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AESA BASED IPM PACKAGE

AESA based IPM - Amla

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

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FOREWORD

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

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

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

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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 AMLA

Amla plant description

Amla is a member of Euphorbiaceae to which most of the xerophytes. Amla is a hardy drought resistant fruit tree. A rare combination of character is its ability to withstand water stagnation too. It is also known as aonla,, amali and nelli etc. The amla fruits are a rich source of Vitamin C. The special attribute is its capacity to retain Vitamin C even in a dried state which is not possible in other fruits. The vitamin C supplied by its fruits and dried powder is even superior to synthetic Vitamin C. One part or other is used in the cure of cough, bronchitis, jaundice, diabetes, dyspepsia, diarrhea and fever. Fruit pulp contains 14 g of carbohydrate, 0.5 g protein, 1.2 g iron, 0.3 mg vitamin B and 600 mg of Vitamin C per 100g. Probably this fruit extract is used in a number of ayurvedic and homeopathic preparations which are said to prevent greying of hairs and falling of hairs. The probable centres of origin are the South and Central India, Sri Lanka, Malaysia and South China.

The tree is small to medium in size, reaching 8 to 18 m in height, with a crooked trunk and spreading branches. The branchlets are glabrous or finely pubescent, 10–20 cm long, usually deciduous; the leaves are simple, subsessile and closely set along branchlets, light green, resembling pinnate leaves. The flowers are greenish-yellow. The fruit is nearly spherical, light greenish yellow, quite smooth and hard on appearance, with six vertical stripes or furrows.

Though amla is a subtropical fruit, it thrives very well and comes to yield in tropical humid conditions also. If young plants are protected from both extremes of temperature, the mature trees can tolerate right from freezing (0°C) to as high as 46°C. Similarly if the young plants are protected from severe drought during summer and water stagnation during heavy rains, then the adult trees tolerate these two adverse conditions. In a well-drained loamy soil the amla trees grow faster, they can grow in heavy clay also provided slight drainage is arranged during heavy rains in their early crop growth phase of first 2 – 3 years. They also fairly tolerate alkalinity in soils (pH 8.5) and irrigation water.

I. PESTS

A. Pests of National Significance

1. Insect pests

- **1.1 Bark eating caterpillar: *Inderdela tetraonis* Moore (Lepidoptera: Metarbalidae)**
- **1.2 Apical twig gall maker: *Betonsa stylophora* Swinhoe (Lepidoptera: Thyrididae)**
- **1.3 Mealy bug: *Ferrisia virgata* Cockerell (Homoptera: Coccidae)**
- **1.4 Aphids: *Setaphis bougainvilleae* Theob. (Hemiptera, Aphididae)**

2. Diseases

- **2.1 Leaf rust: *Phakopsora phyllanthi* Diet.**
- **2.2 Ring rust: *Ravenelia emblicae* Stydlia.**

3. Weeds

- **3.1 Purple nut sedge: *Cyperus rotundus* L. (Cypraceae)**
- **3.2 Bermuda grass: *Cynodon dactylon* (L.) Pers (Poaceae)**
- **3.3 Tridax: *Tridax procumbens* L. (Asteraceae)**
- **3.4 Large crabgrass: *Digitaria sanguinalis* L. (Poaceae)**
- **3.5 Yellow foxtail: *Setaria glaucae* L. (Poaceae)**
- **3.6 Tick weed: *Cleome viscose* L. (Capparidaceae)**
- **3.7 Torpedo grass: *Panicum repens* L. (Poaceae)**
- **3.8 Horse purslanes: *Trainthema monogyne* L. (Aizoaceae)**

B. Pests of Regional Significance

1. Insect pests**

- **1.1 Pomegranate butterfly: *Virachola isocrates* Fabricius (Lepidoptera: Lycaenidae)**
- **1.2 Fruit sucking moths: *Achaea* sp. (Lepidoptera: Noctuidae)**
- **1.3 Hairy caterpillar: *Euproctis* sp. (Lepidoptera: Lymantriidae)**
- **1.4 Leaf roller: *Gracillaria theivora* Walsingham (Lepidoptera: Gracillariidae)**
- **1.5 Leaf miner: *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae)**
- **1.6 White fly: *Aleurolobus barodensis* Maskell (Hemiptera: Aleyrodidae)**

2. Diseases

- **2.1 Soft rot: *Phomopsis phyllanthi* Punith**

3. Disorders

- **3.1 Internal necrosis**

4. Rodents

- **4.1 Lesser bandicoot (*Bandicota benglesis* Gray)**
- **4.2 Soft furred field rat (*Melordia meltada* Gray)**
- **4.3 House rat (*Ratus rattus* L.)**

5. Birds

- **5.1 Rose ringed parakeet**

II AGRO-ECOSYSTEM ANALYSIS (AESA) BASED INTEGRATED PESTS 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 forces the participants/farmers to observe closely and intensively. It is a focal point for the analysis and for the discussions that follow, and the drawing can be kept as a record.

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

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

Principles of AESA based IPM:

Grow a healthy crop

- Select a variety resistant/tolerant to major pests
- Select healthy seeds/seedlings/ planting material
- Treat the seeds/seedling/planting material with recommended pesticides especially biopesticides
- Follow proper spacing
- Soil health improvement (mulching and green manuring whenever applicable)
- Nutrient management especially organic manures and biofertilizers based on the soil test results. If the dosage of nitrogenous fertilizers is too high the crop becomes too succulent and therefore susceptible to insects and diseases. If the dosage is too low, the crop growth is retarded. So, the farmers should apply an adequate for best results. The

phosphatic fertilizers should not be applied each and every season as the residual phosphate of the previous season will be available for the current season also.

- Proper irrigation
-

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

Farmers should:

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

Plant compensation ability:

Compensation is defined as the replacement of plant biomass lost to herbivores and has been associated with increased photosynthetic rates and mobilization of stored resources from source organs to sinks (e.g., from roots and remaining leaves to new leaves) during active vegetative growth period. Plant tolerance to herbivory can arise from the interaction of a variety of plant traits and external environmental factors. Several studies have documented such compensation through increased growth and photosynthetic rate.

Understand and conserve defenders

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

Insect zoo:

In field various types of insects are present. Some are beneficial and some may be harmful. Generally farmers are not aware about it. Predators (friends of the farmers) which feed on pests are not easy to observe in crop field. Insect zoo concept can be helpful to enhance farmers' skill to identify beneficial and harmful insects. In this method, unfamiliar/unknown

predators are collected in plastic containers with brush from the field and brought to a place for study. Each predator is placed inside a plastic bottle together with parts of the plant and some known insect pests. Insects in the bottle are observed for certain time and determined whether the test insect is a pest (feeds on plant) or a predator (feeds on other insects).

Pest: Defender ratio (P: D ratio):

Identifying the number of pests and beneficial insects helps the farmers to make appropriate pest management decisions. Sweep net, visual counts etc. can be adopted to arrive at the numbers of pests and defenders. The P: D ratio can vary depending on the feeding potential of natural enemy as well as the type of pest. The natural enemies of amla pests can be divided into 3 categories 1. parasitoids; 2. predators; and 3. pathogens.

Model Agro-Ecosystem Analysis chart

Date:
Village:
Farmer:

Decision taken based on the analysis of field situations

Soil conditions :
Weather conditions :
Diseases types and severity :
Weeds types and intensity :
Rodent damage (if any) :
No. of insect pests :
No. of natural enemies :
P: D ratio :

The general rule to be adopted for management decisions relying on the P: D ratio is 2: 1. However, some of the parasitoids and predators will be able to control more than 2 pests. Wherever specific P: D ratios are not found, it is safer to adopt the 2: 1, as P: D ratio. Whenever

the P: D ratio is found to be favourable, there is no need for adoption of other management strategies. In cases where the P: D ratio is found to be unfavourable, the farmers can be advised to resort to inundative release of parasitoids/predators depending upon the type of pest. In addition to inundative release of parasitoids and predators, the usage of microbial biopesticides and biochemical biopesticides such as insect growth regulators, botanicals etc. can be relied upon before resorting to synthetic chemical pesticides.

Decision making:

Farmers become experts in crop management:

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

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

AESA methodology:

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

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

- While walking in the field, manually collect insects in plastic bags. Use a sweep net to collect additional insects. Collect plant parts with disease symptoms.
- Find a shady place to sit as a group in a small circle for drawing and discussion.
- If needed, kill the insects with some chloroform (if available) on a piece of cotton.
- Each group will first identify the pests, defenders and diseases collected.
- Each group will then analyze the field situation in detail and present their observations and analysis in a drawing (the AESA drawing).
- Each drawing will show a plant representing the field situation. The weather condition, water level, disease symptoms, etc. will be shown in the drawing. Pest insects will be drawn on one side. Defenders (beneficial insects) will be drawn on another side. Write the number next to each insect. Indicate the plant part where the pests and defenders were found. Try to show the interaction between pests and defenders.
- Each group will discuss the situation and make a crop management recommendation.
- The small groups then join each other and a member of each group will now present their analysis in front of all participants.

- The facilitator will facilitate the discussion by asking guiding questions and makes sure that all participants (also shy or illiterate persons) are actively involved in this process.
- Formulate a common conclusion. The whole group should support the decision on what field management is required in the AESA plot.
- Make sure that the required activities (based on the decision) will be carried out.
- Keep the drawing for comparison purpose in the following weeks.

Data recording

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

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

Data to be recorded:

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

Some questions that can be used during the discussion

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

Advantages of AESA over ETL:

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

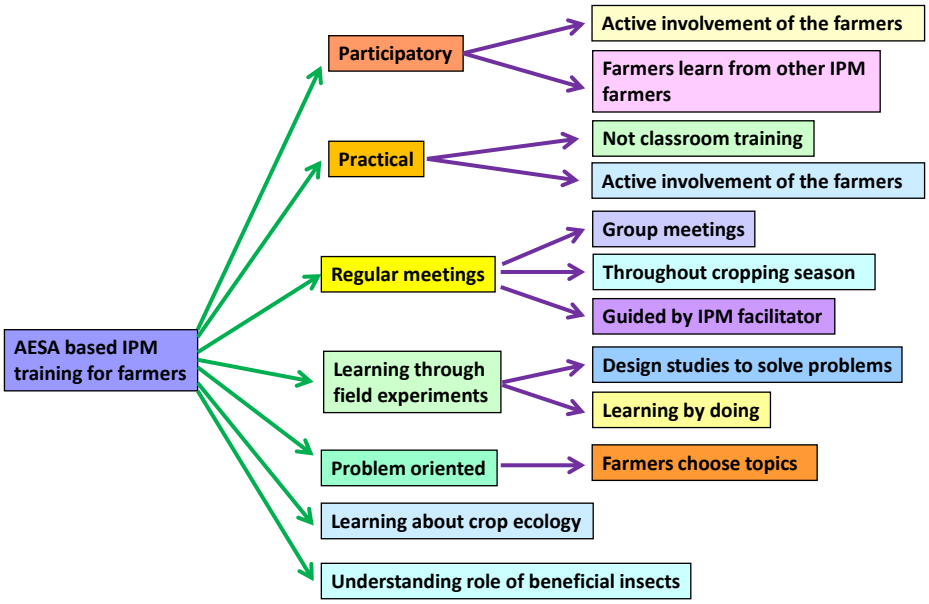
AESA and farmer field school (FFS):

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

Farmers can learn from AESA

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

FFS to teach AESA based IPM skills:



B. Field scouting

AESA requires skill. So only the trained farmers can undertake their 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 at the main field should commence soon after crop establishment after transplanting and at weekly intervals thereafter. In each of the fields, select five spots randomly. Select five random plants at each spot for recording counts of insects as per procedure finalized for individual insects.

For sucking pests:
Aphids, whitefly: Count and record the number of both nymphs and adults on five randomly selected leaves per plant.
Thrips: Count and record the number of nymphs and adults of thrips present on five terminal per plant (tapping method also can be used to count thrips).
Leaf miner: Only the number of live mines on five randomly selected leaves per plant should be counted and recorded.

For diseases:
Whenever scouting, be aware that symptoms of plant disease problems may be caused by any biotic factors such as fungal, bacterial, viral pathogens or abiotic factors such as weather, fertilizers, nutrient deficiencies, pesticides and abiotic soil problems. In many cases, the cause of the symptom is not obvious. Close examination, and laboratory culture and analysis are required for proper diagnosis of the causal agent of disease. Generally fungal diseases cause the obvious symptoms with irregular growth, pattern & colour (except viruses), however abiotic

problems cause regular, uniform symptoms. Pathogen presence (signs) on the symptoms can also be observed like fungal growth, bacterial ooze etc. Specific and characteristic symptoms of the important plant diseases are given in description of diseases section.

Root sampling: Always check plants that appear unhealthy. If there are no obvious symptoms on plants, examine plants randomly and look for lesions or rots on roots and stems. Observe the signs of the causal organism (fungal growth or ooze). 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 stem damaged/infested/infected due to rot should be counted and incidence should be recorded.

Leaf sampling: Examine all leaves and/or leaflets 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 flower and fruit sampling: Carefully examine the stems and fruits of plants for symptoms and signs of fungal or bacterial diseases. The stems and fruits should be split or taken apart and examined for discoloration caused by fungi and bacteria. Count the number of plant, fruit, infected due to disease and percent disease incidence should be recorded.

C. Surveillance through pheromone trap catches for *anar butterfly***:**
Pheromone traps for two insects viz., *anar butterfly* @ 2/fixed field have to be installed. Install the traps for each species separated by a distance of >75 feet in the vicinity of the selected fixed field. Fix the traps to the supporting pole at a height of one foot above the plant canopy. Change of lures should be made at 2-3 week interval (regular interval). During each week of surveillance, the number of moths/trap should be counted and recorded year round. The trapped moths should be removed and destroyed after each recording.

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

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

III. ECOLOGICAL ENGINEERING FOR PEST MANAGEMENT

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

Natural enemies may require

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

Ecological engineering for pest management – Above ground:

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

Ecological engineering for pest management – Below ground:

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

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

Ecological Engineering Plants

Attractant plants

Cowpea

Carrot

Sunflower

Buckwheat

Alfalfa

Mustard

Cosmos

Anise

Caraway

Dill

Parsely

Marigold

Repellent plants

***Ocimum* sp**

Peppermint

Spear mint

Border plants

Sorghum

Maize

Pearl Millet

Intercrops

French bean

Blackgram

Greengram

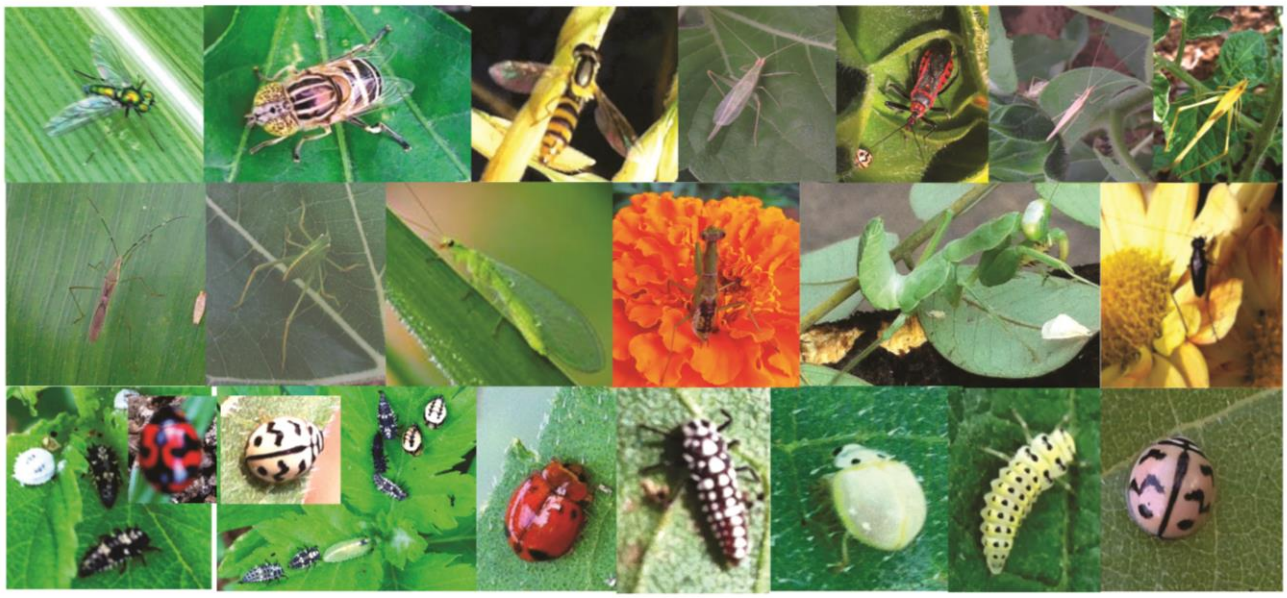
Groundnut

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

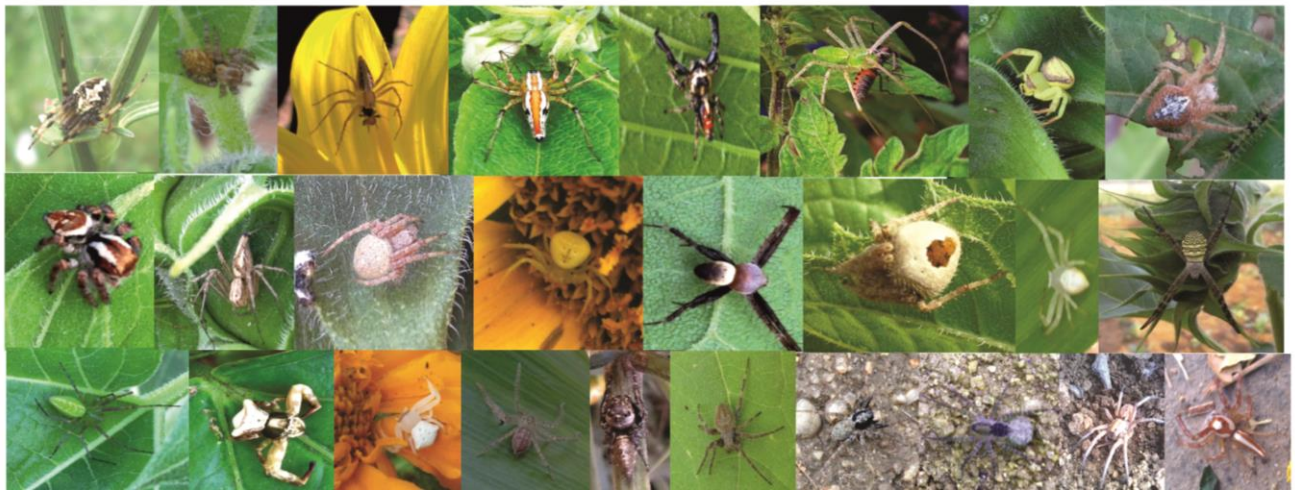
Biodiversity of natural enemies observed in Ecological Engineering field at NIPHM

Biodiversity of natural enemies: Parasitoids

Biodiversity of natural enemies: Predators



Biodiversity of natural enemies: Spiders



A. Resistant/ tolerant varieties:

Sr. no.	Variety	Tolerant/ resistant
1.	NA-10 (Narendra-10), Kanchan	*B. stylophora*, *G. acidula*, *I. quadrinotata, Alternaria* sp.
2.	Banarasi and Chakaiya.	Rust

***For detailed and updated information nearest KVK, SAU / ICAR Institute may be contacted**

IV. CROP STAGE/WISE IPM

Management	Activity
Pre planting*	
	Common cultural practices: • Timely planting should be done. • Field sanitation, roguing • Destroy the alternate host plants • Apply manures and fertilizers as per soil test recommendations • Sow the ecological engineering plants • Sow the intercrops as per the season. • Sow/plant sorghum/maize/pearl millet in 4 rows all around the crops as a guard/barrier crop.
Nutrients	• Apply 4 tonnes of well decomposed farm yard manure peracre • Apply 90:120:48 of NPK along with elemental sulphur 10 kg and micro nutrients 10 kg per acre. • 15 kg of FYM and 0.5 kg of phosphorus should be applied to each pit before planting.
Weeds	• Regular weeding should be done
Resting stages of soil borne pathogens, pests	**Cultural control:** • Deep summer ploughing of fields to control soil borne pathogens and subsequently reduces their initial population build up. • Soil solarization: Cover the beds with polythene sheet of 45 gauge (0.45 mm) thickness for three weeks before sowing for soil solarization which will help in reducing the soil-borne pests including weeds.
Planting*	
	Common cultural practices: • Use resistant/tolerant planting material/seedlings • Follow proper plant spacing • Use healthy, certified and weed free planting material.
Nutrients	• Application of nitrogen 30 g/tree of each year during September – October up to 10 years. • The young plants should be given 15-20 kg of well rotten FYM and the mature trees should be given 1 kg of Super Phosphate and 1-1.5kg of muriate of potash • The above fertilizers should be given in two split doses to mature, bearing tree, once during September-October and during April-May. • After setting of the fruits the plants needs to be irrigated after fertilizer application.
Weeds	• Same as in pre planting stage
Resting stages of soil borne pathogens, pests	• Same as in pre planting stage

***** Apply *Trichoderma viride/ harzianum* and *Pseudomonas fluorescens* as seed/seedling/planting material, nursery treatment and soil application (if commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).	
Vegetative stages	
	Common cultural practices: • Collect and destroy crop debris • Provide irrigation at the critical stages of the crop • Avoid water logging • Avoid water stress during flowering stage • Follow judicious use of fertilizers • Enhance parasitic activity by avoiding chemical pesticide spray, when 1-2 larval parasitoids are observed in the crops field. **Common mechanical practices:** • Collect and destroy disease infected and insect infested plant parts. • Collect and destroy eggs and early stage larvae • Handpick the older larvae during early stages • Hand pick the gregarious caterpillars and cocoons which are found on stem/branches and destroy them in kerosene mixed water. • Use yellow sticky traps @ 4-5 trap/acre • Use light trap @ 1/acre and operate between 6 pm and 10 pm • Install pheromone traps @ 4-5/acre for monitoring adult moths activity (replace the lures with fresh lures after every 2-3 weeks) • Erecting of bird perches @ 20/acre for encouraging predatory birds such as King crow, common mynah etc. • Set up bonfire during evening hours at 7-8 pm. **Common biological practices:** • Conserve natural enemies through ecological engineering • Augmentative release of natural enemies
Nutrients	• As indicated during planting stage.
Weeds	• Same as indicated during pre planting stage.
Bark eating caterpillar	**Cultural control:** • Keep orchard clean by proper sanitation. • Detect early infestation by periodically looking out for drying young shoots. • Collect loose and damaged bark & destroy. • Kill larvae by inserting iron spike or wire into hole.
Apical twig gall maker	**Cultural control:** • Adopt training and pruning to discourage overcrowding of branches. • Galled shoots should be pruned and destroyed along with the pest after harvest.
Aphids	**Cultural control:** • Clipping off and destruction of affected leaf and shoot. • Collect and destroy alternate weed hosts. • Eract yellow pan traps @ 4-5 trap/acre **Biological control:**

	• *Scymnus*, *Chilomens sexmaculatus*, *Chrysoperla zastrowi sillemi* and other coccinellids, Predatory mantids, green lace wings, ladybird beetles and parasitic wasps
Mealy Bug	**Cultural control:** • Follow clean cultivation and maintenance of health and vigour of the tree. • Prune affected parts and destroy them at early stages of infestation. • Early detection of mealy bugs - presence of ants - indicator • Cutting of infested twigs and leaves and burying them **Biological control:** • Field release of green lace wing *Chrysoperla zastrowi sillemi* • Several species of ladybird beetles such as o *Chilocorus* sp. o *Cryptolaemus montrouzieri* are efficient predator.
Pomegranate butterfly	**Cultural control:** • Clean cultivation and maintenance of health and vigour of the tree should be followed. • Infested fruits should be identified, collected and destroyed to prevent further spread of infestation. **Mechanical control:** • Remove weeds of compositae family • Detect early infestation by periodically looking for drying branches. **Biological control:** • Release of *Trichogramma chilonis* @ 1.0 lakhs/ acre four times at 10 days interval.
Whitefly	**Cultural Control:** • Clipping of and destruction of infested leaves. • Avoid water stress and water log conditions. • Avoid planting in low land areas. **Mechanical Control:** • Remove the puparia bearing leaves and immediately disposing by burning or burying to prevent emergence of adult white flies • Use yellow sticky traps. **Biological Control:** • Release parasitoids*Encarsia* sp*, Eretmocerus* sp. • **Release** predators *Dicyphus hesperus* (mirid bug), dragonfly, spider, robber fly, praying mantis, fire ants, coccinellids, lace wings, big eyed bugs (*Geocoris* spp.) etc.
Leaf miner	**Cultural control:** • Avoid pruning live branches more than once a year, so that the cycles of flushing are uniform and short. • Do not apply nitrogen fertilizer at the times of the year when leaf miner populations are high and flush growth will be severely damaged.. • Set up yellow pan water trap/sticky traps 15 cm above the canopy for monitoring and management of leaf minor @ 8-10 traps/acre.

	Biological control: • Release natural enemies wasp like *Pnigalio* spp and *Closterocerus* spp.
Hairy caterpillars and Leaf roller**	**Cultural control:** • Hand pick caterpillars and destroy the infest plant parts along with larva.
Rust	**Cultural control:** • Grow tolera**n**t/resistant cultivars like Banarasi and Chakaiya. • Maintain proper plant distance and aeration by training and pruning. • Severely infected plant parts should be pruned and destroyed.
Flowering and fruiting stages	
	Common cultural practices: • Same as in vegetative stage. **Common mechanical practices:** • Same as in vegetative stage **Common biological practices:** • Same as in vegetative stage •
Nutrients	• Same as indicated during planting stage.
Weeds	• Same as indicated during pre planting stage.
Apical twig gall maker	• Same as indicated during vegetative stage
Mealy Bug	• Same as indicated during vegetative stage
Pomegranate butterfly	• Same as indicated during vegetative stage
Fruit sucking moths**	**Cultural control:** • Collect and destroy the infested plant parts along with the larva. **Biological control:** • Release or increase population of biocontrol agents like *Charops obtusus* Morley*, Rhogas* spp., *Apanteles hyposidrae* Wilkinson*, Euplectrus maternus*
Hairy caterpillars and Leaf roller**	• Same as indicated during vegetative stage
Rust	• Same as indicated during vegetative stage
Fruit rot	**Cultural control:** • Prune and destroy pruned cuttings and debris by burning, burying, or ploughing them into the soil. • Avoid injury to fruits.

Post harvest	
Pest & diseases	**<u>Cultural methods:</u>** **<u>Mechanical control:</u>** • Remove and destroy all the affected fruits to reduce, the incidence of Anar butterfly.

****** Pests of regional significance:

V. RODENT PEST MANAGEMENT

Lesser bandicoot: ***Bandicota bengalensis* Gray** **Soft furred field rat:** ***Melordia meltada* Gray** **House rat:** ***Ratus rattus* L.**	**Cultural practices:** • Plough the fields to demolish the rodent habitat and maintain weed free fields to reduce alternate source of food and habitat • Practice clean cultivation/maintain weed free fields which reduces the harboring/hiding points for rodents. • Practice trapping with locally available traps using bait. In areas, where *Rattus rattus* is a problem, wonder traps/multi-catch traps work better and enable to trap more animals into a single trap. • Identify live rodent burrows and smoke the burrows with burrow smoker for 2-3 minutes

VI. INSECTICIDE RESISTANCE AND ITS MANAGEMENT

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

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

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

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

VII. NUTRITIONAL DEFECIENCY/ DISORDER

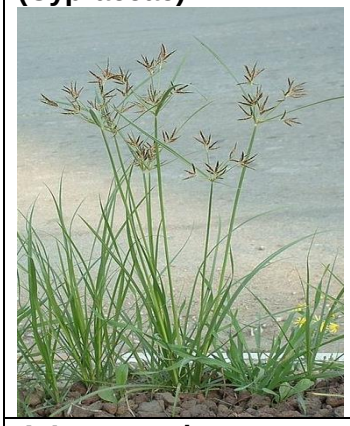
1. Internal necrosis

Disorder symptoms:

- Internal necrosis in amla fruits is caused by Boron deficiency.
- The symptoms start with the browning of the innermost part of mesocarpic tissue at the time of endocarp hardening in the 2nd or 3rd week of September which later extends towards the epicarp resulting into brownish black appearance of the flesh.

Control measures: Spray 0.6% borox during September to October thrice at an interval of 10-15 days.

VIII. COMMON WEEDS

1. Purple nutsedge: ***Cyperus rotundus* L.** **(Cypraceae)** 	**2. Bermuda grass:** ***Cynodon dactylon* (L.) Pers** **(Poaceae)** 	**3. Tridax:** ***Tridax procumbens* L.** **(Asteraceae)** 
4. Large crabgrass: ***Digitaria sanguinalis* L.** **(Poaceae)** 	**5. Yellow foxtail:** ***Setaria glaucae* L.** **(Poaceae)** 	**6. Tick weed:** ***Cleome viscose* L.** **(Capparidaceae)** 
7. Torpedo grass: ***Panicum repens* L.** **(Poaceae)** 	**8. Horse purslanes:** ***Trainthema monogyne* L.** **(Aizoaceae)** 	

4

IX. DESCRIPTION OF INSECT-PESTS

1. Bark eating caterpillar:

Biology:

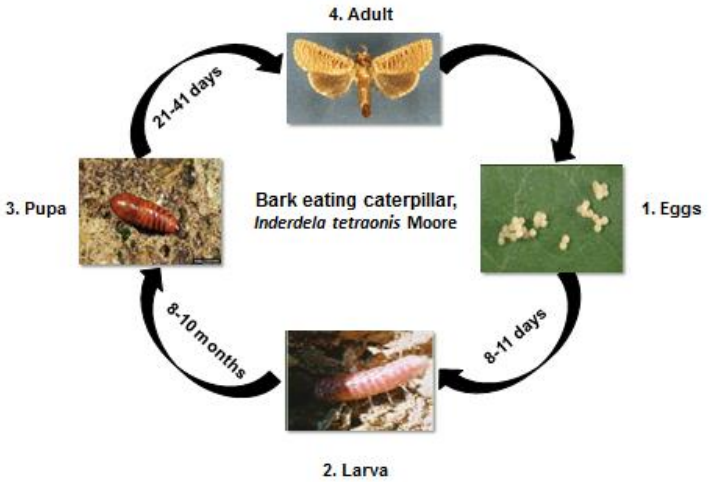
Eggs: 350 on bark in May-June, larval period is about 8-11 days. Spherical eggs, usually singly, are laid in bark cracks. No. of generation : 1/year

Larva: Larval period 8-10 months till about 3rd week of April. The larval stage is for about 10 months. The larva is brown to black, shiny, sparsely hairy and measures 4.5-5.0 cm before pupation.

Pupa: Pupation inside larval tunnel, pupal period is about 21-41 days.

Adult: Moth is creamy white with brown markings on the forewing. Moth longevity is 3 days.

Life cycle:



http://www.yourarticlelibrary.com/wp-content/uploads/2014/01/clip_image0086_thumb.jpg
http://www.docstoc.com/docs/145645830/Identification-Symptoms-and-nature-of-damage-Fruit-fly-Stone

Damage symptoms:

- Make tunnels in the main trunk and branches
- Larvae construct loose irregular webbing of silken threads
- Deterioration of vitality, reduction in yield

Bore hole **Tunneling trunk**

http://www.ikisan.com/crop%20specific/eng/links/ap_citrusInsect%20Management.shtml
http://agritech.tnau.ac.in/crop_protection/crop_prot_crop_insectpest%20_Amla.html#4a
http://tnau.ac.in/eagri/eagri50/ENTO331/lecture16/006.html
http://www.kkwagrifaculties.org/html/Theory%20notes/ENT%20-%20353.pdf

Favourable conditions:

- Attacks in April at initiation of new growth after dormancy.

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

2. Apical twig gall maker

Damage symptoms:

- In the beginning of the infestation terminal shoots swell, which increases in size with the passage of time.

- The young insects penetrate from apical portion of the shoot after the monsoon and feed inside the tissue, changing into galls. Growth of shoot is hampered and few lateral shoots develop below galls
- Full size galls can be seen in the month of October-November.

Nursery plants infested with shoot gall maker

http://www.baifwadi.org/index.php?option=com_content&view=article&id=133:amla-a-profitable-fruit-for-growing-in-semiarid-lands&catid=51:factsheets&Itemid=86

Favourable conditions:

- Favourable condition is rainy season.
- Attacks during monsoon on onset of new growth.

Management:

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

3. Aphids

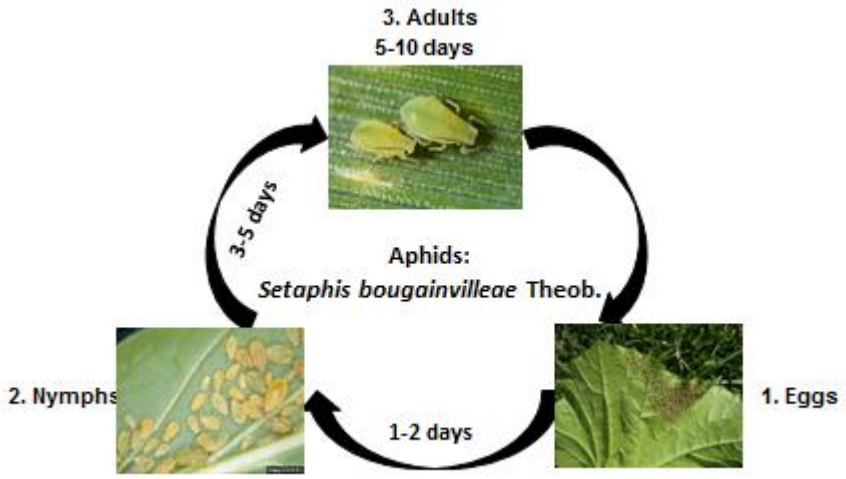
Biology:

Eggs: Eggs hatch after one or two days. Young aphids, called nymphs.

Nymph: Oval or slightly elongated, reddish brown with six segmented antennae

Adult: Aphids reproduce in two ways: by laying eggs and laying live young, which birth process is depends on environmental conditions and the availability of food. When food is plentiful, aphids give birth to live young. Populations develop quickly as this pest has many young, a short life span and pre-adult insects can also give birth.

Life cycle:



http://agritech.tnau.ac.in/crop_protection/crop_prot_crop_insectpest%20_Amla.html#4a

Damage symptom:

- Nymph and adults suck sap by remaining on the under surface of leaves
- Yellowing of leaves wit sugary executes (honey dew)

Foliage infested

Favourable condition:

- The incidence of this pest is mainly seen from July to October with the peak period in September.

Natural enemies of aphids:

Parasitoids: *Aphidius colemani*

Predators: ***Dicyphus hesperus,*** **Lacewing, Ladybird beetle**

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

4. Mealy Bug

Biology:

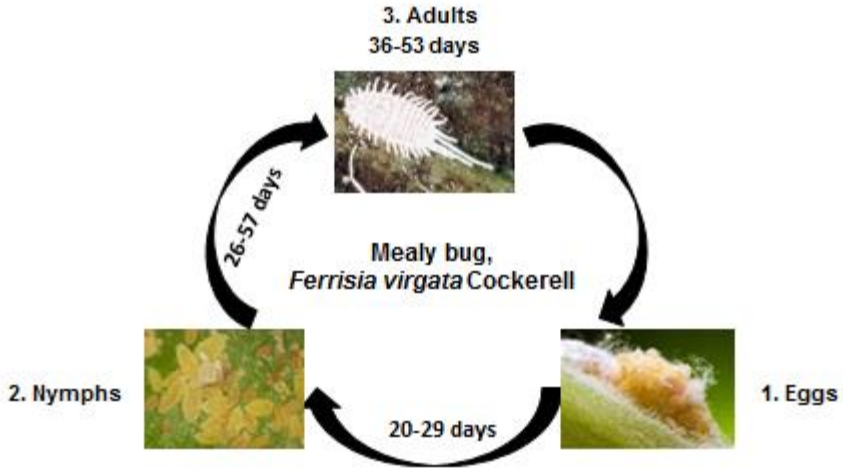
Nymph: Yellowish to pale white.

Adult: Females apterous, long, slender covered with white waxy secretions

Incubation period 3 to 4 hours. Egg masses on leaves under female.

The developmental period of nymph of male and female varies from 31 to 57 and 26 - 47 days respectively. Longevity of male is 1-3 days and female is 36-53 days**.**

Life cycle:



http://agritech.tnau.ac.in/crop_protection/crop_prot_crop_insectpest%20_Amla.html#4a
http://www.duroibugs.co.za/pests/mealybug.htm
http://www.kkwagrifaculties.org/html/Theory%20notes/ENT%20-%20353.pdf

Damage symptoms:

- Insect covers tender growing points with white mass and suck the sap
- Nymphs and adult female remains clustered on ventral surface of leaves, terminal shoots and sometimes on fruit and suck cell sap and reduce the plant vitality
- Yellowing of leaves, premature shedding of fruits.

Infested plant parts

http://agritech.tnau.ac.in/crop_protection/crop_prot_crop_insectpest%20_Amla%20-%20Copy_clip_image006_0000.jpg

Favourable condition:

- Moist and warm conditions are most favourable

Natural enemies of mealy bug: Predetors: *Chrysoperla* spp., *Coccinellids* spp.

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

White fly

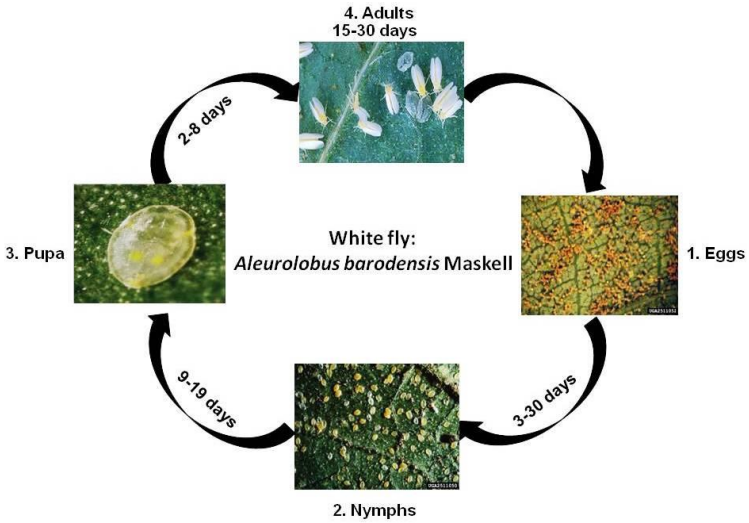
Biology:

Egg: Females lay eggs in a line near the midrib or anywhere on the lower surface of the leaves. Eggs are yellowish with a small curved stalk. Colour changes to black about two hours after the eggs are laid.

Nymph & Pupa: Neonate nymphs are pale yellow in colour, flat and oval in shape, later turn shiny black. Its body is surrounded by fringes of wax. The fourth instar being the pupal stage, is flat, oval, grayish in colour and slightly bigger than the nymph. There is a 'T' shaped white marking on the thorax, which splits at the time of adult emergence.

Adult: Pale yellow body with hyaline wings dusted with waxy bloom, exhibit brisk fluttering movements

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=25110503.
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:

- Yellowing of leaves
- Leaf turns pinkish or purple and later gradually dry.
- Infested leaves show white and black dots.

Natural enemies of whitefly:

Parasitoids- Nymphal and pupal:*Encarsia formosa,Eretmocerus* sp.

Predators: *Dicyphus* spp., Lacewing, Ladybird beetle, .Big-eyed bugs, *Hesperus* spp. (mirid bug)

5. Pomegranate/ Anar butterfly:

Biology:

Eggs: On calyx of flowers or on fruits, egg period is about 7-10 days.

Larva: Short, stout, dark brown with short hairs and whitish patches all over the body and 2 cm long. Larva: Larval period is about 18 to 47 days.

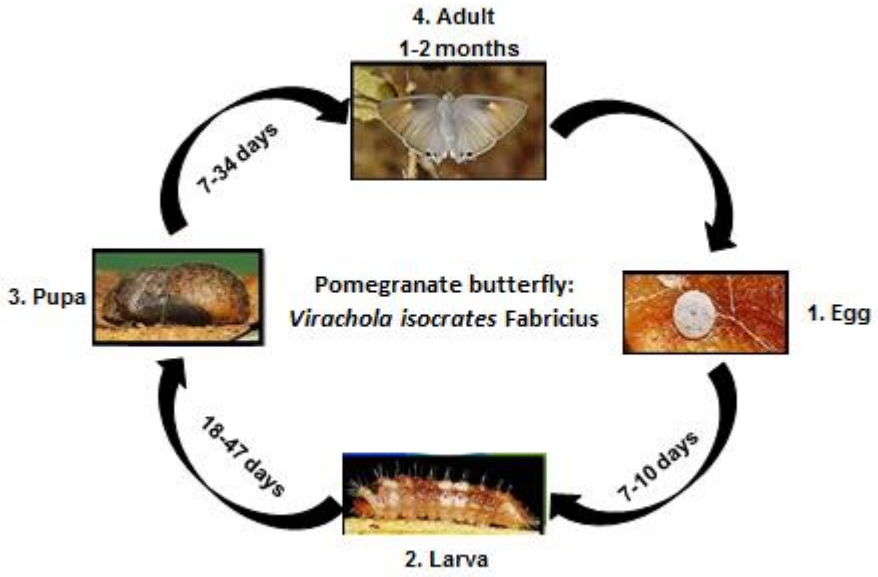
Pupa: Pupation inside the fruit or on fruit stalk, pupal period is about 7-34 days.

Adults: Medium sized, males are bluish violet while females are brownish violet with orange patch on forewings

Life cycle: 1-2 months. No. of generation are 4 per year. Pest is active throughout the year.

Life cycle:

3. Adults

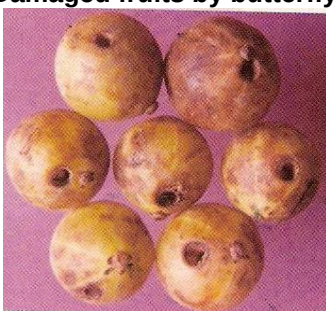


http://www.ifoundbutterflies.org/386-virachola/virachola-isocrates

Damage symptoms:

- Caterpillars bore the fruits, feed on pulp and seeds.
- Damaged fruits subsequently get infected by bacteria resulting in rotting of fruits.
- Such rotten fruit gives offensive smell and fall down.
- The excreta of the larva around the entry holes are seen.

Damaged fruits by butterfly



Favourable condition:

- Attack of this insect occurs during September-October, coinciding well with the fruiting

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

6. Leaf miner:

Biology:

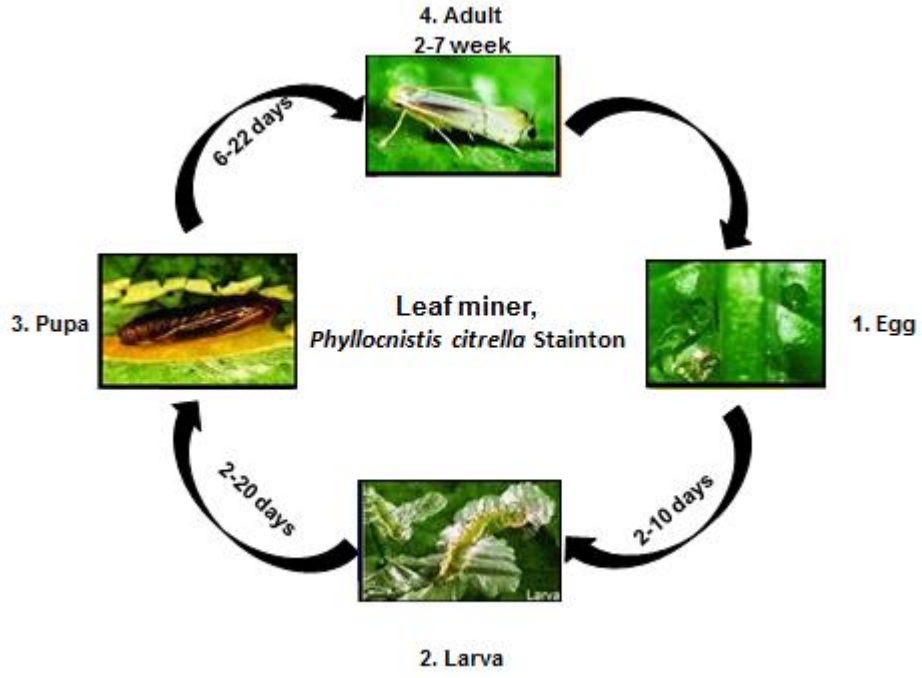
Eggs: Females lay eggs in the evening and at night. Each egg looks like a water droplet. Immediately after hatching (2 – 10 days depending on weather conditions), larva immediately enters the leaf tissue and begin feeding.

Larva: Fully developed larvae are minute (1/8" or 3 mm), translucent greenish yellow, and located inside the leaf mine.

Pupa: Larvae go through four stages of moults (instars) and development to pupa takes from 5 – 20 days. Pupal stage lasts 6 – 22 days.

Adults: Adults generally are too minute to be easily noticed**.** Active dusk to dawn. Life cycle takes 2 – 7 weeks to complete, depending on temperature & other weather conditions.

Life cycle:



http://aggie-horticulture.tamu.edu/galveston/Gardening-Handbook/PDF-files/GH-006--citrus-leafminer.pdf

Damage symptoms:

- Newly emerged leaves are preferred feeding sites
- Larvae may also form mines in succulent stems and sometimes fruit.
- Larvae feed by creating mines on the underside of young leaves
- Severely damaged leaves typically become curled and distorted

Natural enemies of leaf miner:

Parasitoids: 1. *Pnigalio* spp. 2. *Closterocerus* spp.

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

Natural Enemies of Pineapple Insect Pests

Parasitoids

Egg parasitoids

Add natural enemies
Parasitoids
Nymphal and adult :

1. Aphidius colemani

Nymphal and pupal:

2. *Encarsia formosa* **3.*Eretmocerus* sp.**

Egg, larval & pulal parasitoid

4. *Pnigalio* spp. (Eulophid Wasp)

5. *Closterocerus* spp.

Predators

6. Dicyphus hesperus

7. *Chrysoperla* spp.

8. *Coccinellids*

***9.* Big-eyed bugs *Hesperus* (mirid bug)**

1. http://biobee.in/products-and-services/solutions/bio-aphidius/
2. http://www.buglogical.com/whitefly-control/encarsia-formosa/
3. http://www.dongbufarmceres.com/main/mboard.asp?strBoardID=c_
4. http://nathistoc.bio.uci.edu/hymenopt/Pnigalio.htm
5. http://bugguide.net/images/raw/
6,. http://nathistoc.bio.uci.edu/hemipt/Dicyphus.htm
7. http://aem.asm.org/content/74/13/4175/F1.large.jpg
8. 9. http://commons.wikimedia.org/wiki/File:Geocoris_punctipes

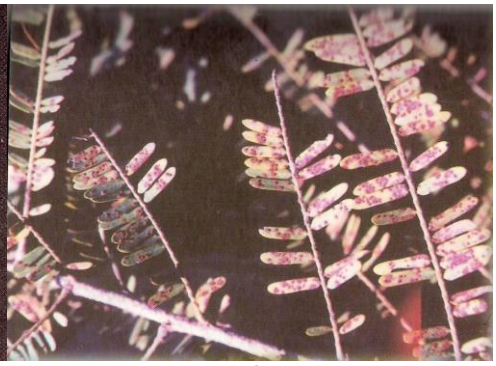
X. DESCRIPTION OF DISEASES

1. Rust:

Disease symptoms:

- On fruits initially few black pustules appear which later develop in to a ring.
- The pustules join together and cover big area of the fruit.
- On leaves, pinkish brown pustules develop which may be arranged in group or scattered as infection of fruit does not go on leaves and vice-versa.
- Teleospores of *Ravenelia emblicae* causes the fruit and leaf infection.

Rust on fruits



Rust on leaves

http://svrsh2.kahaku.go.jp/fungi/image/a11.jpg
http://www.scielo.br/img/fbpe/fb/v26n3/a08fig07.gif

Favourable condition:

- Favourable condition is after monsoon in September.

2. Soft rot:

Disease symptoms:

- Smoke brown to black round lesions develop on fruits within 2-3 days of infection.
- The diseased parts later show olive brown discoloration with water soaked areas extending toward both the ends of fruits forming an eye shaped appearance.
- Infected fruits become dark brown, crinkled with softening of underlining tissues and get deformed.
- Fungus causes infection both in young and mature fruits, but mature fruits are found to be more susceptible

http://www.extension.org/pages/31522/phomopsis-cane-and-leaf-spot-and-fruit-rot-of-grapes#.Uw8GoIaQZpI
http://amarillo.tamu.edu/files/2010/11/PhomopsisEggplantOP.pdf

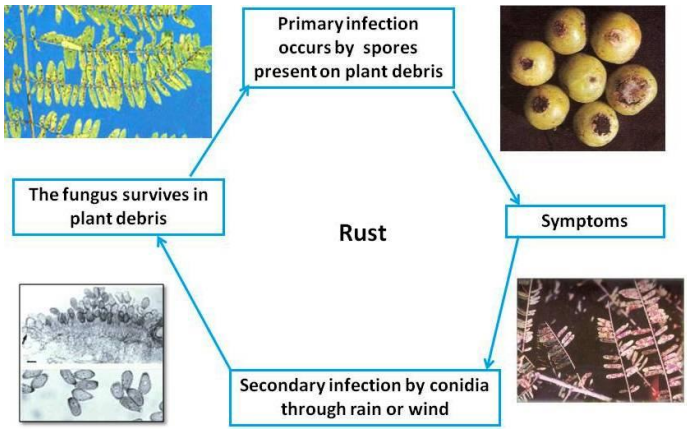
Favourable conditions:

- Disease is favored by hot and wet weather. The optimum temperature for fungal growth is 29˚C and it grows well up to 32˚C.

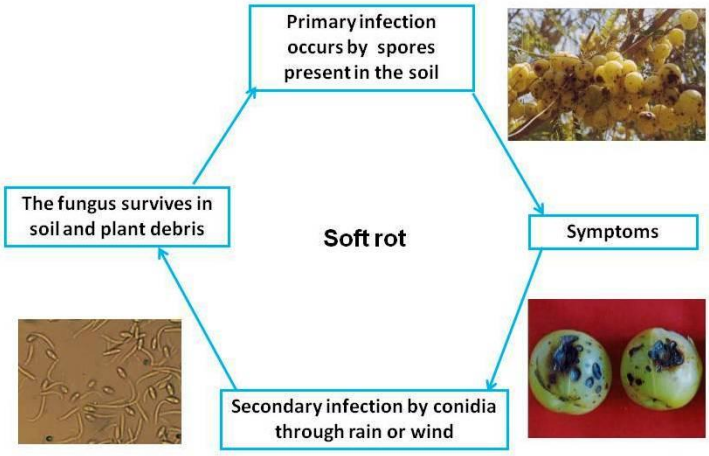
http://plantpath.caes.uga.edu/extension/Fungi/images/phmp1.jpg
http://plantpath.caes.uga.edu/extension/Fungi/phomopsis.html

Disease cycles:

1. **Rust:**



2. **Soft rot**



XI. DESCRIPTION OF RODENT PESTS

1) Lesser bandicoot

Distribution and Identification:

Distributed throughout India and infests almost all crops. It is a robust rodent (200 to 300 g body weight) with a rounded head and a broad muzzle. Dorsum covered with grey-brownish rough hairs. Tail is naked, shorter than head and body. Breeds throughout the season and litter size 6-8 in normal conditions.

Burrows are characterized by the presence of scooped soil at the entrance and mostly burrow openings are closed with soil.

Damage symptoms:

During sowing, the sown seed material will be dug out and damaged by the bandicoots

Often they hoard and damage the tubers.

2. House rat

Distributed throughout India. Medium sized (80-120g) slender rodent. Commonly found in houses and on plantation crops. Very good climber with longer tail than head and body. Inhabitation on trees and other places and won't make any burrows in fields

XII. SAFETY MEASURES

A. At the time of harvest:

- Fruits should be graded according to colour, size and maturity. Immature fruits should be removed and set aside to ripen as some fruit species will ripen after harvest while others will tend to rot.
- Diseased and damaged fruits should be removed as these will infect the other healthy fruits.
- Fruits should be handled gently to avoid bruising.
- They should be washed in clean water and drained to remove all water. Chlorinated water (up to 100 ppm) can be used if preferred.
- To increase the self-life of the harvested fruits they can be stored at the ambient temperature in low energy cool chambers. Some fruits may spoil if the storage temperature is too low. The skin and flesh go brown due to injury through chilling.
- Care should be taken to avoid bruising during transport

B. Post-harvest storage:

Post-harvest operations:

- Remove immature, damaged and diseased fruits and grading should be done for the remaining fruits according to their size, weight, colour and maturity into three grades.
- Washing of fruits should be done using chlorinated water (100 ppm) and drain them.

Packaging of fresh fruits

- For short distance transport gunny bags or baskets (40-45 kg capacity) made of pigeon pea stems lined with newspaper as cushioning material can be used.
- For long distance transport corrugated fiber board boxes give better protection from fruit damage.

Storing of fresh fruits

- Depending up on the variety, the mature fruits can be stored at room temperature for about 6-9 days.
- The shelf-life can be extended up to 12-18 days if fruit are stored in low energy cool chambers. As mature fruits can be stored up to 2 months at 5-7ºC.
- The shelf-life can be extended for up to 75 days if fruits are kept in 15% brine solution (150 g salt/l) at room temperature.

XIII. 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 the region.
3	Plant early in the season	Avoid late planting as this may lead to reduce yield and incidence of white grubs and diseases.
4	Use disease free seedling from certified agencies.	Do not use seedlings from disease infected areas/agencies
5.	Apply only recommended herbicides at recommended dose, proper time, as appropriate spray solution with standard equipment along with flat fan or flat jet nozzles.	Pre-emergent as well as soil incorporated herbicides should not be applied in dry soils. Do not apply herbicides along with irrigation water or by mixing with soil, sand or urea.
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 planting based on soil test results.	Do not apply any micronutrient mixture after planting 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 normal room temperature (keep them in refrigerator).
11	Release parasitoids only after noticing adult moth catches in the pheromone trap or as pheromone	Do not apply chemical pesticides within seven days of release of

	trap or as per field observation.	parasitoids.
12	In case of pests which are active during night spray recommended biocides/ chemicals at the time of their appearance in the night.	Do not spray pesticides at midday since, most of the insects are not active during this period.
13	Spray pesticides thoroughly to treat the undersurface of the leaves, particularly for white fly	Do not spray pesticides only on the upper surface of leaves.
14	Apply short persistent pesticides to avoid pesticide residue in the soil and produce.	Do not apply pesticides during preceding 7 days before harvest.
15	Follow the recommended procedure of trap or border crops technology.	Do not apply long persistent on trap crop, otherwise it may not attract the pests and natural enemies.

XIV. BASIC PRECAUTIONS IN PESTICIDES USAGE

A. Purchase

1. Purchase only just required quantity e.g. 100, 250, 500, 1000 g/ml for single application in specified area.
2. Do not purchase leaking containers, loose, unsealed or torn bags.
3. Do not purchase pesticides without proper/approved labels.
4. 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.
4. Never keep them together with food or feed/fodder.
5. Keep away from reach of children and livestock.
6. Do not expose to sunlight or rain water.
7. Do not store weedicides along with other pesticides.

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
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. Do not eat, drink, smoke or chew while preparing solution
11. The operator should protect his bare feet and hands with polythene bags

E. Equipments

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

F. Precautions for applying pesticides

1. Apply only at recommended dose and dilution
2. Do not apply on hot sunny day or strong windy condition
3. Do not apply just before the rains and after the rains.
4. Do not apply against the windy direction
5. Emulsifiable concentrate formulations should not be used for spraying with battery operated ULV spraying
6. Wash the sprayer and buckets etc with soap water after spraying
7. Containers buckets etc used for mixing pesticides should not be used for domestic purpose
8. Avoid entry of animals and workers in the filled immediately after spraying

G. Disposal

1. Left over spray solution should not be drained in ponds or water lines etc. throw it in barren isolated area if possible

2. The used/empty containers should be crushed with a stone/stick and buried deep into soil away from water source.
3. Never reuse empty pesticides container for any other purpose.

XV. PESTICIDE APPLICATION TECHNIQUES

<table>
<tr><th></th><th></th><th>Equipment</th><th></th></tr>
<tr><td colspan="4">Category A: Stationary, crawling pest/ disease</td></tr>
<tr><td>Vegetative stage

i) for crawling and soil borne pests

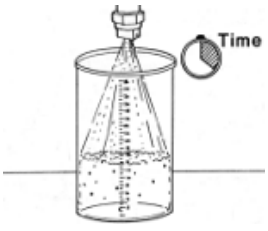
ii) for small sucking leaf borne pests</td><td>Insecticides and fungicides</td><td>• Lever operated knapsack sprayer (Droplets of big size)
• Hollow cone nozzle @ 35 to 40 psi
• Lever operating speed = 15 to 20 strokes/min
or
• Motorized knapsack sprayer or mist blower (Droplets of small size)
• Airblast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

Reproductive stage

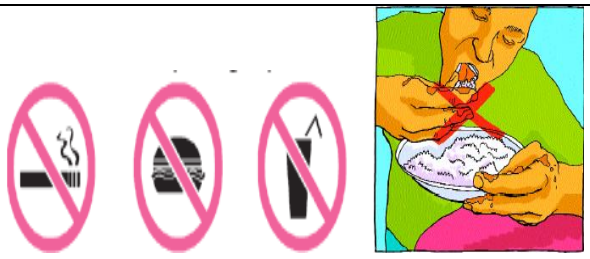
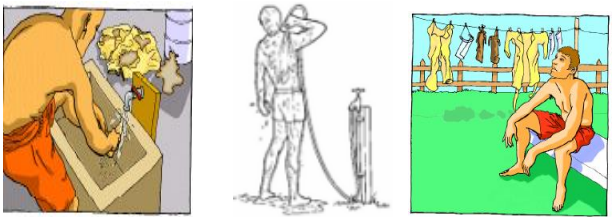
(Field Pests)</td><td>Insecticides and fungicides</td><td>• Motorized knapsack sprayer or mist blower (Droplets of small size)
• Airblast nozzle
• Operating speed: 2/3rd throttle Or
• Battery operated low volume sprayer (Droplets of small size)
Spinning disc nozzle</td><td> 
  </td></tr>
</table>

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

XVI. OPERATIONAL, CALIBRATION AND MAINTENANCE GUIDELINES IN BRIEF

1.	For application rate and dosage see the label and leaflet of the particular pesticide.	 
2.	It is advisable to check the output of the sprayer (calibration) before commencement of spraying under guidance of trained person.	 

3.	Clean and wash the machines and nozzles and store in dry place after use.	
4.	It is advisable to use protective clothing, face mask and gloves while preparing and applying pesticides.	 
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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