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# AESA BASED IPM PACKAGE
# PAPAYA


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**Department of Agriculture and Cooperation**
**Ministry of Agriculture**
**Government of India**

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

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## FOREWORD

Intensive agricultural practices relying heavily on chemical pesticides are a major cause of wide spread ecological imbalances resulting in serious problems of insecticide resistance, pest resurgence and pesticide residues. There is a growing awareness world over on the need for promoting environmentally sustainable agriculture practices.

Integrated Pest Management (IPM) is a globally accepted strategy for promoting sustainable agriculture. During last century, IPM relied substantially on economic threshold level and chemical pesticides driven approaches. However, since the late 1990s there is conscious shift to more ecologically sustainable Agro-Eco System Analysis (AESA) based IPM strategies. The AESA based IPM focuses on the relationship among various components of an agro-ecosystem with special focus on pest-defender dynamics, innate abilities of plant to compensate for the damages caused by the pests and the influence of abiotic factors on pest buildup. In addition, Ecological Engineering for pest management - a new paradigm to enhance the natural enemies of pests in an agro-ecosystem is being considered as an important strategy.The ecological approach stresses the need for relying on bio intensive strategies prior to use of chemical pesticides.

Sincere efforts have been made by resource personnel to incorporate ecologically based principles and field proven technologies for guidance of the extension officers to educate, motivate and guide the farmers to adopt AESA based IPM strategies, which are environmentally sustainable. I hope that the AESA based IPM packages will be relied upon by various stakeholders relating to Central and State government functionaries involved in extension and Scientists of SAUs and ICAR institutions in their endeavour to promote environmentally sustainable agriculture practices.

A Srivastava

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(Avinash K. Srivastava)

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## FOREWORD

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

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

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

(Utpal Kumar Singh)

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## PREFACE

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

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

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

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

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

(K. SATYAGOPAL)

**CONTENTS**

# AESA BASED IPM PACKAGE FOR PAPAYA

## Papaya-Plant description:

The papaya (*Carica papaya* L.; Family: Caricaceae), papaw, or pawpaw is native to the tropics of the Americas, perhaps from southern Mexico and neighboring Central America. It was first cultivated in Mexico several centuries before the emergence of the Mesoamerican classical civilizations.

The papaya is a large, tree-like plant, with a single stem growing from 5 to 10 m tall, with spirally arranged leaves confined to the top of the trunk. The lower trunk is conspicuously scarred where leaves and fruit were borne. The leaves are large, 50–70 cm in diameter, deeply palmately lobed, with seven lobes. Unusually for such large plants, the trees are dioecious. The tree is usually un-branched, unless lopped. They appear on the axils of the leaves, maturing into large fruit - 15–45 cm long and 10–30 cm in diameter. The fruit is ripe when it feels soft and its skin attains an-amber to orange hue.

India is the leading papaya producer, with a 38.61 percent share of the world production during 2008–2010, followed by Brazil (17.5%) and Indonesia (6.89%). Papaya fruit is a source of nutrients such as provitamin A carotenoids, vitamin C, folate and dietary fiber. Papaya skin, pulp and seeds also contain a variety of phytochemicals, including lycopene and polyphenols. The ripe fruit of the papaya is usually eaten raw, without skin or seeds.

## I. PESTS

### A. Pests of National Significance

**1. Insect pest and mites**

**1.1 Mealybug: *Paracoccus marginatus* Williams & Granara de Willink (Hemiptera: Pseudococcidae)**

**1.2 Grasshopper: *Poecilocerus pictus* Fab (Orthoptera: Pyrgomorphidae)**

**2. Diseases**

**2.1 Stem or Foot or Collar rot: *Pythium* spp*. Phytophthora* spp*., Rhizoctonia* spp.**
**2.2 Papaya ring spot disease: *Papaya Ring Spot Virus***
**2.3 Papaya mosaic disease: *Papaya mosaic virus* (Potex virus)**
**2.4 Anthracnose: *Gloeosporium papayae* P Henn / *Colletotrichum gloesporioides* (Penz.) Penz. &. Sacc**

**Postharvest diseases**

**2.5 Anthracnose: *Gloeosporium papayae* P Henn**
**2.6 Rhizopus rot: *Rhizopus stolonifer* (Ehrenb.: Fr.) Vuill.**
**2.7 Fruit rot: *Alternaria alternata* (Fr.) Keissl.**
**2.8 Phomopsis rot: *Phomopsis caricae-papayae* Petr. & Cif.**
**2.9 Stem end rot: *Botryodiplodia theobromae* Leavitt and Munnecke (*Lasiodiplodia theobromae*)**

**3. Nematodes**

**3.1 Reniform nematode: *Rotylenchulus reniformis* Linford and Oliveira (Tylenchida: Hoplolaimidae)**

**4. Weeds**

**Grasses**

**4.1 Large crabgrass: *Digitaria sanguinalis* L.(Scop.) (Poaceae)**
**4.2 Yellow foxtail: *Setaria glauca* (L.) P. Beauv. (Poaceae)**
**4.3 Goosegrass: *Eleusine indica* (L.) Gaertner. (Poaceae)**
**4.4 Bermuda grass: *Cynodon dactylon* (L.) Pers. (Poaceae)**

**Broad leaf**

**4.5 Carrot grass: *Parthenium hysterophorus* L. (Asteraceae)**
**4.6 Coat buttons: *Tridax procumbens* L. (Fabaceae)**
**4.7 Yellow spider flower: *Cleome viscosa L.* (Capparidaceae)**
**4.8 Asthma herb/Spurge: *Euphorbia hirta* L. (Euphorbiaceae)**
**4.9 Cock's comb: *Celosia argentea* L. (Amaranthaceae)**
**4.10 Pigweed: *Amaranthus viridis* Hook. F. (Amaranthaceae)**
**4.11 Goat weed: *Ageratum conyzoides* L. (Asteraceae)**

**Sedge**

**4.12 Purple nutsedge: *Cyperus rotundus* L. (Cyperaceae)**
**4.13 Flat sedge: *Cyperus iria* L. (Cyperaceae)**
**4.14 Umbrella sedge: *Cyperus difformis* L. (Cyperaceae)**

**5. Birds**

**5.1. Jungle crow: *Corrus macrocercus culminates* wagker (Passeriformes: Dicruridae)**

**5.2. Myna: *Acridotheres tristis* L. (Passeriformes: Sturnidae)**

**5.3. Roseinged parakeet: *Psittacula krameri* (Psittaciformes: Psittacidae)**

**B. Pest of Regional Significance**

**1. Insect pests**

**1.1 Cotton whitefly: *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae)**

**1.2 Scale insect: *Aspidiotus destructor* Signoret (Homoptera: Diaspididae)**

**1.3 Aphid: *Aphis gossypii* Glover, *Myzus persicae* Sulzer (Hemiptera: Aphididae)**

**1.4 Fruit fly: *Bactrocera diversus* Coquillett, *B. cucurbitae* Coquillett (Diptera: Tephritidae)**

**1.5 Grey weevil: *Myllocerus viridans* (Coleoptera: Curculionidae)**

**1.6 Stem borer: *Dasyses rugosellus***

**2. Diseases**

**2.1 Damping off of seedling: *Pythium* spp. *Phytophthora* spp., *Rhizoctonia* spp.**

**2.2 Powdery mildew: *Oidium caricae* F. Noack**

**2.3 Papaya leaf curl disease: *Papaya leaf curl virus***

**3. Nematode**

**3.1 Root-Gall Nematode: *Meloidogyne incognita***

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

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

Farmers should:

- Monitor the field situations of the orchard at least once a week (soil, water, plants, pests, natural enemies, weather factors etc.).
- Make decisions based on the field situations 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. Plant tolerance to herbivory can arise from the interaction of a variety of plant traits and external environmental factors. The ability of the plant to compensate for the reduced

acquisition of resources by the production of new organs or by remobilization of reserves may also mitigate biotic stress effects.

**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 orchard 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 papaya 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 orchard in groups (about 5 farmers per group). Walk across the orchard 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 orchard, 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 of the orchard. 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:**

- Check the plant growth weekly.
- **Crop situation (e.g. for AESA):**Plant health; pests, diseases, weeds; natural enemies; soil condition; irrigation; weather conditions
- **Input costs:** Seeds; fertilizer; pesticides; labour;
- **Harvest yield**: (Kg/acre); price of produce (Rs./Kg)

**Some questions that can be used during the discussion:**

- Summarize the present situation of the orchard.
- 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.

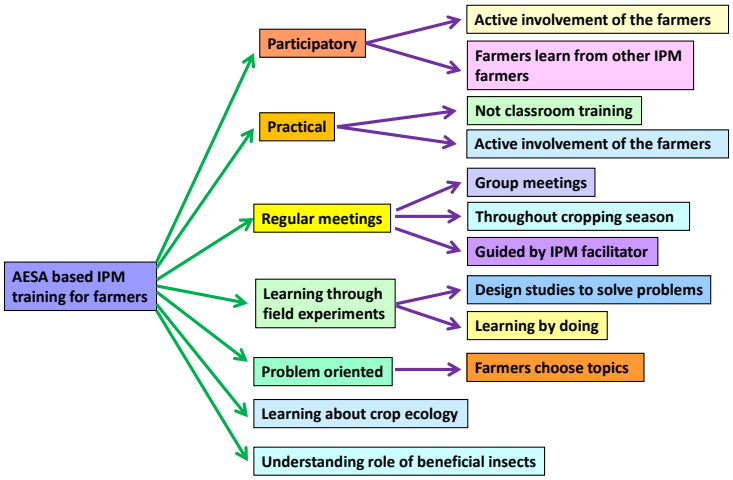
**AESA and farmer field school (FFS)**

AESA is a season-long training activity that takes place in the farmer orchard. 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 insect 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 main field should commence soon after crop establishment and at weekly intervals thereafter. In field, select five spots randomly. Select five random plants at each spot for recording counts of insects as per procedure finalized for individual insects.

**For insect pest**

**Aphids, whitefly:** Count and record the number of both nymphs and adults on five randomly selected leaves per plant.

**Scale insects:** Number of scale infested shoots per five tender shoots from each of the four directions of the selected tree should be counted

**Borers:** Count the number of young and grown up larvae on each plant and record.

**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). It is often necessary to wash the roots with water to examine them properly. If the roots are well developed, cut 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 and/or sheaths of each plant for lesions. 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. Determine the percent area of leaf infection by counting the number of leaves (leaf area diameter)/plant infected due to disease and incidence should be recorded.

**Stem and flowers/fruits sampling:** Carefully examine the stem and flowers/fruits of plants for symptoms and signs of fungal or bacterial diseases. The stem, flower, and fruits should be split or taken apart and examined for discoloration caused by fungi and bacteria. Count the number of stems and flowers/fruits infected due to disease and percent disease incidence should be recorded.

**C. Surveillance through pheromone trap catches:**
Pheromone traps for fruit fly @ 4-5/acre have to be installed. Install the traps for each species separated by a distance of >75 feet in the vicinity of the 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 should be counted and recorded. The trapped moths should be removed and destroyed after each recording.

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

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

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

### Ecological Engineering for Pest Management – Below Ground:

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

- Crop rotations with leguminous plants which enhance nitrogen content.
- Keep soils covered year-round with living vegetation and/or crop residue.
- Add organic matter in the form of farm yard manure (FYM), vermicompost, crop residue which enhance below ground biodiversity of beneficial microbes and insects.
- Application of balanced dose of nutrients using biofertilizers based on soil test report.
- Application of biofertilizers with special focus on mycorrhiza and plant growth promoting rhizobia (PGPR)
- Application of *Trichoderma harzianum/ viride* and *Pseudomonas fluorescens* for treatment of seed/seedling/planting materials in the nurseries and field application (if commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).

### Ecological Engineering for Pest Management – Above Ground:

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

**Natural enemies may require:**

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

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

- Raise the flowering plants / compatible cash crops along the field border by arranging shorter plants towards main crop and taller plants towards the border to attract natural enemies as well as to avoid immigrating pest population
- Grow flowering plants on the internal bunds inside the field
- Not to uproot weed plants those are growing naturally such as *Tridax procumbens, Ageratum* sp, *Alternanthera* sp etc. which act as nectar source for natural enemies,
- Not to apply broad spectrum chemical pesticides, when the P: D ratio is favourable. The plant compensation ability should also be considered before applying chemical pesticides.
- Reduce tillage intensity so that hibernating natural enemies can be saved.
- Select and plant appropriate companion plants which could be trap crops and pest repellent crops. The trap crops and pest repellent crops will also recruit natural enemies as their flowers provide nectar and the plants provide suitable microclimate.

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

## Plants suitable for Ecological Engineering for Pest Management

### Attractant plants

**Cowpea**

**Carrot**

**Sunflower**

**Buckwheat**

**French bean**

**Alfaalfa**

**Mustard**

**Cosmos**

**Anise**

**Caraway**

**Dill**

**Parsley**

**Repellent plants**

***Ocimum* sp**

**Peppermint/Spearmint**

**Border plants**

**Maize**

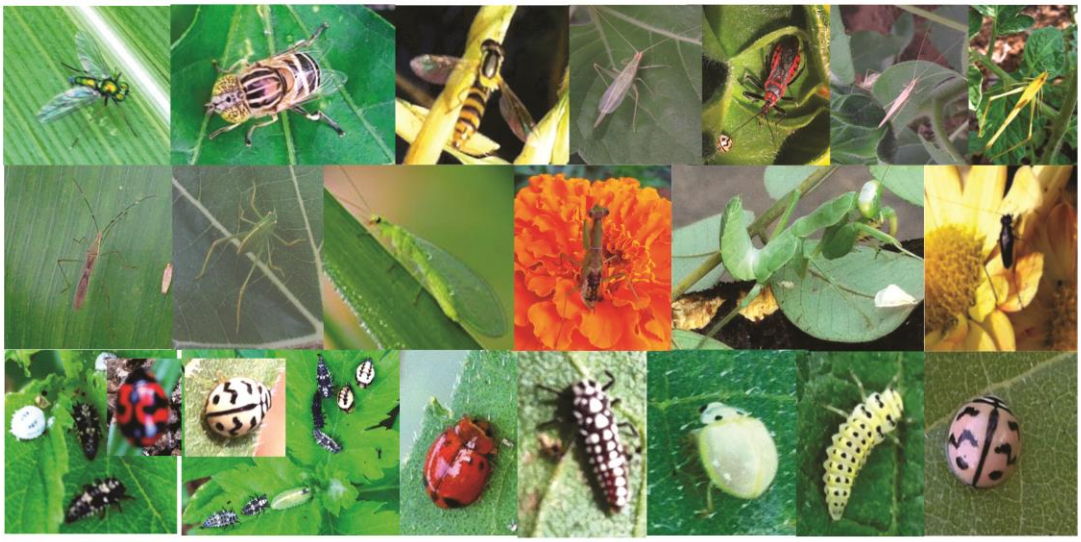
**Sorghum**

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.

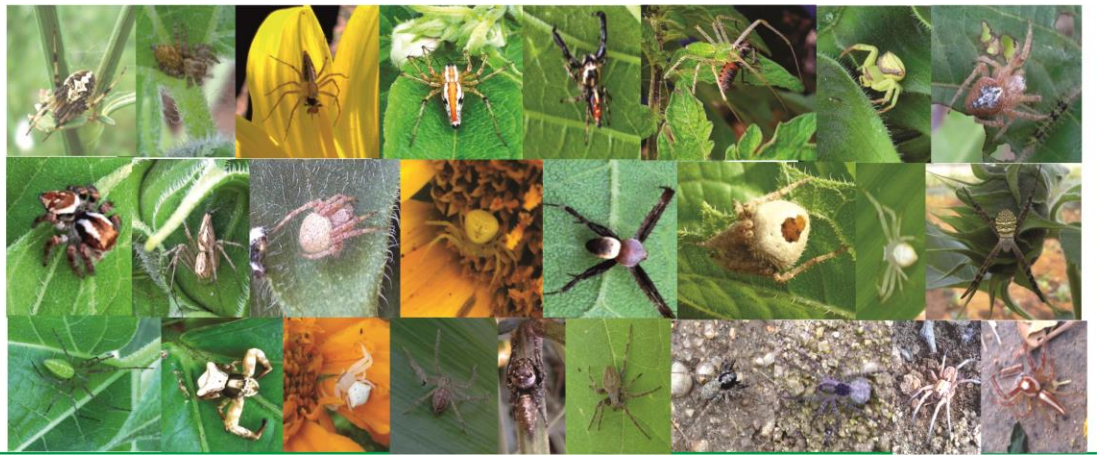
**Biodiversity of natural enemies observed in Ecological Engineering field at NIPHM**

**Biodiversity of natural enemies: Parasitoids**

**Biodiversity of natural enemies: Predators**



**Biodiversity of natural enemies: Spiders**



## IV. CROP STAGE WISE IPM

| Management | Activity |
|---|---|
| **Pre-planting*** | |
| | **Common cultural practices:**<br>• Deep ploughing of fields during summer to control nematodes population and weeds.<br>• Soil solarization<br>• Timely sowing should be done.<br>• Field sanitation, rogueing.<br>• Destroy the alternate host plants<br>• Apply manures and fertilizers as per soil test recommendations.<br>• Plant tall border crops like maize, sorghum or millet to reduce white fly and aphids population.<br>• Crop rotation with graminaceous crops<br>• Adopt ecological engineering by growing the attractant, repellent, and trap crops around the field bunds. |
| **Nutrients** | Papaya plant needs heavy doses of manures and fertilizers. Apart from the basal dose of manures fertilizers are also required.<br><br>• Nutrient should be applied on the basis of soil test values and recommendation for the particular agro--ecological region.<br>• Papaya seedlings are planted in pits of 60 x 60 x 60 cm. size.<br>• The pits are dug in summer about a fortnight before planting.<br>• The pits are filled with top soil along with 20 Kg. of farmyard manure., 1 Kg. neem cake and 1 Kg. bone meal.<br>• Application of 200 g. N/pit is optimum for fruit yield but papain yield increases with increase in N up to 300 g/pit. |
| **Weeds** | • Plough the field before planting to destroy existing weeds. |
| **Soil and seed borne pathogens, nematodes** | **Cultural control:**<br>• **Intercropping** of marigold reduces nematode population<br>• Nursery should be raised in nematode free sites or fumigated or solarized beds<br>• Application of decomposed poultry manure @ 200 g / sq. m<br><br>**Biological control:**<br>• Apply neem cake @ 100 Kg/acre at the time of transplanting for reducing nematodes and borer damage. |
| **Sowing/Seedling*** | |
| **Nutrients** | • Planting is done in pits already filled with top soil and farm yard manure.<br>• Apply 20 g each of *Azospirillum* and Phosphobacterium per plant at planting and again six months after planting. |
| **Weeds** | • Use weed free seedlings for planting.<br>• Remove existing weeds manually in and around the pits at the time of planting.<br>• Mulching with organic materials around the pits.<br>• To suppress the weeds between rows, intercropping of leguminous crops after non-leguminous ones, shallow rooted crops after deep rooted ones are beneficial. No intercrops are taken after the onset of flowering stage. |

| | |
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| | • Use straw or plastic mulch to avoid weed growth and to maintain soil moisture for longer period. In between the rows. |
| **Soil borne diseases** | **Cultural control:**<br>• Seedling raised in insect proof conditions.<br>• Sow 4-5 seeds/bag then retain 3 seedlings.<br>• 2 month old seedling is ready for transplanting<br>• Papaya don't withstand water logging, hence well drained upland fields should be selected for cultivation.<br>• Under drip, ring method should be followed.<br>• **Wind break**: should be grown to protect from strong wind also save tree from cold damage<br>**Mechanical control:**<br>• Remove and destroy virus infected seedlings/plants.<br>**Biological control**<br>• Apply Neem seed kernel extract (NSKE) 5%/groundnut oil @ 1-2% on to the plants to manage the vector population. |
| **Nematodes and insects** | **Cultural control:**<br>• Use resistant/tolerant varieties.<br>• Sowing should be completed within recommended periods.<br>• Intercropping with sunnhemp or marigold or daincha.<br><br>**Biological control:**<br>• Use mahua [*Madhuca longifolia*], castor, neem and karanj [*Pongamia pinnata*] cakes, biogas sludge applied at 1.0 t/acre during pit preparation.<br>• Apply 2 tons of FYM enriched with *Pochonia chlamydosporia* and *Paecilomyces lilacinus/*acre before sowing, along with 100-200 Kg of neem or pongamia cake.<br>• Apply neem based products (Neemagon, Bioneem, Neemraj etc.) for controlling this pest. |
| *Application of *Trichoderma harzianum/ viride* and *Pseudomonas fluorescens* for treatment of seed/seedling/planting materials in the nurseries and field application (if commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required). | |
| **Vegetative stage** | |
| | **Common cultural practices:**<br>• Collect and destroy diseased and insect infected plant parts.<br>• Provide irrigation at critical stages of the crop<br>• Avoid water stress and water stagnation conditions.<br>• Enhance parasitic activity by avoiding chemical spray, when 1-2 larval parasitoids are observed<br>**Common mechanical practices:**<br>• Collection and destruction of eggs and early stage larvae<br>• Handpick the older larvae during early stages<br>• The infested shoots may be collected and destroyed<br>• Handpick the gregarious caterpillars and the cocoons which are found on stem and destroy them in kerosene mixed water.<br>• Use yellow sticky traps for aphids and whitefly @ 4-5 trap/acre.<br>• Use light trap @ 1/acre and operate between 6 pm and 10 pm<br>• Install pheromone traps @ 4-5/acre for monitoring adult moths activity (replace the lures with fresh lures after every 2-3 weeks) |

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| | • Erecting of bird perches @ 20/acre for encouraging predatory birds such as King crow, common mynah etc.<br>• Set up bonfire during evening hours at 7-8 pm<br><br>**<u>Common biological practices:</u>**<br>• Conserve natural enemies through ecological engineering<br>• Augmentative release of natural enemies.<br>• Collection and destruction of eggs and early stage larvae<br>• Handpick the older larvae during early stages<br>• The infested shoots may be collected and destroyed<br>• Handpick the gregarious caterpillars and the cocoons which are found on stem and destroy them in kerosene mixed water.<br>• Use yellow sticky traps for aphids and whitefly @ 4-5 trap/acre.<br>• Use light trap @ 1/acre and operate between 6 pm and 10 pm |
| **Nutrients** | • Apply 50 g each of N, P and K per plant at bi-monthly intervals from the third month of planting.<br>• The application of 25 % N in organic form, 75 % N in inorganic form along with green manure crops is beneficial.<br>• Apply 20 g each of *Azospirillum* and Phosphobacterium per plant again at six months after planting. |
| **Weeds** | • Inter cultivation is recommended during the first year to check weed growth. Weeding should be done on regular basis especially around the plants.<br>• Earthing up is done before or after the onset of monsoon to avoid water-logging and also to help the plants to stand erect.<br>• In subsequent seasons to suppress the weeds between rows, intercropping of leguminous crops after non-leguminous ones, shallow rooted crops after deep rooted ones are beneficial. No intercrops are taken after the onset of flowering stage.<br>• Use straw or plastic Mulch to avoid weed growth and to maintain soil moisture for longer period. |
| **Mealybugs** | **<u>Cultural control</u>:**<br>• Removal of weeds and alternate host plants like hibiscus, bhindi, custard apple, guava etc in and nearby vineyards throughout the year.<br><br>**<u>Mechanical control</u>:**<br>• Detrash the crop on 150 and 210 DAP.<br><br>**<u>Biological control</u>:**<br>• Conserve the natural enemies. |
| **Aphids**** | **<u>Cultural control</u>:**<br>• Check transplants for aphids before planting.<br>• Reflective mulches such as silver colored plastic can deter aphids from feeding on plants.<br>• Sturdy plants can be sprayed with a strong jet of water to knock aphids from leaves.<br>**<u>Biological control:</u>**<br>• Release 1st instar larvae of green lacewing bug (*Chrysoperla zastrowi sillemi carnea*) @ 4,000 larvae/acre.<br>• Spraying with tobacco decoction (1 Kg tobacco boiled in 10 l of water for 30 minutes and making up to 30 l + 100 g soap). |

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| | **Chemical control:**<br>• Organic control includes insecticidal soaps (1%) and horticultural mineral oils (1%) |
| **Whitefly**** | **Cultural control:**<br>• Water sprays may also be useful in dislodging adults.<br>• A small, hand-held, battery-operated vacuum cleaner has also been recommended for vacuuming adults off leaves. Vacuum in the early morning or other times when it is cool and whiteflies are sluggish. Kill insects by placing the vacuum bag in a plastic bag and freezing it overnight. Contents may be disposed of the next day. Fumigating with asmall petrol socked cotton ball.<br>• For biological control follow common practices. |
| **Stem borer**** | **Cultural control:**<br>• Pierce the infested plants with a sharp needle or knife to kill the caterpillar in the stem.<br>• For others see common practices. |
| **Papaya hoppers** | • Removal of weeds and alternate host plants such as Hibiscus, bhindi, custard apple, guava etc.<br>• For other practices follow common practices. |
| **Mite** | • See common cultural practices<br>• Spray NSKE(5%) |
| **Foot Rot** | **Cultural control :**<br>• The crop should be irrigated by adopting the ring method of irrigation so that the water does not come in direct contact with the stem.<br>• Avoid water logging.. |
| **Anthracnose** | **Cultural control:**<br>• Diseased leaves, twigs, gall midge infected leaves and fruits, should be collected and burnt.<br>• Covering the fruits on trees, 15 days prior to harvest with news or brown paper bags. |
| **Powdery mildews**** | **Mechanical control:**<br>• Prune diseased leaves to reduce primary inoculum load.<br>• Keep proper spacing during sowing.<br>**Chemical control:**<br>• Thiophanate methyl 70% WP @ 286 g in 300-400 l of water/acre (Thiophanate methyl 70% WP @ 0.1% along with sticker @ 0.05%) |
| **Papaya mosaic virus** | **Cultural control:**<br>• Good field sanitation such as removal and destruction of affected plant reduce the spread of the disease.<br>• Losses can be minimized controlling the population of aphid. |
| **Papaya leaf curl virus**,** | **Cultural control:**<br>• Uproot the virus affected plants<br>• Avoid growing tomato, tobacco near papaya.<br>• Control whitefly vector.<br>• Removal and destruction of the affected plants is the only control measure to reduce the spread of the disease.<br>• The field should be kept weed free. Tobacco, tomato. sunnhemp, cape gooseberry, chilli, petunia, *Datura stramonium, Zinnia elegans* etc. should not be grown nearby papaya field. |
| **Papaya ring spot virus** | **Cultural control:**<br>• Use of yellow sticky strap to control of aphid vector. |

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| | • Use of resistant varieties.<br>• Early detection of infected plants and prompt removal can check the spread of the disease.<br>• Rogue out infected plants of papaya as early as possible to avoid further infection within the field.<br>• Avoid taking mixed crop of tobacco, chilli, *Zinnea,* tomato and gooseberry in papaya field or nearby. |
| **Flowering/Maturity stage** | |
| **Nutrients** | • Apply recommended micronutrients, if symptoms are observed.<br>• Micro-nutrients viz., $ZnSO_4$ (0.5%) and $H_2BO_3$ (0.1%) are sprayed in order to increase growth and yield characters. |
| **Weeds** | • Remove weeds around the plants.<br>• Continue the u straw or plastic mulch to avoid weed growth and to maintain soil moisture for longer period. |
| **Fruit fly**** | **Cultural control:**<br>• Prior to harvest, collect and dispose off infested and fallen fruits to prevent further, multiplication and carry-over of population.<br>• Ploughing of orchard during November-December to expose pupae to sun's heat which kills them.<br>• If infestation is heavy, bait splash on the trunk only, once or twice at weekly interval is recommended. To prepare bait splash, mix 100 g of jaggery in one litre of water and add 1 ml of deltamethrin by using an old broom.<br>• Managing fruit flies also reduces anthracnose disease and prevents late fruit fall.<br>**Physical control:**<br>• Hot water treatment of fruit at 48 ± 1 ºC for 45 min.<br>• Male annihilation technique: Set up fly trap using methyl eugenol. Prepare methyl eugenol 1 ml/L of water + 1 ml of malathion solution. Take 10 ml of this mixture per trap and keep them at 25 different places in one ha between 6 and 8 am. Collect and destroy the adult flies<br>**Biological control:**<br>• See common practices. |
| **Scale insects**** | **Cultural control:**<br>• Prune heavily infested plant parts to open the tree canopy and destroy' them immediately and preferably during summer.<br>• These should be placed in a pit constructed on one corner of the orchard. Allow branches and twigs to dry until the parasites escape.<br>• Burn the remaining debris.<br>• Removal of attendant ants may permit natural enemies to control the insect. |
| **Grey weevil**** | **Cultural control:**<br>• Collection and destruction of infested and fallen fruits at weekly interval till harvest fruit.<br>• Destroy all left over seeds in the orchard and also in the processing industries. |
| **Whitefly**, Mealybug, stem borer**, aphid**,** | • Same as in vegetative stage. |

| | |
|---|---|
| **mite** | |
| **Diseases** | • Same as in vegetative stage. |
| **Birds** | **Mechanical control**:<br><br>• Install bird scarers or metallic ribbons to ward off the birds. |
| **Post-harvest** | |
| **Anthracnose, Stem end rot, Aspergillus rot, Rhizopus rot, Fruit rot, Phomopsis** | **Cultural control:**<br>• Avoid harvesting of immature fruits<br>• Cool fruits immediately after harvest and store in well ventilated containers.<br>• The disease can be checked by sorting the fruit at 100 ºC or below but the rot appears after 2-3 days when such fruits are brought back to 20 ºC or above.<br><br>**Physical control:**<br>• Hot water treatment at 49 ºC for 20 min.<br><br>**Botanical control:**<br>• Postharvest dip treatment of fruits with botanical fungicides could also control the diseases during storage. |

$Pesticides dosage use is based on high volume sprayer.

** Regional pests.

## 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. NUTRIENT DEFICIENCY SYMPTOMS IN PAPAYA

| Nutrient | Fig. |
|---|---|
| **Nitrogen:** Nitrogen deficiency causes slow growth and older leaves become paler with reduced leaf area and rate of leaf production. Leaf petioles short, thin and compressed.<br>**Correction Measure:** Foliar spray of urea @2%. |  |
| **Phosphorus:** The deficiency of P causes complete cessation of elongation, older leaves becoming increasingly irregularly necrotic, leaf production is reduced, and marginal choruses and premature death are caused. P deficiency causes a blue or dark green coloration of leaves.<br>**Correction Measure:** Soil application of phosphatic fertilizer as per the recommendation. |  |

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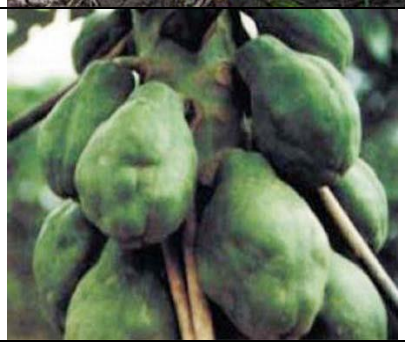
| **Potassium:** Deficiency of potassium causes marked reduction in growth, leaves profusely smaller, leaf margins necrosis and premature yellowing of plant. Purplish brown patches appear at the base of the petioles. Fruits are badly shaped, poorly filled and unsuitable for marketing.<br>**Correction Measure:** Foliar spray of KCl @2% |  |
| **Magnesium:** Symptoms show green banding around the margin and next to the midrib. Leaves turn yellowish brown margin. Plant height reduced marginal yellowing of leaf margin extends towards the midrib. Purplish mottling of leaf petiole and malformation of leaves.<br>**Correction Measure:** Foliar spray of MgSO4 @ 1-2%. |  |
| **Sulphur:** Deficiency causes chlorosis and delaying of green colour in newly emerging leaves, reduced plant growth and reduced leaf size. The leaf blades become very soft and tear easily.<br>**Correction Measure:** Foliar spray of $MgSO_4$@1%. |  |
| **Boron**: Distortion of newer leaves and the growing point dies. Leaves show chlorotic symptom with inward cupping with stunted growth. Bushy appearance of shoot.<br>**Correction Measure:** Soil application of borax @ 2-3 g/plant. |  |

| | |
|---|---|
| **Manganese**: Marginal chlorosis of young leaves, which later turn brown. Fruits with raised spots which are dark brown or black in colour. Leaves give striped appearance from the edges.<br>**Correction Measure:** Foliar spray of $MnSO_4$ @1-2%. |  |

Source: APHU (2010), Naidu, V.S.G.R. 2012,
http://agritech.tnau.ac.in/agriculture/plant_nutri/
http://nhb.gov.in/report_files/banana/BANANA.htm
http://agritech.tnau.ac.in/agriculture/plant_nutri/banana_nitrogen.html
http://upload.wikimedia.org/wikipedia/commons/thumb/6/60/Amaranthus_viridis.jpg/220px-Amaranthus_viridis.jpg

## VII. COMMON WEEDS

| | | |
|---|---|---|
|  |  |  |
| **1 Large crabgrass: *Digitaria sanguinalis* L.(Scop.) (Poaceae)** | **2 Yellow foxtail: *Setaria glauca* (L.) P. Beauv. (Poaceae)** | **3 Goosegrass: *Eleusine indica* (L.) Gaertner. (Poaceae)** |
|  |  |  |
| **4 Bermuda grass: *Cynodon dactylon* (L.) Pers. (Poaceae)** | **5 Carrot grass: *Parthenium hysterophorus* L. (Asteraceae)** | **6 Coat buttons: *Tridax procumbens* L. (Fabaceae)** |

| | | |
|---|---|---|
|  |  |  |
| **7 Yellow spider flower: *Cleome viscosa L.* (Capparidaceae)** | **8 Asthma herb/Spurge: *Euphorbia hirta* L. (Euphorbiaceae)** | **9 Cock's comb: *Celosia argentea* L. (Amaranthaceae)** |
|  |  |  |
| **10 Pigweed: *Amaranthus viridis* Hook. F. (Amaranthaceae)** | **11 Goat weed: *Ageratum conyzoides* L. (Asteraceae)** | **12 Purple nutsedge: *Cyperus rotundus* L. (Cyperaceae)** |
|  |  | |
| **13 Umbrella sedge: *Cyperus difformis* L. (Cyperaceae)** | **14 Flat sedge: *Cyperus iria* L. (Cyperaceae)** | |

## VIII. DESCRIPTION OF INSECT, MITE AND NEMATODE PESTS

**1. Papaya mealybug:**

**Biology:**

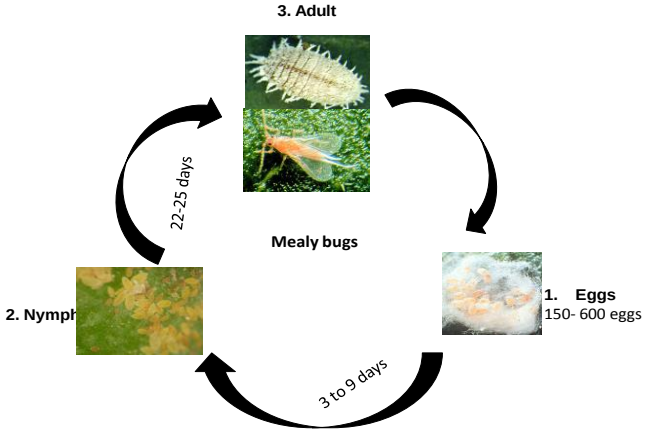
**Egg:** Females usually lay 100 to 600 eggs. Eggs are greenish yellow and are laid in an **ovisac sac** that is three to four times the body length and entirely covered with white wax. Egg-laying usually continuous over a period of one to two weeks.

**Nymph:** Eggs hatch in about 10 days, and nymphs or crawlers begin to actively search for feeding sites.

**Adult:** The adult female is yellow, approximately 3 mm long and 1.4 mm wide and is covered with a white waxy coating. Adult males are pink, especially during the pre-pupal and pupal stages, but appear yellow in the first and second instars. Adult males are approximately 1.0 mm

long, with an elongate oval body that is widest at the thorax (0.3 mm).

**Life cycle:**




**Damage symptoms:**

- Initially the affected portion will be cholotic, later changed to brown and dry away.
- These bug excrete honey dew and as a result infested portion becomes shiny and moist and to this, secondary infection by sooty fungus,Capnodium occurs results in black covering the affected parts.
- Papaya mealy bug is polyphagous pest. Symtopms can be observed on ground parts of leaves, stem and fruits as clusters of cotton like masses .

1. Waxy coating on Papaya fruit 2. Crinkled Papaya leaf

1. http://iapps2010.files.wordpress.com/2010/09/papaya-mealybug.jpg
2. http://entnemdept.ufl.edu/creatures/fruit/mealybugs/papaya_mealybug.htm

**Natural enemeis of papaya mealybugs**

**Parasitoids***: Acerophagus papaya*, *Phygadium* spp*.*
**Predators:** *Spalgis epius* (West wood), *Cryptolaemus montrouzieri, Rodolia fumida*

The entomogenous fungus *Beauveria bassiana.*

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

**2. Whitefly:**

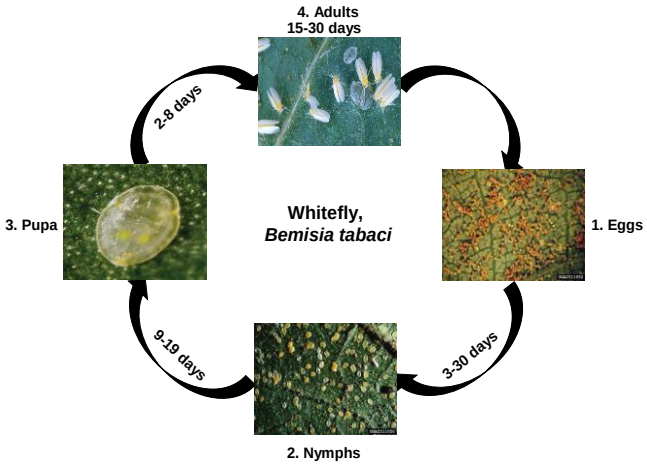
**Biology:**

**Egg:** The females mostly lay eggs near the veins on the underside of leaves. Each female can lay about 300 eggs in its lifetime. Eggs are small (about 0.25 mm), pear-shaped, and vertically attached to the leaf surface through a pedicel. Newly laid eggs are white and later turn brown.

**Nymph:** Upon hatching, the first instar larva (nymph) moves on the leaf surface to locate a suitable feeding site. Hence, it is commonly known as a "crawler." If then inserts its piercing and sucking mouthpart and begins sucking the plant sap from the phloem. Adults emerge from puparium through a T-shaped slit, leaving behind empty pupal cases or exuviae.

**Adult:** The whitefly adult is a soft-bodied, and moth-like fly. The wings are covered with powdery wax and the body is light yellow in color. The wings are held over the body like a tent. The adult males are slightly smaller in size than the females. Adults live from one to three weeks.

**Life cycle:**




1.http://m.animal.memozee.com/m.view.php?q=%EB%8B%B4%EB%B0%B0%EA% B0%80%EB%A3%A8%EC%9D%B4&p=3
2. http://www.forestryimages.org/browse/detail.cfm?imgnum=2511050
3 http://www.fera.defra.gov.uk/plants/publications/documents/factsheets/bemisia.pdf
4. http://www.entomology.umn.edu/cues/inter/inmine/Whitefg.html

**Damage symptoms**

- Both the adults and nymphs suck the plant sap and reduce the vigor of the plant. In severe infestations, the leaves turn yellow and drop off. When the populations are high they secrete large quantities of honeydew, which favors the growth of sooty mould on leaf surfaces and reduces the photosynthetic efficiency of the plants.

**Crowding on lower surface of leaf**

http://203.64.245.61/fulltext_pdf/EB/2001-2010/eb0122.pdf

## Natural enemies of whitefly:

**Parasitoids:** *Encarsia formosa, Eretmocerus* spp., *Chrysocharis pentheus*
**Predators:** *Dicyphus hesperus* , Lacewing, Ladybird beetle, Big-eyed bugs (mirid bug) (*Geocoris*sp)

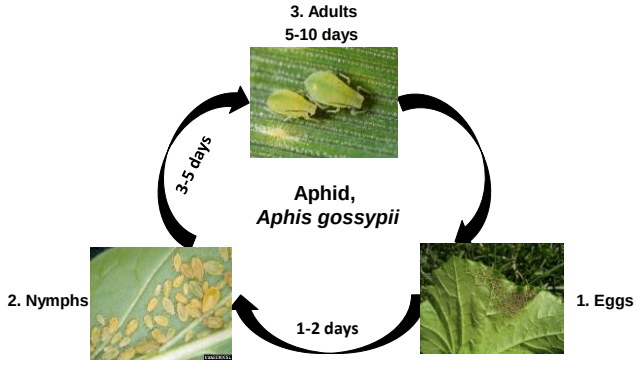
*For management refer to page number----------

**3. Aphid:**

## Biology:

**Egg:** Eggs are very tiny, shiny-black, and are found in the crevices of bud, stems, and barks of the plant. Aphids usually do not lay eggs in warm parts of the world.
**Nymph:** Nymphs (immature stages) are young aphids, they look like the wingless adults but are smaller. They become adults within 7 to 10 days.
**Adult:** Adults are small, 1 to 4 mm long, soft-bodied insects with two long antennae that resemble horns. Most aphids have two short cornicles (horns) towards the rear of the body

## Life cycle:



1.. http://www.flickr.com/photos/23293858@N04/2672985270/
2. http://pubs.ext.vt.edu/2902/2902-1081/2902-1081.html
3. http://www.flickr.com/photos/25848431@N02/7479982150/

**Damage symptoms:**

- Infesting tender shoots and under surface of the leaves.
- Curling and crinkling of leaves
- Stunted growth
- Development of black sooty mould due to the excretion of honeydew

**Natural enemies of aphid:**

**Parasitoids:** *Aphidius colemani, Aphelinus* sp.,

**Predators:** Fire ant, Robber flies, Big-eyed bug (*Geocoris* sp), Earwig**,** Ground beetle, Cecidomyiid fly, Dragon fly, Praying mantis, Lacewing, Ladybird beetle, Spider etc.

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

**4. Red Spider mite:**

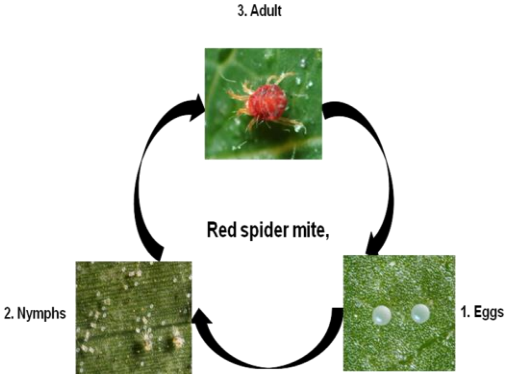
**Biology:**

**Egg:** Eggs reddish, spherical and provided with a small filament. Incubation period is 4-6 days, before hatching becomes light orange colour.

**Nymph:** Upon hatching, it will pass through a larval stage and two nymphal stages before becoming adult. Developmental stages include six legged larva, protonymph and deutonymph.

**Adult:** Adult female elliptical in shape, bright crimson anteriorly and dark pruplish brown posteriorlym. Mites spin a web of silken threads on the leaf. Each developmental stage is followed by a quiescent stage and life cycle completed in 10-14 days.

**Life cycle:**



1.http://bugguide.net/node/view/348888
2. http://entomology.k-state.edu/extension/insect-photo-gallery/Corn-Insects.html
3. http://nathistoc.bio.uci.edu/Other%20Arachnids/Acari4.htm

**Damage symptoms:**

- Spider mites usually extract the cell contents from the leaves using their long, needle-like mouthparts. This results in reduced chlorophyll content in the leaves, leading to the formation of white or yellow speckles on the leaves.
- In severe infestations, leaves will completely desiccate and drop off. The mites also produce webbing on the leaf surfaces in severe conditions.
- Under high population densities, the mites move to using strands of silk to form a ball-like mass, which will be blown by winds to new leaves or plants, in a process known as "ballooning."

**Natural enemies of red spider mite:**

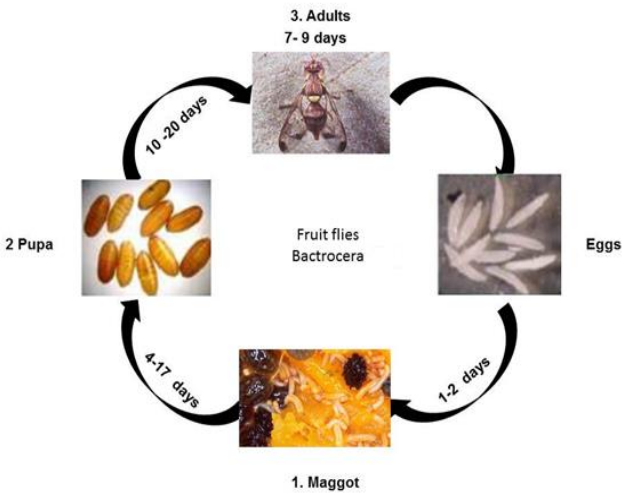
**Predators:** Anthocorid bugs (*Orius* spp.), mirid bugs, syrphid/hover flies, green lacewings (*Mallada basalis* and *Chrysoperla*sp.), predatory mites (*Amblyseius alstoniae*, *A. womersleyi, A. fallacies* and *Phytoseiulus persimilis*), predatory coccinellids (*Stethorus punctillum*), staphylinid beetle (*Oligota* spp.), predatory cecidomyiid fly (*Anthrocnodax occidentalis*), predatory gall midge (*Feltiella minuta*), Predatory thrips etc.
*For management refer to page number----------

**5. Fruit fly:**

**Biology:**

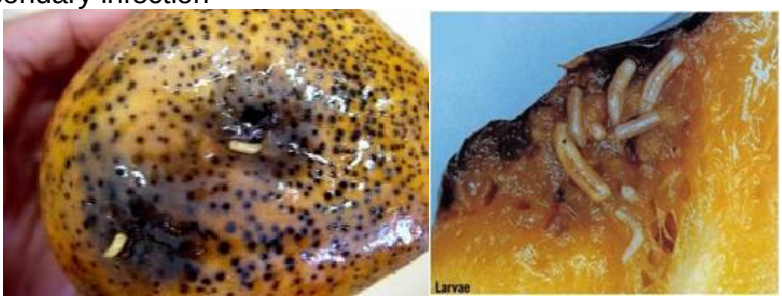
**Egg:** Female flies insert eggs under the skin of fruit in clusters of 10 to 50 about 1/25 to 1/8 inch below the fruit surface. The eggs measure about 1/25 by 1/250 inch and are white, elongate, and elliptical. They hatch in 1-1/2 days.
**Larva:** The white larva is legless, and resembles an elongated cone. The mouth is at the pointed end of the body. There are 3 larval stages, or instars. The third instar is about 2/5 inch long. The entire larval stage lasts for 11-15 days.
**Pupa:** When mature, larvae drop to the ground and pupate in the soil. The puparium is yellowish-brown and seed-like. Adults emerge in about 10 days.
**Adult:** Generally, the abdomen has two horizontal black stripes and a longitudinal median stripe extending from the base of the third segment to the apex of the abdomen. These markings may form a "T" shaped pattern, but the pattern varies considerably. Females begin to lay eggs about 8 days after emergence from the puparium. Under optimum conditions, a female can lay more than 3,000 eggs during her lifetime, but under field conditions approximately 1,200 to 1,500 eggs per female is considered to be the usual production. Ripe fruit are preferred for egg laying, but immature ones may be also attacked.

**Life cycle:**




**Damage symptoms:**

- The female punctures outer wall of mature fruits with the help of its pointed ovipositor and insert eggs in small clusters inside mesocarp of mature fruits.
- On hatching, the maggots feed on fruit pulp and the infested fruits start rotting due to further secondary infection




**1. 2.**

1,2: http://agritech.tnau.ac.in/crop_protection/crop_prot_crop_insectpest%20_-papaya.html

**Natural enemies of fruit fly:**

**Parasitoids:** *Opius fletcheri, Fopius arisanus*, *Diachasmimorpha kraussi*
**Predator:** Ants

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

**6. Grasshopper:**

**Biology:**

**Egg:** Adult females lay eggs along the midrib and lateral veins of the leaves. The egg period is 4 to 11 days.
**Nymph:** The nymphs resemble the adults, but lack wings. Instead, they have slightly extended wing pads. They are pale green in color. They tend to move sideways when disturbed. The nymphal period varies from one to four weeks depending on the temperature.
**Adult:** The adults are wedge-shaped, pale green insects. They have fully developed wings with

a prominent black spot on each forewing. The adults may live for one to two months.

**http://www.projectnoah.org/spottings/13154081**

**Damage symptoms:**

- Both nymphs and adults suck the sap from the lower leaf surfaces through their piercing and sucking mouthparts. While sucking the plant sap, they also inject toxic saliva into the plant tissues, which leads to yellowing. When several insects suck the sap from the same leaf, yellow spots appear on the leaves, followed by crinkling, curling, bronzing, and drying, or “hopper burn”.

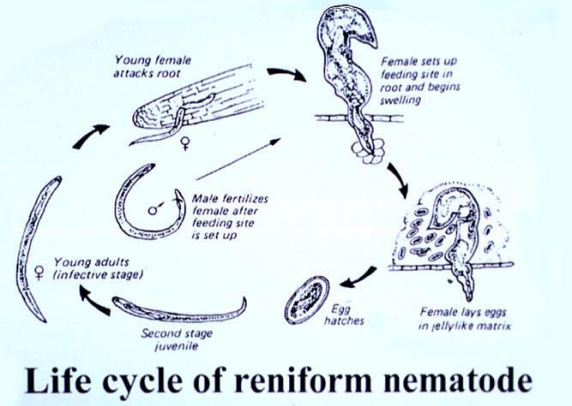
**Natural enemies of grass hopper:**

**Parasitoids:** *Lymaenon empoascae* (egg), *Anagrus flaveolus*, *Stethynium triclavatum*
**Predators:** Birds, praying mantis, blister beetle, ground beetle, spider, hoverfly etc.,

**7. Reniform nematode:**

**Biology :**

- The predominant reniform species found on papayas in most of the world is *R. reniformis.*
- Many commonly cultivated crops as well as weeds are hosts of the reniform nematodes.
- Because of their small size, they do not travels distances of more than a few inches in their lifetime.
- Juveniles that hatch from eggs are less than 500 µm long.
- After undergoing several molts, female juveniles become young adults and penetrate the root cortext and become sedentary.
- The portion of the body that remains outside the root enlarges and becomes kidney-shaped, hence the name "reniform." After maturation the female secrets a gelatinous substance around her body (the sand-like bodies referred to above) into which she lays about 100 eggs.
- A complete life cycle is possible in about 25 days. The reniform nematode feeds near the phloem in papaya roots inducing the formation of giant cells.
- These are centers of high metabolic activity that compete with other parts of the plant for food and nutrients.
- The nematode also may feed in the root cortex and cause mechanical breakdown of the cortical cells, thus providing suitable sites for attack by fungi.



Life cycle of reniform nematode

http://plpnemweb.ucdavis.edu/nemaplex/Taxadata/G116S2.HTM

**Symptoms:**

- Above-ground symptoms of plants infected by the reniform nematode are similar to those associated with one or more of the following conditions: 1) lack of proper nutrients, 2) chronic moisture stress, and/or 3) poor soil aeration.
- The above-ground symptoms appear as moderate to severe leaf chlorosis and plant stunting. Some wilting may occur during periods of peak transpirational stress on the plant.
- Below ground symptoms are not readily detectable by the untrained observer. However, reniform nematode presence on the roots may be observed with the aid of a 10x hand lens.
- The small sand-like bodies which remain attached, after the root system is carefully washed, are eggmasses of the nematode.
- Fruits produced are smaller than normal and may be slightly insipid.


http://entnemdept.ufl.edu/creatures/nematode/r_reniformis.htm

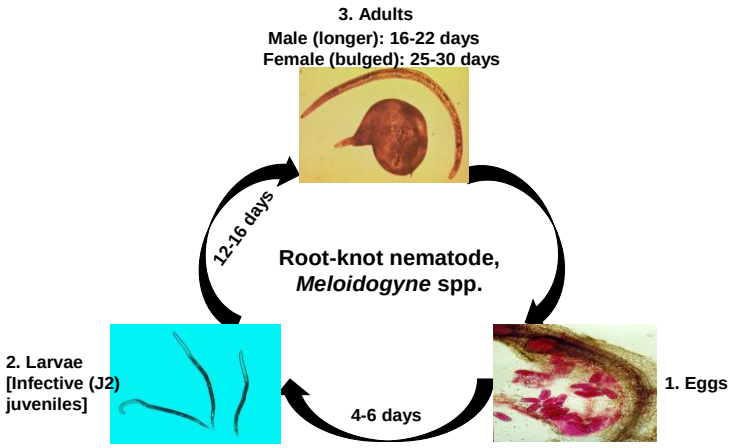
**8. Root knot nematode:**

**Biology:**

- Most species of plant parasitic nematodes have a relatively simple life cycle consisting of the egg, four larval stages and the adult male and female.
- Development of the first stage larvae occurs within the egg where the first molt occurs. Second stage larvae hatch from eggs to find and infect plant roots or in some cases foliar tissues.

- Under suitable environmental conditions, the eggs hatch and new larvae emerge to complete the life cycle within 4 to 8 weeks depending on temperature.
- Nematode development is generally most rapid within an optimal soil temperature range of 70 to 80°F.

**Life cycle:**




1.http://keys.lucidcentral.org/keys/sweetpotato/key/
2. http://nematology.umd.edu/rootknot.html
3. http://www.cals.ncsu.edu/pgg/dan_webpage/Introduction/Images/pyroform.htm

**Damage symptoms:**

- Infected plants in patches in the field
- Formation of galls on host root system is the primary symptom
- Roots branch profusely starting from the gall tissue causing a '**beard root**' symptom
- Infected roots become knobby and knotty
- In severely infected plants the root system is reduced and the rootlets are almost completely absent. The roots are seriously hampered in their function of uptake and transport of water and nutrients
- Plants wilt during the hot part of day, especially under dry conditions and are often stunted
- Nematode infection predisposes plants to fungal and bacterial root pathogens

http://www.hawaiiplantdisease.net/glossary/Gall_galling.htm

**Survival and spread:**

**Primary**: Egg masses in infected plant debris and soil or collateral and other hosts like Solonaceous, Malvaceous and Leguminaceous plants act as sources of inoculums.

**Secondary**: Autonomous second stage juveniles that may also be water dispersed.

**Favourable conditions:**

Loamy light soils.

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

## Natural enemeis of papaya insect pests

### Larval parasiotids

**1. *Fopius arisanus*,** **2. *Diachasmimorpha kraussi***

### Nymphal and adult parasitoids

**3. *Aphidius*** **4. *Aphelinus* sp** **5. *Encarsia formosa***

**6. *Eretmocerus* spp.** **7. *Anagrus flaveolus*** **8. *Stethynium triclavatum***

1. http://www2.hawaii.edu/~messing/projects.htm
2. https://www.spc.int/pacifly/Control/Biocontrol.htm
3. http://www.evergreengrowers.com/aphidius-colemani-133.html
4. http://australianmuseum.net.au/image/Aphelinus-wasp- stings-aphid-Denis-Crawford/
5. http://www.buglogical.com/whitefly-control/encarsia-formosa/
6. http://www.dongbufarmceres.com/main/mboard.asp?strBoardID=c_product01_en
7. http://www.plantwise.org/default.aspx?site=234&page=4279&dsID=5090
8. http://www.nbaii.res.in/IndianMymaridae/Mymaridae/html/Mymaridae/Stethynium_Enock.htm

## Predators

**1. Lacewing**

**2. Ladybird beetle**

**3. Reduviid bug**

**4. Spider**

**5. Robber fly**

**6. Red ant**

**7. Black drongo**

**8. Common mynah**

**9. Big-eyed bug**

**10. Earwig**

**11. Ground beetle**

**12. Pentatomid bug**

**13. Preying mantis**

**14. Predatory mite**

**15. Predatory thrips**

**16. *Oligota* spp**



**17. *Orius* spp.** **18. Hover fly** **19. Mirid bug**

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

## IX. DESCRIPTION OF DISEASES

### 1. Foot rot of papaya:

**Disease symptoms**

- It is characterized by the appearance of water-soaked patches on the stem near the ground level.
- These patches enlarge rapidly and girdle the stem, causing rotting of the tissues, which then turn dark brown or black. Such affected plants withstand strong wind and topple over and die.
- If the disease attack is mild, only one side of the stem rots and the plants remain stunted.
- Fruit if formed are shriveled and malformed. Gradually the plant dies.

**Survival and spread:**

- Resting spore, Oospore, germinate and release zoospores which along with irrigation water spread throughout the field.

**Favourable condition:**

- High relative humidity and rainy condition favors the severe disease development in sick soil

**Disease symptoms:**

http://www.padil.gov.au/pests-and-diseases/pest/main/136594/2659

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

**2. Anthracnose:**

**Disease symptoms**:

- Disease occurs both in field and in storage conditions.
- The spots on fruits first appear as brown superficial discolouration of the skin which develops into circular, slightly sunken areas and 1 to 3 cm in dia.
- Gradually the lesions coalesce and sparse mycelia growth appears on the margins of the spots.
- Under humid conditions, an encrustation of salmon pink spores is released.
- Infection at early stages of fruit results in mummification and deformation.

**Survival and spread**:

- The disease is spread through wind-borne conidia.
- Conidia are also spread by rain splashes.
- Severity of the disease on foliage is increased under conditions of excessive moisture. Lesions develop more slowly on the immature fruits than on the mature fruits.

**Favourable conditions:**

- High relative humidity coupled with higher temperatures favour disease development. Maximum disease development takes place at about 26°C under wet weather condition.

1. 2. 3.

**Anthracnose affected Papaya fruit in field and storage conditions**

1: http://growfoodslowfood.blogspot.in/2012/08/what-is-wrong-with-my-papaya.html
2,3: http://www.pestnet.org/SummariesofMessages/Crops/Fruitsnuts/Papaya/Anthracnose,MarshallIs.aspx

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

**3. Powdery mildews:**

**Disease symptoms:**

- On the undersurface of disease leaves are found patches of whitish powder growth.
- On upper surfaces, leaves at the infection site show blotches of yellow or pale green usually near vein, surrounded by normally colored tissue.
- Occasionally, fungus may attack the stem of young seedling when grown under reduced light condition.
- The spots enlarge and cover the entire leaf area. Severely infected leaves may become chlorotic and distorted before falling. Affected fruits are small in size and malformed.
- Fungus grow superficially on the undersurface of the leaves with drawing nutrients from the cell of leaf surface by specialized absorbing structure known as haustoria.

**Survival and spread:**

- The powdery mildew fungus overwinters in dormant buds. When conditions are favorable for growth of the fungus in spring, spores are produced, released, and cause new infections. Secondary spread of the disease can occur if spores are produced in these new infections

**Favourable condition:**

- The development of powdery mildew in papaya is favour by relative humidity around 80-85% and temperature range of 24-26°C.

1.

2.

1. http://natureassassin.blogspot.in/2009/09/powdery-mildew.html
2. http://frontrangefoodgardener.blogspot.in/2010/08/telling-powdery-mildew-by-its-spots.html\

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

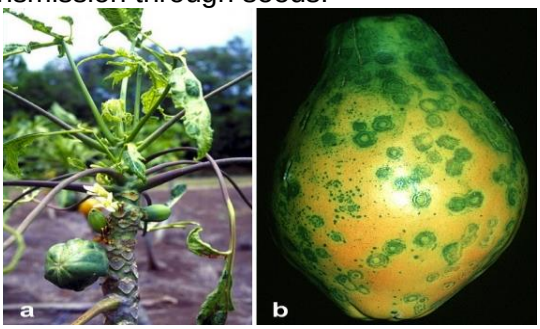
**4. Papaya ring spot disease:**

**Disease symptoms :**

- Infected plant initially shows cholorsis on youngest leaves followed by vein clearing , rugosity and prominent mottling of laminae.
- Malformation and reduction of the lamina which may become extremely filliform.
- Characteristically elongated dark green streak develop on petiole and upper half of the stems, infected fruits show circular concentric rings causes upto 56-60 % yield loss.
- Pathogen belongs to Potyvirus group of Potyviridae family.

**Transmission and favourable conditions:**

- Disease is aphid transmitted and aphids are more active during warmer conditions.
- PRSV is also easily transmitted via mechanical inoculation but there are no confirmed reports of PRSV transmission through seeds.




http://en.wikipedia.org/wiki/Papaya_ringspot_virus

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

**5. Papaya mosaic disease:**

**Disease symptoms:**

- Causes leaf mosaic and stunting in papaya.
- Young seedlings in the greenhouse show vein-clearing and downward cupping of the leaves about 5 days after inoculation.

- A mottle or mosaic develops after 15-20 days.
- Symptoms appear on the young leaves of the plants.
- The leaves are reduced in size and show blister like patches of dark-green tissue, alternating with yellowish-green lamina.
- The leaf petiole is reduced in length and the top leaves assume an upright position.

**Transmission and favourable conditions:**

- Papaya mosaic diseases is mechanically transmissible viruses associated with other viral disease, from papaya mosaic virus in being aphid-borne and restricted in host range to papaya and cucurbits.


1. http://www.weedimages.org/browse/detail.cfm?imgnum=5357068
2. http://www.forestryimages.org/browse/detail.cfm?imgnum=5357067

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

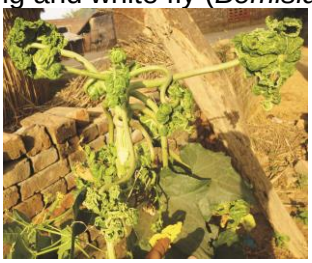
**5. Papaya leaf curl disease:**

**Disease symptoms:**

- Curling, crinkling and distortion of leaves, reduction of leaf lamina, rolling of leaf margins inward and downward, thickening of veins.
- Leaves become leathery, brittle and distorted. Plants stunted.Affected plants does not produce flowers and fruits.
- Spread by whitefly *Bemisia tabaci***.**
- Sometimes all the leaves at the top of the plant are affected by these symptoms. In advanced stages of the disease, defoliation takes place and the growth of the plant is arrested.
- PLCV is in the family *Geminiviridae*. It is not transmitted mechanically. The virus vector is the silverleaf whitefly, *Bemisia tabaci*.

**Transmission and favourable conditions:**

- The virus can not be transferred mechanical means as in the case of mosaic disease. The virus readily transmitted through grafting and white fly (*Bemisia tabaci*).

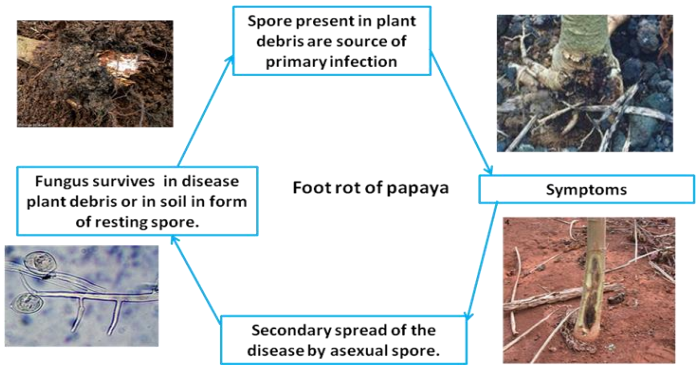
1. 2.

1. https://www.apsnet.org/publications/imageresources/Pages/fi00176.aspx
2. http://www.indiancropdiseases.com/papaya.aspx

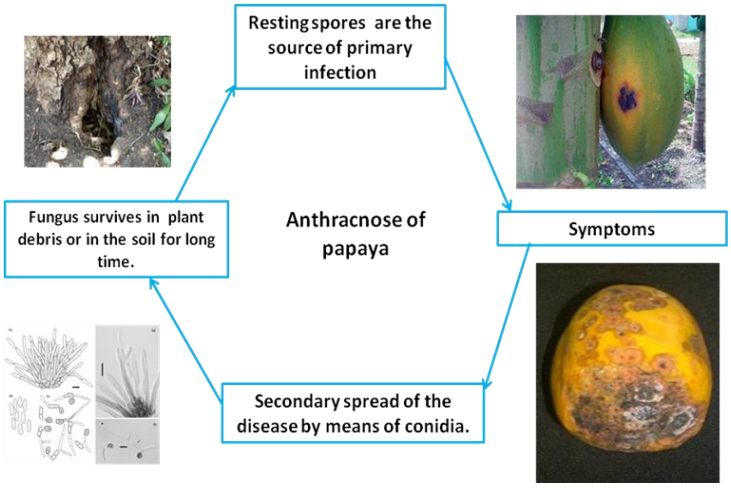
*For management refer to page number----------

## Disease cycle:

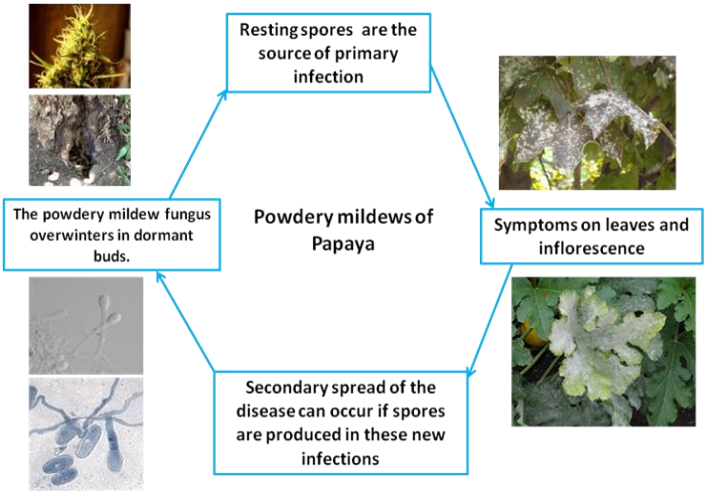
### 1. Foot rot:




### 2. Anthracnose:




### 3. Powdery mildews:



## X. SAFETY MEASURES

**A. Pre-harvest:**

- Picking starts when the plants are 11 months of age and continues for 48 months when the trees are 25 ft (7.5 m) high, too tall for further usefulness.
- The fruits are best packed in single layers and padded to avoid bruising. The latex oozing from the stem may irritate the skin and workers should be required to wear gloves and protective clothing.
- In the usual papaya plantation, each plant may ripen 2 to 4 fruits per week over the fruiting season. Healthy plants, if well cared for, may average 75 lbs (34 kg) of fruit per plant per year, though individual plants have borne as much as 300 lbs (136 kg).
- Home growers may twist the fruit to break the stem, but in commercial operations it is preferable to use a sharp knife to cut the stem and then trim it level with the base of the fruit. However, to expedite harvesting of high fruits, most people should furnish their pickers with a bamboo pole with a rubber suction cup (from the well-known "plumber's helper") at the tip.
- The fruits must be handled with great care to avoid scratching and leaking of latex which stains the fruit skin.
- With the cup held against the lower end of the fruit, the pole is thrust upward to snap the stem and the falling fruit is caught by hand. One man can thus gather 800-1,000 lbs (363-454 kg) daily.
- Papaya plants bear well for 2 years and then productivity declines and commercial plantings are generally replaced after 3-4 years. By that time they have attained heights which make harvesting difficult.

**B. Postharvest:**

**Maturity Indices:**

- Change of skin color from dark-green to light-green with some yellow at the blossom end (color break). Papayas are usually harvested at color break to ¼ yellow for export or at ½ to ¾ yellow for local markets.
- Flesh color changes from green to yellow or red (depending on cultivar) as the papayas ripen.
- A minimum soluble solids of 11.5% is required by the Hawaiian grade standards.

**Quality Indices:**

- Papayas picked ¼ to full yellow taste better than those picked mature - green to ¼ yellow because they do not increase in sweetness after harvest
- Uniformity of size and color; firmness; freedom from defects such as sunburn, skin abrasions, pitting, insect injury, and blotchy coloration; freedom from decay

**Post harvest disorders:**

**1. Physiological and physical disorders:**

- **Skin abrasions**. Result in blotchy coloration such as green islands (areas of skin that remain green and sunken when the fruit is fully-ripe) and accelerate water loss. Abrasion and puncture injuries are more important than impact injury for papayas.
- **Chilling injury.** Symptoms include pitting, blotchy coloration, uneven ripening, skin scald, hard core (hard areas in the flesh around the vascular bundles), water soaking of tissues,

and increased susceptibility to decay. Increased alternaria rot was observed in mature-green papayas kept for 4 days at 2°C, 6 days at 5°C, 10 days at 7.5°C, or 14 days at 10°C. Susceptibility to chilling injury varies among cultivars and is greater in mature-green than ripe papayas (10 vs. 17 days at 2°C; 20 vs. 26 days at 7.5°C).

- **Heat injury.** Exposure of papayas to temperatures above 30°C (86°F) for longer than 10 days or to temperature-time combinations beyond those needed for decay and/or insect control result in heat injury (uneven ripening, blotchy ripening, poor color, abnormal softening, surface pitting, accelerated decay). Quick cooling to 13°C (55°F) after heat treatments minimizes heat injury.

**2. Pathological Disorders:**

- **Anthracnose.** Caused by *Colletotrichum gloesporioides*, is a major cause of postharvest losses. Latent infections of unripe papayas develop as the fruits ripen. Lesions appear as small, brown, superficial, watersoaked lesions that may enlarge to 2.5 cm (1 inch) or more in diameter.
- **Black stem-end rot**. Caused by *Phoma caricae-papayae* attacks fruit pedicel. After harvest, the disease lesion on fruits appear in the stem area which becomes dark-brown to black. Another stem-end rot is caused by *Lasiodiplodia theobromae.*
- **Phomopsis rot.** Caused by *Phomopsis caricae-papayae* begins in the stem end or a fruit skin wound and can develop rapidly in ripe fruits; invaded tissue softens and darkens slightly.
- **Phytophthora stem-end rot.** Caused by *Phytophthora nicotianae* var. *parasitica* begins as water-soaked areas followed by white mycelium that become encrusted.
- **Alternaria rot**. Caused by *Alternaria alternata* follows chilling injury of papayas kept at temperatures below 12°C (54°F).

**Control Strategies:**

1. Careful handling to minimize mechanical injuries
2. Prompt cooling and maintenance of optimum temperature and relative humidity throughout postharvest handling operations
3. Application of fungicides, such as thiabendazole (TBZ)
4. Dipping in hot water at 49°C (120°F) for 20 minutes

**Heat Treatments for Insect Control:**

5. Hot water treatment: 30 minutes at 42°C (107.6°F) followed within 3 minutes by a 49°C (120.2°F) dip for 20 minutes
6. Vapor heat treatment: Fruit temperature is raised by saturated water vapor at 44.4°C (112°F) until the center of the fruit reaches that temperature, and then held for 8.5 hours
7. Forced hot air treatment: 2 hours at 43°C (109.4°F) + 2 hours at 45°C (113°F) + 2 hours at 46.5°C (115.7°F) + 2 hours at 49°C (120.2°F)

Source: **http://postharvest.ucdavis.edu/PFfruits/Papaya/**

## 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. | Grow only recommended varieties. | Do not grow varieties not suitable for the season or region. |
| 3 | Sow early in the season | Avoid late sowing as this may lead to reduced yields and incidence of pests |
| 4 | Always treat the seeds with approved chemicals/bio products for the control of seed borne diseases/pests. | Do not use seeds without seed treatment with biocides/chemicals. |
| 5. | Adopt proper spacing in the field. | Do not damage the seedling while uprooting and transplanting. |
| 6. | 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. |
| 7. | Use NPK fertilizers as per the soil test recommendation. | Avoid imbalanced use of fertilizers. |
| 8. | Use micronutrient mixture after sowing based test recommendations. | Do not apply any micronutrient mixture after sowing without test recommendations. |
| 9. | Conduct AESA weekly in the morning preferably before 9 a.m. Take decision on management practice based on AESA and P: D ratio only. | Do not take any management decision without considering AESA and P: D ratio |
| 10 | Install pheromone traps at appropriate period. | Do not store the pheromone lures at high temperature and preferably store in refrigerator. |
| 11 | 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. |
| 12 | Spray recommended pesticides thoroughly to treat the undersurface of the leaves, particularly for sucking pests. | Do not spray pesticides only on the upper surface of leaves. |
| 13 | Apply short persistent pesticides to avoid pesticide residue in the soil and produce. | Do not apply long persistent pesticides during preceding 7 days before harvest. |
| 14 | Follow the recommended procedure of trap crop technology. | Do not apply long persistent pesticide on trap crop, otherwise it may not attract the pests and natural enemies. |

## XII. BASIC PRECAUTIONS IN PESTICIDES USAGE

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

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

C. Handling
   1. Never carry/ transport pesticides along with food materials.
   2. Avoid carrying bulk pesticides (dust/granules) on head shoulders or on the back.

D. Precautions for preparing spray solution
   1. Use clean water.
   2. Always protect your nose, eyes, mouth, ears and hands.
   3. Use hand gloves, face mask and cover your head with cap.
   4. Use polythene bags as hand gloves, handkerchiefs or piece of clean cloth as mask and a cap or towel to cover the head (Do not use polythene bag contaminated with pesticides).
   5. Read the label on the container before preparing spray solution.
   6. Prepare the spray solution as per requirement
   7. **Do not** mix granules with water, **Do not** eat, drink, smoke or chew while preparing solution
   8. Concentrated pesticides must not fall on hands etc. while opening sealed container. **Do not** smell pesticides.
   9. Avoid spilling of pesticides while filling the sprayer tank.
   10. The operator should protect his bare feet and hands with polythene bags

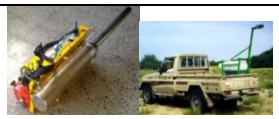
E. Equipment
   1. Select right kind of equipment.
   2. **Do not** use leaky and defective equipment
   3. Select right kind of nozzles
   4. **Do not** blow/clean clogged nozzle with mouth. Use old tooth brush tied with the sprayer and clean with water.
   5. **Do not** use same sprayer for weedicide 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

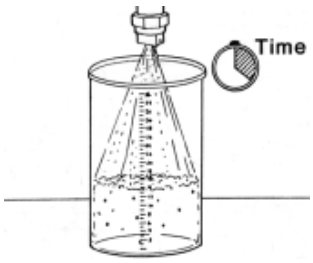
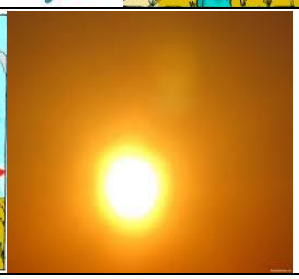
4. Wash the sprayer and buckets etc. with soap water after spraying
5. Containers buckets etc. used for mixing pesticides should not be used for domestic purpose
6. Avoid entry of animals and workers in the field immediately after spraying
7. Avoid tank mixing of different pesticides

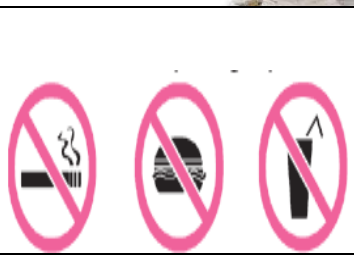
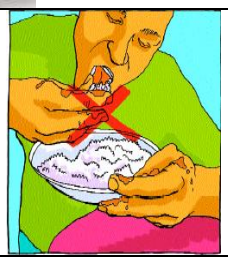
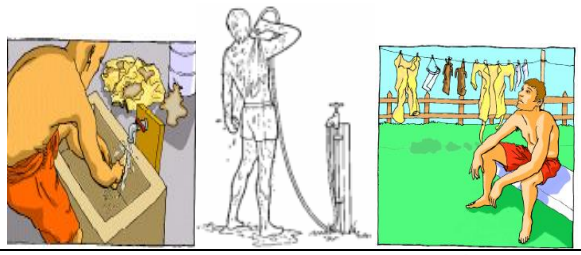
G. Disposal
1. Left over spray solution should not be drained in ponds or water lines etc. throw it in barren isolated area if possible
2. The used/empty containers should be crushed with a stone/stick and buried deep into soil away from water source.
3. Never reuse empty pesticides container for any other purpose.

## XIII. PESTICIDE APPLICATION TECHNIQUES

<table>
<tr><td colspan="4">Equipments</td></tr>
<tr><td colspan="4">Category A: Stationary, crawling pest/disease</td></tr>
<tr><td rowspan="2">Vegetative stage<br>i) For crawling and soil borne pests<br><br>ii) For small sucking leaf borne pests</td><td rowspan="2">Insecticides and fungicides</td><td rowspan="2">• Lever operated knapsack sprayer (Droplets of big size)<br>• Hollow cone nozzle @ 35 to 40 psi<br>• Lever operating speed = 15 to 20 strokes/min<br>or<br>• Motorized knapsack sprayer or mist blower (Droplets of small size)<br>• Airblast nozzle<br>• Operating speed: 2/3rd throttle</td><td>  </td></tr>
<tr><td>  </td></tr>
<tr><td>Reproductive stage</td><td>Insecticides and fungicides</td><td>• Lever operated knapsack sprayer (Droplets of big size)<br>• Hollow cone nozzle @ 35 to 40 psi<br>• Lever operating speed = 15 to 20 strokes/min</td><td>  </td></tr>
<tr><td colspan="4">Category B: Field flying pest/airborne pest</td></tr>
<tr><td>Vegetative stage<br>Reproductive stage<br>(Field Pests)</td><td>Insecticides and fungicides</td><td>• Motorized knapsack sprayer or mist blower (Droplets of small size)<br>• Airblast nozzle<br>• Operating speed: 2/3rd throttle<br>Or<br>• Battery operated low volume sprayer (Droplets of small size)<br>Spinning disc nozzle</td><td>  <br>  </td></tr>
<tr><td>Mosquito/ locust and spatial application (migratory Pests)</td><td>Insecticides and fungicides</td><td>• Fogging machine and ENV (Exhaust nozzle vehicle) (Droplets of very small size)<br>• Hot tube nozzle</td><td>  </td></tr>
</table>

## 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.<br><br>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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