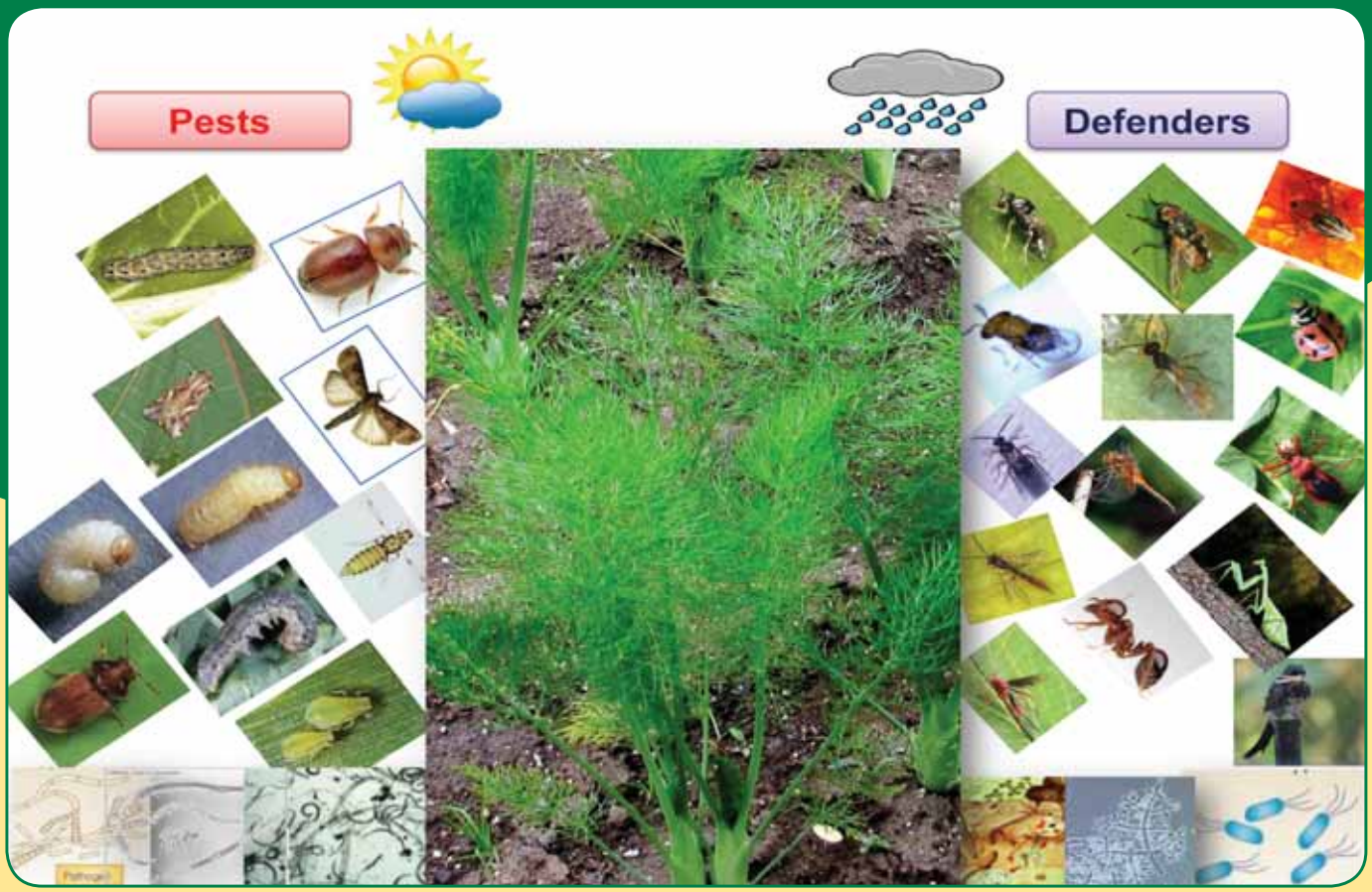
AESA BASED IPM PACKAGE

AESA based IPM – Fennel



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Department of Agriculture and Cooperation
Ministry of Agriculture
Government of India

Important Natural Enemies of Fennel Insect Pests

Parasitoids

***Trichogramma* spp.**

***Carcelia* spp.**

***Chelonus* spp.**

***Bracon* spp.**

Ceranisus menes

***Aphidius* sp**

Predators

Robber fly

Ladybird beetle

Spider

Reduviid bug

Dragonfly

King crow

The AESA based IPM - Fennel, 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 Fennel

Back cover picture Fennel 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)

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AESA BASED IPM PACKAGE FOR FENNEL

Fennel plant description:

Fennel (*Foeniculum vulgare* Mill; Family: Apiaceae) is an herbaceous biennial or perennial plant grown for use as a herb or flavoring. The fennel plant is an erect herb with 4–5 hollow stems and distinctly divided feathery foliage. The leaves are simple and linear and are 2–15 cm in length. The plant produces flowers on flat umbels which can be 20 cm (7.9 in) in diameter and possess 20-50 tiny yellow flowers. The plant may reach 2 m (6.6 ft) in height. Fennel is a short-lived plant and is almost always grown as an annual crop. Fennel may also be referred to as wild fennel or sweet fennel depending on variety and originates from southern Europe and the Mediterranean.

Fennel is a stout and aromatic spice crop in India which is commercially cultivated as an annual herb. Fennel is known in various names in different parts of the country. In Hindi, fennel is known as 'saunf' and in Tamil it is known as 'perungeerakam'. Major production centres of fennel in India are Rajasthan, Andhra Pradesh, Punjab, Madhya Pradesh, Uttar Pradesh, Gujarat, Karnataka, and Haryana.

Cool and dry climate is best for the cultivation of fennel crop. Dry and cool weather during the seed set increases seed yield as well as the quality of the produce. Fennel can be cultivated in all types of soils that are rich in organic matter. Shallow sandy soils are not suitable for fennel cultivation. Best soils for fennel cultivation are black cotton soil and loamy soil containing lime. Proper drainage is also an important requisite for commercial cultivation of fennel crop.

I. PESTS

A. Pests of National Significance

1. Insect pests

1.1 Aphid: *Hyadaphis coriandri* Das. (Hemiptera: Aphididae)

1.2 Thrips: *Thrips flavus* Schrank (Thysanoptera: Thripidae)

1.3 Leaf eating caterpillar/gram pod borer: *Helicoverpa armigera* Hübner (Lepidoptera: Noctuidae)

1.4 Cutworm: *Agrotis ipsilon* Hufnagel, & *Agrotis segetum* Denis & Schiffermüller (Lepidoptera: Noctuidae)

1.5 Cigarette beetle: *Lasioderma serricorne* Fabricius (Coleoptera: Anobiidae)

1.6 Drug store beetle: *Stegobium paniceum* Linnaeus (Coleoptera: Anobiidae)

2. Diseases

2.1 Leaf blight: *Ramularia foeniculi* Sibilia

2.2 Leaf spot: *Cercosporidium punctum* (Delacr.) Deighton

2.3 Damping off: *Pythium aphanidermatum* (Edson) Fitzp. (seedling)

2.4 Wilt: *Fusarium equiseti* (Corda) Sacc.

2.5 Powdery mildew: *Erysiphe polygoni* DC/ *E. heraclei*

2.6 Collar rot: *Sclerotinia sclerotiorum* (Lib.) de Bary

2.7 Root rot: *Rhizoctonia solani* J.G. Kühn

3. Nematode

3.1 Root-knot nematode: *Meloidogyne* spp.

4. Weeds

Broadleaf

4.1 Lamb's quarter: *Chenopodium album* L. (Chenopodiaceae)

4.2 Scarlet pimpernel: *Anagallis arvensis* L. (Primulaceae)

4.3 Yellow sweet clover: *Melilotus indica* (L.) All. (Fabaceae)

4.4 Fine leaf fumitory: *Fumaria parviflora* Lam. (Fumariaceae)

4.5 Corn spurry: *Spergula arvensis* L. (Caryophylliaceae)

4.6 Wild onion: *Asphodelus tenuifolius* Cav. (Xanthorrhoeaceae)

Grasses

4.7 Blue grass: *Poa annua* L. (Poaceae)

4.8 Canary grass: *Phalaris minor* Retz. (Poaceae)

Sedges

4.9 Purple nut sedge: *Cyperus rotundus* L. (Cyperaceae)

4.10 Yellow sedge: *Cyperus campestris* Schrad. ex Nees (Cyperaceae)

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. sun, rain, wind and soil nutrients) and biological factors (i.e. pests, diseases and weeds). All these factors can play a role in the balance which exists between herbivore insects and their natural enemies. Understanding the intricate interactions in an ecosystem can play a critical role in pest management.

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 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 Integrated Pest Management (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)
- Nutrient management through fertilizers 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 of fertilizers for best results. The phosphatic fertilizers should not be applied each and every season as the residual phosphate of the previous season will be available for the current season also.
- Proper irrigation
- Crop rotation

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

Farmers should:

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

- Take representative soil sample and get the soil analysis report showing soil pH, electrical conductivity (EC), organic matter and nutrient status.
- Nutrient management especially through organic manures and biofertilizers based on the soil test results should be followed. If the dose of nitrogenous fertilizers is too high the crop becomes too succulent and therefore susceptible to insects and diseases. If the dosages are too low, the crop growth is retarded. So, the farmers should maintain proper soil fertility level through integrated nutrient management approach for best results.
- Proper irrigation
- Crop rotation
- Observe the number and species of weeds found in per square meter area each in five randomly selected spots/ha.

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. Several studies have documented such compensation through increased growth and photosynthetic rate.

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).

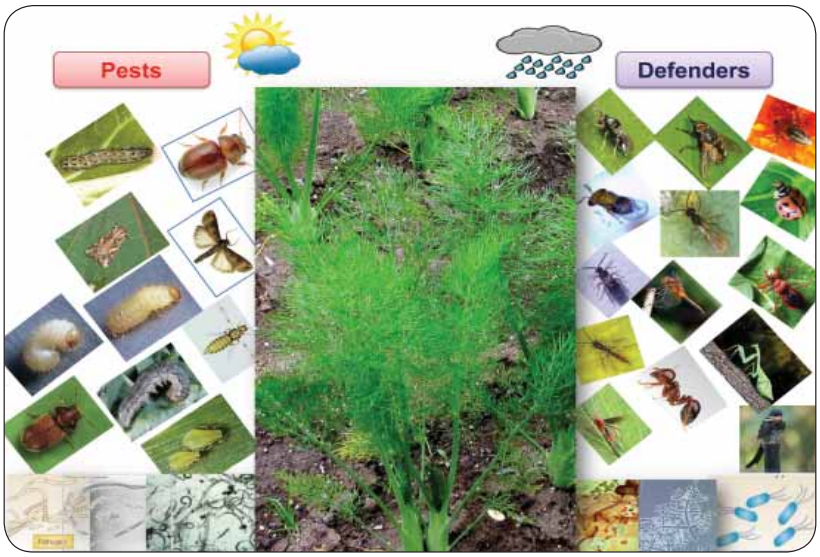
Pest: Defender ratio (P: D ratio):

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 fennel 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 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 situations of the field.
    - Weather: Observe the weather conditions.
    - Take representative soil samples from different spots and send to nearby soil testing laboratory.
    - Discuss the soil analysis report and recommendation provided by soil testing laboratory.
    - Arrange for required quantity of FYM/ vermi compost/fertilizers/soil amendments etc.

- 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/hill representing the field situation. The weather conditions, 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.

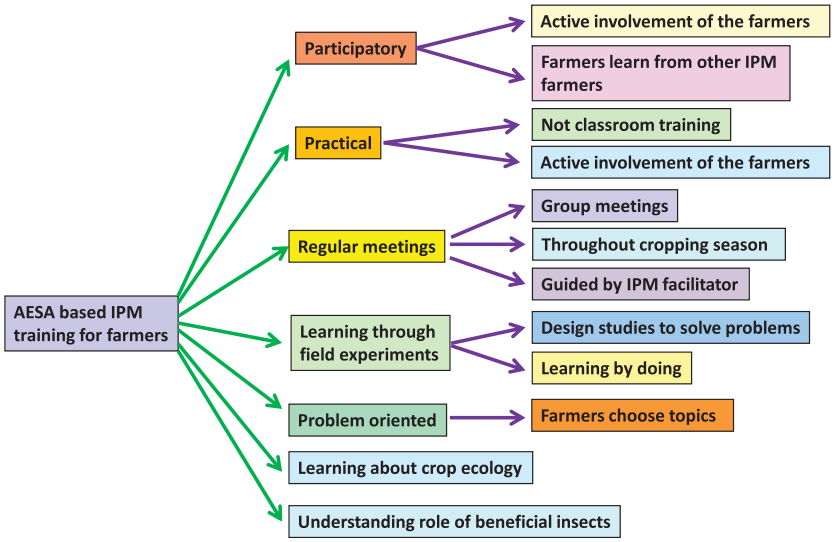
AESA and farmer field school (FFS):

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

For insect pests:

Aphids: 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).

***Helicoverpa*:** Total number of plants, damaged plants due to *Helicoverpa,* number of larvae on individual plants should be counted and recorded.

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

C. Surveillance through pheromone trap catches for *Helicoverpa*:

Pheromone traps for *Helicoverpa armigera* @ 4-5/acre have to be installed. Install the traps separated by a distance of >75 feet in the vicinity of the selected field, if available. 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 should be counted and recorded. The trapped moths should be removed and destroyed.

D. Yellow/blue pan water/ sticky traps:

Set up yellow pan water/sticky traps for monitoring aphids and blue pan water/sticky traps for thrips at 15cm above the canopy @ 4-5 traps/acre. Locally available empty tins can be painted yellow/ blue and coated with grease/Vaseline/castor oil on outer surface may also be used. Count the number of pests on the traps daily and take the appropriate decision regarding management practices.

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).

F. 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:

- Rais the flowering plants/compatible cash crops along the field border by arranging shorter plants towards main crop and taller plants towards the border to attract natural enemies as well as to avoid immigrating pest population
- Grow flowering plants on the internal bunds inside the field
- Not to uproot weed plants those are growing naturally like *Tridax procumbens, Ageratum* sp, *Alternanthera* sp, etc. which act as nectar source for natural enemies,
- Not to apply broad spectrum chemical pesticides, when the P: D ratio is favourable. The plant compensation ability should also be considered before applying chemical pesticides.

Ecological Engineering for Pest Management – Below Ground:

- Crop rotations with leguminous plants which enhance nitrogen content.
- Keep soils covered year-round with living vegetation and/or crop residue.
- Add organic matter in the form of FYM, vermicompost, crop residue which enhance below ground biodiversity.
- Reduce tillage intensity so that hibernating natural enemies can be saved.
- Apply balanced dose of fertilizers and nutrients.
- Apply mycorrhiza and plant growth promoting rhizobacteria (PGPR)
- Apply *Trichoderma* spp. 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 zastrowi sillemi,* earwigs, etc.

Ecological Engineering Plants

Attractant plants

French bean

Cowpea

Cosmos


Carrot


Sunflower


Coriander


Buckwheat


Marigold

Repellent plants


Spearmint


Ocimum spp.

Border plants


Sorghum


Maize


Bajra

Intercrops


Onion


Cowpea

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

Biodiversity of natural enemies observed in Ecological Engineering field at NIPHM

Biodiversity of natural enemies: Parasitoids

Biodiversity of natural enemies: Predators

Biodiversity of natural enemies: Spiders

A. Resistant/tolerant varieties:

Pest/disease	Resistance/ tolerant variety*
Blight and powdery mildew	RF-101, RF-125 (Moderate resistant)
Sugary disease, leaf blight, leaf spot	Gujarat Fennel-1 (GF-1), (VC-14-34), PF-35 (Guj.) (Tolerant/ resistant)
Leaf blight	S-7-9 (Guj.) (Moderate resistant)
Aphid	S-16, E-58, UF-132 (Tolerant)

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

IV. CROP STAGE-WISE IPM

Management	Activity
Pre- sowing*	
	Common cultural practices: • Timely sowing should be done. • Field sanitation, rogueing • Destroy the alternate host plants • Apply manures and fertilizers as per soil test recommendations • Deep ploughing of fields during summer • Follow crop rotation • Sow the ecological engineering plants • Sow/plant sorghum/maize/bajra in 4 rows all around fennel crop as a guard/barrier crop.
Nutrients	• Soil is brought to fine tilth by 2-3 ploughing with harrow or country plough. • For *rabi* drilled fennel apply10 of FYM, 36 Kg Nitrogen (N) and 18 Kg Phosphorous (P) per acre. Whole quantity of FYM should be mixed in the soil at the time of land preparation. • Beds with provision of irrigation channels should be prepared before sowing of seeds to facilitate proper irrigation and intercultural operations.
Weeds	• Deep summer ploughing or solarisation during summer
Soil borne pathogens, nematodes and resting stages of insect pests	**Cultural control:** • Soil solarisation: Cover the beds with polythene sheet of 45 gauge (0.45 mm) thickness for three weeks before sowing which will help in reducing the soil borne pests. • Apply organic amendment viz., mustard, castor or neem cake @ 0.8-1.0 tonnes/acre.
Sowing*	
	Common cultural practices: • Use tolerant/ resistant varieties. • Select healthy, certified, and weed seed free seeds
Nutrients	• Half dose of N (18 Kg/acre) and full dose of P (18 Kg/acre) should be applied as basal dose. • In zinc deficient areas, apply zinc sulphate @ 8 Kg/acre.
Weeds	• Sowing/transplanting should be done in lines to facilitate hoeing and weeding operations during vegetative stage. • Adopt recommended agronomic practices like timely sowing, proper spacing irrigation etc. to obtain the healthy plant stand.

*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: • Collect and destroy crop debris • Avoid water logging • Judicious use of fertilizers • Install light traps in and around the fields • Avoid any stress to the crop as much as possible • Enhance parasitic activity by avoiding chemical spray, when 1-2 larval parasitoids are observed **Common mechanical practices:** • Collect and destroy disease infected and insect infested plant parts • Collect and destroy eggs and early stage larvae • Handpick the older larvae during early stages of the crop • 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. • Set up bonfire during evening hours at 7-8 pm **Common biological practices:** • Conserve natural enemies through ecological engineering • Augmentative release of natural enemies
Nutrients	• Apply remaining 18 Kg of N in two equal splits of 9 Kg each as top dressed at an interval of 30 days and 60 days after sowing.
Weeds	• The crop should be kept free from weeds for initial 40 days by adopting 2-3 hand tool weeding. The 1st weeding and hoeing should be done at 20-25 days after sowing and 2nd and 3rd at 40 and 60 days after sowing.
Aphid and thrips	**Cultural control:** • Spray pressurized water • Use yellow and blue sticky traps @ 4-5 traps/acre for aphid and thrips, respectively, before flowering. **Biological control:** • Release *Coccinella septumpunctata* @ 2000 beetles/ acre (2 releases at 15 days interval)
Cutworm	**Cultural control:** • Attracting cutworm larvae using rice bran – heaps of rice bran should be placed in several places in the late afternoon. They can be removed from the rice bran on the next day and destroyed. • Flood field prior to planting whenever possible farmers can consider temporarily flooding fields, particularly on severely infested fields.
Leaf eating caterpillar/gram pod borer	**Cultural control:** • Grow intercrops such as cowpea, onion, coriander, urdbean in 5 or 4:1 ratio

	• Rotate the fennel crop with a non-host cereal crop i.e. cucurbit, or cruciferous vegetable. • Use of ovipositional trap crops such as marigold @ 100 plants/acre 1 row of marigold for every 18 rows of fennel (marigold seedling of 45 days should be planted along with fennel transplanting) • Collect larvae from marigold flowers and destroy them. **Biological control:** • Release egg parasitoid *Trichogramma pretiosum* @ 50,000 adults (in the form of parasitized card) /acre / week.
Leaf *(Ramularia)* blight	• See in common cultural practices
***Fusarium* wilt**	**Cultural control:** • Avoid water stagnation • Follow the common cultural, mechanical and biological practices
Powdery mildew	• Follow the common cultural, mechanical and biological practices
Damping off	**Cultural control:** • Follow the common cultural, mechanical and biological practices
Collar rot	**Cultural control:** • Avoid water stagnation in the field. • Follow the common cultural, mechanical and biological practices
Root rot	**Cultural control:** • Crop rotation with non-susceptible hosts will reduce populations of *Rhizoctonia* in the soil. • Avoid crop rotations with sugar beets if there is evidence of *Rhizoctonia* in the field. Crop rotations with dry beans may also increase incidence of disease. • Protective seed treatment and good seedbed preparation can reduce root rot. • Earthing up of soil around stems promotes lateral root growth and lessen the effect of root rot on older plants.
Leaf spot	**Cultural control:** • Avoid water stagnation. • Follow the common cultural, mechanical and biological practices
Reproductive stage	
Nutrients	• Incorporate crop residues in soil immediately after harvest.
Weeds	• Remove left over weeds before shedding of seeds to prevent further spread of weeds.
Insect- pests & disease management	• Same as in vegetative stage
Storage insect pest	
Cigarette beetle	**Mechanical control:** • Sticky traps baited with the female sex pheromone, • Store grains in gunny bags with moisture proof lining • Synthetic serricornin is used in commercially available cigarette beetle traps
Drugstore Beetle	**Mechanical control:** • The drugstore beetle sex pheromone, stegobinone (2,3-dihydro-2,3,5-trimethyl-6-(1-methyl-2oxobutyl) -4H-pyran-4-one) is used in commercially available traps and lures
	• Sticky traps baited with the female sex pheromone, stegobinone, can be used to monitor for adult beetles

Cigarette beetle	**Mechanical control:** • Sticky traps baited with the female sex pheromone • Store grains in gunny bags with moisture proof lining • The commercially available cigarette beetle traps with synthetic serricornin
Drugstore beetle	**Mechanical control:** • Use commercially available traps and lures with the drugstore beetle sex pheromone, stegobinone (2,3-dihydro-2,3,5-trimethy l-6-(1-methyl-2oxobutyl) -4H-pyran-4-one) is used in • Use sticky traps baited with the female sex pheromone, stegobinone for monitoring adult beetles

Note: Pesticides dosages and spray fluid volume are based on high volume sprayer

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 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.

VI. NUTRITIONAL DEFICIENCIES/ DISORDERS

Nutrients and their deficiency symptoms:

Nitrogen: Pale or yellow green leaves (chlorosis) symptoms appear first in the older leaves. Reddish tints gradually appear at the leaf margins spread toward the midrib or central vein. Leaves are small. Overall growth is markedly reduced.
Correction measure: Foliar spray of urea 1% or DAP 2% twice at weekly intervals.

Phosphorus: Slow plant growth, leaf colour may intensify, browning or purpling in foliage in some plants, thin stems, reduced lateral breaks, loss of lower leaves.
Correction measure: Soil application of recommended dose of phosphorous should be applied at the time of sowing or planting.

Potassium: Since potassium is very mobile within the plant, symptoms only develop on young leaves in the case of extreme deficiency. Reduced growth, shortened internodes, marginal burn or scorch (brown leaf edges), necrotic (dead) spots in the leaf, reduction of lateral breaks and tendency to wilt readily.

Sulphur: Stunted plant growth, leaves turn to pale yellow. The leaves show a general overall chlorosis. Under severe deficiency, the yellowing is much more uniform over the entire plant including young leaves.
Correction measure: Foliar spray of K_2SO_4 or $CaSO_4$ @ 1% twice at fortnightly interval.

Magnesium: Symptoms appear on the older leaves. Older leaves may fall off, or they develop a triangular arrowhead at the base of the leaf, near the stalk. Reduction in growth, marginal chlorosis, interveinal chlorotis (yellow between the veins) in some species. Eventually the whole leaf becomes yellow.
Correction measures: Foliar spray of magnesium sulphate @ 0.5 % (5g $MgSO_4$ dissolved in 1 lit of water) in the interval of 15 days on the foliage till the symptoms disappear.

Manganese: Symptoms occur on new growth. Leaves appear mottled, light green to yellow green in-between the veins.
Correction measure: Foliar spray of $MnSO_4$ @ 0.5% twice at weekly interval.

Iron: The deficiency of iron shows up first in the young leaves of plants, which develop interveinal chlorosis and it progresses rapidly over the entire leaf. In severe cases, the leaves turn completely white.

Correction measure: Soil application of $FeSO_4$ at 12 Kg/acre followed by foliar spray of $FeSO_4$ @ 0.5% during 3rd, 4th and 5th months.

VII. COMMON WEEDS

1. Lamb's quarters: *Chenopodium album* L. (Chenopodiaceae)

2. Scarlet pimpernel: *Anagallis arvensis* L. (Primulaceae)

3.Sweet clover: *Melilotus indica* (L.) All. (Fabaceae)

4. Fine leaf fumitory: *Fumaria parviflora* Lam. (Fumariaceae)

5. Corn spurry: *Spergula arvensis* L. (Caryophyllaceae)

6. Bluegrass: *Poa annua* L. (Poaceae)

7. Purple nut sedge: *Cyperus rotundus* L. (Cyperaceae)

8. Yellow sedge: *Cyperus campestris* Schrad.ex Nees (Cyperaceae)

9. Wild onion: *Asphodelus tenuifolius* Cav. (Xanthorrhoeaceae)

10. Canary grass: *Phalaris minor* Retz. (Poaceae)

VIII. DESCRIPTION OF INSECT PESTS

1) Aphid:

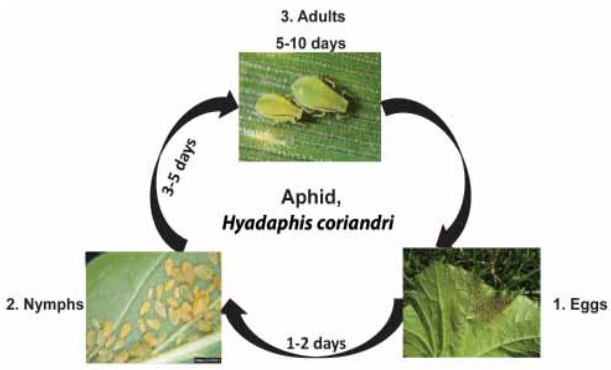
Biology:

Egg: The females produce wingless offspring which are mated by the males and then lay hard-shelled eggs on the branches. The eggs initially are greenish, but soon turn black. In this form the aphids survive the winter. In Spring the eggs hatch to wingless females which produce winged offspring by parthenogenesis.

Nymph: There were three nymphal instars. The first instar nymphs were dull white and became light green in the second instar. The third instar nymphs and adults turned green.

Adult: Adults are yellow-green in color, dusted with greyish wax. They have short, dusky, slightly swollen, siphunculi (or cornicles) that are about twice as long as wide

Life cycle:



Damage symptoms:

- **Direct damage:** Aphids damage plants by puncturing them and sucking their juices. They damage the young and soft parts of plants, such as new leaves and shoots. Signs of damage are leaves not opening properly and being smaller in size. Severe infestation can cause shoots to wilt and dry out.
- **Indirect damage:** Aphids have wings and can move from plant to plant spreading viral diseases, picked up from infected plants. Aphids secrete a sugary liquid that stimulates black sooty mold growth. It can cover the surface of leaves which affects the way they absorb sunlight.

1,2. http://bulletin.ipm.illinois.edu/photos/cowpea_aphids.jpg 3. http://www.agroatlas.ru/content/pests/Aphis_craccivora/Aphis_craccivora.jpg

http://entnemdept.ufl.edu/creatures/veg/aphid/corriander_aphid01.jpg
http://entnemdept.ufl.edu/creatures/veg/aphid/corriander_aphid02.jpg

Natural enemies of aphid:

Parasitoids: *Lysiphlebus* sp, *Diaeretiella* sp, *Aphelinus* sp, *Aphidius colemani* etc.

Predators: Ladybird beetle, lacewing, spiders, hover fly etc.

*For management refer to page number 14

2) Thrips:

Biology:

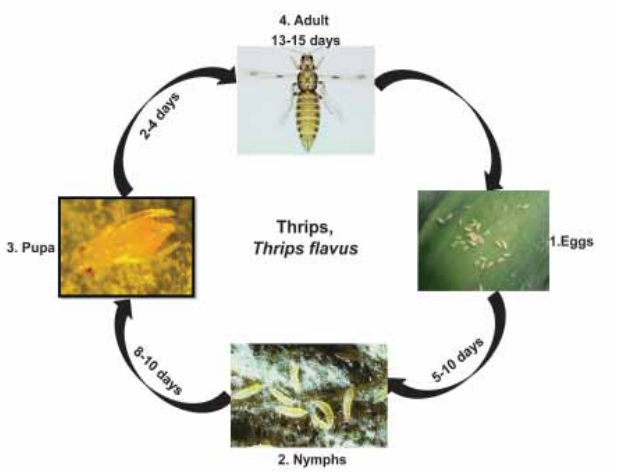
Egg: Eggs are white to yellow, kidney-bean shaped, microscopic in size. Develop within leaf tissue with one end near the leaf surface. Egg stage is 5-10 days.

Larva: Instars I and II are active, feeding stages. Larvae are white to pale yellow, elongate and slender body. Resemble adult, but without wings. Antennae are short and eyes are dark in color. Crawl quickly when disturbed. Larval stage is 8-10 days.

Pre-pupa and pupa: Instars III and IV are inactive, non-feeding stages called pre-pupa and pupa. Pale yellow to brown; body more stout than younger instars. Antennae are bent to head; wing buds are visible. Found in the soil, at the base of the plant. Pre-pupal and pupal period is 2-4 days.

Adult: About 1.5 mm long; elongate, yellow and brown body with two pairs of fringed (hairy) wings. Mouthparts are beak-like and antennae are 7-segmented. Parthenogenic (asexually reproducing) females; males are extremely rare. Feed on young leaves and insert eggs individually into leaves. Adult life span is about 13-15 days month.

Life cycle:



1,2,3,4. http://extension.usu.edu/files/publications/factsheet/ENT-117-08PR.pdf

Damage symptoms:

- **Direct damage:** Thrips damage the undersides of leaves by sucking their juices. They damage young and soft parts of plants such as new leaves and shoots.
- As a result, leaves curl downwards and change to a blackish- silver color. Severe infestation causes young leaves to wilt and dry out.
- **Indirect damage:** Thrips can carry and spread viral diseases.

Natural enemies of thrips:

Parasitoid: *Ceranisus menes*

Predators: Predatory thrips, minute pirate bug, ladybird beetle, lacewing, mirid bug etc.

*For management refer to page number 14

3) Leaf eating caterpillar/gram pod borer:

Biology:

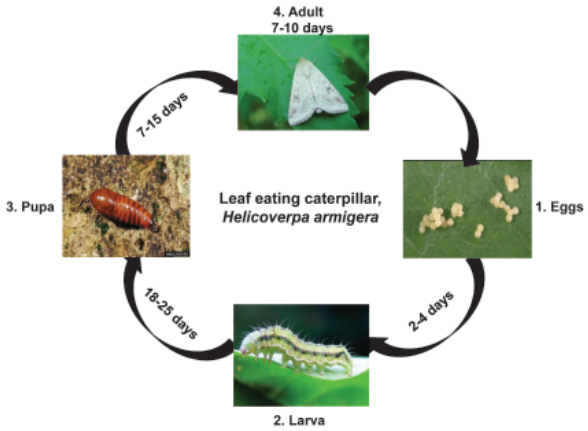
Egg: The spherical, yellowish eggs are laid singly on tender parts and buds of plants. The egg period lasts for 2-4 days.

Larva: Caterpillars vary in colour, initially brown and later turn greenish with darker broken lines along the side of the body. The larval period lasts for 18-25 days. Body covered with radiating hairs. When full grown, they measure 3.7 to 5 cm in length.

Pupa: Pupation takes place inside the soil. Pupal stage lasts 7-15 days.

Adult: Moth is stout, medium sized with brownish/grayish forewings with a dark cross band near outer margin and dark spots near costal margins, with a wing expanse of 3.7cm.

Life cycle:



Damage symptoms:

- Young larva feeds on the leaves.
- Feed on leaves, shoots and buds.

Natural enemies of leaf eating caterpillar/gram pod borer:

Parasitoids: *Trichogramma* spp., *Tetrastichus* spp., *Telenomus* spp, *Bracon* spp., *Campoletis* sp, *Chelonus* spp., *Ichneumon* spp., *Carcelia* spp. etc.

Predators: Lacewing, ladybird beetle, spider, red ant, dragonfly, robber fly, reduviid bug, praying mantis, King crow etc.

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

*For management refer to page number 15

4) Cutworm:

Biology:

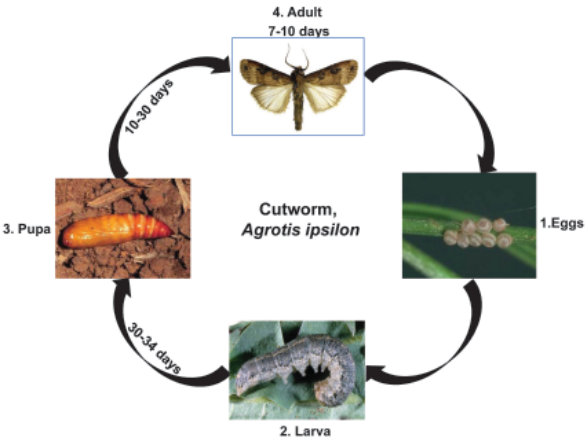
Egg: Each female moth come out at dusk and lay creamy white, dome-shaped eggs (200-350) in clusters of about 30 each, either on the under surface of the leaves of host plants or in the soil.

Larva: Newly emerged young larva is yellow in colour, 1.5 mm long with a shiny, black head and a black shield on the prothorax. The full-grown larva is about 42-45 mm long and is dark or dark brown with a plump and greasy body. Larvae live in the soil and are yellow or blackish- green in color. They have striped markings running down the sides of their bodies. The larval stage varies from 30-34 days

Pupa: Pupae are brown to dark brown, about 1.5 to 2.0 cm in length and are usually found in or on piles of leaf mould. Pupation takes place underground in an earthen chamber. Pupal period is completed in 10 to 30 days

Adult: Adult measures about 25 mm from the head to the tip of the abdomen and looks dark with some grayish patches on the back and dark streaks on the forewings. Adults live for 7-10 days. Total life cycle takes up to 36 days (from egg to adult). The moths usually emerge at night. This pest generally completes three generations in a year.

Life cycle:



Damage symptoms:

- Both adult and caterpillars become active at night.
- During the day time caterpillars hide in crack and crevices in the soil.
- They attack young plants by severing their stems, pulling all parts of the plant into the ground and devouring them.
- Plants with severed stems have difficulty growing again.
- This pest can cause serious damage; particularly when crops are at 25 - 35 days after planting.

1. http://www7.inra.fr/hyppz/IMAGES/7030561.jpg
2. http://entnemdept.ufl.edu/creatures/veg/black_cutworm03.jpg
3. http://www.infonet-biovision.org/res/res/files/308.300x200.jpeg
4. http://www.agroatlas.ru/content/pests/Agrotis_ipsilon/Agrotis_ipsilon.jpg

Natural enemies of cutworm:

Parasitoids: *Trichogramma* spp., *Tetrastichus* spp., *Telenomus* spp., *Bracon* spp., *Campoletis* sp, *Chelonus* spp., *Ichneumon* spp., *Carcelia* spp. etc.

Predators: Lacewing, ladybird beetle, spider, red ant, dragonfly, robber fly, reduviid bug, praying mantis, King crow etc.

*For management refer to page number 14

5) Cigarette beetle:

Biology:

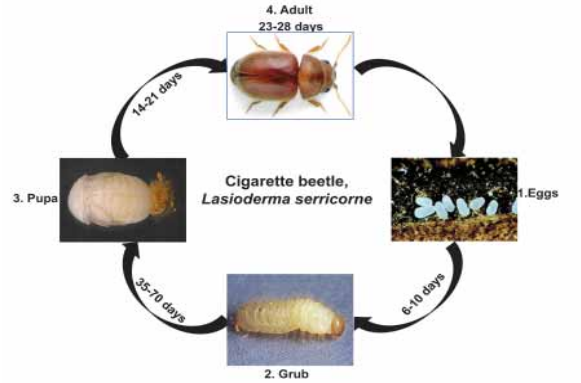
Egg: An egg is pearly white, and is not easily seen with the naked eye. When fully grown, beetle larvae is C-shaped (grub-like) and about 3/16-inch long. Female lays about 30 eggs in a period of 3 weeks. Eggs hatch in 6 to 10 days.

Larva: Larvae are creamy white and covered with long, yellowish-brown hairs. They have a brown head and legs. The larval stage lasts from 5 to 10 weeks.

Pre-pupa and pupa: The pre-pupal and pupal periods last 2 to 3 weeks and are passed in a cell.

Adult: Adults are yellowish- to reddish-brown, oval-shaped, and about 1/10-inch long. The head is bent downward sharply, nearly at right angles to the body, giving a humpbacked appearance when viewed from the side. The wing covers (elytra) are smooth, and the antennal segments are uniform and saw-like (serrate). Adults are strong flyers and active in subdued light at temperatures above 65° F. Adult beetles may live from 23 to 28 days. In temperate climates, beetles begin swarming in May and again in August. Overwintering may be passed in the larval stage, with some adults not too resistant to cold hibernating in crevices. There may be 5 to 6 overlapping generations per year in warm localities with only one generation in the more temperate regions. In warehouses, the life cycle may be completed in 52 days.

Life cycle:



1. http://bru.gmprc.ksu.edu/ImageDB/m_CigEg.jpg
2. http://www.pestid.msu.edu/Portals/0/dnnPhotoGallery/882/571.gif
3. http://www.nbaii.res.in/insectpests/images/Lasioderma-serricorne2.jpg
4. http://www.zin.ru/animalia/coleoptera/images/foto/lasioderma_serricorne_f.jpg

*For management refer to page number 15

6. Drugstore beetle:

Biology:

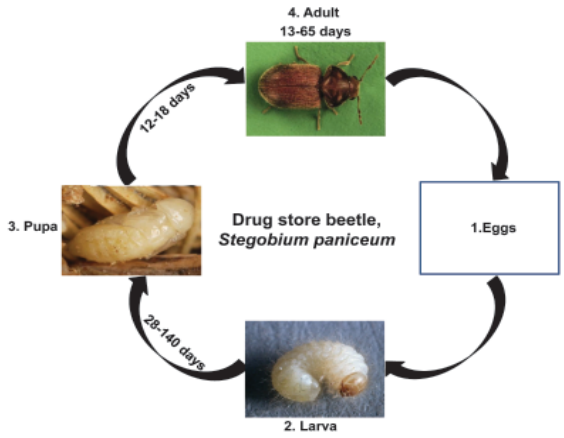
Egg: Females lay up to 75 eggs in the food or substrate.

Larva: The larval period ranges from 4 to 20 weeks. Larvae tunnel through the substrate and when fully grown build a cocoon and pupate.

Pupa: Pupal period is 12 to 18 days.

Adult: The beetles are cylindrical, 2.25 to 3.5 mm long, and are uniform brown to reddish brown in colour. Have longitudinal rows of fine hairs on the elytra (wing covers). The antennae of the cigarette beetle are serrated (like the teeth on a saw) while the antennae of the drugstore beetle are not and end in a 3-segmented club. The elytra (wing covers) of the drugstore beetle have rows of pits giving them striated (lined) appearance. Adult females live approximately 13 to 65 days. The entire life cycle is generally less than two months but can be as long as 7 months.

Life cycle:



Favourable condition

- The duration of the life cycle is highly dependent on the temperature and food source. Development occurs between 60 to 93° F (15 to 34° C) but is optimal at about 85° F (30° C) and 60 to 90% relative humidity.

2. http://entoweb.okstate.edu/ddd/IMAGES/drugstore2.jpg
3. http://bugguide.net/images/raw
4. http://www.ozanimals.com/image/albums/australia/Insect/drugstore-beetle.jpg

*For management refer to page numbers 15, 16

Natural Enemies of Fennel Insect Pests
Parasitoids

Egg parasitoids

1. *Trichogramma* spp.

2. *Tetrastichus* spp.

3. *Telenomus* spp.

Egg-larval parasitoid

4. *Chelonus* spp.

Larval parasitoids

5. *Bracon* spp.

6. *Campoletis* spp

Larval-pupal parasitoid

7. *Carcelia* spp.

Pupal parasitoid

8. *Ichneumon* spp.

Nymphal and adult parasitoids

9. *Lysiphlebus* spp.

10. *Diaeretiella* spp.

11. *Aphelinus* spp.

12. *Aphidius colemani*

13. *Ceranisus menes*

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/Campoletis.htm; 6.http://72.44.83.99/forum/viewthread.php?thread_id=40633&pid=178398;7.http://www.nbaii.res.in/Featured%20insects/Campoletis.html;8.http://www.organicgardeninfo.com/ichneumon-wasp.html;9.http://www.nuetzlinge.de/uploads/pics/lysiphlebus_Aphis_gossypii.jpg;10.http://www.nbaii.res.in/Featured%20insects/diaeretiella4.jpg;11.http://australianmuseum.net.au/Uploads/Images/23077/Pro%20019_big.jpg;12.http://www.goodbugs.org.au/Good%20bugs%20available/Resources/aphidius254a.jpeg; 13. http://agri.mine.utsunomiya-u.ac.jp/hpe/depte/bioproe/bioe/bioimge/AppEntmol1.gif

Predators

1. Lacewing

2. Ladybird beetle

4. Spider

4. Red ant

5. Dragonfly

6. Robber fly

7. Reduviid bug

8. Praying mantis

9. Hover fly

10. Predatory thrips

11. Minute pirate bug

12. King crow

4. 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; 5. http://en.wikipedia.org/wiki/Dragonfly; 6. http://www.warpedphotosblog.com/robber-fly-and-prey; 8. ttp://spirit-animals.com/praying-mantish/; 10. http://chem-gro.com/cart/images/Amblyseius-swirskii.jpg; 11. http://plantdiagnostics.umd.edu/_media/client/diagnostics/fullsize/pirate_bug_l.jpg; 12. http://nagpurbirds.org/blackdrongo/picture/1639;

XI. DESCRIPTION OF DISEASES

1) Leaf (*Ramularia*) blight:

Disease symptoms:

- Symptoms first appear on the lower and older leaves in the month of January, as a minute, angular brown, necrotic spot.
- Later these spots become large and are covered with grayish white erumpent growth.
- At later stage, linear and rectangular spots cover the entire stem, peduncles and fruits.
- Severely affected leaves shrivel and dry up.
- In case of severe attack whole plant turns to brown colour, resulting in drying up of plant

Survival and spread:

- Pathogen survives on infected plant debris in the soil
- Pathogen infects lower part first and then above plant parts
- It spreads through wind and rain splash.

Favorable conditions:

- Disease favours high humidity >80%.

*For management refer to page number 15

2) Leaf spot:

Disease symptoms:

- The disease primarily affects older foliage. Affected leaf tips and stems turn brown to black in color and dry up.
- Examination of the stems and leaves show tiny, discrete, dark brown to black fungal patches.
- Early patches are less than one-sixteenth inch wide, and can be oval, circular or irregular in shape

Survival and spread:

Primary: Through dormant mycelium remains in the infected crop debris, seeds and volunteer plants

Secondary: Through wind dispersed conidia

Favorable conditions:

- Disease favours high humidity >80%.

*For management refer to page number 15

3) Damping off:

Disease symptoms:

- Damping off occurs in two stages, i.e. the pre-emergence and the post-emergence phase.
- In the pre-emergence phase the seedlings are killed just before they reach the soil surface.
- The young radical and the plumule are killed and there is complete rotting of the seedlings.
- The post-emergence phase is characterized by the infection of the young, juvenile tissues of the collar at the ground level.
- The infected tissues become soft and water soaked.
- Infected seedlings are toppled on the ground surface.

Survival and spread:

Primary: Through soil, seed, water

Secondary: By conidia through rain splash or wind

Favourable conditions:

- High humidity, high soil moisture, cloudiness and low temperatures below 24° C for few days.
- Crowded seedlings, dampness due to high rainfall, poor drainage and excess of soil solutes hamper plant growth and increase the pathogenic damping-off.

*For management refer to page number 15

4) *Fusarium* wilt:

Disease symptoms:

- Disease produces wilting symptoms at seedling and later stage of plant growth
- Infected plants turn yellow.
- Fungal growth may be seen in the infected plant stem if cut longitudinally

Survival and dispersal:

- Pathogen is both soil and seed borne and survives as saprophyte in the soil debris as a mycelium and all spore types. It spreads short distances by water splash, planting equipment, and long distances by infected transplants and seeds.
- After the plant dies the fungus invades all tissues, sporulates, and continues to infect neighboring plants.

Favourable condition:

- Soil temperature is between 12.5-14° C and high moisture.

*For management refer to page number 15

5) Powdery mildew:

Disease symptoms:

- The disease symptoms appear at flowering stage in cloudy weather during February-March.
- The powdery fungal growth usually develops first on leaves which later can cover all succulent stems and branches including flowers.
- In severe case seed development may not take place.

Survival and spread:

Primary: Through soil and seed,

Secondary: Dispersal of conidia through wind, rain splashes

Favourable conditions:

- Cool high humid weather (20-25° C) or cloudy weather favours conidial germination and disease development
- High RH > 80% favours disease development

*For management refer to page number 15

6) Collar rot:

Disease symptoms:

- Disease appears in plots where water stagnation near the plant stem is more.
- Collar portion of the affected plants start decaying and the plants turn to yellow colour & die later on.
- Later collar region of the plant/seedlings get rotted and plant topple down.

Survival and spread:

Primary: Dormant mycelium and fruiting bodies survive in the infected crop debris, seeds and volunteer plants

Secondary: Irrigation disperse conidia to nearby plants.

Favourable conditions:

- High humidity, high soil moisture and temperature.
- Crowded seedlings.

*For management refer to page number 15

7) Root rot:

Disease symptoms:

- Symptoms consist of seed decay and brown to reddish lesions on seedling stems and roots just below the soil line.
- These reddish brown lesions may become sunken and girdle the stems and kill the plant.
- Plants may often appear stunted and unthrifty and will die.
- Often the stand will appear uneven because of stunted plants.
- Disease is often found in patches in fields.
- On older plants, the pathogen causes a reddish brown dry cortical root rot that may extend into the base of the stem.
- Foliar symptoms may include yellowing or wilting of leaves.

Survival and spread:

- The disease is mainly soil-borne and pathogen can survive in the soil as sclerotia for several years.
- Sclerotia disseminate by irrigation water, implements, and other cultural operations.

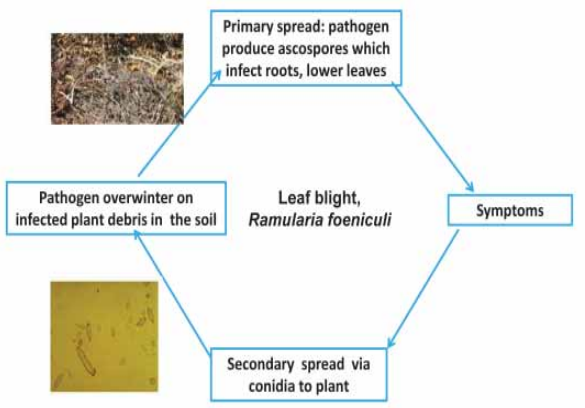
Favourable conditions:

- Dry weather following heavy rains,
- High soil temperature (35-39° C)

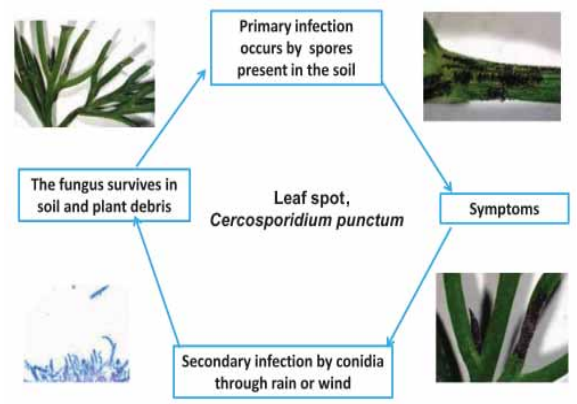
*For management refer to page number 15

Disease cycles:

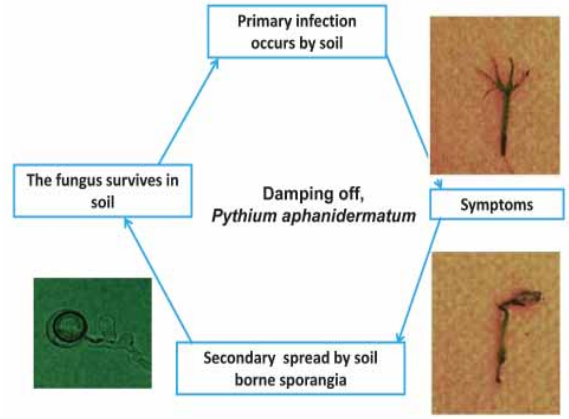
1. Leaf blight:



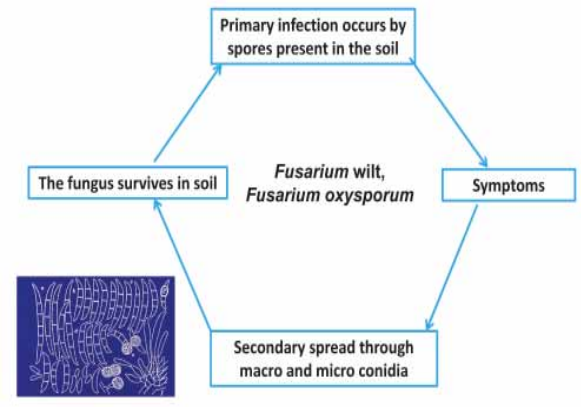
2. Leaf spot:



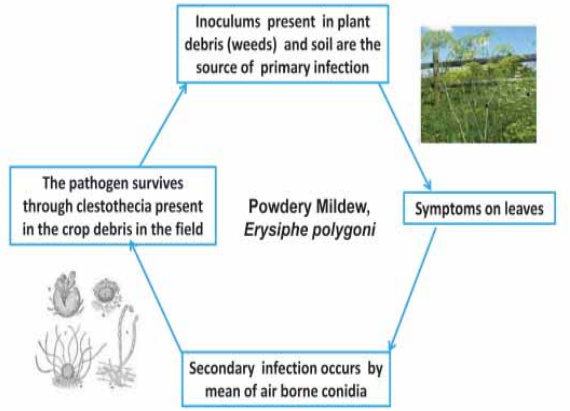
3. Damping off:



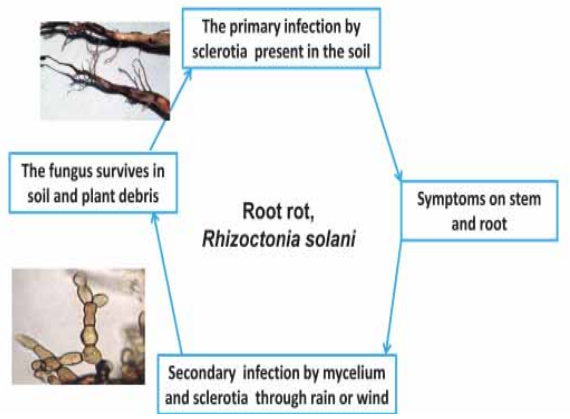
4. *Fusarium* wilt:



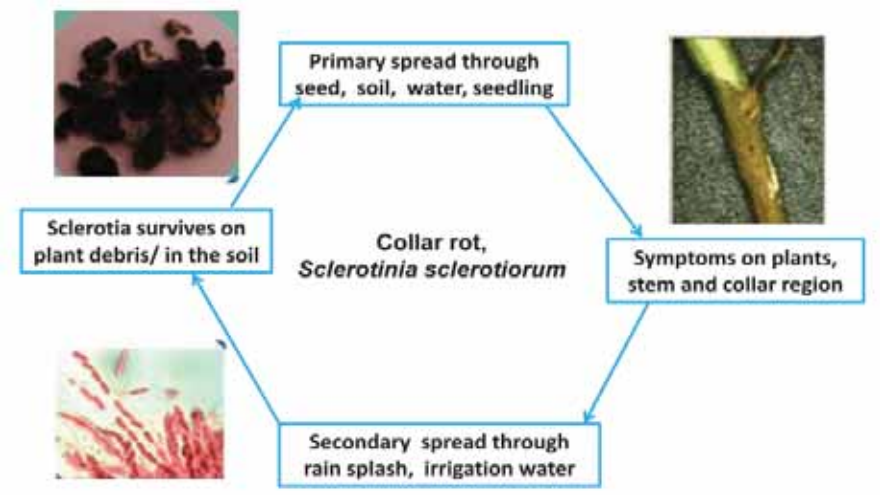
5. Powdery mildew:



6. Root rot:



7. Collar rot:



X. SAFETY MEASURES

A. At the time of harvest:

Harvest the crop only when it is fully matured. Maturity is indicated by the drying up of the plant including the base of the stem. While harvesting. Care should be taken not to cause any damage to the seeds.

Processing- Processing of fennel consist of drying and cleaning. Sun drying is done on clean cemented yards or other suitable clean surfaces. The crop harvest is occasionally turned over to ensure uniform drying. The crop harvest should be heaped and covered during night time to ensure protection from rain. No coloring material should be used to improve the appearance of the product as chemicals and artificial colours are highly objected to by the importing countries.

B. During post-harvest storage:

The crop harvest should be stored to ensure protection from dampness. Drainage should be provided to stack the packed bags to prevent moisture ingress from the floor. Care should be taken to stack the bags 50 to 60 cms away from the wall.

No insecticide should be applied directly under any circumstances, on the dried material. Stored material should periodically be fumigated by engaging only an authorized person. Insects, rodents and other animals should be effectively prevented from getting access to the premises where the material is stored. Stored product should be periodically exposed to the sun. Care should be taken in all stages of cultivation harvesting, post harvest handling, processing, packing, storage and transportation by following sound methods and practices, to prevent contamination and deterioration of quality of produce and to ensure consumer satisfaction.

XI. 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 monocropping.
3	Grow only recommended varieties.	Do not grow varieties not suitable for the season or region.
4	Sow seed 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 biopesticides/ chemicals products for the control of seed borne diseases/ pests.	Do not use seeds without seed treatment with biopesticides/chemicals.
6	Grow nursery on raised seed beds.	Do not raise nursery on flat bed.
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	Apply HaNPV 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	In case of pests which are active during night spray recommended biopesticides/ chemicals at the time of their appearance in the evening.	Do not spray pesticides at midday since, most of the insects are not active during this period.
16	Spray pesticides thoroughly to treat the under surface of the leaves.	Do not spray pesticides only on the upper surface of leaves.
17	Apply short persistent pesticides to avoid pesticide residue in the soil and produce.	Do not apply pesticides during preceding 7 days before harvest.
18	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.

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 Fennel

Coriander

Sunflower

Carrot

Marigold

***Ocimum* spp.**

Mustard

Cosmos

Onion

French bean

Cowpea

Buckwheat

Maize

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