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AESA BASED IPM PACKAGE

JACKFRUIT

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Department of Agriculture and Cooperation
Ministry of Agriculture & Farmers welfare
Government of India

The AESA based IPM - Jackfruit, 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

One of the fallouts of green revolution based on intensive use of inputs including agrochemicals has been it adverse impact on the ecological balance in different agro-ecosystems of the country. The problem has been compounded by unscientific and indiscriminate use of the agrochemicals by the farmers. It is manifest by the problems of pesticide resistance, pest resurgence, pesticide residues and pest replacement, that one sees. This has necessitated promotion of environmentally sustainable agriculture practices. Integrated Pest Management (IPM) meets such a requirement. However, IPM strategies relying on economic thresholds & crop scouting, over the years has become synonymous with chemical pesticide based pest management. Growing awareness of the adverse consequences of agrochemicals is happily effecting a shift to ecological approaches that rely on the intrinsic strengths of the ecosystem services rendered by the agro-ecosystems. Bio-intensive pest management approaches that are ecologically sound, such as Agro-ecosystem Analysis (AESA) in conjunction with ecological engineering for pest management are gaining acceptance globally. Unlike ETL, AESA analyses the crop field situation critically with regards to both abiotic and biotic factors and their interaction for taking informed pest management decisions vis-a-vis a growing crop.

The Government is now emphasizing on soil test based nutrient management and safe & judicious use of pesticides. Under AESA based IPM, chemical pesticides are to be used only as a last resort, as per the policy of Government of India. Ecological engineering for pest management approach, a new paradigm, creates favourable conditions in the crop ecosystem & enhances natural enemies by providing food, shelter and alternate prey, thereby supporting biological control. Reliance on chemical pesticides for pest management can be reduced with such ecological approaches and the balance and stability can be restored in the agro-ecosystems.

The AESA based IPM package of practices for various crops developed by the experts, incorporating the latest knowledge/information on AESA based PHM in conjunction with ecological engineering for pest management will be useful for extension functionaries from State and Central Government agencies, researchers / scientists from ICAR/SAUs and farmers for managing important crop pests and disseminating novel and innovative technologies for sustainable agriculture.

A Dalwai 25/06/2015

Dated: 25.06.2015

[Ashok Dalwai]

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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 Jackfruit

Jackfruit - Plant description:

The jackfruit (*Artocarpus heterophyllus* Lam.; Family: Moraceae), also known as jack tree, jakfruit, or sometimes simply jack or jak). It is native to parts of South and Southeast Asia. The jackfruit has played a significant role in Indian agriculture for centuries. The flesh of the jackfruit is starchy and fibrous and is a source of dietary fiber. The flavor is comparable to a combination of apple, pineapple, mango and banana. Varieties are distinguished according to characteristics of the fruit's flesh. The tree produces long taproot. All parts leave milky white very sticky latex. The jack fruit flowers are borne on stout twigs, on the trunk and older branches. The thick rubbery rind has short, blunt spines and the fruits have upto 500 seeds. There are two types, soft flesh and firm flesh. In Indo-China, there are 2 varieties, being the "hard" version (more crunchy, drier and less sweet but fleshier), and the "soft" version (more soft, moisture, much sweeter with a darker gold-color flesh than the hard variety). In India, the commonly grown varieties are Singpore, Jak, Konker prolific, PLR-I, PLR-II, PP I, Burliar I. It is grown in Tamilnadu, Kerala, West Bengal, Bihar, Uttar Pradesh, Orissa and Assam. Deep well draine soil is necessary for cultivation. The crop comes up well in the plains and upto an cultivation of 1200m.

I. PESTS

A. Pests of National Significance

1. **Insect pests**
   - 1.1. **Shoot and fruit borer: *Glyphodes caesalis* (Walker), (Lepidoptera: Pyralidae)**
   - 1.2. **Spittle bugs: *Cosmocarta relata* Distant (Hemiptera: Cercopidae)**
   - 1.3. **Mealybug: *Drosicha mangiferae* Stebbins (Hemiptera: Margarodidae)**
   - 1.4. **Bud weevil: *Ochyromera artocarpi* Marshall (Coleoptera: Curculionidae)**
   - 1.5. **Bark eating caterpillar: *Indarbela tetraonis* (Moore) (Lepidoptera: Cossidae)**
   - 1.6. **Aphid: *Greenidea artocarpi* (Westwood) (Hemiptera: Aphididae)**
   - 1.7. **Leaf webber: *Glyphodes bivitralis* Gueneé (Lepidoptera: Crambidae)**

2. **Diseases:**
   - **2.1 Soft rot or fruit rot: *Rhizopus artocarpi* Racib.**
   - **2.2 Dieback: *Botryodiplodia theobromae* Pat.**
   - **2.3 Leaf spot: *Phyllosticta artocarpina* Speg.**
   - **2.4 Pink disease: *Botryobasidium salmonicolaor* (Berk. & Broome) & *Corticium Salmonicolor* (Berk. & Broome)**

3. Weeds:

Broadleaf

- **3.1 Asthma herb: *Euphorbia hirta* L. (Euphorbiaceae)**
- **3.2 Cock's comb: *Celosia argentea* L. (Amaranthaceae)**
- **3.3 Pigweed: *Amaranthus viridis* Hook. F. (Amaranthaceae)**
- **3.4 Goat weed: *Ageratum conyzoides* L. (Asteraceae)**
- **3.5 *C*arrot grass: *Parthenium hysterophorus* L. (Asteraceae)**
- **3.6 Coat buttons: *Tridax procumbens* L. (Fabaceae)**
- **3.7 Tick weed: *Cleome viscosa* L. (Cappariaceae)**
- **3.8 Horse Purslane: *Trainthema portulacastrum L.* (Aizoaceae)**
- **3.9 Creeping thistle: *Cirisium arvense* (L.) Scop (Asteraceae)**

Grasses

- **3.10 Bermuda grass: *Cynodon dactylon* (L.) Pers. (Poaceae)**
- **3.11 Large crabgrass: *Digitaria sanguinalis* L.(Scop.) (Poaceae)**
- **3.12 Yellow foxt*ail: Setaria glauca (*L.) P. Beauv. (Poaceae)**
- **3.13 Goose *grass: Eleusine indica* (L.) Gaertner. (Poaceae)**
- **3.14 Rabbit/crow foot grass: *Dactyloctenium aegyptium* (L.) Willd (Poaceae)**
- **3.15 Buffalow grass: *Paspalum conjugatum* Berggius (Poaceae)**

Sedges

- **3.16 Purp*le nutsedge: Cyperus rotundus* L. (Cypraceae)**
- **3.17 Umbrella sedge : *Cyperus difformis* L. (Cyperaceae)**

B. Pests of Regional Significance

1. **Insect pests**
   - 1.1. **Stem borer: *Batocera rufomaculata* (DeGeer) (Coleoptera: Cerambycidae)**
   - 1.2. **Pink waxy scale: *Ceroplastes rubens* Maskell (Hemiptera: Coccidae)**
   - 1.3. **Thrips: *Pseudodendrothrips dwivarna* Ramakrishna & Margabandhu (Thysanoptera: Thripidae)**
   - 1.4. **Aphid: *Toxoptera aurantii* (Boyer.) (Hemiptera: Aphididae)**
   - 1.5. **Castor capsule borer: *Dichocrocis punctiferalis* (Gunee) (Lepidoptera: Crambidae)**
   - 1.6. **Fruit fly, *Bactrocera umbrosa* Fabricius (Diptera: Tephritidae)**

2. Disease

2.1. Rust: *Uredo artocarpi* Berk. & Broome

2.2. Anthracnose: *Colletotrichum gloeosporioides* (Penz.) Penz. &. Sacc

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 orchard 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 tree, how to analyze the orchard situation and how to make proper decisions for their tree 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 orchard situations with regards to pests, defenders, soil conditions, plant health and the influence of climatic factors and their relationship for growing a healthy tree.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 tree

- Select a variety resistant/tolerant to major pests
- Select healthy planting materials
- 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 tree becomes too succulent and therefore susceptible to insects and diseases. If the dosage is too low, the tree 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 orchards regularly (climatic factors, soil and biotic factors)

Farmers should:

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

http://photos.wikimapia.org/p/00/02/59/48/15_big.jpg

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 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 tree orchard. 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 orchard and brought to a place for study. Each

insect is to be 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 Jackfruit 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 orchard situation

Soil condition	**:**
Weather condition	**:**
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 tree management

Farmers have to make timely decisions about the management of their trees. AESA farmers have learned to make these decisions based on observations and analysis viz. abiotic and biotic factors of the tree ecosystem. The past experience of the farmers should also be considered for decision making. However, as orchard 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 orchards 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 tree height, tree 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 orchard and their intensity.
    - Water: Observe the water situation of the orchard.
    - Weather: Observe the weather condition.
- While walking in the orchards, 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 orchard situation in detail and present their observations and analysis in a drawing (the AESA drawing).
- Each drawing will show a plant representing the orchard situation. The weather conditions, water level, disease symptoms, etc. will be shown in the drawing. Pest insects will be drawn on one side. Defenders (beneficial insects) will be drawn on another side. Write the number next to each insect. Indicate the plant part where the pests and defenders were found. Try to show the interaction between pests and defenders.
- Each group will discuss the situation and make a tree 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

orchard 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

- **Tree situation (e.g. for AESA):** Plant health; pests, diseases, weeds; natural enemies; soil condition; irrigation; weather conditions
- **Input costs:** Planting materials; 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 tree management aspect is most important at this moment?
- Is there a big change in tree 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 orchard between pests and defenders?
- Were you able to identify all pests and diseases?
- Do you think the tree 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 tree (tree ecology, growth stage, natural enemies, weather condition, etc.) and their own economic and social situation before they can make the right tree 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.

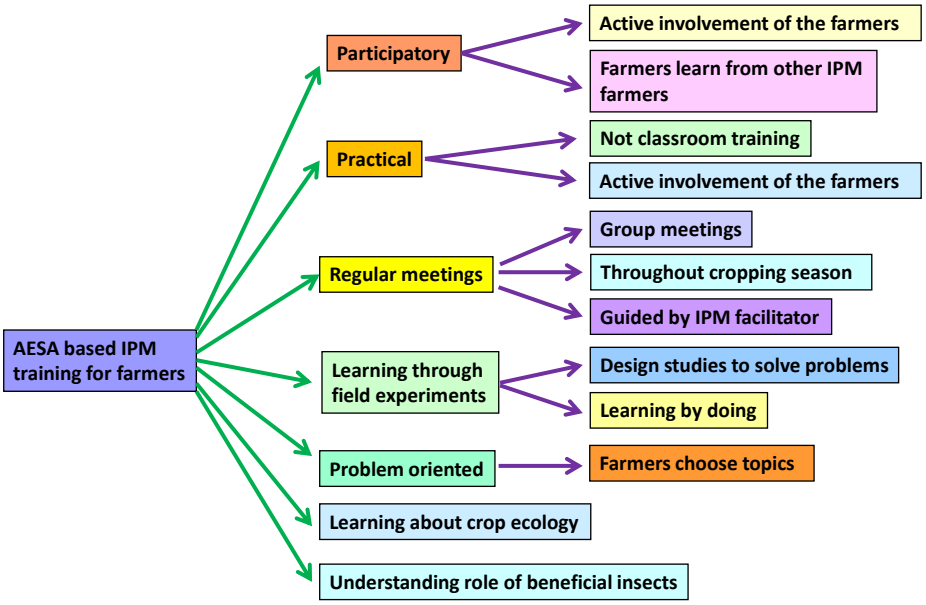
AESA and farmer field school (FFS):

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 tree and their related management practices. The process is always learner-centered, participatory and relying on an experiential learning approach and therefore it has become an integral part of FFS.

Farmers can learn from AESA

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

FFS to teach AESA based IPM skills:



B. Field scouting

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

Surveillance on pest occurrence in the orchard should commence soon after tree establishment and at weekly intervals thereafter. In each orchard, select five spots randomly. Select five random plants at each spot for recording counts of insects as per procedure finalized for individual insects.

Sampling in fruit crops:

A person doing sampling is known as an inspector or scout. The fruit crops are perennial in nature and before starting the surveillance process an inspector or scout who is going to implement the activity should know about the nature of crop as well as different crop stages and its growth stages. Knowing crop and its nature helps in identifying the important pests and diseases because the pests and diseases infest and infect, respectively, certain stage or part of the plant.

Sampling patterns:

Different methods of sampling are reported and being utilized for sampling in crops as well as in fruit plants such as random, scattered etc. However, some of them are specific to the crop/disease/pests and growth stage (some of them are to be utilized at initial stage and/or for subsequent plant growth stage). Also the sampling methods may differ based on the nature and requirement of the study such as estimating disease incidence and/or disease severity. For a common orchard study, the assessment methods should not only be easy and quick in use for a wide range of conditions, but also adequately reliable, reproducible, and accurate/precise. However, this is not always possible. Generally, in fruit crops the following sampling patterns are used:

- **Zig-zag pattern**. Sampling a fallow orchard or one with no obvious symptoms in the current crop to see the incidence as well as sampling of viral, wilt disease.
- **Circle pattern**. Sampling within the drip line of trees and shrubs and for powdery mildew, downy mildew and leaf spot diseases etc.
- **Star pattern**. Sampling from a damaged area.

Sampling frequency:

Sampling frequency or interval depends on pest generation interval or number of generations per year, potential for population increase between generations, stage of crop- pathogen infection etc. Generally, if initial survey is already implemented and some results are with the surveillance manager, then based upon the results of pest/disease incidence/intensity and weather parameters, the surveillance frequency/interval is decided to get comprehensive view of the pests and diseases development/population dynamics as well as biocontrol agent's population (if present in the crop ecosystem). In subsequent survey, monitoring for the pest, pathogen, and biocontrol agent must be carried out to get the following detailed information:

- **Relative pest measuring estimates:** Counting the representative samples in a given area.
- **Absolute pest measuring estimates:** Counting all individuals in a population in a given area which determine total pest population size in a given area. It is very effective pest surveillance research tool but very time consuming, therefore, not practical and/or not economically feasible.
- **Get an idea of number of pests per unit:** To estimate pests per plant and/or area to make the decision.
- **Get an idea of weather at the site:** In addition to the pest estimation, the prevailing weather conditions, which may affect pest development and/or population buildup, are observed and recorded.
- **Get an idea of biocontrol agents:** To strengthen the management strategies, biocontrol agent population size, if available, in a given area is to be determined.

For insect pests:

Mealybug: Count and record the number of both nymphs and adults on five randomly selected leaves per tree.

Leaf webber: Count the number of webs formed in each direction, thus covering the whole tree.

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

Defoliator/ 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). Always check plants that appear unhealthy. It is often necessary to wash the roots with water to examine them properly. If the roots are well developed, cut into them to examine the roots for internal infections (discolouration& signs). Count the total number of pseudostem damaged/infested/infected due to rotshould be counted and incidence should be recorded.

Leaf sampling: Examine all leaves and or sheaths on each plant for lesions and determine the amount area of leaf infection. Leaf diseases cause most damage during the planting material and flowering stages of plant growth. Observe for the symptoms and signs on the infected plant parts. Count thenumber of leaves (leaf area diameter)/plant infected due to disease and incidence should be recorded.

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

C. Surveillance through pheromone trap catches:

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

D. Blue pan water/sticky traps

Set up blue sticky traps 1 foot above the canopy for monitoring thrips @ 4 traps (15 X 7.5 cm)/acre. Locally available empty tins can be painted blue/ coated with grease/ Vaseline/castor oil on outer surface may also be used as blue sticky trap. Count the number of thrips on the traps daily and take up the intervention when the population exceeds approximately 100 thrips per trap.

E. Light traps

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

III. ECOLOGICAL ENGINEERING FOR PEST MANAGEMENT

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

Ecological Engineering for Pest Management – Below ground:

There is a growing realization that the soil borne, planting material 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 tree residue.
- Add organic matter in the form of farm yard manure (FYM), vermicompost, tree 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 rhizobacteria (PGPR)

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 trees along the orchard border by arranging shorter plants towards main tree 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 orchard
- 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 trees and pest repellent trees. The trap trees and pest repellent trees 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

Cluster bean

Cowpea

Carrot

Sunflower

Buckwheat

French bean

Alfalfa

Maize

Mustard

***Coreopsis* spp.**

Cosmos

Dandelion

Anise

Caraway

Dill

Parsley

Repellent plants

***Ocimum* sp.**

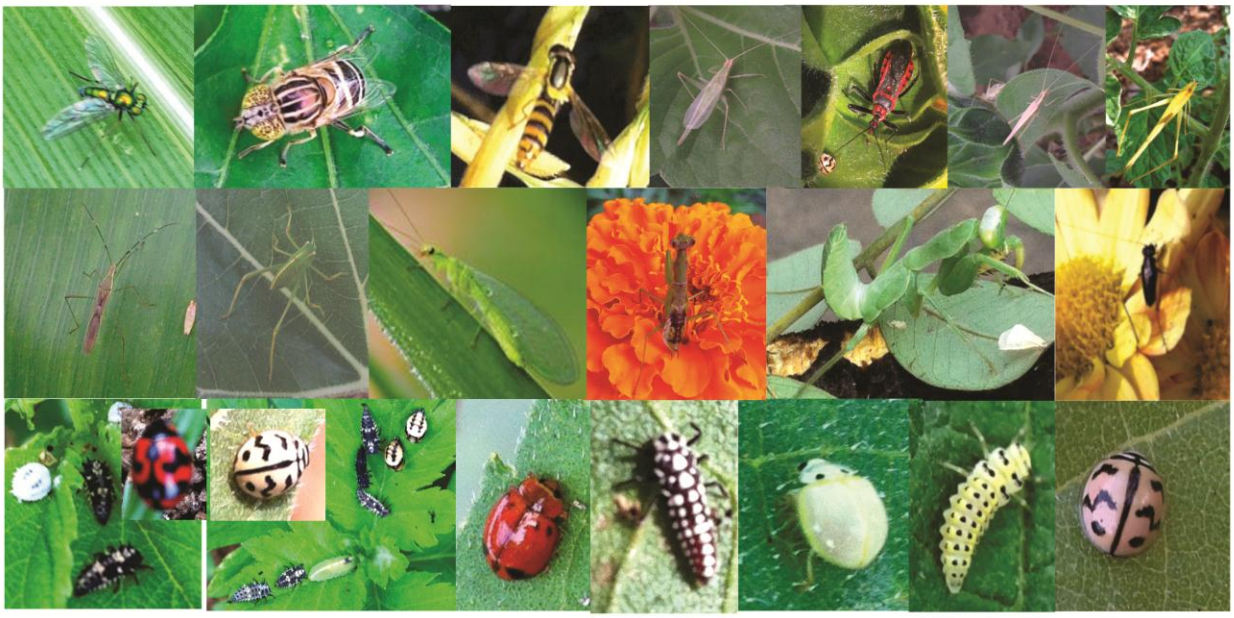
Peppermint

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

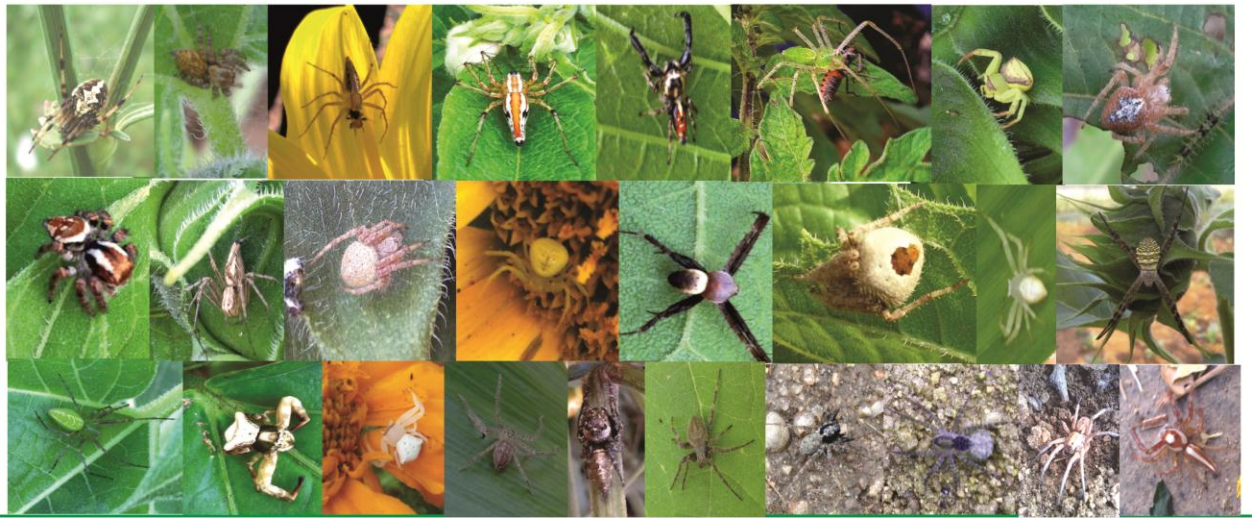
Biodiversity of natural enemies observed in Ecological Engineering field at NIPHM

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: • Deep ploughing of orchard immediately after harvest to expose eggs and pupae of mealy bugs. • Heavy irrigation of orchard in October also helps in destruction of eggs of mealy bug. • After removing the webs of bark eating caterpillars following measures should be adopted: • All the borer holes except the fresh one, should be plugged with mud plastering.
Nutrients	• Dig pits of 1 m x 1 m x 1 m. • Fill up the pits with top soil mixed with 10 Kg of FYM and 1 Kg of neem cake per pit.
Weeds	• Summer deep ploughing to destroy stubbles, rhizomes of perennial weeds. • Ploughing the field before planting to destroy existing weeds in the field.
Planting	
	Common mechanical practices: • Remove new sprouts emerging from root stock at frequent intervals. • Shift the grafts frequently from one place to another to prevent them from striking roots into the ground.
Nutrients	• Transplant the saplings / planting materials in pits already prepared and filled with manures
Weeds	• Before transplanting, pits and surrounding area should be free from weeds
Pests, Soil-borne pathogens	**Cultural control:** • Nursery beds should be raised. • Nursery beds should be fumigated with 4% formalin
Vegetative (1-5 years onward)*	
	Common cultural practices: • Collect and destroy tree debris • Collect and destroy disease infected and insect damaged plant parts • Enhance parasitic activity by avoiding chemical spray, when 1-2 larval parasitoids are observed • Provide timely irrigation, organic manure, fertilizer as per the recommended dose, drainage, weeding, mulching, intercultural operation etc. **Common mechanical practices:** • After mud plastering 25 cm. wide, 400 gauge alkathene (polythene) should be fastened to the tree trunk with the help of sutli, about 30 cm. above the ground level to prevent migration of freshly hatched first instars nymphs of mealy bugs in the month of December-January. • The affected leaves and young shoots may be pruned

<table>
<tr><td></td><td>and they may be destroyed along with the pest. This practice will help in bringing down the pest population.
• Prune and burn affected twigs for the control of scales and mealy bugs. Sticky band should be fixed on main trunk to prevent the movement of ants.
• The affected parts should be nipped off and destroyed.

<u>Common biological practices:</u>
• Conserve natural enemies through ecological engineering
• Augmentative release of natural enemies.
• Ladybird beetle, Adalia sp, Synharmonia sp, Exochomus sp, Stethorus sp @ 30-50 adults/infested tree.
• Lacewing and Syrphus sp. @ 10-20 first instar larvae/tree</td></tr>
<tr><td>Nutrients</td><td>The manures and fertilizers should be applied in two splits during May - June and September – October on the basis of soil test report or in general as per schedule given below:

<table><tr><th>Manures & Fertilizers (kg per pit)</th><th>1 year old</th><th>Annual Increase</th><th>6th year and above</th></tr><tr><td>FYM</td><td>10.000</td><td>10.000</td><td>50.000</td></tr><tr><td>N</td><td>0.150</td><td>0.150</td><td>0.750</td></tr><tr><td>P</td><td>0.080</td><td>0.080</td><td>0.4000</td></tr><tr><td>K</td><td>0.100</td><td>0.100</td><td>0.500</td></tr></table></td></tr>
<tr><td>Weeds</td><td>• Keep the pits and surrounding areas weed-free by hand tool weeding.
• Use straw or plastic mulch to manage the weeds and conserve the soil moisture in the tree basins.
• Grow the annual or perennial recommended intercrops like Corn, Vegetables (e.g. Okra, Brinal, Chilli, Tomato etc.), Citrus, Banana, Pineapple etc. <u>or</u> Cover crops like Pulses (e.g. green gram, Bengal Gram etc.) and Groundnut.
• Whenever intercrops are not grown between the rows, slashing and mowing of weed may be adopted.
•</td></tr>
<tr><td>Shoot and fruit borer</td><td><u>Cultural control:</u>
• Attacked shoots should be clipped off and destroyed.
• Clean hole and pour kerosene/petrol/crude oil or formalin into the stem borer hole and subsequently close entrance of the tunnel by plugging with cotton wool and paste the mud.
• Use light trap@1/acre
<u>Physical control:</u>
• To protect them from egg laying, fruit may be covered with polythene bags and the affected parts removed and destroyed.
<u>Botonical control:</u>
• Spraying neem oil may be recommended.</td></tr>
<tr><td>Spittle bugs</td><td><u>Cultural control:</u>
• Keep orchard clean and healthy.</td></tr>
</table>

	• Cut dried branches **Physical control:** • Light, accessible spittlebug infestations can be removed by hand or by a strong water spray. • Cut dried branches **Biological control**: • Pipunculid fly, *Verrallia virginica* caused 50-60% parasitism of adult spittlebugs.
Mealybug	**Cultural control:** • Flooding of orchard with water in the month of October kill the eggs. • Ploughing of orchard in November. • Raking of soil around tree trunk to expose the eggs to natural enemies and sun, removal of weeds • Fastening of alkathene sheet (400 gauge)/grease band of 25 cm wide afterwards mud plastering of trunk at 30 cm above the ground in the middle of December. • In July –August destruction of infested fallen leaves with scales **Biological control:** • Raking of soil around tree trunk to expose the eggs to natural enemies and sun, removal of weeds and releasing 10-15 grubs • Releasing 10-15 grubs of cocinellid predator, *C. montrozieri* per tree.
Bud weevil	**Physical control:** • Remove the infested shoots, flower buds and fruits to check infestation. **Biological control:** • Pipunculid fly, *Verrallia virginica* caused 50-60% parasitism of adult spittle bugs.
Bark eating caterpillar	**Cultural control:** • Remove and destroy dead and severely affected branches of the tree • Remove alternate host, silk cotton and other hosts
Aphid**	**Physical control:** • Collect and destroy the damaged plant parts along with nymphs and adults **Biological control:** • Release coccinellid predators
Pink waxy scale**	**Cultural control:** • Prune heavily infested plant parts to open the tree canopy and destroy' them immediately. • Prune infested parts (branches and twigs) preferably during summer. • These should be placed in a pit constructed on one corner of the orchard. Allow branches and twigs to dry until the parasites escape. • Burn the remaining debris. • Removal of attendant ants may permit natural enemies to control the insect.

Leaf Webber	**<u>Physical control</u>**: • Mechanical clipping and burning of affected shoots **<u>Biological control:</u>** • Release of pupal parasitoid, *Tetrastichus howardi* @20,000 / ac. • Release of egg parasitoid, *Trichogramma chilonis* @ 2cc / ac.
Thrips**	**<u>Cultural control</u>** • Spraying strong jet of water to dislodge and wash out the pest
Castor capsule borer**	**<u>Cultural control:</u>** • Prune heavily infested plant parts to open the tree canopy and destroy' them immediately **<u>Biological control</u>** • The natural enemies, *Hexamermis* spp and *Apanteles taragammae* have been found to be potential bio-control agents of the pest.
Dieback	**<u>Cultural control:</u>** • Every care should be taken to prevent introduction of disease in newly planted orchards. **<u>Mechanical control:</u>** • Any infected portion should immediately be pruned, followed by spraying/ pasting of copper oxychloride or pasting with cow dung at the cut ends. • Pruning should be done in such a way that some healthy portion is also removed, to ensure complete eradication of pathogen (3 "below the infection site).
Leaf spot	**<u>Cultural control:</u>** • Affected branches should be pruned
Rust**	**<u>Cultural control:</u>** • Affected branches should be pruned
Anthracnose**	• Follow common cultural, mechanical and biological practices **<u>Cultural control:</u>** • Diseased leaves, twigs, gall midge infected leaves and fruits, should be collected and burnt. • Covering the fruits on tree, 15 days prior to harvest with news or brown paper bags.
Pink disease	**<u>Cultural control:</u>** • Pruning of infected branches
Reproductive*	
Nutrients	• Micronutrient deficiency, if any, should be corrected by application of particular nutrients.
Weeds	• Use straw or plastic mulch to manage the weeds and conserve the soil moisture in the tree basins. • Keep the pits and surrounding areas weed-free by hand tool weeding. • Whenever intercrop(s) not grown between the rows of trees, slashing and mowing of weed may be adopted.
Anthracnose, Dieback,	Same as vegetative stage

Pink disease	
Soft Rot or Fruit Rot,	**<u>Physical control:</u>** • Remove affected fruits.
Maturation *	
Stem borer, shoot and fruit borer, pink waxy** scale, Thrips**, aphid**, castor capsule borer****	Same as vegetative stage
Postharvest	
Anthracnose**	**<u>Physical control</u>**: • Hot water treatment at 52 ^{0}C for 4-5 min. • Fruits should be sprayed with the mixture of bio-inoculants.

Note: ** Pests of regional significance

V. INSECTICIDE RESISTANCE AND ITS MANAGEMENT

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

Causes of resistance development: The causes and rate at which insecticide resistance develops depend on several factors, including the initial frequency of resistance alleles present in the population, how rapidly the insects reproduce, the insects' level of resistance, the migration and host range of the insects, the insecticide's persistence and specificity, and the rate, timing and number 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 orchards to determine if and when control measures are warranted. Monitor and consider natural enemies when making control decisions. After treatment, continue monitoring to assess pest populations and their control.

2) **Focus on AESA.** Insecticides should be used only as a last resort when all other non-chemical management options are exhausted and P: D ratio is above 2: 1. Apply biopesticides/chemical insecticides judiciously after observing unfavourable P: D ratio and when the pests are in most vulnerable life stage. Use application rates and intervals as per label claim.

3) **Ecological engineering for pest management:** Flowering plants that attract natural enemies as well as plants that repel pests can be grown as border/inter tree.

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 orchards, adjacent "refuge" orchards, or habitat attractions within a treated orchard that facilitate immigration. These susceptible individuals may outcompete and interbreed with resistant individuals, diluting the resistant genes and therefore the impact of resistance.

VI. NUTRITIONAL DISORDERS

Nutrients	Fig.
Magnesium: Yellowing of older leaves between lateral veins on either side of midrib. Chlorosis spreads from margin towards midrib. **Correction Measure:** Soil application of dolomite 5 kg/tree/year.	
Boron: Fruits show splitting or cracking with characteristic reddish purple colour. Leaves show chlorosis and brittleness. Terminal shoot poorly developed. **Correction Measure:** Soil application of borax @25 g/tree/year.	
Iron: Young leaves show interveinal chlorosis while veins remain green with stunted growth. In severe cases entire leaf becomes yellow. **Correction Measure:** Soil application of FeSO4 @ 0.5 kg/tree/ year.	
Manganese: Leaves become yellow but veins remain green. **Correction Measure:** Soil application of MnSO4@0.5 kg/tree/year.	

VII. COMMON WEEDS

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

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

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

4. Goat weed: *Ageratum conyzoides* L. (Asteraceae)

5. Carrot grass: *Parthenium hysterophorus* L. (Asteraceae)

6. Coat buttons: *Tridax procumbens* L. (Fabaceae)

7. Tick weed: *Cleome viscosa* L. (Cappariaceae)

8. Horse Purslane: *Trainthema portulacastrum L.* (Aizoaceae)

9. Creeping thistle: *Cirisium arvense* (L.) Scop (Asteraceae)

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

11. Large crabgrass: *Digitaria sanguinalis* L.(Scop.) (Poaceae)

12. Yellow foxt*ail: Setaria glauca (*L.) P. Beauv. (Poaceae)

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

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

15. Buffalow grass: *Paspalum conjugatum* Berggius (Poaceae)

16. Purp*le nut sedge: Cyperus rotundus* L. (Cypraceae)

17. Umbrella sedge : *Cyperus difformis* L. (Cyperaceae)

VIII. DESCRIPTION OF INSECT PESTS

1. Shoot and fruit borer

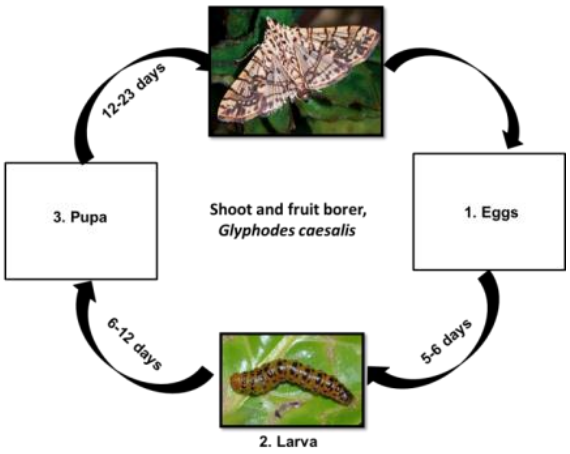
Biology

Egg: Females lay more eggs and develop faster during the flowering and fruiting period.

Larva: The caterpillar is reddish brown with black spots and bores into the tender shoots and developing fruits, occasionally causing substantial damage

Adult: The adult moth is pale brown with a number of dark brown spots, and orange stripes outlined in dark brown, on each wing

Life cycle



Damage symptoms:

- The fruit borer causes about 30–40% damage in jackfruit from flower bud formation up to fruit ripening.

http://www.pcaarrd.dost.gov.ph/home/ssentinel/index.php?option=com_content&view=article&id=1824%3Anatural-enemies-control-jackfruit-fruit-borer&Itemid=41

Natural enemies of shoot and fruit borer:

Parasitoids: *Bracon* sp.*,chelonus* sp.*, Systasis* sp.

*For management refer to page number 23

2. Spittle bugs

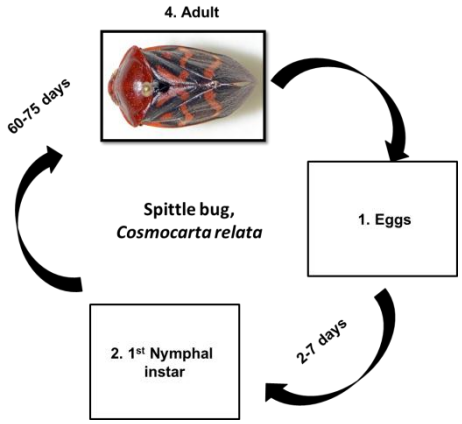
Biology:

Eggs: Pine spittlebugs overwinter as eggs inserted in dead twigs or slits cut into the bark of living stems. The eggs hatch in early May and the young nymphs migrate to the tender one-year-old growth.

Nymphs:
The nymphs begin to produce the frothy spittle from their anus. The spittle apparently protects the nymphs from predators, parasites and dry weather. As the spittle drops onto lower branches, black sooty mold may cover the needles. The young nymphs are yellowish with black markings; older nymphs become more brown. Several nymphs may join together in one large spittle mass and the nymphs constantly abandon old masses to make new ones. The nymphs mature by July and soon leave the spittle in order to molt into the winged adult.

Adults:
The adults do not form spittle masses but quickly jump and fly if disturbed. The adults are mottled gray with two faint parallel lines running across the wings.

Life cycle:



Damage symptoms:

- Larvae feeds on twigs of the tree

(http://dacsplanet.com/blog/wp-content/uploads/2009/05/spittlebug.jpg**)**

*For management refer to page number 24

3. Mealy bug:

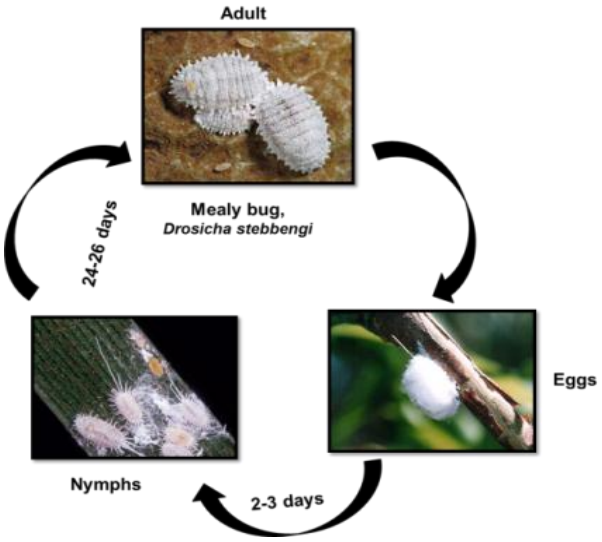
Biology:

Eggs: Females lay their eggs directly on the host in a fluted ovisac that is attached to the body of the adult female**.** Inseminated eggs produce hermaphrodites and uninseminated eggs produce males.

Nymphs: The first instar nymphs are also called as crawlers, which are mobile. They settle on the plants, start sucking the sap and form the colonies

Adults: Females actually are hermaphrodites that frequently inseminate themselves. Adult males mate with females, but it is not clear if their sperm are used for reproduction.

Life cycle:



Damage symptoms:

- The adult bugs are covered with whitish powder and colonize between bark of tree trunk, young shoots and panicles
- The nymphs' ascent the trees and settle on inflorescence causing flower drop, affecting fruit set.
- They also excrete honey dew, a sticky substance, which facilitates development of sooty mould

http://www.dhakatribune.com/sites/default/files/imagecache/870x488_article_high/article/2014/04/18/insects.jpg

Natural enemies of mealybug:

Predators: *Menochilus sexmaculatus, Rodolia fumida, Cryptolaemus montrozieri*

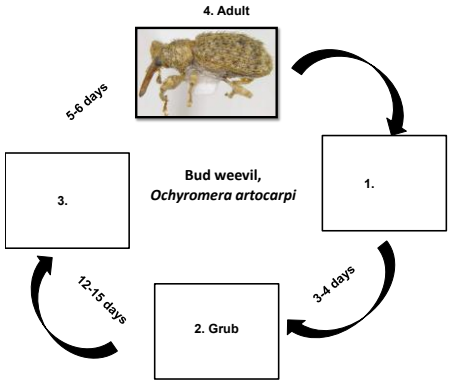
*For management refer to page number 24

4. Bud weevil

Biology:

Egg: The egg is pearly white, smooth and oblong oval measuring on an average 0.42mm.in length and 0.28mm. in width.
Grub: The eggs hatch in 3 to 4 days and the newly hatched legless grub is pale white with a pale brown head and measures 0.56mm in length. It bores through the tissue in all directions and becomes mature in 12 to 15 days. The full-grown grub is whitish in color measuring 4-9mm. in length. It head is light brown but darker at the frontal region and much narrower than thorax and with a conspicuous dark line in frons.
Pupae: The pupal stage lasts for 5 to 6 days. The adult emerges by boring a hole on the outer skin.
Adults: The adult is a small, active, greyish brown weevil measuring 3.5mm. in length and 1mm. in breadth, with the whole body thinly clothed with fine setiform golden scales and set with suberect setae and elytra bearing numerous irregular and ill-defined small bare spots. It is often found in groups feeding on the tissue inflorescence.

Life cycle:



Damage symptoms:

The bud weevil (Ochyromeraartocarpi) is a specific pest of jackfruit. The small whitish grubs bore into tender flower buds and fruits, and induce premature drop. These greyish brown adult weevils are found nibbling the leaves

http://www.nbaii.res.in/insectpests/images/Ochyromera-artocarpi7.jpg

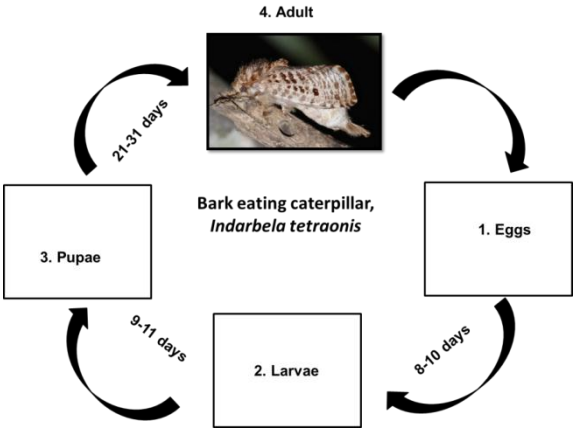
*****For management refer to page number 24

5. Bark eating caterpillar:

Biology:

Egg: Females lay about 2000 eggs in clusters of 15-20 on the bark of the host tree. Eggs hatch in 8-10 days.
Larvae: Caterpillars are about 50-60 mm long with dark brown heads and with dirty brown bodies. Larvae become full grown by December but continue to feed slowly until April.
Pupae: Pupae are 16-20 mm long, stout, reddish brown with two rows of spines on each abdominal segment. Pupation takes place in April and pupal period varies between 21-31 days.
Adults:Adults are pale brown with head and thorax dark brown, abdomen, fore-wings pale reddish brown with numerous dark brown bands.

Life cycle:



Damage symptoms:

The newly hatched larvae nibble the bark of the tree and after 2-3 days bore into the same and feed. This disturbes the continuity of flow of sap which results in poor growth and less fruiting. Silk webs which consist of excreta and chewed wood particles can be seen, more commonly at the junction of two branches, hanging on the bark of infested trees.

*For management refer to page number 23

6. Aphid:

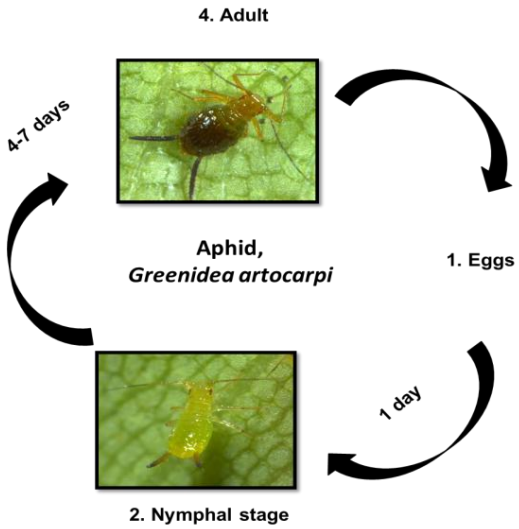
Biology:

Eggs: Eggs are white in colour and laid along the veins of leaves.

Nymphs: There are four nymphal stages (instars). The general appearance of each stage is similar except for increase in size during subsequent instars. The first, second, third and fourth nymphal stages last 1-2, 2, 2, and 3 days respectfully.

Adults: Aphids are small, soft-bodied, pear-shaped insects that have a pair of cornicles (wax-secreting tubes) projecting out from the fifth or sixth abdominal segment.Wingless, female, aphids are yellowish green, gray green or olive green with a white waxy bloom covering the body. The winged, female, adult aphids have a dusky green abdomen with dark lateral stripes separating the body segments and dusky wing veins.Male aphids are olive-green to brown in color. The aphid attacks generally during 2nd and 3rd week of December and continues till March.

Life cycle



Damage symptoms:

- Both nymph and adults suck the sap from leaves, buds and pods.
- Curling may occur for infested leaves and at advanced stage plants may wither and die.
- Plants remain stunted and sooty molds grow on the honey dew excreted by the insects.

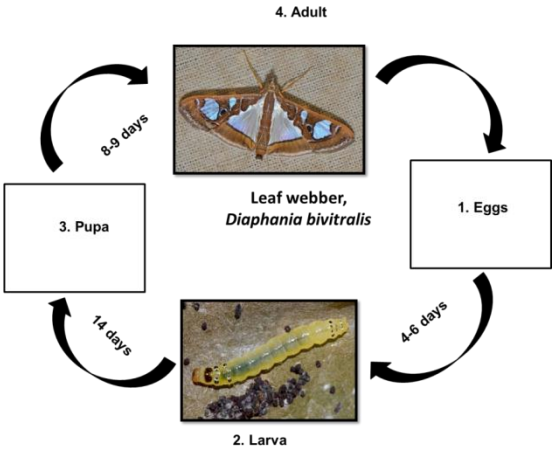
*For management refer to page number 24

7. Leaf webber:

Eggs: The eggs are minute, measuring only about 0.4–0.6 mm in width and 0.8 mm in length. The shape varies from spherical to flattened. Their color is white initially, but changes to yellow after about 24 hours. The eggs are distributed in small clusters, usually two to seven per cluster. They are deposited principally on the buds, flowers, and other actively growing portions of the plant. Hatching occurs in about four days. Egg production to be 300–400 eggs per female.

Larva: There are five instars. Total larval development time averages 14 days. Mean duration (range) of each instar is about 2.5 (2-3), 2 (1-3), 2 (1-3), 2.5 (2-3), and 5 (4-7) days, respectively. Prior to pupation larvae tend to turn a dark copper color. When mature , larvae often attain a length of 2.5 cm.

Pupa: Pupation usually occurs in a leaf fold; often dead, dry material is used. There is only weak evidence of a cocoon, usually just a few strands of silk. The pupa is elongate, measuring about 13 mm in length and 4 mm in width. It is light brown to dark brown in color, and tapers to a point at both ends. Pupation usually lasts about eight to nine days.
Adult: Emerging moths fly during much of the evening hours, but most flight occurs three to five hours after sundown, with peak flight at approximately midnight . he female moth produces a pheromone that attracts males, with peak production occurring at five to seven hours after sunset.
Life cycle:

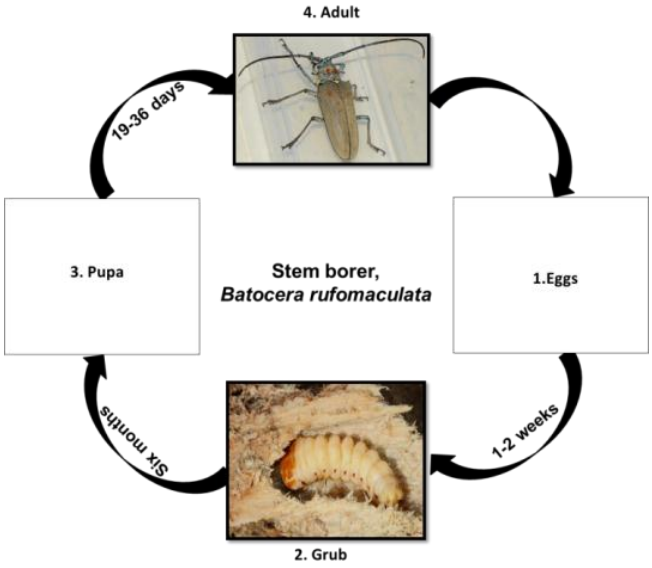


*For management refer to page number 24

8. Stem borer:

Biology:

Egg: The female cuts the tree bark and lays eggs singly into these cuts, laying a total of up to 200 eggs. Egg is a brownish-white cylinder, 6.2 mm, with narrowly rounded ends. On hatching the larvae start to tunnel into the sapwood of the trunk or branches.
Larva: Larval development takes about 2 years. As a very large species, the larval tunnel measuring 2 or 3 centimeters in width that is correspondingly large and very damaging to the tree. The larvae tunnel through the sapwood and because of their size, they make large tunnel which interfere with sap flow and affect foliage and fruit production.
Adult: The adult beetle emerges by a short tunnel running to the exterior and ending in a circular exit-hole. The maximum life recorded for the adult is eight months.
Life cycle:



Damage symptoms:

- Grub tunnels in the sapwood on the trunk or branches
- Grub bore into the sap wood and making irregular tunnels.
- Feeding the vascular tissues
- interruption of nutrient and water transport on the tissue
- Drying of terminal shoot in early stage
- Frass comes out from several points and sometimes sap oozes out of the holes
- Wilting of branches or entire tree

Infestation of borer on tree trunk

*For management refer to page number 26

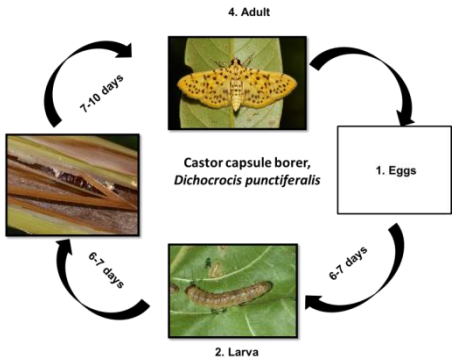
9.Castor capsule borer:

Biology:

Egg: The female moths lay eggs on the tender parts of the plant.

Larva: Pale greenish with pinkish tinge and fine hairs with dark head and prothoracic shield. The caterpillar that hatches out bores into the shoot if the plant is young and knit the planting materials capsules if the plant is old. The full-grown caterpillar is stout, reddish brown in colour and measures 15 to 25 mm. long. It pupates in a silken cocoon.

Adult: Adults have yellow wings with black dots



Damage symptoms:

- The caterpillars bore into shoot and planting materials capsules and cause extensive damage to the tree and characteristic webbing of capsules along with excreta is seen.
- Capsules with bore holes
- Damaged capsules webbed together
- Peduncle and capsules having galleries made of silk and frass.

Natural enemies of shoot and capsule borer:

Parastioids:*Bracon brevicornis*, *Brachymeria euploeae*

Predators:*Chrysoperla zastrowisillemi*, ladybird beetle, reduviid bug, spider, fire ant, robber fly, black drongo (King crow), common mynah, big-eyed bug (*Geocoris* sp), earwig, ground beetle, pentatomid bug (*Eocantheconafurcellata*), preying mantis etc.

*For management refer to page number 25

Natural Enemies of Jackfruit Insect Pest

Parasitoids

Egg parasitoids

1. *Polynema* spp.

2. *Gonatoceru* ssp

3. *Tetrastichus* sp

Larval parasitoids

4. *Fopiusaris anus*

5. *Diachasmimorpha kraussi*

6. *Hormius* sp

7. *Pediobius bruchicida*

8. *Tetrastichus* spp.

9. *Bracon greeni*

10. *Aprostocetus* spp.

Nymphal and adult parasitoids

11. Tiny parasitic wasp

12. *Inostemma psyllae*

13. *Platygaster* sp.

14*. Systasis dasyneurae*

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9. http://www.flickr.com/photos/king777/6965853794/
10. http://bugguide.net/node/view/679101
11. http://bugguide.net/node/view/205018/bgimage
12. http://species.wikimedia.org/wiki/File:Inostemma_boscii.jpg
13. http://www.pbase.com/tmurray74/image/122701891
14. http://www.nbaii.res.in/Pteromalidae/gallery.php

Predators

1.*Mallada boninensis*

2.*Plexippus paykullii*

3. *Menochilus sexmaculatus*

4. *Rodolia fumida*

5. *Cryptolaemus montrozieri*

6. *Rhizoglyphus* sp

7. *Camponatus spoecophylla*

8. *Smaragdina* sp.

9. Purplish pirate bug

10. Brown lacewings

11. Carabid beetle

12. Reduviid bug

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3. http://cyy4993.blogspot.in/2012/11/beetle-coccinellidae-coccinella.html
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IX. DESCRIPTION OF DISEASES

1) Soft rot or fruit rot:

Disease symptoms:

- Young fruits and male inflorescences are badly attacked by the fungus and only a small percentage of the fruits reach maturity.
- Female inflorescence and matured fruits are not usually attacked.
- The disease is a soft rot. A large number of the affected fruits falls off early. In the first stage of attack ·the fungus appears as greyish growth with abundant mycelia which gradually becomes denser forming a black growth.

Survival and spread:

- The fungus gradually advances until the whole fruit or the entire inflorescence rots and falls off.

Favourable conditions:

- Warm, humid, rainy conditions favour the development of rot. Wind, rain and insects dislodge and spread the tiny

http://www.apsnet.org/publications/imageresources/Pages/FI00155.aspx

*For the management refer page no 26

2) Dieback:

Disease symptoms:

- The most of die-back becomes evident by discolouration and darkening of the bark some distance from the tip.
- The dark area advances and young green twigs start withering first at the base and then extending outwards along the veins of leaf edges.
- The affected leaves turn brown and their margins roll upwards.
- At this stage, the twig or branch dies, shrivels and falls.
- There may be exudation of gum from affected branches. Such branches are often affected by shoot borers.
- Infected twigs show internal discolouration

Survival and spread:

- Infected twigs may cause the spreading of die back

Favourable conditions:

- Relative humidity above 80 percent and temperature of 25-31°C and rains

http://macsystems.com/Aug11-2011.jpg

*For the management refer page no 25

3) Leaf spot:

Disease symptoms:

- Produces dark brick red spots on both the surface of leaf which upon maturity become greyish studed with dark colour, pin headed fruiting bodies of the fungus.

Survival and spread:

- The fungus overwinters on old leaves . Young rapidly expanding leaves are infected.

Favourable conditions:

- Temperature of 25°C and Relative Humidity 95-97%

http://www.growables.org/information/TropicalFruit/images/1_guava_algal_leaf_spot_4.jpg

*For the management refer page no 25

5) Rust:

Disease symptoms:

- Rust generally develops late in the summer, and in years when disease is severe, it can cause the trees to defoliate in a matter of a few weeks. If this happens on a regular

basis, the overall growth of the trees can be reduced and yields can be affected.

- Another consequence of defoliation is that if it occurs early in the summer, the trees will put out new growth that is then at risk of being damaged by early frosts. On the other hand, if defoliation occurs in the fall, the trees may go dormant earlier than usual, which then protects them from early frosts.
- Initially, symptoms of fig rust are visible as small, yellowish spots on the upper surface of the leaves. As these spots (or lesions) grow larger, they turn a reddish-brown color but remain relatively smooth.
- On the lower surface of the leaf, the lesions are a reddish-brown color and have a slightly raised, blister-like appearance. Heavily infected leaves often turn yellow or brown, particular y around the edges, and drop prematurely.

Survival and spread:

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

Favourable conditions:

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

http://www.itfnet.org/v1/wp-content/uploads/2012/09/plate-1.jpg

*For the management refer page no 25

6.Pink disease:

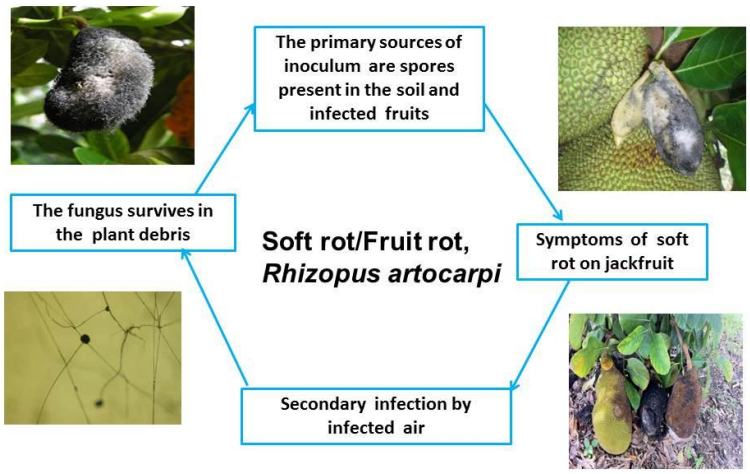
Disease symptoms

- It is widespread in tropical and subtropical areas.
- Disease appears as a pinkish powdery coating on the stem.
- Pink colour represents profuse conidial production of fungus.
- Young woody branches of the affected trees lose their leaves & show die back symptoms.
- Pink encrustation is seen on the lower shaded side.

*For the management refer page no 25

Disease cycle

1. Soft rot:



http://miamieverydayphoto.blogspot.in/2011/08/lasiodiplodia-rot.html
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http://mushroomobserver.org/images/320/30895.jpg

XI. Safety measures

A. At the time of harvest

Jackfruit should be harvested at the right stage of maturity. The maturity indices used for whole, fresh fruit can be used for choosing the correct harvesting stage of raw fruit for minimal processing. A maturity study conducted at the Federal Land Development Authority's (FELDA) farm verified that the fruit is fully matured after 14 weeks (100 days) from bagging,which is equivalent to 16 weeks from anthesis. At this stage, the ripened fruit has good eating quality in termsof aroma, texture, sweetness and taste—the total soluble solids (TSS) content has reached about 24°Brix, total sugar about 11–15%,while the total titratable acidity (TTA) is about 0.3%. It is recommended that fruit be harvested in the morning, as field heat is still low and tolerable to the produce. Harvesting is done by cutting the stalk using a sharp knife and holding the fruit to avoid it dropping.

B. During post-harvest storage

In-field handling

Harvested fruit should be packed in bulk containers made of either plastic or wood and delivered to the MP plant by lorry or pick-up van.

Packinghouse operations

Fruit received from farms should be inspected to ensure that the quantity (weight) and the quality meet the required specifications. The fruit should then undergo some minimum postharvest operations prior to minimal processing to ensure maintenance of high quality raw materials for processing. The minimum packing house operations include sorting, washing and rinsing. Washing of produce should be done using chlorinated water to remove dirt, foreign matter, latex stains and any field contamination. After washing, produce must be rinsed properly to remove excess moisture from the surface of the fruit.

Ripening

Prior to the minimal processing, fruit should be ripened fully to achieve optimum aroma, sweetness, taste and eating quality. Fruit should be kept at ambient temperature to allow natural ripening within3–4 days. However, uneven ripening is a major problem in the natural ripening process, especially for large-sized fruit. An induced ripening method is recommended for jackfruit to achieve more uniform ripening of the fruit. Induced ripening is done by keeping the fruit in a static or closed ripening chamber, equipped with an ethylene gas tank and a flow rate controller. Ethylene gas with a concentration of 50 parts per million (ppm) is flushed into the chamber set at 25°C. After 24 hours, the chamber is opened to allow continuation of the ripening process under ambient conditions. The fruit ripens 3–4 days after the treatment with ethylene gas.

Minimal processing operation

Fruit ready for minimal processing should be shifted to a hygienic processing room to avoid microbial contamination of the cut surface. Basic operations may include cutting the skin using a clean knife to remove the core, taking individual fruitlets and sorting the fruitlets according to the required size, maturity and colour. Only full fruitlets (not half or partly cut) are recommended for retailing. However, fruitlets with or without seeds can be prepared according to the consumers' preference. Multiple handling of the fruitlets should be minimised during minimal processing to avoid injuries and contamination.

Packaging

Minimally processed products should be packed properly using a suitable packing material and system. Packaging aims to protect the product from physicaland microbiological hazards since their natural protector (the fruit skin) has been removed. The common packaging methods for MP jackfruit include polyethylene bags, polystyrene trays wrapped with polyvinyl chloride (PVC) film and polypropylene containers with lids. Sealing packages may also involve altering the concentration of respiratory gases inside the package to create a modified atmosphere system.Modified atmosphere packaging has also been found to be capable of preserving freshness and extending the shelf life of MP products such as pineapple, pomelo, durian and jackfruit (Anon. 1997).

Storage

After packaging, MP jackfruit should be kept at a chilled temperature for storage before distribution. A storage temperature of 2°C was found to be suitable for extending the shelf life of MP jackfruit for 3 weeks (Anon. 1997)

XII. DO'S AND DON'TS IN IPM

S. No.	Do's	Don'ts
1.	Deep ploughing is to be done on bright sunny days during the months of May and June. The orchard should be kept exposed to sun light at least for 2-3 weeks	Do not plant or irrigate the orchard after ploughing, at least for 2-3 weeks, to allow desiccation of weed's bulbs and/or rhizomes of perennial weeds.
2.	Adopt inter-treeping of recommended trees.	Do not disturb the plant roots by adopting ploughing away from the pits.
3.	Grow only recommended varieties.	Do not grow susceptible varieties.
4	Always treat the planting material with approved chemicals/biopesticides for the control of planting materials borne diseases/pests	Do not use planting material without planting materials treatment with biopesticides/chemicals.
5	Plant in rows at optimum depths under proper moisture conditions for better establishment.	Do not plant planting material beyond 5-7 cm depth.
6	Apply only CIBRC recommended pesticides against a particular pest at the recommended dose, at the right time, with right methods with standard equipment e.g. Flat-fan or flood- jet nozzles for herbicides.	Non-recommended pesticides should not be applied in the Orchard field.
7	Maintain optimum and healthy plant stand.	Orchard plants should not be exposed to moisture deficit stress at their critical stages.
8	Use NPK fertilizers as per the soil test recommendation.	Avoid imbalanced use of fertilizers.
9	Use micronutrient mixture after sowing based on soil test recommendations.	Do not apply any micronutrient mixture after sowing without soil test recommendations.

10	Conduct weekly AESA in the morning preferably before 9 a.m. Take decision on management practice based on AESA and P: D ratio only.	Do not take any management decision without considering AESA and P: D ratio
11	Install pheromone traps at appropriate period.	Do not store the pheromone lures at normal room temperature (keep them in refrigerator).
12	Release parasitoids only after noticing adult moth catches in the pheromone trap or as pheromone trap or as per orchard observation	Do not apply chemical pesticides within seven days of release of parasitoids.
13	Apply NPV of respective Lepidopteran moth if available at recommended dose when a large number of egg masses and early instar larvae are noticed. Apply NPV only in the evening hours after 5 pm.	Do not apply NPV on late instar larva and during day time.
14	In case of pests which are active during night spray recommended biopesticides/chemicals at the time of their appearance in the evening.	Do not spray pesticides at midday since, most of the insects are not active during this period.
15	Spray pesticides thoroughly to treat the under surface of the leaves, particularly for mites, and other sucking pests harbouring the lower side of leaves.	Do not spray pesticides only on the upper surface of leaves.
16	Apply short persistent pesticides to avoid pesticide residue in the soil and produce.	Do not apply pesticides during preceding 7 days before harvest.
17	Follow the recommended procedure of trap tree technology.	Do not apply long persistent on trap tree, otherwise it may not attract the pests and natural enemies.

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