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AESA BASED IPM PACKAGE

ARECANUT

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Department of Agriculture and Cooperation
Ministry of Agriculture
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The AESA based IPM – Arecanut *(Areca catechu* L.*)*, was compiled by the NIPHM working group under the Chairmanship of Dr. Satyagopal Korlapati, IAS, DG, NIPHM, and guidance of Shri. Utpal Kumar Singh, 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)

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AESA BASED IPM PACKAGE FOR ARECANUT

Arecanut - Plant description:

Arecanut (*Areca catechu* L.; Family: Arecaceae) is a palm which grows in much of the tropical Pacific, Asia, and parts of East Africa. Plants have large, evergreen leaves that are either palmately ('fan-leaved') or pinnately ('feather-leaved') compound and spirally arranged at the top of the stem. The leaves have a tubular sheath at the base that usually splits open on one side at maturity. The inflorescence is a spadix or spike surrounded by one or more bracts or spathes that become woody at maturity. The flowers are generally small and white, radially symmetric, and can be either uni- or bisexual. The sepals and petals are three each, and may be distinct or joined at the base. The stamens are six, with filaments that may be separate, attached to each other, or attached to the pistil at the base. The fruit is usually a single-seeded drupe (sometimes berry-like) but some genera (e.g. *Salacca*) may contain two or more seeds in each fruit The seed contains alkaloids such as arecaidine and arecoline, which, when chewed, are intoxicating and slightly addictive. The seed also contains condensed tannins (procyanidins) called arecatannins which are carcinogenic. The areca palm is also used as an interior landscaping species. It is often used in large indoor areas such as malls and hotels.

I. PESTS

A. Pests of National Significance

1. Insect and mite pests

1.1 Spindle bug: *Carvalhoia/ arecae* Miller & China (Hemiptera: Miridae)

1.2 Inflorescence caterpillar: *Tirathaba mundella* Walker (Lepidoptera: Pyralidae)

1.3 Pentatomid bug: *Halyomorpha marmorea* (Fab.) (Hemiptera: Pentatomidae)

1.4 Root grub: *Leucopholis burmeisteri* Brenske), *Leucopholis lepidophora* Blanch (Coleoptera: Melolonthidae)

1.5 White mite/sorghum mite: O*ligonychus indicus* Hirst (Acarina: Tetranychidae)

1.6 Red mite/palm mite: *Raoiella indica* Hirst (Acarina: Tenuipalpidae)

2. Diseases

2.1 Koleroga or mahali or fruit rot: *Phytophthora meadii* McRae

***2.2* Inflorescence die back: *Colletotrichum gloeosporioides* Penz.**

2.3 Anabe roga or basal stem rot or foot rot: *Ganoderma lucidum* (Leys) Karst

2.4 Bud rot or crown rot: *Phytophthora meadii* McRae

2.5 Yellow leaf disease: Phytoplasma disease transmitted by the plant hopper, *Proutista moesta* (Hemiptera: Derbidae)

3. Nematode

3.1 Burrowing nematode: *Radopholus similis* (Cobb) Thorne

4. Rodents

4.1 Lesser bandicoot: *Bandicota bengalensis* (Gray) (throughout India)

4.2 Palm rat/house rat: *Rattus rattus* (Linnaeus) (throughout India)

5. Weeds

Grasses

5.1 Barnyard grass: *Echinochloa crusgalli* (L.) Beauv. (Poaceae)

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

5.3 Congo grass: *Imperata cylindrica* (L.) Raeusch. (Poaceae)

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

Broadleaf

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

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

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

5.8 *C*arrot grass: *Parthenium hysterophorus* L. (Asteraceae)

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

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

5.11 Crofton weed: Eupatorium odoratum L. syn *Chromolaena odorata* L. R.M. king & H. Rob (Asteraceae)

5.12 Mile a minute: *Mickania micrantha* H.B.K. (Asteraceae)

5.13 Sensative plants: *Mimosa pudica* L. (Fabaceae)

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

Sedges

5.15 Purple nutsedge: *Cyperus rotundus* L. (Cyperaceae)

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

B. Pests of Regional Significance

1. Insect pests

1.1 Scale insects: res scale: *Aonidiella orientalis* Newstead; mussel scale: *Ischnaspis longinostris* (Hemiptera: Diaspididae)

1.2 Stem weevil: *Diocalandra stigmaticollis* Gyll. (Coleoptera: Curculionidae)

2. Storage pests

2.1 Arecanut beetle: *Caccotrypes carpophagus* Horn (Coleoptera: Scolytidae)

2.2 Coffee bean weevil: *Araecerus fasciculatus* D. (Coleoptera: Anthribidae)

2.3 Cigarette beetle: *Lasioderma serricorne* (F.) (Coleoptera: Anobiidae)

2.4 Rice moth: *Corcyra cephalonica* (Stainton) (Lepidoptera: Galleriidae)

3. Diseases

3.1 Collar rot of seedlings: *Fusarium* spp., *Rhizoctonia* spp.

3.2 Stem bleeding: *Thielaviopsis paradoxa* Von. Hon.

4. Diseases in storage

4.1 *Aspergillus niger* van Tieghem*, A. flavus* Link.*, A. chivalieri*

4.2 *Botryodiplodia theobromae* Pat

4.3 *Rhizopus* sp.

5. Weeds

Broad leaf

5.1 Ragweed: *Ambrosia psilostachya* DC. (Asteraceae)

5.2 Field bindweed: *Convolvulus arvensis* L. (Convolvulaceae)

Sedges

5.3 Yellow nutsedge: *Cyperus esculentus* L. (Cyperaceae)

5.4 Flat sedge: *Cyperus difformis* L. (Cyperaceae)

II. AGRO-ECOSYSTEM ANALYSIS (AESA) BASED INTEGRATED PEST MANAGEMENT (IPM)

A. AESA:

The IPM has been evolving over the decades to address the deleterious impacts of synthetic chemical pesticides on environment ultimately affecting the interests of the farmers. The economic threshold level (ETL) was the basis for several decades but in modern IPM (FAO 2002) emphasis is given to AESA where farmers take decisions based on larger range of field observations. The health of a plant is determined by its environment which includes physical factors (i.e. soil, rain, sunshine hours, wind etc.) and biological factors (i.e. pests, diseases and weeds). All these factors can play a role in the balance which exists between herbivore insects and their natural enemies. Understanding the intricate interactions in an ecosystem can play a critical role in pest management.

Decision making in pest management requires a thorough analysis of the agro-ecosystem. Farmer has to learn how to observe the crop, how to analyze the field situation and how to make proper decisions for their crop management. This process is called the AESA. Participants of AESA will have to make a drawing on a large piece of paper (60 x 80 cm), to include all their observations. The advantage of using a drawing is that it requires the participants/farmers to observe closely and intensively. It is a focal point for the analysis and for the discussions that follow, and the drawing can be kept as a record.

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

- Plant health at different stages
- Built-in compensation abilities of plants
- Pest and defender population dynamics
- Soil conditions

- Climatic factors
- Farmers past experience

Principles of AESA based IPM:

Grow a healthy crop

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

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

Farmers should

- Monitor the plantation 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 tomato 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 situation

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

The general rule to be adopted for management decisions relying on the P: D ratio is 2: 1. However, some of the parasitoids and predators will be able to control more than 2 pests. Wherever specific P: D ratios are not found, it is safer to adopt the 2: 1, as P: D ratio. Whenever the P: D ratio is found to be favourable, there is no need for adoption of other management strategies. In cases where the P: D ratio is found to be unfavourable, the farmers can be advised to resort to inundative release of parasitoids/predators depending upon the type of pest. In addition to inundative release of parasitoids and predators, the usage of microbial biopesticides and biochemical biopesticides such as insect growth regulators, botanicals etc. can be relied upon before resorting to synthetic chemical pesticides.

Decision making

Farmers become experts in crop management

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

- Farmers are capable of improving farming practices by experimentation

- Farmers can share their knowledge with other farmers

AESA methodology

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

    - Plant: Observe the plant height, number of branches, 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

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

Data to be recorded

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

Some questions that can be used during the discussion

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

Advantages of AESA over ETL:

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

enemies, plant compensation ability and abiotic factors are not considered. In AESA based IPM emphasis is given to natural enemies, plant compensation ability, abiotic factors and P: D ratio.

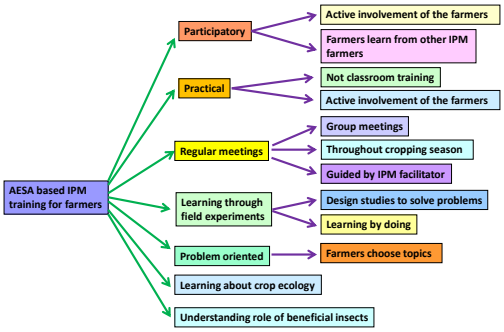
AESA and farmer field school (FFS):

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

Farmers can learn from AESA:

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

FFS to teach AESA based IPM skills:



B. Field scouting

AESA requires skill. So only the trained farmers can undertake 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 insect pests:
For mites: Count and record the number of both nymphs and adults on five randomly selected leaves per plant.

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

Root sampling: Always check plants that appear unhealthy. If there are no obvious symptoms on plants, examine plants randomly and look for lesions or rots on roots and stems. Observe the signs of the causal organism (fungal growth or ooze). It is often necessary to wash the roots with water to examine them properly. If the roots are well developed, cut them to examine the roots for internal infections (discolouration & signs). Count the total number of roots damaged/infested/infected due to rot should be counted and incidence should be recorded.

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

C. Surveillance through pheromone trap catches:
Pheromone traps for @ 4-5/acre field have to be installed, if available. Install the traps for each species separated by a distance of >75 feet in the vicinity of the selected fixed field. Change of lures should be made at 2-3 week interval (regular interval). Total number of moths/trap/week should be recorded year round. The trapped moths should be removed and destroyed after each recording.

D. 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).

E. Nematode extraction:
Collect 100 to 300 cm^3 (200-300 g) representative soil sample. Mix soil sample and pass through a coarse sieve to remove rocks, roots, etc. Take a 600 cc subsample of soil, pack lightly into a beaker uniformly. Place soil in one of the buckets or pans half filled with water. Mix soil and water by stirring with paddle; allow to stand until water almost stops swirling. Pour all but heavy sediment through 20-mesh sieve into second bucket; discard residue in first bucket; discard material caught on sieve. Stir material in second bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 200-mesh sieve into first bucket; discard residue in second bucket. Backwash material caught on 200-mesh sieve (which includes large nematodes) into 250-ml beaker. Stir material in first bucket; allow to stand until

water almost stops swirling. Pour all but heavy sediment through 325-mesh sieve into second bucket; discard residue in first bucket. Backwash material caught on 325-mesh sieve (which includes small to mid-sized nematodes and silty material) into 250-ml beaker. More than 90% of the live nematodes are recovered in the first 5-8 mm of water drawn from the rubber tubing and the sample is placed in a shallow dish for examination.

III. ECOLOGICAL ENGINEERING FOR PEST MANAGEMENT

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

Ecological Engineering for Pest Management – Below Ground:

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

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

Ecological Engineering for Pest Management – Above Ground:

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

Natural enemies may require:

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

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

- Raise the flowering plants / compatible cash crops along the field border by arranging shorter plants towards main crop and taller plants towards the border to attract natural enemies as well as to avoid immigrating pest population
- Grow flowering plants on the internal bunds inside the field

- Not to uproot weed plants those are growing naturally such as *Tridax procumbens, Ageratum* sp, *Alternanthera* sp etc. which act as nectar source for natural enemies,
- Not to apply broad spectrum chemical pesticides, when the P: D ratio is favourable. The plant compensation ability should also be considered before applying chemical pesticides.
- Reduce tillage intensity so that hibernating natural enemies can be saved.
- Select and plant appropriate companion plants which could be trap crops and pest repellent crops. The trap crops and pest repellent crops will also recruit natural enemies as their flowers provide nectar and the plants provide suitable microclimate.

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

Plants suitable for Ecological Engineering for Pest Management

Attractant plants

Sunflower

Buckwheat

Mustard

Marigold

Sweet clover

Spearmint

French bean

Carrot

Alfalfa

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.

IV. CROP STAGE-WISE IPM

Management	Activity
Pre planting*	
	<u>Common cultural practices:</u> • Prepare proper pits. • Timely planting should be done. • Maintain proper spacing. • A pit of size of 90 x 90 x 90 cm is preferred when the soils are deep and well drained. In heavy soils with added impedance to drainage, pit size of 60 x 60 x 60 cm is preferable. • Pits should be filled with top soil, farm yard manure and sand. Fill the pit with FYM, red earth and sand mixture. • Seedling should be planted at the center of the pit and put soil to cover up to the collar region of the seedling.
Weeds	**<u>Cultural control:</u>** • Banana can be raised as a shade crop in the interspaces during the initial years. • Prepare beds of 1-1.5 m width and of convenient length with 75 cm space between beds. • In areas where drainage is poor, prepare raised beds (10-20 cm height)
Nursery stage*	
	<u>Common cultural practices:</u> • Select fully ripen nuts for use as seeds. • Select early early-bearing and high yielding varieties.Select planting sites with deep well-drained soil without high water trouble. • Do deep ploughing or digging. • Soil solarization by using transparent polyethylene sheets in nursery plots • Select good mother palm i.e. must be of 20 years of age, yield more than 80 nuts/annum, etc.
Nutrients	• Apply basal dose of well decomposed FYM or vermicompost @ 2 t/ acre treated with *Trichoderma* 2-3 weeks before planting seed nuts in sand bed nursery. • Recyling biomass using areca materials • Polythene bags (25x 15cm, 150 gauge) filled with potting mixture (top soil: farm yard manure: sand 7:3:2) can also be used to raise

	secondary nursery.
Weeds	• Periodical weeding and mulching with organic materials should be done. • In nursery, weeds should be removed manually.
Seed and seedling stage*	
	<u>Common cultural practices:</u> • Sow seeds in the spacing of 5-6 cm cover the seed nuts with sand. • Transplant sprouts 90 days old having two to three leaves in the secondary nursery at a spacing of 30×30 cm. • Prepare secondary beds of 150 cm width of convenient length. • Provide shade by growing banana or *Coccinia indica* by artificial pandal. • Apply recommended dose of fertilizer or manure. • Provide irrigation properly.
Nutrients	• Apply 12 Kg of green leaf and 12 Kg compost or farm yard manure per plant at the time of planting. • A fertilizer dose of 100 g N, 40 g P_2O_5 and 140 g K_2O per palm per year is recommended. Terracing should be provided in undulated lands to prevent soil erosion.
Weeds	• Weeds should be removed from pits at the time of planting. • Straw/ leaf mulches are provided after planting to suppress the weed growth around young seedlings. • Cover crop and intercrop may be grown between the rows.
***** Apply *Trichoderma viride/ harzianum* and *Pseudomonas fluorescens* as seeds/ seedlings/ planting materials treatment and soil application (if commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).	
Vegetative stage	
	<u>Common cultural practices:</u> • Collect and destroy crop debris • Provide irrigation at critical stages of the crop. • Avoid water logging. • Regulate shade in thickly shaded areas. • Enhance parasitic activity by avoiding chemical spray, when 1-2 larval parasitoids are observed. • Remove and destroy collateral/alternate hosts such as castor, ginger, turmeric in the immediate vicinity. • Maintain optimum plant density. • Ensure adequate shade of 65-70% in endemic areas and irrigate the crop before attaining critical period. • Fill gaps with healthy disease free materials. • Mulching the plant basins with green leaves and other organic materials during summer months conserves and maintains the population of native beneficial microflora. **<u>Common mechanical practices:</u>** • Handpick the older larvae during early stages • Collect and destroy plant parts infested with insect pest and diseases • Handpick the gregarious caterpillars and the cocoons which are

	found on stem and destroy them in kerosene mixed water. • Use yellow sticky traps @ 4-5 trap/acre • Use light trap @ 1/acre and operate between 6 pm and 10 pm • Install pheromone traps @ 4-5/acre for monitoring adult moths activity (replace the lures with fresh lures after every 2-3 weeks) • 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 **<u>Common biological practices:</u>** • Conserve natural enemies through ecological engineering Augmentative release of natural enemies
Nutrients	• For seedlings, 1/3 of the recommended dose of chemical fertilizers (100 g N, 40 g P_2O_5 and 140 g K_2O per palm) is sufficient during first year; 2/3 during the second year and full dose from third year onwards. • Under rainfed conditions, 1/3 of the recommended dose in April-May and 2/3 in September-October should be applied. Under irrigated conditions, the April-May dose can be applied in February. • During February or April-May, broadcast the fertilizer around the base of each palm after weeding and mix with the soil by light forking • During September-October, open the basin to a radius of 75 to 100 cm and to a depth of 15-20 cm, apply the fertilizer and cover with dug soil.
Weeds	• Timely hoeing & hand tool weeding should be done manually / mechanically during initial years. • Soil should be loosened with light digging in October-November. • Weeding is done twice or thrice a year by spade digging.
Phytophagous mite	• Common cultural, mechanical and biological practices **<u>Cultural control:</u>** • Collect and destroy the heavily infested and drying leaves of young palm in the initial foci of colonization
Scales	• Common cultural, mechanical and biological practices **<u>Biological control:</u>** • Release *Chilocorus nigritus* periodically @ 4-5 beetles/palm • Conserve predators such as coccinellid beetles (*C. nigritus* and *C. circumdatus*)
Spindle bugs	• Common cultural, mechanical and biological practices **<u>Cultural control:</u>** • Digging and forking of the soil before and after the monsoon will help in eliminating the various developmental stages of the beetle.
Basal stem rot/foot rot/anaberoga/*Ganoderma* Wilt	• Common cultural, mechanical and biological practices **<u>Cultural control:</u>** • Improve drainage.

	• Avoid dense planting. • Avoid flood irrigation and water flowing from infected palms to healthy palms. • Avoid repeated ploughing and digging in the diseased gardens. • Balanced manuring and fertilizer application. • Cutting and burning of dead palms along with the bole and roots should be followed strictly.
Yellow leaf disease	• Common cultural, mechanical and biological practices **<u>Mechanical control:</u>** • Remove and destroy the diseased palms in the mildly affected areas to prevent the spread. **<u>Cultural control</u>** • Biomass recycling and excess application of phosphorus 100g/palm
Nematodes	• Common cultural, mechanical and biological practices **<u>Mechanical control:</u>** • Mechanically remove left over/residual parts of the plant
Reproductive stage	
Nutrients	• Apply deficient micronutrients if any based on soil test recommendations
Weeds	• Intercultural operations should be done manually or mechanically from time to time to reduce the weed incidence.
Bud rot	**<u>Mechanical control:</u>** • Remove and destroy the diseased palms in the mildly affected areas to prevent the spread.
Root grub	• Common cultural, mechanical and biological practices **<u>Cultural control:</u>** • Deep summer ploughing to expose the immature stages for avian predation. **<u>Mechanical control:</u>** • Collection and destruction of beetles emerging from the soil during pre-monsoon showers in the evening hours • Install light traps @ 1 trap/acre and operate between 6 pm and 10 pm **<u>Biological control:</u>** • Conserve and augment entomopathogenic nematodes such as *Heterorhabditis* spp. and *Steinernema* spp. • Application of neem cake @ 2 Kg/palm/year at the base of the plant during June-July
Inflorescence stage	
Inflorescence caterpillar	• Common cultural, mechanical and biological practices **<u>Mechanical control:</u>** • Affected spadices may be opened and if all the female flowers have been damaged the inflorescence should be removed and

	burnt.
Inflorescence die back or bud shedding	**<u>Mechanical control:</u>** • Remove the fully affected inflorescence and destroy them to prevent spread.
Nut formation stage	
Koleroga/mahali/fruit rot/bud rot	**<u>Mechanical control:</u>** • Collect all the infected nuts and other plant parts and destroy • Cover the bunches with polybags
Pentatomid bug	• Common cultural, mechanical and biological practices **<u>Mechanical control:</u>** • Remove and destroy the alternate hosts such as chillies, ladies finger, bitter gourd etc.
Harvest and storage	
Storage pests: **Coffee bean weevil** **Cigarette beetle**	• Common cultural, mechanical and biological practices **<u>Mechanical control:</u>** • Sun dry the fully ripened nuts by evenly spreading on ground or cement floor

V. RODENT PEST MANAGEMENT

- Disturb and destroy the habitat of the rodents by ploughing the field and trimming of the bunds.
- Practice burrow smoking using paddy straw or other natural smoking materials in 'ANGRAU/ NIPHM burrow fumigator' for 2-3 minutes for each burrow.
- Set up the local traps @ 8-10/acre for trapping immigrant rodent population.
- Application of 0.005% bromadiolone in ready to use form (wax blocks) or loose bait in packets near rodent burrows
- Apply 2% Zinc phosphide poison baits when the rodent infestation is very high. Practice pre-baiting incase of ZNP poison baiting. Don't apply ZNP poisons more than one time in a crop season as rodents develop bait shyness to this poison.
- Encourage the establishment of natural predator like barn owls by establishing barn owl perches/ wooden boxes in and around the crop fields.
- Tie used fertilizer bags on the top of the crown to ward off the rodents.
- Banding polythene sheets or tin sheets to avoid climbing by rodents

<u>Action plan for rodent pest management using rodenticide poison baits</u>

Practice poison baiting with anticoagulant, bromadiolone @ 0.005% (96 parts of broken rice + 2 parts of edible oil + 2 parts of 0.25% CB bromadiolone) on community approach.

- DAY – 1: Close all the burrows in the fields, field bunds, canal bunds and surrounding barren lands etc.
- DAY – 2: Count the re-opened burrows and treat the burrows with Bromadiolone chemical bait packets @ 10 g/burrow.
- DAY – 10: Observe the re-opened burrows and repeat baiting

In cases of high level of infestation (>50 live burrows/ha) practice poison baiting with zinc phosphide @ 2.0% on community approach. PRACTICE PRE-BAITING TO AVOID BAIT SHYNESS

- DAY – 1: Close all the burrows in the fields, field bunds, canal bunds and surrounding barren lands etc.
- DAY – 2: Count the re-opened burrows and practice pre-baiting @ 20 g/burrow (98 parts of broken rice + 2 parts of edible oil)
- DAY – 4: Observe the re-opened burrows and treat the burrow with zinc phosphide poison bait (96 parts of broken rice + 2 parts of edible oil + 2 parts of Zinc phosphide) @ 10g/ burrow. Collect the dead rats, if found any outside and bury them.
- If any residual population is found, practice anti-coagulant poison baiting.

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 DEFICIENCIES/DISORDERS

Nutrient	**Fig.**
Nitrogen: Plants are stunted and generally yellow with lower leaves being most affected. Older leaves are golden yellow colour. **Correction measure:** Foliar application of 2% urea thrice at fortnightly interval or soil application of 1-2 kg urea / tree.	
Potassium: Symptoms first appear on oldest leaves and later spreads to young leaves. Translucent yellow or orange spots develop on leaflets. The tree appears yellow, the trunk is slender with few short leaves. Leaflets with necrotic areas along the margins which later wilt but midrib remain alive. Yellowing is more pronounced and accompanied by irregular brown blotches along the edges of leaflets than along the midrib. **Correction measure:** Soil application of KCl @ 1.3 kg/tree/year	

Calcium: Abnormal growth of young leaves and growing points resembling boron deficiency. Severe deficiency leads to death of the bud. **Correction measure:** Application of gypsum @ 2-5 kg/tree/year.	
Magnesium: Broad light yellow band along the margin of older leaves. The centre of the leaf remaining green. In severe cases leaflet tips may become necrotic. Older leaves become bronzed and dry appearance. Leaflets show necrosis and turn to reddish brown with translucent spots yellowing starts at the tip and spreads to the base. **Correction measure:** Soil application of $MgSO_4$ @ 1-2 kg/tree/year.	
Nut splitting: This is a physiological disorder. Sudden flush of water after a period of water stress is the main cause. Initial symptom appears as premature yellowing of nuts when they are half to three fourth mature. This is followed by splitting of nuts from both sides and the tips which expand longitudinally towards the calyx exposing the kernel. **Control measures:** Improvement of drainage and spraying of Borax @2g/l in the initial stages of disorder are found effective in controlling the disease.	 **http://www.kissankerala.net**

VIII. COMMON WEEDS

1. Barnyard grass: *Echinochloa crusgalli* (L.) Beauv. (Poaceae)

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

3. Congo grass: *Imperata cylindrica* (L.) Raeusch. (Poaceae)

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

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

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

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

8. *C*arrot grass: *Parthenium hysterophorus* L. (Asteraceae)

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

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

11. Crofton weed: *Eupatorium odoratum* L. (Asteraceae)

12. Mile a minute: *Mickania micrantha* H.B.K. (Asteraceae)

13. Sensative plants: *Mimosa pudica* L. (Fabaceae)

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

15. Purple nutsedge: *Cyperus rotundus* L. (Cyperaceae)

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

17. Ragweed: *Ambrosia psilostachya* DC (Asteraceae)

18. Field bindweed: *Convolvulus arvensis* L. (Convolvulaceae)

19. Yellow nutsedge: *Cyperus esculentus* L. (Cyperaceae)

20. Flat sedge: *Cyperus difformis* L. (Cyperaceae)

XI. DESCRIPTION OF INSECT, MITE AND NEMATODE PESTS

1) Spindle bug:

Biology:

Egg: Eggs are laid singly between the leaflets of the spindle. The eggs hatch in 9 days.
Nymph: There are five nymphal stages and it is completed in 15-24 days. The light violet brown nymphs have greenish yellow border.
Adult: Adult bugs are brightly coloured (red and black)

Damage symptoms:

- Inhabit the inner most leaf axils, usually below the spindle.
- Both nymphs andadults suck sap. Infested portions develop necrotic patches leading to drying.
- Spindle fails to unfurl.
- Severe infestation leads to stunting of the palm.
-  

http://www.nbaii.res.in/insectpests/images/Mircarvalhoia-arecae6.jpg
http://www.cpcri.gov.in/index.php?option=com_content&view=article&id=68&Itemid=111

Natural enemies of spindle bug:
Predators: Lacewing, Ladybird beetle, King crow, common mynah, wasp, dragonfly, spider, robber fly, reduviid bug, praying mantid, red ant, big eyed bug, pentatomid bug, earwig, ground beetle etc.
*For the management refer page no……

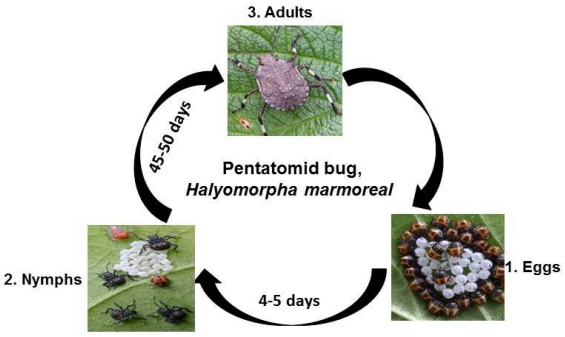
2) Pentatomid bug:

Biology:

Egg: The white or pale green barrel-shaped eggs are laid in clusters (25 eggs) on the lower surface of leaves. Egg period is about 4-5 days
Nymph: Nymphs lack fully developed wings and are tick-like in appearance, ranging in size from 2.4 mm (1st instar) to 12 mm (5th instar). First instars are orange or red in colour and remain clustered around the egg mass. The 2nd instars appear black in colour and subsequent instars (3rd, 4th, and 5th) resemble adults in colour. Each nymphal instar lasts for 10 days.
Adult: Adults are 12 to17 mm long (approximately 1/2 inch), and have a mottled appearance. Alternating dark and light bands occur on the last two antennal segments. Additionally, the head and pronotum are covered with patches of coppery or bluish metallic-colored punctures and the margins of the pronotum are smooth. The exposed lateral margins of the abdomen are marked

with alternate bands of brown and white. Faint white bands are also evident on the legs.

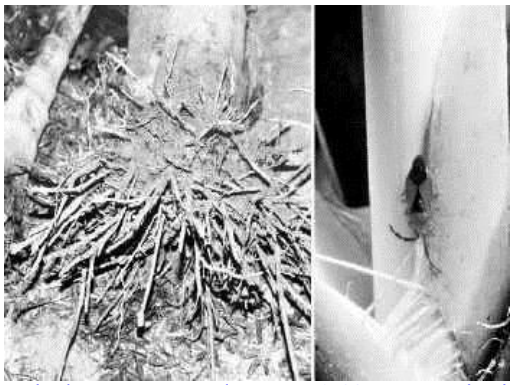
Life cycle:



http://entnemdept.ufl.edu/creatures/veg/bean/brown_marmorated_stink_bug.htm

Damage symptoms:

- The later instar nymphs and adult bugs pierce the tender nuts and suck the kernel sap resulting in drying of kernels and dropping of tender nuts
- Characteristic pinprick black marks are seen at the feeding sites, which subsequently enter into the kernel



http://www.agritech.tnau.ac.in/crop_protection/crop_prot_crop_insectpest%20_Arecanut.html

Natural enemies of pentatomid bug:

Parasitoid: *Anastatus bangalorensis*

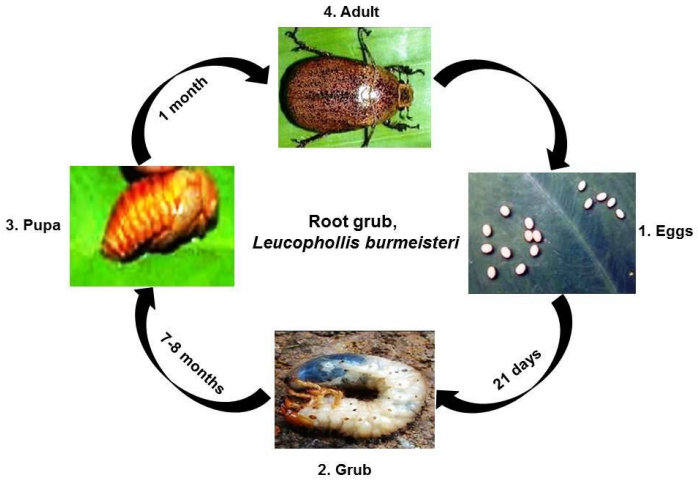
*For the management refer page no……

3) White grub/root grub:

Biology:

Egg: Adult beetles lay eggs in soil mostly up to 10 cm depth. Eggs hatch in about 1 to 3 weeks.
Grub/larva: The grub period with three instars is completed in 7 to 8 months.
Pupa: The pupation takes place in soil in cocoons prepared with mud which lasts about a month
Adult: The adult beetles are chestnut brown in color and emerge during May-June few days after receipt of pre-monsoon showers, between 6.30 and 7.30 PM.

Life cycle:



http://etd.uasd.edu/ft/th9586.pdf

Damage symptoms:

- Root/white grubs occur mostly in sandy and sandy loam soils.
- They are voracious feeders of arecanut roots.
- The early instar grubs feed on the roots of grasses and other humus.
- The second and third instar grubs of these beetles feed on tender and mature roots of the palm. In severe cases, the bole of the palm is also eaten up.
- They also feed on roots of intercrops such as banana, cocoa, tapioca, yams etc.
- Feeding on arecanut seedling roots results in dropping and drying of leaves
- Affected seedlings come off easily since the entire root system is usually eaten up.
- Palms with continuous (few years) infestation show a sickly appearance, with yellowing of leaves, tapering of stem, and reduction in yield.
- The palms may topple in case of severe loss of root system

http://etd.uasd.edu/ft/th9586.pdf

http://www.kissankerala.net:8080/KISSAN-CHDSS/English/Arecanut/pests/2.htm

Natural enemies of white grub/root grub

Parasitoid: Scoliids wasp etc.

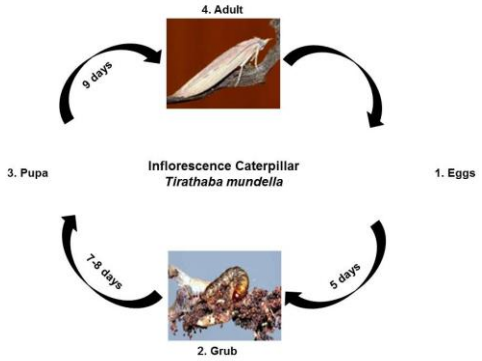
Predators: False vampire bats, garden lizards, wild boar etc.
*For the management refer page no……

4) Inflorescence caterpillar:

Biology:

Egg: Eggs are white, circular and slightly flat and approximately 0.8 mm in diameter. Eggs are laid on flowers from emergence to the end of flowering. Egg period is 5 days.
Larva: Larvae complete their development within the fruit. The red coloured caterpillar penetrates the inflorescence and remains in the tissue for 15 days, tunnelling and destroying the tissue. After this phase it moves to the base of the peduncle changing into a pupa. As the caterpillar destroys the tissues of the inflorescence, a resin coloured liquid gum is exuded from the fruitlets, which upon exposure to air becomes reddish coloured and as it solidifies turns dark brown.
Pupa: Pupa 12 mm long and 5 mm wide with a brown color and a few dark spots. Moth emerges from pupa in 7-11 days.
Adult: The adult moth has a greyish upper wing surface and a cream color underneath with a wingspan of 28-35 mm. The adult can be found during the day or night, flying in a rapid and haphazard fashion.

Life cycle:



http://www.nbaii.res.in/insectpests/Tirathaba-rufivena.php

Damage symptoms:

- The caterpillars feed on the inflorescences especially the tender female flowers and rachillae, web them into a wet mass with silken threads and take shelter in it.
- Burrowing and feeding activities produce visible damage symptoms in the form of frass production and a sticky, gummy exudate.
- Mature caterpillars can damage newly opened inflorescences also.
- In severe cases, they bore into the tender buttons and tender nuts as well.
- Delayed spathe opening, yellowing of spadices, presence of small holes with frass and drying patches on the spathe are the external symptoms of attack.

http://www.agritech.tnau.ac.in/crop_protection/crop_prot_crop_insectpest%20_Arecanut.html

Natural enemies of inflorescence caterpillar:

Predators: Predatory ant, lacewings, ladybird beetles, King crow, common mynah, wasp, dragonfly, spider, robber fly, reduviid bug, praying mantis, red ants, big eyed bugs (*Geocoris* sp), pentatomid bug (*Eocanthecona furcellata*), earwigs, ground beetles, rove beetles etc.
*For the management refer page no……

5) Red mite:

These mites are small and flat, and usually feed on the under surface of leaves. They are slow moving and do not produce silk, as do many tetranychid (spider mite) species.

Biology:

Egg: The eggs are laid in groups, often near the midrib or depressions in the leaflet. The freshly laid egg is attached to the leaf surface and a fine white stripe (slender hair like structure) as long as or longer than the egg is present at one end. The incubation period is 8 days for fertilized eggs and 7.3 days for unfertilized eggs.
Larva: The newly hatched larva is red and has three pairs of legs. A blackish tinge may develop on the posterior end of the dorsum after feeding. The larva typically feeds for 3-5 days and then becomes quiescent for 1.7 to 1.9 days before moulting to the protonymphal stage.
Protonymphs: The reddish protonymph emerges with four pairs of legs and feeds for 2-5 days prior to becoming quiescent. The quiescent phase lasts from 1-4 days before deutonymphs emerge from the exoskeleton. The female protonymph has an ovoid body with a rounded posterior but the male protonymph has a pointed posterior and a nearly triangular body.
Deutonymphs: Deutonymphs are larger than protonymphs but resemble protonymphs with regard to feeding and other habits. The active phase lasts 2-5 days and the subsequent quiescent phase lasts from 2-4 days.
Adult: Females develop dark markings on the dorsum of the body after feeding. The dorsum is smooth, except for the presence of punctae (sculptured depressions). The male is smaller, but similar to the female in shape except for having a tapering of the posterior end of the body. Adult females are larger than males and less active. The life cycle from egg to adult typically requires 23 to 28 days for females and 20 to 22 days for males.

Damage symptoms:

- The reddish mites are easily seen against green leaves.
- Heavy infestations of the mites are typically on the lower surface of the leaves, and yellow speckles and blotches on the leaves are seen from the feeding damage.
- Yellowing of the leaves may often be severe.

- In severe infestations yellowing of leaves is quite prominent.

http://www.cpcri.gov.in/index.php?option=com_content&view=article&id=68&Itemid=111

Natural enemies of red mites:

Predators: Staphylinid beetle, predatory mite etc.
*For the management refer page no……

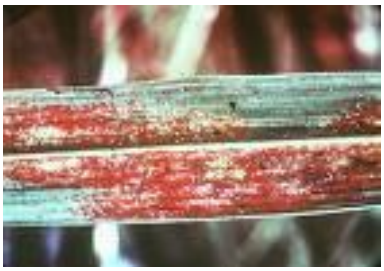
6) White mite:

Biology:

Egg: Adults lay light yellowish rounded eggs on lower surface of leaves.
Nymph: Nymphs are smaller in size than adults.
Adult: Adults are greyish green with black blotches scattered over dorsum. Adults possess 4 pairs of legs. There are 30 overlapping generation in a year

Damage symptoms:

- Adults and nymphs present on the lower surface of leaves.
- Adult males feed very little and the main damage is caused by the females and immature stages.
- The colony is found under white webs.
- Feeds on lower surface of arecanut leaves.



http://www.agritech.tnau.ac.in/crop_protection/crop_prot_crop_insectpest%20_Arecanut.html

Natural enemies of white mite:
Predators: Anthocorid bug, syrphid/hover fly, green lacewing, ladybird beetle, predatory mites etc.
*For the management refer page no……

7) Burrowing nematode:

Damage symptoms:

- Infested palms show general yellowing, reducing growth, vigour and yield
- Appearance of orange-coloured lesions, blackening of tips of lateral and tertiary roots and rotting of roots

*For the management refer page no……

Natural Enemies of Arecanut Insect Pests

Parasitoids

Egg parasitoid **Larval parasitoid**

1. *Anastatus bangalorensis* **2. Scoliids wasp**

1. http://www.nbaii.res.in/Featured_insects/Anastatus-bangalorensis.php
2. http://www.pbase.com/rcm1840/image/85327393&gcmd=add_comment

Predators

1. Lacewing **2. Ladybird beetle** **3. Spider** **4. Predatory ant**

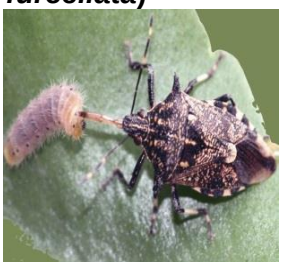
5. Dragonfly **6. Robber fly** **7. Reduviid bug** **8. Praying mantis**

9. Black drongo (King crow) **10. Nabid bug** **11. Common mynah** **12. Big-eyed bug (*Geocoris* sp)**




13. Earwig **14. Ground beetle** **15. Pentatomid bug (*Eocanthecona furcellata*)** **16. Carabid beetle**






17. Cantharid beetle **18. Mirid bug** **19. Hover fly** **20. Predatory mite**




21. Predatory thrips **22. *Orius* spp. (pirate/anthocorid bug)**


4.http://www.alexanderwild.com/Ants/Taxonomic-List-of-Ant-Genera/Pachycondyla/i-5fsCcNh
5. http://en.wikipedia.org/wiki/Dragonfly
6. http://www.warpedphotosblog.com/robber-fly-and-prey
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8. http://spirit-animals.com/praying-mantis/
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17. http://www.kerbtier.de/cgi-bin/enFSearch.cgi?Fam=Cantharidae
18. http://www.britishbugs.org.uk/heteroptera/Miridae/blepharidopterus_angulatus.html
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21. http://biocontrol.ucr.edu/hoddle/persea_mite.html
22. http://en.wikipedia.org/wiki/File:Orius_insidiosus_from_USDA_2_(cropped).jpg

X. DESCRIPTION OF DISEASES

1) Koleroga/mahali/fruit rot/bud rot:

Disease symptoms:

- Characteristic symptom is rotting and extensive shedding of the immature nuts which lie scattered near the base of the tree.
- Initial symptoms appear as dark green/ yellowish water-soaked lesions on the nut surface near the perianth (calyx).
- The infected nuts lose their natural green lusture, quality and hence have a low market value.
- The lesions on the fruits gradually spread covering the whole surface before or after shedding which consequently rot.
- White mycelial mass envelopes on entire surface of the fallen nuts.
- As the disease advances the fruit stalks and the axis of the inflorescence rot and dry, sometimes covered with white mycelial mats.
- Infected nuts are lighter in weight and possess large vacuoles.
- When infection occurs later in the season, it leads to rotting and drying up of nuts without shedding (known as 'Dry Mahali').

1. Shedding of immature nuts

2. Water soaked lesion near perianth

http://icargoa.res.in/Extension%20Folder%20No-67-arecanut%20fruit%20rot.pdf

Survival and spread:

- Disease spreads through heavy winds and rain splashes.
- The fruit bunches infected towards the end of rainy season may remain mummified on the palm and such nuts provide inoculum for bud rot or crown rot or the recurrence of fruit rot in the next season.

Favourable conditions:

- The severity, persistence and spread of fruit rot are related to the pattern of rain. The disease appears usually 15 to 20 days after the onset of regular monsoon rains and may continue up to the end of the rainy season.
- Continuous heavy rainfall coupled with low temperature (20 to 23 °C), high relative humidity >90%) and intermittent rain and sunshine hours favour the outbreak of fruit rot.

2) Inflorescence die back:

Disease symptoms:

- Disease appears on rachillae of the male flowers and then in the main rachis as brownish patches which soon spreads from tip downwards covering the entire rachis causing wilting.
- The female flowers of the infected rachis shed and the whole inflorescence shows 'die back' symptom.
- The fruiting bodies of the fungus (conidia) appear as concentric rings in the discolored areas.
- The disease is severe mostly during dry condition (February-March).
- Button shedding followed by die-back of inflorescence is a severe problem in arecanut plantations during monsoon periods.

http://www.kissankerala.net:8080/KISSAN-CHDSS/English/Arecanut/Disease/6.htm

Survival and spread:

- Spread is through air borne conidia.

3) Yellow leaf disease:

Disease symptoms:

- Yellowing of tips of leaflets in 2 or 3 leaves of outermost whorl.
- Brown necrotic streaks run parallel to veins in unfolded leaves.
- The yellowing extends to the middle of the lamina. Tips of the chlorotic leaves dry up. In advanced stage all the leaves become yellow.
- Yellowing of leaves is conspicuous during October to December.
- Finally the crown leaves fall off leaving a bare trunk. Root tips turn black and gradually rot.

http://www.kissankerala.net:8080/KISSAN-CHDSS/English/Arecanut/Disease/1.htm

Survival and spread:

- Phytoplasma Like Organism (*Phytoplasma*)
- Vector: Plant hopper (*Proutista moesta*)

4 Anabe roga/foot rot:

Disease symptoms:

- The leaf lets in outer whorls become yellow and spreads to the whole leaf and the leaves droop down covering the stem.
- Later, the inner whorl leaves also become yellow. Subsequently all the leaves droop, dry up and fall off, leaving the stem alone.
- Then the stem becomes brittle and easily broken by heavy wind.
- The base of the stem shows brown discoloration and oozing of dark fluid.
- Bracket shaped fructifications of the fungus called 'anabe' appears at the base of the trunk.
- Roots become discoloured, brittle and dried.
- When infected trunk is cut open brown discoloration can be seen up to one metre from ground level.

http://www.kissankerala.net:8080/KISSAN-CHDSS/English/Arecanut/Disease/4.htm

Survival and spread:

- The disease is severe in neglected, ill-drained and over-crowded gardens especially with hard, black loamy acid soils of higher iron and calcium contents.

- Soil borne, but secondary spread is through air-borne spores.

5) Bud rot:

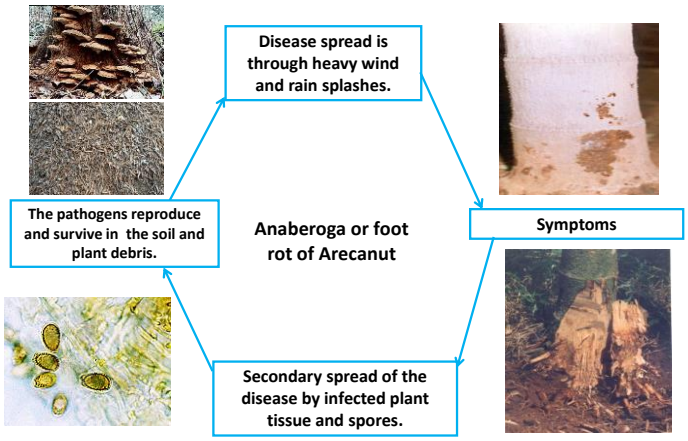
Disease symptoms:

- Initial symptom is the characteristic change of spindle leaf colour from green to yellow and then brownish.
- The leaves rot and the growing bud rots causing death of the palm.
- The affected young leaf whorl can be easily pulled off.
- The outer leaves also become yellow and droop down one by one leaving a bare stem.

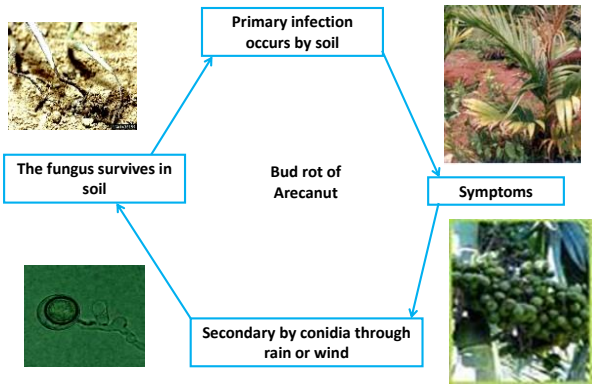

http://www.cpcri.gov.in/index.php?option=com_content&view=article&id=68&Itemid=111
http://agritech.tnau.ac.in/crop_protection/crop_prot_crop%20diseases_plantation_arecanut.html

Disease cycles:

1. Anabe roga or foot rot



2. Bud rot



XI. DESCRIPTION OF RODENT PESTS

1) Lesser bandicoot: • Distributed throughout India and infests almost all crops. • 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. • Nocturnal and fossorial. Burrows are characterized by the presence of scooped soil at the entrance and mostly burrow openings are closed with soil. • It is major pest under wetland conditions •	
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. • Breeds throughout the year producing 5 to 7 litters a year. Serious pest in residential premises and in orchards and horticultural crops. • Very severe in gardens with improper spacing and close planting	 *Rattus rattus*

Damage symptoms

The rodents cause damage to stem, crown, raw fruit and ripening fruit during the development. More damage occurs at fruit ripening stage of crop.

XII. SAFERY MEASURES

A. At the time of harvest:
Harvesting of nuts at correct stages is very important for obtaining the produce of better quality. After harvesting, ripe nuts will have to be sun dried for about 45 days. It is essential to spread the nuts in single layer for drying. Proper drying of nuts is very important to avoid fungal infection of nuts in drying yards. Turning of nuts once in a week may be attended for ensuring uniform drying and better quality of produce.

B. During post-harvest storage:
A method of preserving fresh ripe nuts by steeping in mixed preservative solution has been developed to avoid the problems encountered during the preservation of fresh ripe nuts in garden fresh condition. It consists of washing freshly harvested areca fruits in chlorinated water to remove adhering dirt. The fruits are then blanched in boiling calcium chloride (0.2%) solution. This treatment reduces microbial load, destroys enzymes and preserves the firmness of husk. The fruits are then immersed in solution containing 0.1% sodium benzoate and 0.2% potassium metabisulphite acidified to a pH of 3.5 to 4.0 using hydrochloric acid. The fruits can be preserved in fresh ripe condition for 10-12 months.

Nambiar et al. (1971) developed a technology for management spoilage of arecanuts. There is no problem of infection when the nuts are harvested without soil contact and dried in hot air oven at 65 °C for 63 h as compared to 3.6% of the nuts contracting disease in conventional method of harvest followed by drying in mechanical dryer at 62 °C for 72 h. However, treating nuts with fungicides such as blitox or Bordeaux mixture followed by drying on cement floor significantly reduced the percentage of infection. Infection is less when the nuts are stored in polythene lined gunny bags compared to those stored in plain gunny bags.

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 April, 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.
3.	Grow only recommended varieties.	Do not grow varieties not suitable for the season or the region.
4	Plant early in the season	Avoid late planting as this may lead to reduced yields and incidence of white grubs and other pests .
5	Always treat the seedlings with approved chemicals/biopesticides for the control of seed borne diseases/pests.	Do not use seeds without seed treatment with biopesticides/chemicals.
6.	Plant in rows at optimum depths under	Do not plant seedlings beyond 5-7 cm depth.

	proper moisture conditions for better establishment	
7.	Apply only recommended herbicides at recommended dose, proper time, as appropriate spray solution with standard equipment along with flat fan or flat jet nozzles.	Pre-emergent as well as soil incorporated herbicides should not be applied in dry soils. Do not apply herbicides along with irrigation water or by mixing with soil, sand or urea.
8.	Maintain optimum and healthy crop stand which would be capable of competing with weeds at a critical stage of crop weed competition	Crops should not be exposed to moisture deficit stress at their critical growth stages.
9	Use NPK fertilizers as per the soil test recommendation	Avoid imbalanced use of fertilizers.
10	Use micronutrient mixture after sowing based on test recommendations.	Do not apply any micronutrient mixture after sowing without test recommendations.
11	Conduct weekly AESA in the morning preferably before 9 a.m. Take decision on management practice based on AESA and P: D ratio only.	Do not take any management decision without considering AESA and P: D ratio
12	Install pheromone traps at appropriate period.	Do not store the pheromone lures at normal room temperature (keep them in refrigerator).
13	Release parasitoids only after noticing adult moth catches in the pheromone trap or as pheromone trap or as per field observation	Do not apply chemical pesticides within seven days of release of parasitoids.
14	In case of pests which are active during night like Noctuids 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 undersurface of the leaves, particularly for mites etc.	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 crop technology.	Do not apply long persistent pesticides on trap crop; otherwise it may not attract the pests and natural enemies.

XIV. BASIC PRECAUTIONS IN PESTICIDE USAGE

A. Purchase

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

B. Storage

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

C. Handling

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

D. Precautions for preparing spray solution

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

E. Equipment

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

F. Precautions for applying pesticides

1. Apply only at recommended dose and dilution
2. **Do not** apply on hot sunny day or strong windy condition; **Do not** apply just before the rains and after the rains; **Do not** apply against the windy direction

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

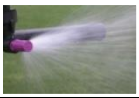
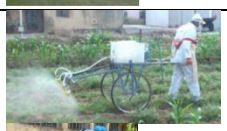
G. Disposal

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

XV. PESTICIDE APPLICATION TECHNIQUES

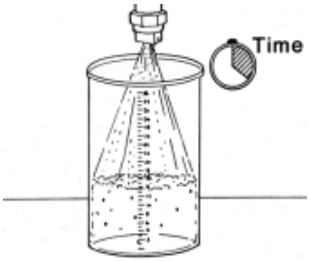
<table>
<tr><td colspan="4">Equipment</td></tr>
<tr><td colspan="4">Category A: Stationary, crawling pest/disease</td></tr>
<tr><td rowspan="2">Vegetative stage
i) for crawling and soil borne pests

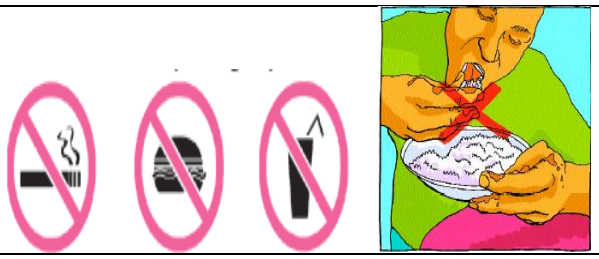
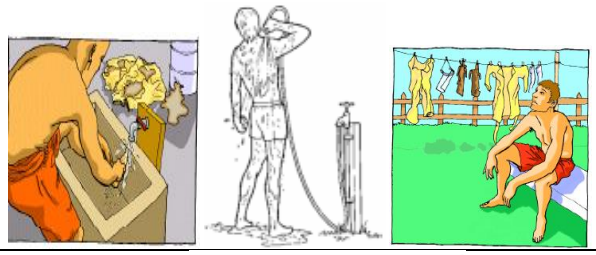
ii) for small sucking leaf borne pests</td><td rowspan="2">Insecticides and fungicides</td><td rowspan="2">• Lever operated knapsack sprayer (Droplets of big size)
• Hollow cone nozzle @ 35 to 40 psi
• Lever operating speed = 15 to 20 strokes/min
or
• Motorized knapsack sprayer or mist blower (Droplets 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</td><td>Insecticides and</td><td>• Motorized knapsack</td><td>  </td></tr>
</table>

Reproductive stage *(Field Pests)*	fungicides	sprayer or mist blower (Droplets of small size) • Airblast nozzle • Operating speed: 2/3rd throttle ***Or*** • Battery operated low volume sprayer (Droplets of small size) Spinning disc nozzle	 
Mosquito/ locust and spatial application *(migratory* Pests)	Insecticides and fungicides	• Fogging machine and ENV (Exhaust nozzle vehicle) (Droplets of very small size) • Hot tube nozzle	 
Category C: Weeds			
Post-emergence application	Weedicide	• Lever operated knapsack sprayer (Droplets of big size) • Flat fan or floodjet nozzle @ 15 to 20 psi • Lever operating speed = 7 to 10 strokes/min	 
Pre-emergence application	Weedicide	• Trolley mounted low volume sprayer (Droplets of small size) • Battery operated low volume sprayer (Droplets of small size)	  

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. Do not apply pesticides without protective clothing and wash clothes immediately after spray application.	 
5.	Do not apply in hot or windy conditions.	 
6.	Operator should maintain normal walking speed while undertaking application.	

7.	Do not smoke, chew or eat while undertaking the spraying operation	
8.	Operator should take **properbath 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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