiidae)

1.3 Leaf hopper: *Orosius albicinctus* Distant (Hemiptera: Cicadellidae)

2. Diseases

2.1 Phyllody: *Phytoplasma* like organism

2.2 Dry root rot: *Rhizoctonia bataticola* Taubenh

2.3 *Phytophthora* blight: *Phytophthora parasitica* var. *sesame* Dastur

2.4 *Alternaria* blight: *Alternaria sesame* Kawamura (Mohanty & Behera)

3. Weeds

Broadleaf

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

3.2 Swine cress: *Coronopus didymus*(L.) Sm. (Brassicaceae)

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

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

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

3.6 Cock's comb: *Celosia argentea* L. (Amaranthaceae)

3.7 Common purselane: *Portulaca oleracea* L. (Portulacaceae)

3.8 Asthma herb: *Euphorbia hirta* L. (Euphorbiaceae)

Grasses

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

3.10 Rabbit/crow foot grass: *Dactyloctenium aegyptium* (L.) Willd (Poaceae)

3.11 Crab grass: *Digiteria sanguinalis* (L.) Scop. (Poaceae)

3.12 Burmuda grass: *Cynodon dactylon* (L.) Pers. (Poaceae)

Sedges

3.13 Purplenut sedge: *Cyperus rotundus* L. (Cyperaceae)

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

B. Pest of Regional Significance

1. Insect pests

1.1 Sphinx moth or hawk moth: *Acherontia styx* Westwood (Lepidoptera: Sphingidae)

1.2 Bihar hairy caterpillar: *Spilosoma obliqua* Walker (Lepidoptera: Arctiidae) (Himachal Pradesh, Uttar Pradesh, Bihar, Delhi, Punjab)

1.3 Red hairy caterpillar: *Amsacta albistriga* Walker (Lepidoptera: Arctiidae) (Rajasthan)

1.4 Pod bug: *Elasmolomus sordidus* Fabricius (Hemiptera: Lygaeidae)

1.5 Pentatomid bug: *Nezara viridula* (Linnaeus) (Hemiptera: Pentatomidae)

1.6 Cotton aphid: *Aphis gossypii* Glover (Hemiptera: Aphididae)

2. Diseases

2.1 Wilt: *Fusarium oxysporum* Schlecht. f. sp. *sesame* (Maharashtra, Rajasthan)

2.2 Bacterial blight: *Xanthomonas campestris* Dowson pv. *sesame* (Assam, Uttar Pradesh, Madhya Pradesh, Delhi)

2.3 Powdery mildew: *Sphaerotheca fuliginea* (Schltdl.) Pollacci, *Leveillula taurica*(Lév.) G. Arnaud, *Erysiphe cichoracearum* (DC) (Rajasthan)

3. Nematode

3.1 Pigeon pea cyst nematode: *Heterodera cajani* Koshy (Tylenchida: Heteroderidae)

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 factors
- Farmers past experience

Principles of AESA based IPM:

Grow a healthy crop:

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

as the residual phosphate of the previous season will be available for the current season also.

- Proper irrigation
- Crop rotation

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

Farmers should:

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

Plant compensation ability:

Compensation is defined as the replacement of plant biomass lost to herbivores and has been associated with increased photosynthetic rates and mobilization of stored resources from source organs to sinks (e.g., from roots and remaining leaves to new leaves) during active vegetative growth period.

Understand and conserve defenders:

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

Insect zoo:

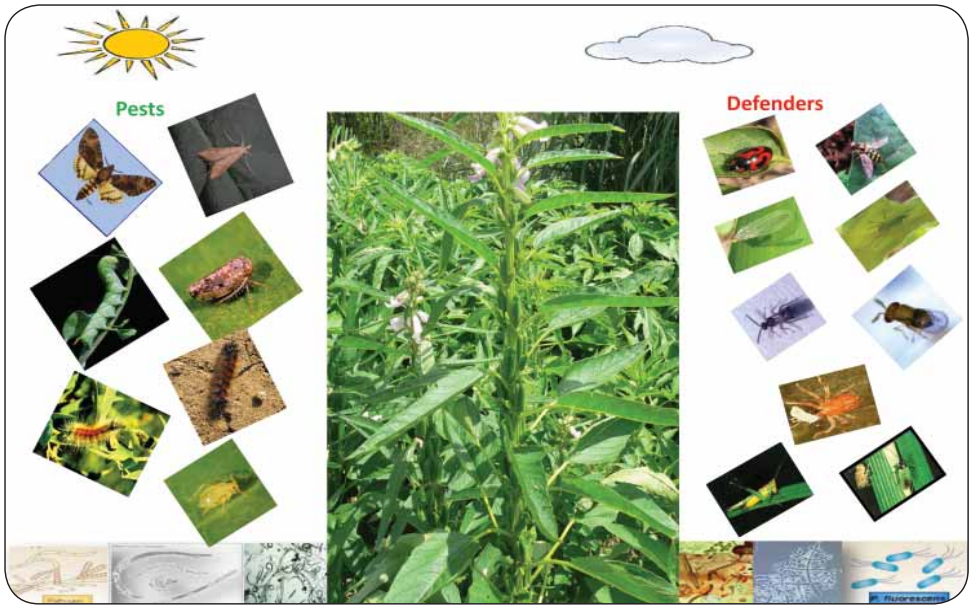
In field various types of insects are present. Some are beneficial and some may be harmful. Generally farmers are not aware about it. Predators (friends of the farmers) which feed on pests are not easy to observe in crop field. Insect zoo concept can be helpful to enhance farmers' skill to identify beneficial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

Pest: Defender ratio (P: D ratio):

Identifying the number of pests and beneficial insects helps the farmers to make appropriate pest management decisions. Sweep net, visual counts etc. can be adopted to arrive at the numbers of pests and defenders. The P: D ratio can vary depending on the feeding potential of natural enemy as well as the type of pest. The natural enemies of Sesame 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 situations

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 leaves, crop stage, deficiency symptoms etc.
    - Insect pests: Observe and count insect 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 water situation of the field.
    - Weather: Observe the weather conditions.
- While walking in the field, manually collect insects in plastic bags. Use a sweep net to collect additional insects. Collect plant parts with disease symptoms.
- Find a shady place to sit as a group in a small circle for drawing and discussion.
- If needed, kill the insects with some chloroform (if available) on a piece of cotton.
- Each group will first identify the pests, defenders and diseases collected.
- Each group will then analyze the field situation in detail and present their observations and analysis in a drawing (the AESA drawing).
- Each drawing will show a plant representing the field situation. The weather condition, water level, disease symptoms, etc. will be shown in the drawing. Pest insects will be drawn on one side. Defenders (beneficial insects) will be drawn on another side. Write the number next to each insect. Indicate the plant part where the pests and defenders were found. Try to show the interaction between pests and defenders.
- Each group will discuss the situation and make a crop management recommendation.
- The small groups then join each other and a member of each group will now present their analysis in front of all participants.
- The facilitator will facilitate the discussion by asking guiding questions and makes sure that all participants (also shy or illiterate persons) are actively involved in this process.
- Formulate a common conclusion. The whole group should support the decision on what field management is required in the AESA plot.
- Make sure that the required activities (based on the decision) will be carried out.
- Keep the drawing for comparison purpose in the following weeks.

Data recording:

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

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

Data to be recorded:

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

Some questions that can be used during the discussion:

- Summarize the present situation of the field.
- What crop management aspect is most important at this moment?
- Is there a big change in crop situation compared to last visit? What kind of change?
- Is there any serious pest or disease outbreak?
- What is the situation of the beneficial insects?
- Is there a balance in the field between pests and defenders?
- Were you able to identify all pests and diseases?
- Do you think the crop is healthy?

- What management practices are needed at this moment?
- When will it be done? Who will do it? Make sure that responsibilities for all activities are being discussed.
- Are you expecting any problems to emerge during the coming week such as congenial weather conditions for pest buildup?
- What 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 problems of the ETL is that it is based on parameters that are changing all the time, and that are often not known. The damage or losses caused by a certain density of insects cannot be predicted at all. In ETL the due recognition of the role of natural enemies in decreasing pest population is ignored. Farmers cannot base their decisions on just a simple count of pests. They will have to consider many other aspects of the crop (crop ecology, growth stage, natural enemies, weather condition, etc.) and their own economic and social situation before they can make the right crop management decisions. In ETL based IPM, natural enemies, plant compensation ability and abiotic factors are not considered. In AESA based IPM emphasis is given to natural enemies, plant compensation ability, abiotic factors and P: D ratio.

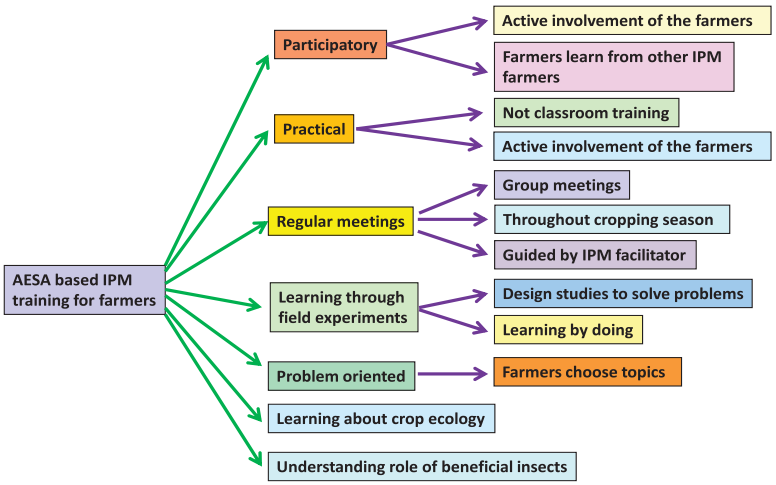
AESA and farmer field school (FFS):

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

Farmers can learn from AESA:

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

FFS to teach AESA based IPM skills:



B. Field scouting:

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

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

Aphids and leaf hoppers- Indicate the total number found (top two leaves, middle two leaves and bottom one leaves) and the total number of leaves checked (20 plants calculate the average per leaf)

Leaf webber or roller and capsule borer larvae: Indicate the total number of fruiting parts checked. Indicate the total number of pods with pod borer damage.

For Diseases:

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

Root sampling:

Always check plants that appear unhealthy. If there are no obvious symptoms on plants, examine plants randomly and look for lesions or rots on roots and stems. Observe the signs of the causal organism (fungal growth Or ooze). Always check plants that appear unhealthy. It is often necessary to wash the roots with water to examine them properly. If the roots are well developed, cut into them to examine the roots for internal infections (discolouration & signs). Count the total number of root 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, flower and pod sampling:

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

C. Surveillance through pheromone traps:

Pheromone traps for *Antigastra, Acherontia, Spilosoma* and *Amsacta* @ 4-5/acre have to be installed, if available. Install the traps for each species separated by a distance of >75 feet in the vicinity of the selected field. Fix the traps to the supporting pole at a height of one foot above the plant canopy. Change of lures should be made at 2-3 week interval (regular interval). During each week of surveillance, the number of moths/trap/week should be counted and recorded year round. The trapped moths should be removed and destroyed after each recording.

D. Light traps:

Set up light traps 1 trap/acre 15 cm above the crop canopy for monitoring and mass trapping of insects. Light traps

with exit option for natural enemies of smaller size should be installed and operate around the dusk time (6 pm to 10 pm).

E. Nematode extraction:

Collect 100 to 300 cm^3 (200-300 g) representative soil sample. Mix soil sample and pass through a coarse sieve to remove rocks, roots, etc. Take a 600 cc subsample of soil, pack lightly into a beaker uniformly. Place soil in one of the buckets or pans half filled with water. Mix soil and water by stirring with paddle; allow to stand until water almost stops swirling. Pour all but heavy sediment through 20-mesh sieve into second bucket; discard residue in first bucket; discard material caught on sieve. Stir material in second bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 60 mesh sieve to collect cysts into first bucket; discard residue in second bucket. Stir material in first bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 325-mesh sieve into second bucket; discard residue in first bucket. Backwash material caught on 325-mesh sieve (which includes small to mid-sized nematodes and silty material) into 250-ml beaker. More than 90% of the live nematodes are recovered in the first 5-8 mm of water drawn from the rubber tubing and the sample is placed in a shallow dish for examination.

III. ECOLOGICAL ENGINEERING FOR PEST MANAGEMENT

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

Natural enemies may require:

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

Ecological engineering for pest management – Above ground:

- Raise the flowering plants/compatible cash crops along the field border by arranging shorter plants towards main crop and taller plants towards the border to attract natural enemies as well as to avoid immigrating pest population
- Grow flowering plants on the internal bunds inside the field
- Not to uproot weed plants those are growing naturally 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.

Ecological engineering for pest management – Below ground:

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

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

Ecological Engineering Plants

Attractant plants


Cluster bean


Cowpea


Carrot


Sunflower


Buckwheat


French bean


Mustard


Parsley


Dill


Anise


Caraway

Repellent plants


Ocimum spp.


Peppermint

Border plants


Sorghum


Maize


Bajra/pearl millet

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. CROP STAGE-WISE IPM

Management	Activity
Pre-sowing*	
	Common cultural practices: • Timely sowing should be done. • Field sanitation, rogueing • Crop rotation • Deep ploughing of fields during summer • Sow the ecological engineering plants • Destroy the alternate host plants • Eradicate weeds and volunteer sesame plants • Pre-monsoon deep ploughing (two/three times) to expose the hibernating pupae to sunlight and predatory birds. • Sow / plant sorghum/maize/bajra in 4 rows all around sesame crop as a guard/barrier crop.
Nutrients	• Deep summer ploughing to break hard pan and to facilitate rain water absorption & deep root penetration. • Based on soil test report, apply manure and fertilizers following Integrated Nutrient Management approach. • Incorporate well decomposed FYM @ 2 to 4 t or vermicompost @ 1 to 2 t per acre during last preparatory cultivation.
Weeds	• At the time of field preparation, cultivate the field to destroy the weeds already grown in the field. • Keep the boundary & bunds of the field free from weeds.
Soil borne pathogens, dry root rot disease, nematodes and resting stage of insects	**Cultural control:** • Raising African marigold nursery 15 days prior to sowing. • Ensure proper spacing during sowing. **Biological control:** • Apply neem cake @ 80 Kg/acre. • Seed treatment: Treatment with *Trichoderma viride* @ 4 g/Kg of seed or NSKE 4%
***Alternaria* leaf blight, *Phytophthora* blight, dry root rot**	**Cultural control:** • Avoid planting overlapping crops in adjacent area. Crop rotations, viz., sesame-maize-cabbage, okra- sesame - maize, maize - sesame -maize and sesame - finger millet-egg plant are reported effective in reducing disease incidence. • Crop rotation with non-host crops, particularly with paddy. • Provide good drainage **Seed treatment:** Treatment with *Trichoderma* @ 4 g/Kg of seed, *Pseudomonas fluorescens* @ 2 g/Kg seed or *Bacillus subtilis* @ 2 g/Kg seed or NSKE 4%
Sowing/seedling*	
	Common cultural practices: • Use resistant/tolerant varieties. • Use healthy, certified and weed seed free seeds.
Nutrients	• Seed treatment should be done with *Azotobactor* or *Azospirillium* culture @ 240 g/acre. • For rainfed sesame, apply N-P-K @ 16-24-16 Kg/acre at the time of sowing. • For irrigated crop apply N-P-K @ 12-24-16 Kg/acre at the time of sowing.

	• Application of sulphur @ 20 Kg/acre increases the yield if soils are deficient in sulphur. • Placement of fertilizer at seeding using seed drills is more effective than broadcast application.
Weeds	• Use sowing in lines to facilitate inter culture operations. • Adopt stale seed bed technique to control early germinating weeds. • Use straw mulch to control weed growth and to conserve soil moisture.
* Apply *Trichoderma viride/harzianum* and *Pseudomonas fluorescens* as seed/seedling/planting material, nursery treatment and soil application (if commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).	
Vegetative stage*	
	Common cultural practices: • Destroy crop debris • Provide irrigation at critical stages of the crop • Avoid water logging • Avoid water stress during flowering stage • Enhance parasitic activity by avoiding chemical spray, when 1-2 larval parasitoids are observed • Remove alternate weed hosts **Common mechanical practices:** • Collect and destroy disease infected and insect infested plant parts • Collection and destruction of eggs and early stage larvae • Handpick the older larvae during early stages of the crop • The infested shoots and pods may be collected and destroyed • Handpick the gregarious caterpillars and the cocoons which are found on stem and destroy them in kerosene mixed water. • Use yellow sticky traps @ 4-5 trap/acre • Use light trap @ 1/acre and operate between 6 pm and 10 pm • Install pheromone traps @ 4-5/acre for monitoring adult moths activity (replace the lures with fresh lures after every 2-3 weeks) • Erect bird perches @ 20/acre for encouraging predatory birds such as King crow, common mynah etc. **Common biological practices:** • Conserve natural enemies through ecological engineering • Augmentative release of natural enemies • Spray neem oil @ 5 ml/l as foliar sprays
Nutrients	• In irrigated crop, apply second haft of N i.e. 12Kg/acre as top dressing at 30-35 days after sowing.
Weeds	• Sesame is sensitive to weed competition during the first 15-25 days after sowing. • A minimum of two weedings, one after 15 days after sowing and another at 35 days after sowing are required to keep the field relatively weed free. • Row seeded crop facilitates use of blade harrows for inter-cultivation. • Two inter-cultivations, 15 days after sowing and 35 days after sowing followed by one hand weeding keeps the field free of weeds. • Use of pre-emergence herbicides followed by one hand weeding around 30 days after sowing is the most appropriate way of weed management in sesame.

Leaf roller and gall fly	• Follow common cultural, mechanical and biological practices **Chemical control:** • Quinalphos 25% EC @ 800 ml in 200-400 l of water/acre. • Carbaryl 10% D.P. @ 10 Kg/acre
Leaf hopper	• Follow common cultural, mechanical and biological practices **Chemical control:** • Oxydemeton–methyl 25% EC@ 480 ml in 200-400 l of water/acre.
Hawk moth**	• Follow common cultural, mechanical and biological practices **Cultural control:** • Deep ploughing exposes the pupae for predation to insectivorous birds. • Hand picking (collection) and destruction of caterpillars.
Bihar hairy caterpillar**	• Follow common cultural, mechanical and biological practices **Cultural control:** • Irrigate once to avoid prolonged mid season drought to prevent pre-harvest infestation. **Mechanical control:** • Dig the trenches of 1 inch depth between the fields to kill the larvae in pits.
Phyllody	• Follow common cultural, mechanical and biological practices **Cultural control:** • Intercropping of sesamum + redgram (6 : 1) **Biological control:** • Spray neem oil @ 5 ml/l for vector (leaf hopper) control.
***Alternaria* leaf blight, *Phytophthora* blight, dry root rot**	• Follow common cultural, mechanical and biological practices • Same as in pre-sowing stage
Wilt**	**Cultural control:** • Soil amendment with farm yard manure @ 5 t/acre is helpful in reducing the incidence of the disease
Powdery mildew**	**Cultural control:** • Bower system (maintain gapping) of cropping reduces the disease incidence.
Maturity stage	
Nutrients	• Correct micronutrients deficiency with foliar spray.
Weeds	• Remove left over weeds after harvest of the crop to prevent weed seed spread.
Leaf roller, gall fly, leaf hopper, hawk moth, Bihar hairy caterpillar**, phyllody, *Alternaria* leaf blight, *Phytophthora* blight, dry root rot, wilt** and powdery mildew****	• Follow common cultural, mechanical and biological practices • Same as in vegetative stage
Reproductive stage	

Leaf roller, gall fly, leaf hopper, hawk moth, Bihar hairy caterpillar**, phyllody, *Alternaria* leaf blight, *Phytophthora* blight, dry root rot, wilt**, powdery mildew**	• Follow common cultural, mechanical and biological practices • Same as in vegetative stage

Note: The pesticide dosages and spray fluid volumes are based on high volume sprayer.
** Pests of regional significance

V. 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. Sesame 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/inter crop.

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 out compete and interbreed with resistant individuals, diluting the resistant genes and therefore the impact of resistance.

VI. COMMON WEEDS

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

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

3) Crab grass: *Digiteria sanguinalis* (L.) Scop. (Poaceae)

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

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

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

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

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

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

10) Cock's comb: *Celosia argentea* L. (Amaranthaceae)

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

12) Asthma herb: *Euphorbia hirta* L. (Euphorbiaceae)

13) Purplenut sedge: *Cyperus rotundus* L. (Cyperaceae)

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

VII. DESCRIPTION OF INSECT PESTS

1) Leaf webber or roller and capsule borer :

Biology:

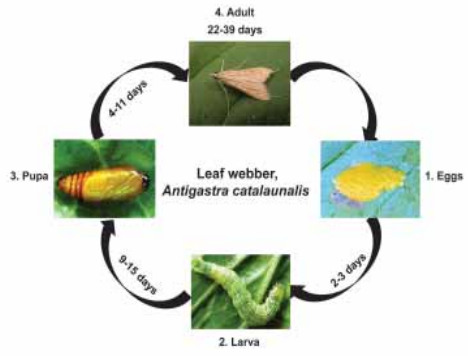
Egg: Eggs are laid singly on the under surface of leaves, on capsules and branches. Eggs are minute and conical in shape. Freshly laid eggs are white in colour, which later change to dark white before hatching.

Larva: It is a cylindrical caterpillar, which is referred as the neonate larva just after hatching and passes through five larval instars before going in to pupation. The larva is greenish in colour with black head and about 15 mm in length.

Pupa: The pupa is slender, long necked and greenish-reddish-brown in colour. A pair of eyes is present on anterior end. The body is light reddish brown, greenish white at first. It changes gradually to pale reddish white, dark reddish, reddish brown and pale whitish later on.

Adult: The adult is medium sized moth with reddish yellow forewings

Life cycle:



2. http://bugguide.net/node/601542

4. http://en.wikipedia.org/wiki/Antigastra_catalaunalis#mediaviewer/File:Antigastra_catalunalis.jpg

Damage symptoms:

- The young larvae roll together a few top leaves and feed them.
- Later, some more leaves are affected.
- In the early stage of infestation, the plant dies without producing any branch or shoot.
- In later stage of attack, infested shoots stop growing.
- At flowering, larvae feed inside the flowers and on capsule formation, larvae bore into capsule and feed on developing seeds.

Damage symptoms

Natural enemies of leaf webber or roller and capsule borer :

Parasitoids: Trichogrmma spp., *Bracon hebator, B. brevicornis, Phanerotoma handecasisella, Campoplex* sp, *Erioborus* sp, and *Apanteles* spp. etc.

Predators: *Eocantheconia furcellata, Cicindella* spp., lacewing, ladybird beetle, spiders, red ant etc.

*For management refer to page number 14

2) Gall fly:

Biology:

Maggot: The maggot is white to orange in colour, legless and with body tapering exteriorly, grows up to 3 to 4 mm in length. Maggots feed inside the floral buds and young capsules leading to formation of galls of up to 6 mm in diameter.

Pupa: Maggot pupates inside the galls.

Adult: The adult is a 5 mm long red-bodied midge (mosquito-like fly). Female midges lay eggs along the veins of terminal leaves.

Damage symptoms

http://agritech.tnau.ac.in/crop_protection/sesamum/crop_prot_crop_insect_oil_sesamum_4.html

Damage symptoms:

- Young larvae are less frequent on pods than on other plant parts. They feed externally by making a loose web, which sticks several leaves together.
- The larvae feed on leaves and young shoots. Excreta (frass) remains between the leaves and the loose web.
- At a later stage, the larvae infest the sesame fruit capsule making an entrance hole on the lateral side and feeding on the seeds inside the capsule; they leave excreta on the seeds.

Natural enemies of gall fly:

Parasitoids: *Pteromalus fasciatus* etc.

Predators: Spider, ladybird beetle, lacewing etc.

*For management refer to page number 15

3) Leaf hopper:

Damage symptoms:

- Both nymphs and adults suck the sap from leaves and transmit phyllody disease.
- Curling of leaf edges and leaves turn red or brown.
- The leaves dry up and shed.

Damage symptoms

http://agritech.tnau.ac.in/crop_protection/sesamum/crop_prot_crop_insect_oil_sesamum_5.html

Natural enemies of leaf hopper:

Predators: Spider, ladybird beetle, lacewing etc.

*For management refer to page number 15

4) Sphinx moth:

Biology:

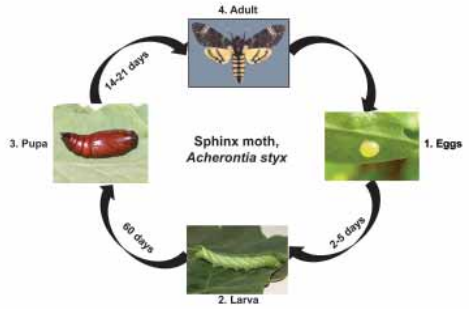
Egg: Eggs are globular is shape and are laid singly on the under surface of leaves. The egg period is 2-5 days.

Larva: Larva is stout, green with yellowish oblique stripes and curved anal horn. The larval period lasts for 60 days.

Pupa: It pupates in earthern cocoon in soil. The pupal period lasts 14-21 days and 7 months in summer and winter, respectively.

Adult: The adult moth is giant hawk moth, brownish with a characteristic skull marking on the thorax and violet yellow bands on the abdomen. Hind wings yellow with black markings.

Life cycle



1,2,3,4: http://tnau.ac.in/eagri/eagri50/ENTO331/lecture09/linseed/pdf/lec09.pdf

Damage symptoms:

- The damage is caused by the larvae which feed voraciously on leaves and defoliate the plants.
- The moth is also harmful as it sucks honey from the honey combs in apiaries.

Damage symptom

http://tnau.ac.in/eagri/eagri50/ENTO331/lecture09/linseed/pdf/lec09.pdf

Natural enemies of sphinx moth:

Predators: Lacewing, ladybird beetle, reduviid bug, spider, red ant, black drongo (King crow), common mynah, big-eyed bug (*Geocoris* sp), pentatomid bug (*Eocanthecona furcellata*), preying mantis etc.

*For management refer to page number 14

Natural Enemies of Sesame Insect Pests

Parasitoids

Larval parasitoids

1. *Campoplex* spp.

2. *Bracon* spp.

3. *Ichneumon* spp.

4. *Cremastus* spp.

5. *Pteromalus fasciatus*

1. http://wildyorkshire.blogspot.in/2011/04/campopleginae-ichneumonidae-perhaps.html; 3. http://www.naylorgallery.com/?p=1273; 4. http://digiins.tari.gov.tw/search_Result.php?searchKey=&page=454; 5. http://www.boldsystems.org/index.php/Taxbrowser_Taxonpage?taxid=173764

Predators

1. Lacewing

2. Ladybird beetle

3. Reduviid bug

4. Spider

5. Red ant

6. Pentatomid bug *(Eocanthecona furcellata)*

7. Preying mantis

8. Black drongo

9. Common mynah

5. 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; 6. http://nickdobbs65.wordpress.com/tag/herbie-the-love-bug/ 7. http://spirit-animals.com/praying-mantis/; 8. http://nagpurbirds.org/blackdrongo/picture/1639; 9. http://nickdobbs65.wordpress.com/tag/herbie-the-love-bug/;

VIII. DESCRIPTION OF DISEASES

1) Phyllody

Disease symptoms:

- All floral parts are transformed into green leafy structures followed by abundant vein clearing in different flower parts.
- In severe infection, the entire inflorescences is replaced by short twisted leaves closely arranged on a stem with short internodes, abundant abnormal branches bend down.
- Finally, plants look like witches broom.
- If capsules are formed on lower portion of plant they do not yield quality seeds

Disease symptoms

http://agritech.tnau.ac.in/crop_protection/crop_prot_crop%20diseases_oilseeds_sesame.html

Transmission and favourable conditions:

- The disease is transmitted through jassids and the phytoplasma survives in leaf hopper throughout its life.

*For the management refer page numbers 14, 15

2) Dry root rot:

Disease symptoms:

- The fungus attacks young seedling, their stems become water soaked soft and incapable of supporting the seedling which falls over and dies.
- On older seedlings elongated brownish black lesions appear which increase in length and width girdling the stem and plant dies.

Disease symptoms

http://agritech.tnau.ac.in/crop_protection/crop_prot_crop%20diseases_oilseeds_sesame.html

Survival and spread:

- The pathogen survives in seed and soil.

Favourable conditions:

- High soil temperatures and moisture stress conditions favour the development of the pathogen.

*For the management refer page number 12

3) *Phytophthora* blight:

Disease symptoms:

Disease can occur at all stages of the plant.

- Initial symptom is water soaked spots on leaves and stems.
- The spots are chestnut brown in the beginning later turn to black.
- Premature leaf fall occurs.
- In humid weather, severity of disease increases, main root is affected, diseased plants are easily pulled out and produce shriveled seeds and gives blighted appearance.

Survival and spread:

- The pathogen survives in soil

Favourable conditions:

- High soil moisture favours the development of the pathogen.
- The disease is severe in the area of heavy soil with high rainfall

*For the management refer page numbers 12, 14

4) *Alternaria* blight

Disease symptoms:

- The pathogen attacks all parts of the plant at all stages.
- Small, dark brown water soaked, round to irregular lesions, with concentric rings, 1-8 mm in diameter appear on the leaves and under excessive atmospheric and soil humidity the spot increases in size and number.
- The lesions may also appear on the midrib and veins of the leaves.
- Milder attacks cause only defoliation, in severe cases the plant may die.

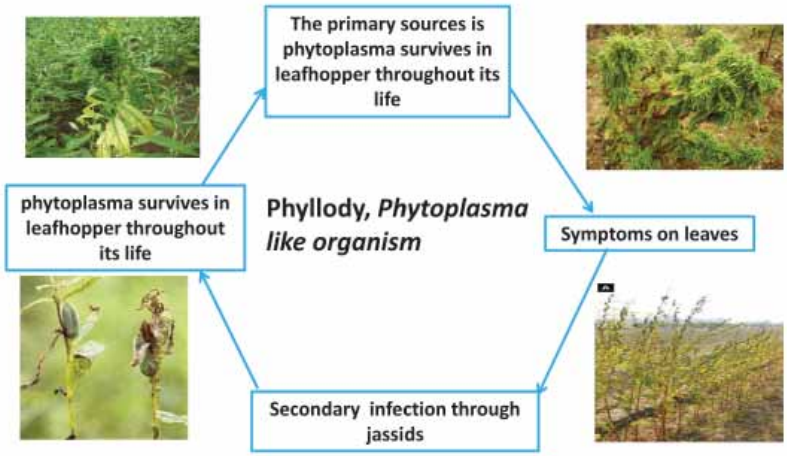
Transmission and favourable conditions:

- The pathogen is seed borne.
- Temperature of 20-30° C and high humid conditions favour the disease.

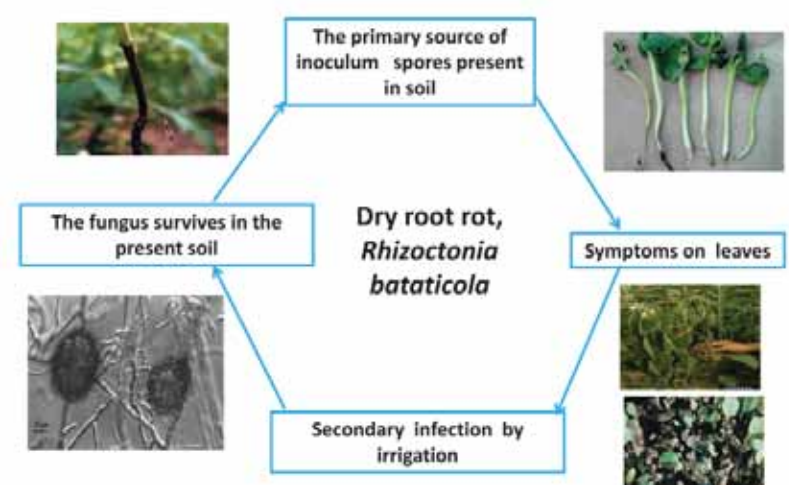
*For the management refer page numbers 12, 14

Disease cycles:

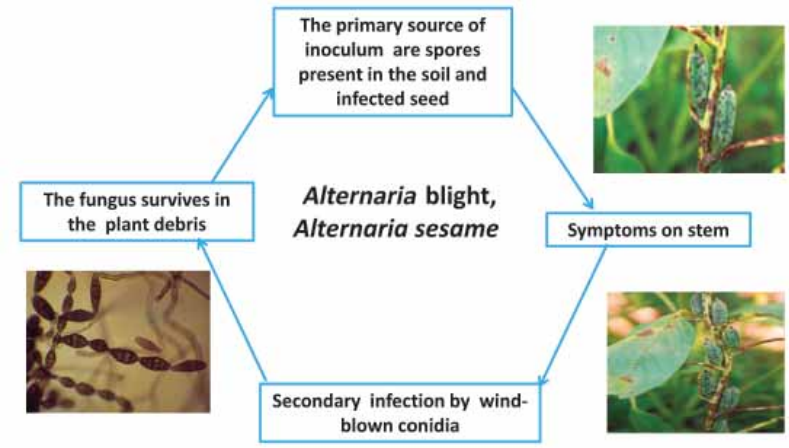
1. Phyllody:



2. Dry root rot:



3. *Alternaria* blight:



IX. SAFETY MEASURES

A. At the time of harvest:

- Harvest the crop, when leaves and capsules turn yellow and defoliation starts. The capsules at base of plants mature first and then start maturing upwards. Plants should be harvested as and when they are yellowish–brown. After harvest, stock the bundles erect on the threshing floor for five to seven days for drying and then thresh
- Observe the crop, considering the average duration of the crop.
- Twenty five percent of the leaves from the bottom are shed and the top leaves loose their colour and turn yellow at maturity.
- The colour of the stem turns yellow.
- The colour of the capsules turns yellow upto the middle.
- Harvest before the bottom capsules turn brown.
- Examine the 10th capsule from the bottom by opening. If the seeds turn black, harvest may be taken up for the black seeded varieties.
- The capsules will dehisce resulting in yield reduction, if harvest is delayed.
- Timely harvesting ensures optimum quality and consumer acceptance.
- Harvest the seed crop at its physiological maturity as delayed harvesting may result in shattering of seeds in the field.
- Pull out the plants from the bottom.
- Stack in the open, one over the other in circle with the stem pointing out and the top portion pointing inside.
- Cover the top with straw, so that humidity and temperature increases. Cure like this for three days.
- Shake the plants. About 75% of the seeds will fall off.
- Dry the plants in the sun for 2 more days. Shake the plants once again. All the mature seeds will fall off.
- Winnow the seeds and dry in the sun for 3 days. Stir once in 3 hours to give uniform drying.
- Tag the bundles properly and keep at proper place.
- Collect the seeds and store in gunny bags.
- Take utmost care to clean cloths/bags/containers/equipments used in harvesting, threshing and processing.
- Avoid harvesting during adverse weather conditions.

B. During post harvest storage:

- It has been noticed that there is about 5 to 10 percent loss from the time of harvest to cleaning and storing. The losses noticed are mainly contributed to the factor of un-uniform maturity. The capsules in the primary branches mature earlier than the secondary branches and the capsules in the lower portion of the plant, mature earlier than those in the upper portion. This results in poor filling of the seeds in the capsules of the secondary branches and in the upper portion of the plant. The poorly filled seeds have lesser weight and they are lost while winnowing. To avoid losses during storage following practices can be adopted.
- Proper cleaning and grading of produce.
- Use efficient and good packaging for storage as well as for transportation.
- Use proper technique in storage.
- Use pest control measures in storage.
- Proper care in handling (loading and unloading) of packages.

X. DO'S AND DON'TS IN IPM

S. No.	Do's	Don'ts
1.	Deep ploughing is to be done on bright sunny days during the months of May and June. The field should be kept exposed to sun light at least for 2-3 weeks.	Do not plant or irrigate the field after ploughing, at least for 2-3 weeks, to allow desiccation of weed's bulbs and/or rhizomes of perennial weeds.
2.	Adopt crop rotation.	Avoid monocroping
3.	Grow only recommended varieties.	Do not grow varieties not suitable for the season or the region.
4	Sow early in the season	Avoid late sowing as this may lead to reduced yields and incidence of white grubs and diseases.
5	Always treat the seeds with approved chemicals/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 on test recommendations.	Do not apply any micronutrient mixture after sowing without test recommendations.
11	Conduct weekly AESA 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	In case of pests which are active during night spray recommended biopesticides/chemicals at the time of their appearance during evening time.	Do not spray pesticides at midday since, most of the insects are not active during this period.
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 pesticides on trap crop, otherwise it may not attract the pests and natural enemies.

XI. 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	Harvest interval (days)
1.	Oxydemeton-methyl Highly toxic 	Class Ib Moderately hazardous	Severe – diarrhoea, pinpoint and non - reactive pupils, respiratory difficulty, pulmonary edema, cyanosis, loss of sphincter control, convulsions, coma and heart block	**First aid measures:** Atrophine sulphate **Treatment of poisoning:** For ingestion lavage stomach with 5 % sodium bicarbonate, if not vomiting. For skin contact, wash with soap and water (eyes – wash with isotonic saline). Wear rubber gloves while washing contact areas. In addition to atropine give 2 – PAM (2 – pyridine aldoximemethiodide). 1 g and 0.25g for infants intravenously at slow rate over a period of 5 minutes and administer again periodically as indicated. More than one injection may be required. Avoid morphine, theophylline, aminophylln, barbiturates Phenothiaznines	7 days
2.	Quinalphos Highly toxic 	Class II Moderately hazardous	-do-	-do-	-do-

XII. BASIC PRECAUTIONS IN PESTICIDE 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** store expose to sunlight or rain water; **Do not** 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. Equipments

1. Select right kind of equipment.
2. **Do not** use leaky and defective equipments
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.

XIII. PESTICIDE APPLICATION TECHNIQUES

Equipment			
Category A: Stationary, crawling pest/disease			
Vegetative stage i) For crawling and soil borne pests ii) For small sucking leaf borne pests	Insecticides and fungicides	• Lever operated knapsack sprayer (droplets of big size) • Hollow cone nozzle @ 35 to 40 psi • Lever operating speed = 15 to 20 strokes/min *or* • Motorized knapsack sprayer or mist blower (droplets of small size) • Airblast nozzle • Operating speed: 2/3rd throttle	 
Reproductive stage	Insecticides and fungicides	• Lever operated knapsack sprayer (droplets of big size) • Hollow cone nozzle @ 35 to 40 psi • Lever operating speed = 15 to 20 strokes/min	
Category B: Field flying pest/airborne pest			
Vegetative stage Reproductive stage *(Field Pests)*	Insecticides and fungicides	• Motorized knapsack sprayer or mist blower (droplets of small size) • Airblast nozzle • Operating speed: 2/3rd throttle *Or* • Battery operated low volume sprayer (droplets of small size) • Spinning disc nozzle	 
Mosquito/ locust and spatial application *(migratory* Pests)	Insecticides and fungicides	• Fogging machine and ENV (exhaust nozzle vehicle) (droplets of very small size) • Hot tube nozzle	
Category C: Weeds			
Post-emergence application	Weedicide	• Lever operated knapsack sprayer (droplets of big size) • Flat fan or floodjet nozzle @ 15 to 20 psi • Lever operating speed = 7 to 10 strokes/min	 
Pre-emergence application	Weedicide	• Trolley mounted low volume sprayer (droplets of small size) • Battery operated low volume sprayer (droplets of small size)	

XIV. 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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Ecological Engineering Plants for Sesame

Cluster bean

Cowpea

Carrot

Sunflower

Buckwheat

French bean

Mustard

Parsley

Dill

Anise

Caraway

Maize

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