AESA BASED IPM PACKAGE

PHALSA

Pests

Defenders

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FOREWORD

One of the fallouts of green revolution based on intensive use of inputs including agrochemicals has been an 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 ETI, 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.

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[Signature]

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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)
PREFACE

Need for environmentally sustainable agricultural practices is recognised worldwide in view of the widespread 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 ETM based approached 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 PHALSA

Phalsa - Plant description:

Phalsa (*Grewia asiatica*, L.; Family: Malvaceae) is indigenous throughout much of India and Southeast Asia. It is cultivated commercially mainly in the Punjab and around Bombay. It is a large, scraggly shrub or small tree to 4.5 m or more, the phalsa has long, slender, drooping branches, the young branchlets densely coated with hairs. The alternate, deciduous, widely spaced leaves are broadly heart-shaped or ovate, pointed at the apex, oblique at the base, up to 20 cm long and 16.25 cm wide, and coarsely toothed, with a light, whitish bloom on the underside. Small, orange-yellow flowers are borne in dense cymes in the leaf axils. The round fruits on 2.5 cm peduncles are produced in great numbers in open, branched clusters. Largest fruits are 1.25-1.6 cm wide. The skin turns from green to purplish-red and finally dark-purple or nearly black. It is covered with a thin, whitish bloom and is thin, soft and tender. The soft, fibrous flesh is greenish-white stained with purplish-red near the skin and becoming suffused with this color as it progresses to over ripeness. The flavor is pleasantly acid, somewhat grapelike. Large fruits have 2 hemispherical, hard, buff-colored planting materials 5 mm wide. Summer is the fruiting season. Only a few fruits in a cluster ripen at any one time, so continuous harvesting is necessary. Average yield per plant is 20 to 25 lbs (9-11 kg) in a season.
I. Pests

A. Pests of National Significance

1. Insect and mite pests
   1.1 Phalsa bug: *Gargara mixta* (Buckton) (Hemiptera: Membracidae)
   1.2 Mealybug: *Drosicha mangiferae* (Green) (Hemiptera: Coccidae)
   1.3 Bark eating caterpillar: *Indarbela tetraonis* Moore (Lepidoptera: Cossidae)
   1.4 Hairy caterpillar: *Euproctis fraterna* (Moore) (Lepidoptera: Lymantriidae)
   1.5 Psylla: *Psylla* sp. (Hemiptera: Psyllidae)
   1.6 Brown beetle: *Anomala* sp. (Coleoptera: Scarabaeidae)
   1.7 Beetle: *Oxycetonia* sp. (Coleoptera: Scarabaeidae)
   1.8 Phalsa caterpillar: *Giaura sceptica* Swinhoe (Lepidoptera: Nolidae)
   1.9 Aphid: *Aphis craccivora* Koch (Hemiptera: Aphididae)

2. Diseases
   2.1 Leaf spot/ Brown spot: *Cercospora grewiae* Srivastva and Mehta
   2.2 Rust: *Dasturella grewiae* (Pat. & Har.) Thirum.
   2.3 *Phyllosticta* leaf spot: *Phyllosticta grewiae* Died.

3. Weeds

Broadleaf
   3.1 Tick weed: *Cleome viscosa* L. (Capparidaceae)
   3.2 Coat buttons: *Tridax procumbens* L. (Asteraceae)
   3.3 Carrot grass: *Parthenium hysterophorus* L. (Asteraceae)
   3.4 Horse purslane: *Trainthema monogynae* L. (Aizoaceae)
   3.5 Silk leaf: *Lagascea mollis* Cav. (Asteraceae)
   3.6 Starbur: *Acanthospermum hispidum* DC. (Asteraceae)
   3.7 Spurge: *Euphorbia hirta* L. (Euphorbiaceae)

Grasses
   3.8 Crab grass: *Digiteria sanguinalis* (L.) Scop. (Poaceae)
   3.9 Yellow foxtail: *Setaria glauca* (L.) P. Beauv. (Poaceae)
   3.10 Bermuda grass: *Cynodon dactylon* (L.) Pers. (Poaceae)
   3.11 Torpedo grass: *Panicum repens* L. (Poaceae)

Sedge
   3.12 Purple nutsedge: *Cyperus rotundus* L. (Cyperaceae)

4. Nematodes
   4.1 Root-knot nematode: *Meloidogyne* sp
   4.2 Spiral nematode: *Helicotylenchus* sp

5. Rodents
   5.1 Soft furred field rat: *Millardia meltada*
   5.2 Smaller bandicoot: *Bandicata bengalensis*
   5.3 common house rat: *Rattus rattus*
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. Farmers have to learn how to observe the fruit crop, how to analyze the field situation and how to make proper decisions for their fruit crop management. This process is called the AESA. Participants of AESA will have to make a drawing on a large piece of paper (60 x 80 cm), to include all their observations. The advantage of using a drawing is that it forces the participants/farmers to observe closely and intensively. It is a focal point for the analysis and for the discussions that follow, and the drawing can be kept as a record.

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

- Select a variety resistant/tolerant to major pests
- Select healthy planting materials
- Treat the planting materials with recommended pesticides preferably 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 fruit crop becomes too succulent and therefore susceptible to insects and diseases. If the dosage is too low, the fruit 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
Observe the orchard regularly (climatic factors, soil and biotic factors)

Farmers should
- Monitor the orchard 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 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). Plant tolerance to herbivory can arise from the interaction of a variety of plant traits and external environmental factors. Several studies have documented compensatory regrowth via side braches, through increased growth and photosynthetic rates.

Understand and conserve defenders
- Know defenders/natural enemies to understand their role through regular observations of the agro-ecosystem
- Avoid the use of poisonous chemicals that kill the natural enemies of pests

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 fruit 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 phalsa pests can be divided into 3 categories; 1. parasitoids; 2. predators; and 3. pathogens.

![Model Agro-Ecosystem Analysis chart](image)

- **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**: 

Decision taken based on the analysis of field situation
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 fruit crop management**

Farmers have to make timely decisions about the management of their fruit crops. AESA farmers have learned to make these decisions based on observations and analysis viz. abiotic and biotic factors of the fruit 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, fruit 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 fruit crop management recommendation.
- The small groups then join each other and a member of each group will now present their analysis in front of all participants.
- The facilitator will facilitate the discussion by asking guiding questions and makes sure that all participants (also shy or illiterate persons) are actively involved in this process.
- Formulate a common conclusion. The whole group should support the decision on what field management is required in the AESA plot.
- Make sure that the required activities (based on the decision) will be carried out.
- Keep the drawing for comparison purpose in the following weeks.

Data recording

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

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

Data to be recorded

- **Plant growth (weekly):** Height of plant; number of leaves
- **Fruit crop 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); Price of produce (Rs./Kg)

Some questions that can be used during the discussion

- Summarize the present situation of the field?
- What fruit crop management aspect is most important at this moment?
- Is there a big change in fruit 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 fruit crop is healthy?
- What are the 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 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 fruit crop (fruit crop ecology, growth stage, natural enemies, weather condition, etc.) and their own economic and social situation before they can make the right fruit 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 an integral part of 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 fruit 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 insect pests, diseases, weeds etc., situation.

Surveillance on pest occurrence at the main field should commence soon after fruit 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.

**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:**

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

*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). It is often necessary to wash the roots with water to examine them properly. If the roots are well developed, cut them to examine the roots for internal infections (discolouration & signs). Count the total number of roots damaged/infested/infected due to rot should be counted and incidence should be recorded.

Leaf sampling: Examine all leaves and/or sheaths of each plant for lesions. Leaf diseases cause most damage during the planting materialsling 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, flowers and fruits sampling: Carefully examine the stem, flowers and fruits of plants for symptoms and signs of fungal or bacterial diseases. The stem, flower and fruits should be split or taken apart and examined for discoloration caused by fungi and bacteria. Count the number of stems, flowers and fruits infected due to disease and percent disease incidence should be recorded.

Field scouting for weeds: Scouting is all about early detection. And when it comes to weed detection, sooner is always better. The key to successful weed management is identifying resistance early, when the infestation can still be controlled. Timely scouting is key to making appropriate management decisions. Scout fields early and often to keep weeds under control. In-season scouting should begin shortly after planting to evaluate weed control efficacy and to determine if additional control is needed. Continue to monitor weed sizes and populations throughout the season. Failure to scout and apply post herbicides in a well-timed manner could reduce the efficacy and increase the risk of herbicide resistance.

C. Surveillance through pheromone trap catches:
Pheromone traps for bark eating caterpillar, mango hairy caterpillar, phalsa caterpillar @ 4/acre 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 field. Fix the traps to the supporting pole at a height of one foot above the plant canopy. Change of lures should be made at 2-3 week interval (regular 21 intervals). During each week of surveillance, the number of moths/trap should be counted and entered.

Procedure for observation: Total number of pest / trap/week should be recorded year round. The trapped moths should be destroyed and removed after each recording.

D. Yellow pan water/sticky traps:
Set up yellow pan water/sticky traps 15 cm above the canopy for monitoring target pests @ 4- 5 traps (15 x 7.5 cm)/acre. Locally available empty tins can be painted yellow/ coated with grease/ Vaseline/ castor oil on outer surface may also be used as yellow sticky trap. Count the number of Aphids on the traps daily and take up the intervention when the population exceeds 100 per trap.

E. Light traps
Set up light traps @ 1 trap/acre 15 cm above the fruit crop canopy for monitoring and mass trapping insects. Light traps with exit option for natural enemies of smaller size should be installed and operate around the dusk time (6 pm to 10 pm).
F. Nematode extraction:
Collect 100 to 300 cm$^3$ (200-300 g) representative soil sample. Mix soil sample and pass through a coarse sieve to remove rocks, roots, etc. Take a 600 cc subsample of soil, pack lightly into a beaker uniformly. Place soil in one of the buckets or pans half filled with water. Mix soil and water by stirring with paddle; allow to stand until water almost stops swirling. Pour all but heavy sediment through 20-mesh sieve into second bucket; discard residue in first bucket; discard material caught on sieve. Stir material in second bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 60 mesh sieve to collect cysts into first bucket; discard residue in second bucket. Stir material in first bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 325-mesh sieve into second bucket; discard residue in first bucket. Backwash material caught on 325-mesh sieve (which includes small to mid-sized nematodes and silty material) into 250-ml beaker. More than 90% of the live nematodes are recovered in the first 5-8 mm of water drawn from the rubber tubing and the sample is placed in a shallow dish for examination.

III. ECOLOGICAL ENGINEERING FOR PEST MANAGEMENT

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

Ecological Engineering for Pest Management – Below ground:

There is a growing realization that the soil borne, planting materials and planting materialsling 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.

- Fruit crop rotations with leguminous plants which enhance nitrogen content.
- Keep soils covered year-round with living vegetation and/or fruit crop residue.
- Add organic matter in the form of farm yard manure (FYM), vermicompost, fruit 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 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 fruit crops along the field border by arranging shorter plants towards main fruit 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 fruit crops and pest repellent fruit crops. The trap fruit crops and pest repellent fruit crops will also recruit natural enemies as their flowers provide nectar and the plants provide suitable microclimate.

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

**Plants suitable for Ecological Engineering for Pest Management**

**Attractant plants**

![Cowpea](image1)

*Cowpea*

![Carrot](image2)

*Carrot*

![Sunflower](image3)

*Sunflower*

![Buckwheat](image4)

*Buckwheat*

![French bean](image5)

*French bean*

![Alfalfa](image6)

*Alfalfa*
Mustard                               Cosmos                                     Anise

Caraway                                         Dill

Marigold                                 Chrysanthemum                                 Coriander

Repellent plants

Ocimum sp                                 Peppermint                                     Marigold
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

<table>
<thead>
<tr>
<th>Management</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-sowing</strong>:</td>
<td></td>
</tr>
<tr>
<td><strong>Common cultural practices</strong>:</td>
<td>- Destroy the alternate host plants</td>
</tr>
<tr>
<td></td>
<td>- Sow the ecological engineering plants</td>
</tr>
<tr>
<td></td>
<td>- Sow sorghum/maize/ pearl millet in 4 rows all around the main fruit crop as guard/barrier fruit crop</td>
</tr>
<tr>
<td><strong>Nutrients</strong></td>
<td>- Apply nutrients on the basis of soil test report and recommendation for the particular agro-climatic zone.</td>
</tr>
<tr>
<td></td>
<td>- Prepare nursery in July by sowing planting materials on raised beds 2cm deep in lines 10cm apart. Cover the planting materials with mixture of sand + F.Y.M 50: 50 ratio.</td>
</tr>
<tr>
<td></td>
<td>- The pits of 0.5 cubic meter size are dug during summer - a month before planting.</td>
</tr>
<tr>
<td></td>
<td>- Fill the pits with top soil mixed with 10 kg FYM treated with <em>Trichoderma</em>.</td>
</tr>
<tr>
<td><strong>Weed</strong></td>
<td>- Deep ploughing during summer</td>
</tr>
<tr>
<td></td>
<td>- Ploughing the field before planting to destroy existing weeds in the field.</td>
</tr>
<tr>
<td><strong>Water management</strong></td>
<td>- Proper drainage as fruit crop is water sensitive</td>
</tr>
<tr>
<td><strong>Planting</strong>:</td>
<td></td>
</tr>
<tr>
<td><strong>Common cultural practices</strong>:</td>
<td>- Collect and destroy plant parts infested with insect pest and diseases</td>
</tr>
<tr>
<td></td>
<td>- Remove and destroy fruit crop residues.</td>
</tr>
<tr>
<td></td>
<td>- Avoid planting during wet weather condition</td>
</tr>
<tr>
<td></td>
<td>- Take up planting in shade free area</td>
</tr>
<tr>
<td><strong>Nutrients</strong></td>
<td>- Planting is done with 6-7 month old planting materials during January in pits already filled with top soil and farm yard manure.</td>
</tr>
<tr>
<td></td>
<td>- Planting is done at 1.0 x 1.5 meter apart in lines.</td>
</tr>
<tr>
<td></td>
<td>- Apply 20 g each of <em>Azospirillum</em> and mycorrhiza per plant at planting.</td>
</tr>
<tr>
<td><strong>Weeds</strong></td>
<td>- Use weed free healthy seedlings for planting.</td>
</tr>
<tr>
<td></td>
<td>- Remove weeds from the pit, if any and then plant the planting materials.</td>
</tr>
<tr>
<td></td>
<td>- In case of direct sowing use the weed-free healthy seedlings.</td>
</tr>
<tr>
<td><strong>Soil borne pathogens</strong></td>
<td>Cultural Control:</td>
</tr>
<tr>
<td></td>
<td>- Care should be taken that water should not stagnate near the root zone</td>
</tr>
<tr>
<td><strong>Nematodes</strong></td>
<td>Cultural control:</td>
</tr>
<tr>
<td></td>
<td>- Regular inspection of orchards, sanitation and planting materials certification are recommended as preventive measures</td>
</tr>
</tbody>
</table>
### Vegetative state

**Common cultural practices:**
- Collect and destroy fruit crop debris
- Collect and destroy disease infected and insect damaged plant parts
- Provide irrigation at critical stages of the fruit crop
- Enhance parasitic activity by avoiding chemical spray, when 1-2 larval parasitoids are observed
- Remove weed plants
- Pruning of plants at a height of 0.9-1.2 m from the soil surface during December-January for better quality fruit

**Common mechanical practices:**
- Handpick the older larvae during early stages of plants
- 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

**Common biological practices:**
- Conserve natural enemies through ecological engineering
- Augmentative release of natural enemies

**Nutrients**
- Apply 5 kg of farm yard manure to each bush after pruning in January.
- The bushes may be applied 50 to 100 grams of urea in two parts i.e., during March and April depending upon the age.
- High N dose lead to profuse shoots growth which is not desirable for good fruiting.
- The manures and fertilizers should be applied in 20-30 cm deep and 30 cm wide trench around the trunk.

**Weeds**
- Weeding should be done on regular basis especially around the plants.
- Phalsa requires two hoeings, one after pruning in January and second in April-May. If the intensity of weeds increases in rainy season, remove the weeds by ploughing or hand tool weeding
- To suppress the weeds between rows, leguminous crops like moth bean, cluster bean, chickpea and vegetables can be grown as intercrop during initial years.
- Use straw or plastic ‘mulch’ to avoid weed growth and to
<table>
<thead>
<tr>
<th>Pest/Occurrence</th>
<th>Control Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintain soil moisture for longer period.</td>
<td></td>
</tr>
<tr>
<td><strong>Aphids</strong></td>
<td>• Follow common cultural, mechanical and biological practices</td>
</tr>
<tr>
<td><strong>Cultural control:</strong></td>
<td>• Judicious use of nitrogenous fertilizers</td>
</tr>
<tr>
<td><strong>Biological control:</strong></td>
<td>• Spray azadirachtin 5% W/W neem extract concentrate @ 80 g in 160 l of water/acre</td>
</tr>
<tr>
<td></td>
<td>• Release 1st instar larvae of green lacewing @ 4000/acre</td>
</tr>
<tr>
<td><strong>Phalsa bug</strong></td>
<td>• Follow common cultural, mechanical and biological practices</td>
</tr>
<tr>
<td><strong>Bark eating caterpillar</strong></td>
<td>• Follow common cultural, mechanical and biological practices</td>
</tr>
<tr>
<td><strong>Cultural control:</strong></td>
<td>• Keep orchard clean and healthy</td>
</tr>
<tr>
<td><strong>Mechanical control:</strong></td>
<td>• Bark eating caterpillar infested galleries should be removed.</td>
</tr>
<tr>
<td></td>
<td>• Collect and destroy gregariously feeding larvae of hairy caterpillar.</td>
</tr>
<tr>
<td></td>
<td>• Keep the orchard free from weeds to avoid pest infestation</td>
</tr>
<tr>
<td><strong>Biological control:</strong></td>
<td>• Release of egg parasitoid <em>Trichogramma chilonis</em> @ 20,000/acre</td>
</tr>
<tr>
<td></td>
<td>• Use of 5% NSKE</td>
</tr>
<tr>
<td><strong>Brown and phalsa beetle</strong></td>
<td>• Follow common cultural, mechanical and biological practices</td>
</tr>
<tr>
<td><strong>Cultural control:</strong></td>
<td>• Keep orchard clean and healthy</td>
</tr>
<tr>
<td><strong>Mealybug</strong></td>
<td>• Follow common cultural, mechanical and biological practices</td>
</tr>
<tr>
<td><strong>Cultural control:</strong></td>
<td>• Remove weeds like <em>Clerodendrum infortunatum</em> and grasses by ploughing during June-July.</td>
</tr>
<tr>
<td></td>
<td>• Plough orchards during summer to expose the eggs to natural enemies and extreme heat.</td>
</tr>
<tr>
<td></td>
<td>• Flooding of orchard with water in the month of October kill the eggs.</td>
</tr>
<tr>
<td></td>
<td>• Raking of soil under the tree trunks and mixing with some soil dust in the early part of November for control of early instar mealy bug</td>
</tr>
<tr>
<td></td>
<td>• Soil solarization with thin polythene sheet for 30-40 days during hot summer</td>
</tr>
<tr>
<td></td>
<td>• Tree banding with 300 mm alkathene sheet 400 gauge</td>
</tr>
<tr>
<td></td>
<td>• Grow sunhemp as trap crop and marigold as repellent crop</td>
</tr>
<tr>
<td><strong>Leaf spot or brown spot</strong></td>
<td>• Follow common cultural, mechanical and biological practices</td>
</tr>
<tr>
<td><strong>Mechanical control:</strong></td>
<td>• Prune diseased leaves and malformed panicles harbouring the pathogen to reduce primary inoculum load.</td>
</tr>
<tr>
<td><strong>Rust</strong></td>
<td>• Follow common cultural, mechanical and biological practices</td>
</tr>
<tr>
<td><strong>Cultural control:</strong></td>
<td></td>
</tr>
<tr>
<td>----------------------</td>
<td></td>
</tr>
<tr>
<td>- Diseased leaves, twigs, gall midge infected leaves and fruits, should be collected and burnt.</td>
<td></td>
</tr>
</tbody>
</table>

**Phyllastica spot**
- Follow common cultural, mechanical and biological practices

**Cultural control:**
- Every care should be taken to prevent introduction of disease in newly planted orchards.
- The affected branches should be collected and burnt.

## Reproductive stage

### Common cultural practices:
- Remove weeds around the plants.
- Collect and destroy the plant debris and diseased plants.
- Maintain proper drainage

### Common biological practices:
- Conserve natural enemies through ecological engineering
- Augmentative release of natural enemies

### Nutrients
- When the bushes become four years of age increase the dose of nitrogen to 200gm in split dose.
- Apply 100gm N in March and rest 100g N in April at months interval.
- Apply recommended micronutrients, if deficiency symptoms are observed.

### Weeds
- Remove weeds around the plants.
- Use straw or plastic mulch to avoid weed growth and to maintain soil moisture for longer period.

**Hairy caterpillar and Mealybug**
- Same as in vegetative stage.

**Rust**
- Same as in vegetative stage

**Leaf spot and Phyllastica leaf spot**
- Same as in vegetative stage

### Psylla

**Cultural control:**
- Follow common cultural, mechanical and biological practices

**Biological control:**
- Follow common cultural, mechanical and biological practices

## V. RODENT PEST MANAGEMENT

### Rodents damage found in ripened fruits

**Cultural control:**
- Practice clean cultivation/maintain weed free fields which reduces the harbouring/hiding points for rodents.
- Practice trapping with locally available traps using lure @ 8-10 traps/acre. In areas, where *Rattus rattus* is a problem, wonder traps/multi-catch traps work better and enable to trap more animals into a single trap.
• Identify live rodent burrows and smoke the burrows with burrow smoker for 2-3 minutes
• Erect owl perches @ 5-6/acre to promote natural control of rodents

**Chemical control:**
• 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/ac) 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, orchid 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 tomato + 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 tomato + 2 parts of edible oil + 2 parts of zinc phosphide) @ 10g/ burrow. Collect the dead rats, if found any outside and bury them.

**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/interfruit crop.

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. COMMON WEEDS

1) Tick weed: *Cleome viscosa* L. (Capparidaceae)

2) Coat buttons: *Tridax procumbens* L. (Asteraceae)

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

4) Horse Purslane: *Trainthema monogynae* L. (Aizoaceae)

5) Silk leaf: *Lagascea mollis* Cav. (Asteraceae)

6) Starbur: *Acanthospermum hispidum* DC. (Asteraceae)

7) Spurge: *Euphorbia hirta* L. (Euphorbiaceae)

8) Crab grass: *Digitaria sanguinalis* (L.) Scop. (Poaceae)

9) Yellow foxtail: *Setaria glauca* (L.) P. Beauv. (Poaceae)
10) Bermuda grass: *Cynodon dactylon* (L.) Pers. (Poaceae)

11) Torpedo grass: *Panicum repens* L. (Poaceae)

12) Purple nutsedge: *Cyperus rotundus* L. (Cypraceae)

### VIII. DESCRIPTION OF INSECT AND NEMATODE PESTS

1) Mango mealybug:

Reproduction in mealybug is mostly parthenogenetic.

**Biology:**

**Egg:** Mature female lays eggs in ovisacs. Each ovisac contains 150-600 eggs, majority of which are female. Egg clusters are usually embedded in a cocoon of waxy filaments.

**Nymph:** Eggs hatch in 3 to 9 days into nymphs called ‘crawlers’, which are very mobile. The nymphal stage lasts for 22-25 days. They settle on the plants, start sucking the sap and form the colonies.

**Adult:** Individual mealy bug take 25-30 days to grow into adults under normal conditions. In general they have 4 female instars and 5 male instars, but unlike most other scale insects, the prepupa is quite mobile and although it may have wing buds, the legs and antennae are well developed. 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.

There are 2 or 3 generations each year depending on the climate.

**Life cycle:**

![Life cycle of Mango mealybug](http://www.ipm.ucdavis.edu/PMG/GARDEN/PLANTS/INVERT/LIFECYCLES/lcmealybugs.html)
**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.

1. ![Image 1](http://www.nbaii.res.in/insectpests/Drosicha-mangiferae.php)
2. ![Image 2](http://www.nbaii.res.in/insectpests/Drosicha-mangiferae.php)

**Natural enemies of mango mealybug:**

**Parasitoid:** *Leptomastix dactylopii*

**Predators:** *Menochilus sexmaculatus, Rodolia fulida, Cryptolaemus montrozieri, lacewing, spiders etc.*, 

*For management refer to page number 25*

**2) Hairy caterpillar:**

**Biology:**

**Egg:** Eggs are laid in masses on the undersurface of leaves. The egg period is 5-9 days. Eggs hatch into larvae and feed on foliage.

**Larvae:** Larva is reddish brown with red head surrounded by white hairs arising on warts and a long preanal tuft. The early instar larvae feed gregariously on the foliage. The larval period is 29-35 days.

**Pupae:** Larva pupates in a cocoon of hairs on the leaves or leaf folds. Pupal period lasts for 10-12 days.

**Adults:** Adult yellow moth with pale transverse lines on the forewings.

**Life cycle:**
1. Eggs
2. Larva
3. Pupa
4. Adult

Mango hairy caterpillar
Euproctis fraterna

Damage symptoms:
- The early instar larvae feed gregariously on the foliage.

Parasitoids: Trichogrammatoidea australicum, Trichogramma perkinsi
Predators: Orius spp., mirid bug, hover fly, predatory mite, Stethorus punctillum, staphylinid beetle, cecidomyiid fly, Feltiella minuta, lacewing etc.,

*For management refer to page number 25

3) Bark eating caterpillar:

Biology:

Egg: Eggs are laid in clusters of 15-20 directly on the bark of branch or bole. The freshly laid eggs were pale colored and oval in shape and became creamy white after some time. eggs hatch in 8-10 days.

Larva: Fully grown larval are 4-5cm long, Larva bores a short tunnel downwards in to the wood, usually at the junction of a dead branch or snag and the bole. The full grown larva is 1 1/2-2 inches long, smooth skinned with dark chitinised patches on the segments.

Pupa: Pupation takes place in the tunnel in the wood; the pupa possesses rows of teeth or hooks on the abdominal segments by means of which it climbs out of the larval tunnel to release the mouth. The pupal period lasts about 3 weeks.

Adult: Males, length varies from 22- 25 mm while in females 32-34 mm. Males are smaller than females. Adults emerge out during night time to feed, Males are smaller than females. The male adults are whitish grey, short, stout with brownish streaks on pale whitish forewings. Hind wings are pale. The female moths are pale brownish with forewings having row of dark rusty red spots. In females, abdomen has a tuft of hairs at its tip.

Life cycle:

**Damage symptoms:**
- Make tunnels in the main trunk and branches
- Larvae construct loose irregular webbing of silken threads
- Deterioration of vitality
- Reduction in yield

![Bores the bark](http://agropedialabs.iitk.ac.in/agrilore/?q=node/2898)

**Natural enemies of bark eating caterpillar:**
- **Predator:** Green tree ant

*For management refer to page number 25

### 4) Brown beetle:

**Biology:**

- **Egg:** In mid-summer, eggs are laid in the soil, up to a depth of about 6 inches.
- **Grub:** These eggs hatch 3 to 4 weeks later and the young grubs ascend and feed on the grass roots near the surface. The full fed grubs are 23-26 mm in length and the width range from 6-9 mm.
- **Pupa:** In April, they resurface and resume feeding until the first of June when they go down to a depth of about 6 inches to pupate. They pass through a prepupal period of about 6 days, and then pupate, and 2 weeks later the adults emerge. There is one generation each year, although a few individuals do not transform with the others, therefore requiring 2 years for their development.
- **Adult:** The adults are dark brown with black thoracic region. The beetles are 18-19 mm in length while the width ranges from 9-10 mm.
Life cycle:

1. Eggs
2. Grub
3. Pupa
4. Adult

Brown beetle, *Anomala* sp

Damage symptoms:
- Buds and flowers with irregular feeding marks.

*For management refer to page number 25*

5) Psylla:

**Biology:**

**Egg:** Adult female lays 80-100 eggs on either side of the midrib of a single leaf. The egg, shaped like a grains of rice, is attached to the host by a small protrusion extending from the rounded end. A curled filament extends from the pointed end. The egg is creamy white when laid but turns yellow to orange as it develops towards hatching. Incubation period 5-6 days.

**Nymph:** The nymph passes through five instars, each of which ends in a molt. The first instar is creamy yellow. It is long, cylindrical and about the size of the egg. Each successive stage is larger, flatter and more oval than the last. The fourth instar nymph is yellow-green to light tan, while the fifth instar is dark green to dark brown. Third, fourth and fifth instars have progressively larger wing pads. All stages have two conspicuous red eyes. Nymphal period 4-5 weeks.

**Adult:** There are two adult forms: winter form and summer form. The winter form adult measures about 1/10 inch (2.5 mm) long, whereas the summer form is only 1/12 inch (2 mm) long. Wings of both forms are held roof-like over the abdomen.

Life cycle:
Damage symptoms:

- Nymphs and adults are phloem feeders. Honeydew, produced by nymphs, drips or runs onto fruit, causing dark russet blotches or streaks. This results in downgrading of fresh and sometimes processing fruit.
- In large numbers, pear psylla can stunt and defoliate trees and cause fruit drop. A carry-over effect may reduce fruit set the following year. These symptoms, called psylla shock, are caused by toxic saliva injected into the tree by feeding nymphs. When psylla are controlled to prevent fruit russet, psylla shock does not occur.
- Pear psylla also transmits a mycoplasma disease organism through its saliva. The disease damages sieve tubes in the phloem, which prevents synthesized nutrients moving down the tree and results in root starvation. Diseased trees may either decline slowly or collapse suddenly and then die. Trees suffering slow decline can recover if psylla density is low. The severity of the disease depends on the origin of the rootstock.

Natural enemies of psylla
Parasitoids: Tiny parasitic wasp, Inostemma apsyliae
Predators: Ladybird beetle, pirate bug, lacewings etc.,

*For management refer to page number 26

6) Aphid:
Biology:

**Egg:** Fecundity of one female varies from 25 to 115 eggs.

**Nymph:** Nymphal period lasts 8-12 days, including 4 molts. Though smaller than adults, nymphs resemble the wingless forms in shape. Nymphs are green, the last instar having five to seven pairs of white spots on the back of its abdomen.

**Adult:** Females live 9-25 days. Adult lives openly, forming big colonies. These soft-bodied, pear-shaped insects have antennae which are shorter than their bodies and a pair of cornicles (tailpipe-like appendages). They may be winged or wingless but the wingless forms are most common. The aphid has a dark green to black body between 2 and 2.6 mm long with white appendages.

Life cycle:

![Life cycle of Aphid](http://www.brisbaneinsects.com/brisbane_softbugs/CowPeaAphid.htm)


**Damage symptoms:**

- The pest is a polyphagous species.
- The aphids injure plant especially strongly.
- Insects populate young slender shoots and leaves. These leaves become yellow and dry up.
- Damaged plants do not produce flowers and bolls. The species transfers dangerous virus diseases.
  - At high density of aphids the yield may be decreased by 18-50%.

*For management refer to page number 25*

7) Root-knot nematode and spiral nematode

Amongst nematodes infesting phalsa the root-knot nematodes (*Meloidogyne incognita, M. javanica and M. arenaria*) and spiral nematode (*Helicotylenchus Sp.*) are the most serious pests. Characteristic symptoms of infestation by root-knot nematodes are formation of galls or knots on roots, yellowing of leaves, stunting and eventual wilting of the affected plants.

**Biology:**

- Most species of plant parasitic nematodes have a relatively simple life cycle consisting of the egg, four larval stages and the adult male and female.
- They are microscopic in size.
- Development of the first stage larvae occurs within the egg where the first moult occurs. Second stage larvae hatch from eggs to find and infect plant roots or in some cases foliar tissues.
Under suitable environmental conditions, the eggs hatch and new larvae emerge to complete the life cycle within 4 to 8 weeks depending on temperature.

Nematode development is generally most rapid within an optimal soil temperature range of 70 to 80°F.

The disease is most serious on light, sandy soils and in furrow irrigated areas. Attack by nematodes may greatly increase the severity of bacterial, *Fusarium* and *Verticillium* wilt diseases.

**Life cycle:**

Life stages are microscopic in size.

1. Eggs
2. Larvae
   - Infective (J2) juveniles
3. Adults
   - Male (longer): 16-22 days
   - Female (bulged): 25-30 days

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**Damage symptoms:**

- Infected plants in patches in the field
- Formation of galls on host root system is the primary symptom
- Roots branch profusely starting from the gall tissue causing a ‘beard root’ symptom
- Infected roots become knobby and knotty
- In severely infected plants the root system is reduced and the rootlets are almost completely absent. The roots are seriously hampered in their function of uptake and transport of water and nutrients
- Plants wilt during the hot part of day, especially under dry conditions and are often stunted
- Planting materialslings infected in nursery do not normally survive transplanting and those surviving have reduced flowering and fruit production
- Nematode infection predisposes plants to fungal and bacterial root pathogens

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2. [http://nematology.umd.edu/rootknot.html](http://nematology.umd.edu/rootknot.html)
Survival and spread:

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

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

Favourable condition
- Infected volunteer plants
- Monocultures
- Weeds in fields
- Warm temperatures and moist but well-aerated sandy soils
Continuous growing of susceptible fruit crops (no rotation)

*For management refer to page number 23

Natural Enemies of Phalsa Insect Pests

Parasitoids

Egg Parasitoids

1. *Trichogrammatoidea australicum*
2. *Trichogramma perkinsi*

Larval parasitoid

3. *Apanteles flavipes*
Nymphal and adult parasitoids

4. *Leptomastix dactylopii*  
5. Tiny parasitic wasp  
6. *Inostemma apsyllae*

1. http://www.nbaii.res.in/Introductions/images/  
5. http://bugguide.net/node/view/205018/bgimage  
**Predators**

1. *Chilomenes sexmaculatus*  
2. *Rodolia fumida*  
3. *Cryptolaemus montrozieri*

4. *Stethorus punctillum*  
5. Staphylinid beetle  
6. Cecidomyiid fly

7. Lacewing  
8. Spider  

10. Mirid bug  
11. Hover fly  
12. Predatory mite

13. *Feltiella minuta*  
14. Weaver ant
### IX. DESCRIPTION OF DISEASES

#### 1) Leaf spot/brown spot:

**Disease symptoms:**
- The disease is caused by fungus *Cercospora grewiae*.
- The brown spot of phalsa is quite wide spread in the Punjab and is very severe from June to August. It results in premature leaf-fall when the attack is severe.
- The disease first appears as tiny lesions on the upper and lower surface of the leaf. In the beginning, these lesions are covered with a white mass of fungus. Gradually, the lesions enlarge and become reddish brown to dark brown.
- Many times, several lesions coalesce to form big spots which are very conspicuous and may cover a large part of the leaf.

**Survival and spread:**
- The pathogen is seed borne fungus and inoculums present in the seeds are source of primary infection.
- Fungus also survives on fruit and plant debris.

**Favourable conditions:**
- Rains or mists accompanied by cooler nights during flowering are congenial for the disease spread.

*For management refer to page number 26*

#### 2) Rust:

**Disease symptoms:**
- The disease appears in the form of yellow to light brown colour postules having uredospores.
- The severely affected leaves start drying followed by defoliation

http://pdmis.dacnet.nic.in/FruitCropPestReport.aspx
**Survival and spread:**
- Fungus survives in dead twig and other host for long time which is the source of primary infection.

**Favourable conditions:**
- High humidity, frequent rains and a temperature of 24-32°C favours the development of disease.

*For management refer to page number 26

3) *Phylllosticta* hole:

**Disease symptoms:**
- The disease is caused by *phylllosticta grewiae*.
- The disease can appear any time during the growing season of phalsa and may cause considerable damage to the foliage.
- Small brown to dark brown, circular to irregular pin spot like lesions appear on the leaves.

**Survival and spread:**
- Pathogens survive in plant debris which is the source of primary inoculums.

**Favourable conditions:**
- High humidity and moist conditions favours the development of disease. The disease is most common in October-November.

*For management refer to page number 26

**Disease cycle:**

1. Rust:

![Diagram of disease cycle]
X. DESCRIPTION OF RODENT PESTS

1) Lesser bandicoot:

**Distribution and identification:**

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

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

**Damage symptoms:**

Mostly damage occurs at fruiting stage. Bandicoots cut the raw and ripened fruits and hoard them in their burrows.

![Lesser bandicoot image]

2. House rat:

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

![House rat image]

3. Soft furred field rat:

- Distributed in Punjab, Uttar Pradesh southwards to western and southern India, also finds in foothills of eastern Himalayas. Found mostly in semi arid areas.
- Small rodent (40-60gm) with soft fur, dorsum light grey and bicolored tail equal to the head and body.
• It is associated with *T. indica* and *Mus boodga* in northern part and with *Bandicota bengalensis* in southern part.
• Nocturnal and fossorial with simple burrows.
• Found majorly in rain-fed paddy and rice-sugarcane ecosystem.

### XI. SAFETY MEASURES

**A. At the time of harvest**

For uniform ripening of phalsa fruits, apices of shoots may be pinched in mid-May to check further shoot growth. Fruits start ripening in the first week of June and continue for a month. The fruits should be picked when the colour has changed to deep reddish brown and the pulp tastes sweet. Several pickings are necessary as all the fruits do not ripen at one time. The fruit-picking is usually done on alternate days. Fruits are packed in small baskets of size 2kg or in packs. Phalsa fruit is perishable in nature, hence should be transported to the market soon after harvesting.

**B. During post-harvest storage**

Being highly perishable, the fruit must be utilized within 24 hours after picking. The popularity of phalsa fruit is due to its attractive colour ranging from crimson red to dark purple and its pleasing taste. The juice when extracted gives a deep crimson red to dark purple colour and is very popular. It is rated very high in indigenous system of medicine. The juice is extremely refreshing and is considered to have a cooling effect especially in hot summer. Heating the crushed phalsa fruit to 50°C gives the highest recovery of the juice with an appropriate quantity of anthayanin and other soluble and insoluble materials. Studies have shown that addition of cane sugar to the juice has a protective effect on colour stability.
## XII. DO’S AND DON’TS

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Do’s</th>
<th>Don’ts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Deep ploughing is to be done on bright sunny days during the months of May and June. The field should be kept exposed to sun light at least for 2-3 weeks.</td>
<td>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.</td>
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<tr>
<td>2.</td>
<td>Grow only recommended varieties.</td>
<td>Do not grow varieties not suitable for the season or the region.</td>
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<td>3.</td>
<td>Plant early in the season</td>
<td>Avoid late planting as this may lead to reduced yields and incidence of diseases.</td>
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<tr>
<td>4.</td>
<td>Always treat the planting material with approved chemicals/biopesticides for the control of planting materials borne diseases/pests.</td>
<td>Do not use planting material without planting materials treatment with biopesticides/chemicals.</td>
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<tr>
<td>5.</td>
<td>Plant in rows at optimum depths under proper moisture conditions for better establishment.</td>
<td>Do not plant planting materials beyond 5-7 cm depth.</td>
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<tr>
<td>6.</td>
<td>Apply only CIBRC recommended pesticides against a particular pest at the recommended dose, at the right time, with right methods with standard equipments e.g. Flat-fan or flood jet nozzles for herbicides.</td>
<td>Non-recommended pesticides should not be applied in the Orchard field.</td>
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<tr>
<td>7.</td>
<td>Maintain optimum and healthy tree plant stand.</td>
<td>Orchard plants should not be exposed to moisture deficit stress at their critical stages.</td>
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<td>8.</td>
<td>Use NPK fertilizers as per the soil test recommendation.</td>
<td>Avoid imbalanced use of fertilizers.</td>
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<td>9.</td>
<td>Use micronutrient mixture after sowing based on soil test recommendations.</td>
<td>Do not apply any micronutrient mixture after sowing without soil test recommendations.</td>
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<tr>
<td>10.</td>
<td>Conduct weekly AESA in the morning preferably before 9 a.m. Take decision on management practice based on AESA and P: D ratio only.</td>
<td>Do not take any management decision without considering AESA and P: D ratio</td>
</tr>
<tr>
<td>11.</td>
<td>Install pheromone traps at appropriate period.</td>
<td>Do not store the pheromone lures at normal room temperature (keep them in refrigerator).</td>
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<tr>
<td>12.</td>
<td>Release parasitoids only after noticing adult moth catches in the pheromone trap or as pheromone trap or as per field observation.</td>
<td>Do not apply chemical pesticides within seven days of release of parasitoids.</td>
</tr>
<tr>
<td>13.</td>
<td>Apply NPV 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.</td>
<td>Do not apply NPV on late instar larva and during day time.</td>
</tr>
<tr>
<td>14.</td>
<td>In case of pests which are active during night, spray recommended biopesticides/chemicals at the time of their appearance in the evening.</td>
<td>Do not spray pesticides at midday since, most of the insects are not active during this period.</td>
</tr>
</tbody>
</table>
15. Spray pesticides thoroughly to treat the undersurface of the leaves for aphids, mealybugs 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 fruit crop technology. | Do not apply long persistent pesticides on trap fruit crop; otherwise it may not attract the pests and natural enemies.

XVI. References

- http://tnau.ac.in/eagri/eagri50/ENTO331/lecture30/lec030.pdf
- http://bugguide.net/node/view/12234#life_cycle
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