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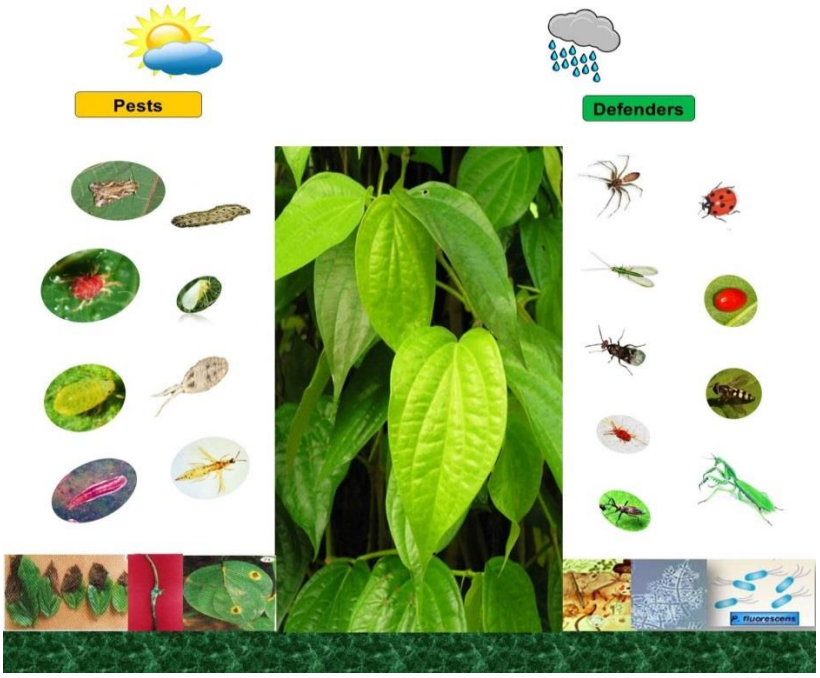
AESA BASED IPM PACKAGE

BETELVINE



Directorate of Plant Protection, Quarantine and Storage
N. H.-IV, Faridabad, Haryana

National Institute of Plant Health Management
Rajendranagar, Hyderabad, Telangana

Department of Agriculture and Cooperation
Ministry of Agriculture
Government of India

The AESA based IPM – Betelvine, 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.

NIPHM Working Group:

Chairman : Dr. Satyagopal Korlapati, IAS, Director General
Vice-Chairmen : Dr. S. N. Sushil, Plant Protection Advisor

: Dr. P. Jeyakumar, Director (PHM)

Core Members :

1. Er. G. Shankar, Joint Director (PHE), Pesticide Application Techniques Expertise.
2. Dr. O. P. Sharma, Joint Director (A & AM), Agronomy Expertise.
3. Dr. Satish Kumar Sain, Assistant Director (PHM), Pathology Expertise.
4. Dr. Dhana Raj Boina, Assistant Director (PHM), Entomology Expertise.

Other members

5. Dr. N. Srinivasa, Assistant Director (RPM), Rodent Expertise.
6. Dr. B. S. Sunanda, Assistant Scientific Officer (PHM), Nematology Expertise.

Contributions by DPPQ&S Experts:

1. Shri. Ram Asre, Additional Plant Protection Advisor (IPM),
2. Dr. K. S. Kapoor, Deputy Director (Entomology),
3. Dr. Sanjay Arya, Deputy Director (Plant Pathology),
4. Dr. Subhash Kumar, Deputy Director (Weed Science)
5. Dr. C. S. Patni, Plant Protection Officer (Plant Pathology)

Contributions by External Experts:

1. Dr. V. K. Kalra HOD (Entomology), CCS Haryana Agricultural University, Hisar-125004, Haryana
2. Director of Research, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur
3. Director of Research, Navsari Agricultural University, Eru Char Rasta, Dandi Road, Navsari-396450 (Gujarat)
4. Director of Research, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli-415712, Dist-Ratnagiri.
5. Directorate of Experiment Station, G. B. Pant University of Agriculture & Technology Pantnagar-263145, Dist. Udham singh Nagar (Uttarakhand, India)
6. Dr. S. K. Panda, Professor & Head, Department of Entamology, College of Agriculture, Odhisha University of Agriculture & Technology, Bhubaneswar-751003
7. Dr. K. C. Sahu, Professor & Head, Department of Plant pathology, College of Agriculture, Odhisha University of Agriculture & Technology, Bhubaneswar-751003
8. Dr. S.N. Mohapatra, Professor & Head, Department of Nematology, College of Agriculture, Odhisha University of Agriculture & Technology, Bhubaneswar-751003

9. Dr. Jayalaxmi Ganguli, Asst. Professor (Entomology), IGKV, Raipur (CG) 492 012
10. Dr. Narendra Lakpale, Asst. Professor, (Plant Pathology) IGKV, Raipur (CG) 492 012.
11. Director of Research, SKUASST, Kashmir, Shalimar-190025

अपर सचिव
भारत सरकार
कृषि मंत्रालय
(कृषि एंव सहकारिता विभाग)
कृषि भवन, नई दिल्ली-110001

सत्यमेव जयते

Avinash K Srivastava
Additional Secretary
Government of India
Ministry of Agriculture
(Department of Agriculture
& Cooperation)
Krishi Bhawan, New Delhi - 110001

FOREWORD

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

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

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

A K Srivastava

Date: 6.3.2014

(Avinash K. Srivastava)

संयुक्त सचिव
भारत सरकार
कृषि मंत्रालय
(कृषि एवं सहकारिता विभाग)
कृषि भवन, नई दिल्ली- 110001

सत्यमेव जयते

Joint Secretary
Government of India
Ministry of Agriculture
(Department of Agriculture & Coopera
Krishi Bhawan, New Delhi-110001

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)

Dr.K. SATYAGOPAL IAS
Director General
Telephone : +91-40- 24015346,
E-mail : dgniphm@nic.in
Tele-Fax : +91-40- 24015346,

National Institute of Plant Health Management
Department of Agriculture & Cooperation
Ministry of Agriculture
Government of India

Rajendranagar,
Hyderabad- 500030.
http://niphm.gov.in

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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Vc AESA BASED IPM PACKAGE FOR BETELVINE

Betel vine-plant description:

The betel (*Piper betle* L.; Family: Piperaceae) is the leaf of a vine which includes pepper and kava. Botanical name of betel vine is *Piper betel*. In India, it is known as 'pan'. Betel vine is a perennial, dioecious, evergreen climber that is grown in tropics and subtropics for its leaves that are used as a chewing stimulant. It is a spreading vine, rooting readily where trailing stems touch the ground. The betel plant is an evergreen and perennial creeper, with glossy heart-shaped leaves and white catkin. The leaves are alternate, entire, 5 to 10 cm long and 3 to 6 cm across. The flowers are small, produced on pendulous spikes 4 to 8 cm long at the leaf nodes, the spikes lengthening up to 7 to 15 cm as the fruit matures.

I. PESTS

A. Pests of national significance:

1. Insect Pests

1.1 Scale insect: *Lepidosaphes ulmi* L. (Hemiptera: Diaspididae)

1.2 Betelvine bug: *Disphinctus politus* Walk. (Hemiptera: Miridae)

1.3 Mealy bug: *Ferrisia virgata* Cockerell (Hemiptera: Pseudococcidae)

1.4 Whitefly: *Dialeurodes pallida* Singh (Hemiptera: Aleyrodidae)

1.5 Red spider mites: *Tetranychus* Dufour (Arachnida: Tetranychidae)

2. Diseases

2.1 Leaf stem and foot rot: *Phytophthora* spp.

2.2 Leaf spot or anthracanose: *Colletotrichum capsici* (Syd.) E.J. Butler & Bisby

2.3 *Sclerotial* wilt or collar rots: *Sclerotium rolfsii* Sacc.

2.4 Powdery mildew: *Oidium piperis* Uppal, Kamat & Patel

2.5 Bacterial leaf spot: *Xanthomonas campestris* Dowson Nematodes

3. Nematodes:

3.1 Root-knot nematodes: *Meloidogyne incognita* Kofoid & White (Tylenchida: Heteroderidae)

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

4. Weeds

Broad leaf

4.1 Yellow sweet clover: *Melilotus indica* (L.) All. (Fabaceae)

4.2 Lambs quarter: *Chenopodium album* L. (Chenopodiaceae)

4.3 Creeping Thistle: *Cirsium arvense* (L.) Scop (Asteraceae)

4.4 Batthal: *Launea nudicaulis* (L.) Hook.f. (Asteraceae)

4.5 Joyweed: *Alternenthera sessiles* (L.) R.Br. *ex* DC. (Amaranthaceae)

4.6 Creeping wood sorrel: *Oxalis corniculata* L. (Oxalidaceae)

4.7 Punarnava: *Boerhavia diffusa* L. (Nyctaginaceae)

4.8 Common puruselene: *Portulaee oleraceae* L. (Portulacaceae)

4.9. Common sorrel: *Rumex dentatus* L. (Polygonaceae)

4.10 Horse purslane: *Trianthema portulacastrurn* L. (Aizoaceae)

Grasses

4.11 Bermuda grass: *Cynodon dactylon* L. (Poaceae)

4.12 Blue grass: *Poa annua* L. (Poaceae)

Sedges

4.13 Nut grass*: Cyperus rotundus* L. (Cyperaceae)

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

5. Rodents

5.1 Lesser bandicoot: *Bandicota bengalensis* Gray

5.2 Black rat: *Rattus rattus* L.

B. Pests of regional significance

1. Insect pests

1.1 Black fly*: Aleurocanthus woglumi* Singh (Hemiptera: Aleyrodidae)

1.3 Thrips: *Thrips tabaci* L. (Thysanoptera: Thripidae)—West Bengal

1.4 Aphids: *Aphis gossypii* Glover (Hemiptera: Aphididae)-West Bengal

1.5 Yellow mite: *Hetnyersonemus lotus* -West Bengal

2. Diseases

2.1 Fusarium wilt: *Fusarium solani* (Mart.) Sacc- West Bengal

3. Nematodes

2.1 Stunt nematodes: *Tylenchorhynchus* sp- Bihar

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. insect 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 Integrated Pest Management (IPM):

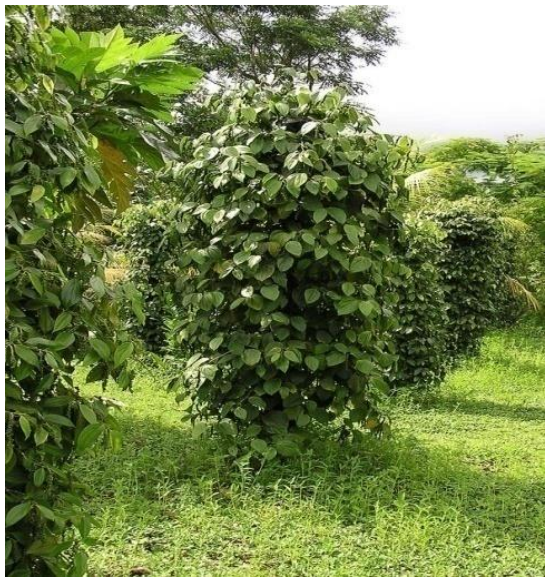
Grow a healthy crop:

- Select healthy seeds/seedlings/planting materials
- Select a variety resistant/tolerant to major pests
- Treat the seeds/seedlings/planting materials 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

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

Farmers should:

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



Plant compensation ability:

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

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 vineyard 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).

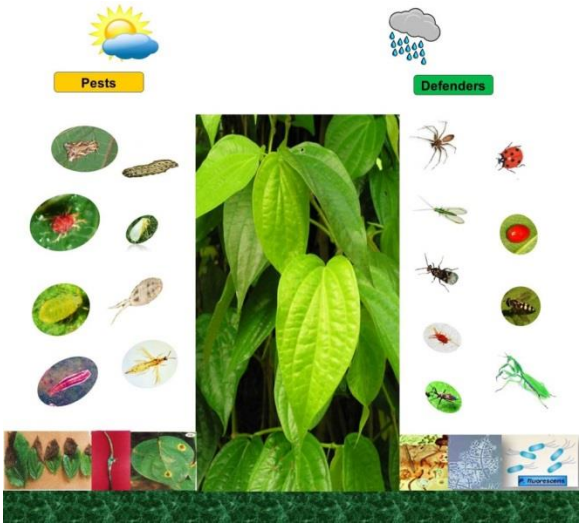
Pest: Defender ratio (P: D ratio):

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 betelvine insect pests can be divided into 3 categories 1. parasitoids; 2. predators; and 3. pathogens.

Model Agro-Ecosystem Analysis Chart

Date:
Village:
Farmer:



Decision taken based on the analysis of vineyard situations

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

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

Decision making:

Farmers become experts in crop management:

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

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

AESA methodology

- Go to the vineyard 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.
    - Insect pests: Observe and count the insect pests at different places on the plant.
    - Defenders (natural enemies): Observe and count parasitoids and predators.
    - Diseases: Observe leaves and stems and identify any visible disease symptoms and severity.
    - 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 conditions.
- While walking in the vineyard, 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 conditions, water level, disease symptoms, etc. will be shown in the drawing. Pest insects will be drawn on one side. Defenders (beneficial insects) will be drawn on another side. Write the number next to each insect. Indicate the plant part where the pests and defenders were found. Try to show the interaction between pests and defenders.
- Each group will discuss the situation and make a crop management recommendation.
- The small groups then join each other and a member of each group will now present their analysis in front of all participants.
- The facilitator will facilitate the discussion by asking guiding questions and makes sure that all participants (also shy or illiterate persons) are actively involved in this process.
- Formulate a common conclusion. The whole group should support the decision on what field management is required in the AESA plot.
- Make sure that the required activities (based on the decision) will be carried out.

- Keep the drawing for comparison purpose in the following weeks.

Data recording

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

- Keep records of what has happened, help us making an analysis and draw conclusions.

Data to be recorded

- **Plant growth (weekly):** Length of plant; number of leaves
- **Crop situation (e.g. for AESA):** Plant health**;** pests, diseases, weeds**;** natural enemies**;** soil condition**;** irrigation**;** weather conditions
- **Input costs:** Seeds**;** fertilizer**;** pesticides**; I**abour
- **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 insect 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 insect 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.

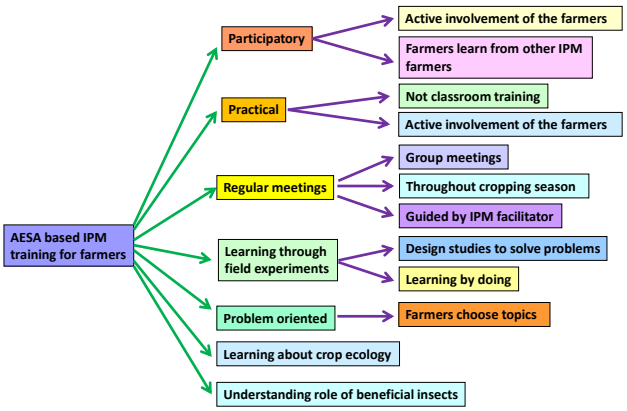
AESA and farmer field school (FFS)

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 this exercise. However, other farmers also can do field scouting in their own fields at regular intervals to monitor the major pest situation.

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

For insect pests:

Whitefly, mites aphids, mealybug: 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 seedling and flowering stages of plant growth. Observe for the symptoms and signs on the infected plant parts. Determine the percent area of leaf infection by counting the number of leaves (leaf area diameter)/plant infected due to disease and incidence should be recorded.

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

D. Yellow pan water/blue sticky traps

Set up yellow pan water traps 15 cm above the canopy for monitoring whiteflies and aphids and blue sticky traps for thrips @ 4-5 traps/acre. Locally available empty tins can be painted yellow/blue and coated with grease/ Vaseline/castor oil on outer surface may also be used as yellow sticky trap. Count the number of whiteflies, aphids and thrips on the traps daily and take up the intervention when the population exceeds 100 per trap.

F. Nematode extraction

Collect 200-300 g representative soil sample. Mix soil sample and pass through a coarse sieve to remove pieces of stones, roots, etc. Take a 600 cc subsample of soil, pack lightly into a beaker uniformly. Place soil in one of the buckets or pans half filled with water. Mix soil and water by stirring with paddle; allow to stand until water almost stops swirling. Pour all but heavy sediment through 20-mesh sieve into second bucket; discard residue in first bucket; discard material caught on sieve. Stir material in second bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 60-mesh sieve 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, lacewing, earwigs, etc.

Plants suitable for Ecological Engineering for Pest Management

Attractant plants

Cowpea

Carrot

Sunflower

Buckwheat

French bean

Alfalfa

Mustard

Cosmos

Anise

Caraway

Dill

Parsley

White Clover

Tansy

Papaya

Marigold

Crotolaria

Sow thistle

Sinapis arvensis

Sinapis alba

Bitter gourd

Bindweed

Brassica rapa

Jatropa

Repellent plants

***Ocimum* sp**

Peppermint/Spearmint

Barrier plant

Rye grass

Border plants

Maize

Sorghum

Trap plants

Castor

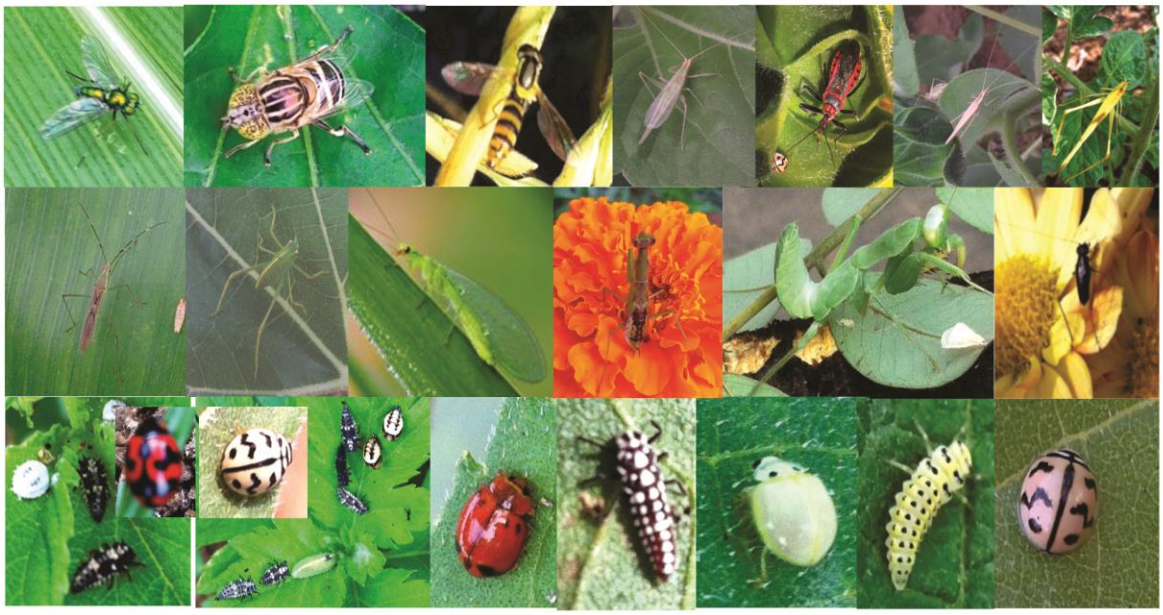
Marigold

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.

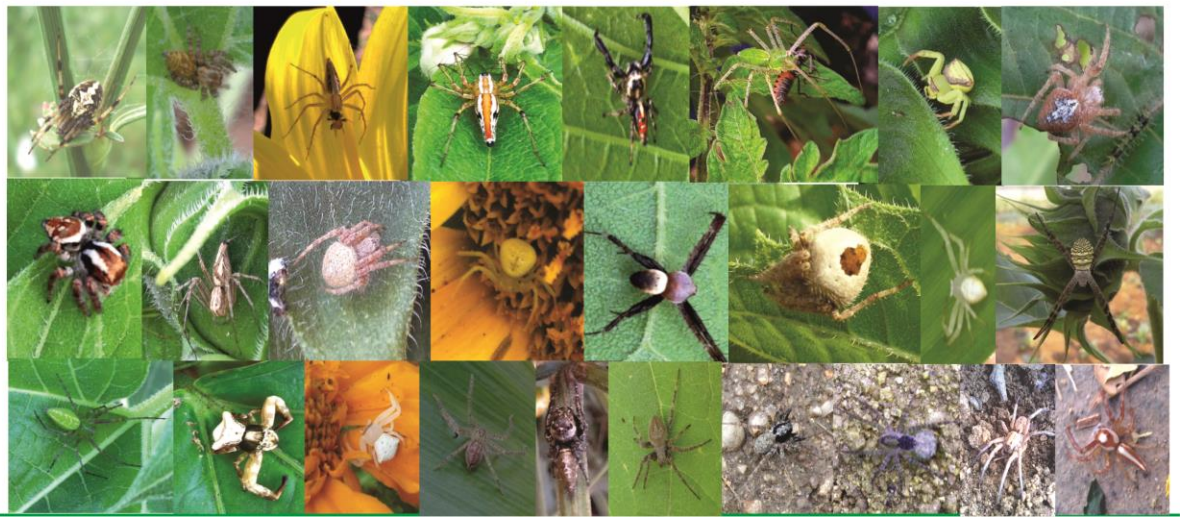
Biodiversity of natural enemies observed in Ecological Engineering field at NIPHM

Biodiversity of natural enemies: Parasitoids

Biodiversity of natural enemies: Predators



Biodiversity of natural enemies: Spiders



IV: CROP STAGE WISE IPM

Stage wise Management	Activity
Pre-planting/Nursery stage*	
	Common cultural practices: • Deep ploughing of fields during summer to manage nematodes population, to expose pupae, propagules of soil borne pathogens and weeds before establishment of the vineyard • Soil solarization is advocated before the establishment of new garden for better plant stand and to minimize initial disease inoculum levels for nematodes and resting stages of insects, diseases and weeds. . • Planting should be done timely and adopt proper spacing, irrigation and fertilizer management. Avoid application of high nitrogenous fertilizer. • Field sanitation • Adopt ecological engineering by growing the attractant, repellent, and trap crops around the field bunds
Nutrients	• Apply farmyard manure @ 10 tons per acre as basal dressing in the last ploughing. The land is laid out into ridges and furrows 45 cm apart and irrigation channels formed at convenient places. • In saline and alkaline soils, apply gypsum @ 1.0 ton per acre and plough the field before sowing live standards.
Weeds	• Destroy all the weeds from planting area after deep ploughing during summer. • Remove all the perennial weds and their rhizomes/suckers before onset of monsoon.
Soil and seed borne pathogens, Nematodes	**Cultural control:** • Trimming of field bunds will destroy the existing rodents. **Mechanical control:** • The affected cutting along with defoliated leaves should be removed from nursery and destroyed. **Biological control:** • To boost the crop use neem cake @ 40 Kg/acre under assured moisture condition in nematode infested field only.
Planting*	
Nutrients	• Apply nutrients based on soil test report and recommendation for the zone. In general, apply 60 kg N/acre/year 50 percent through Neem cake and 50 % through Urea. • Apply 40 kg P_2O_5 and 20 kg K_2O at the time of planting.
Weeds	• Ploughing and levelling of field before setting up of betelvine bareja as well as standing crop. • Drip irrigation should be adopted to reduce weed problem. Drip irrigation produce significantly maximum vine elongation, number of branches and of leaves per ha. • Follow the recommended agronomic management practices of land preparation, plant spacing, fertilizer and

<table>
<tr><td></td><td>irrigation etc. to have healthy plants stand.

• Care should be taken to avoid direct contact of fertilizers with the roots of betelvine.</td></tr>
<tr><td>Nematodes, and soil borne disease</td><td><u>Cultural control:</u>
• Select healthy and disease free planting materials.
• Use resistant tolerant varieties.
• The incidence of diseases viz., Foot rot can be reduced by application of drip irrigation.
• In open type of shorter duration of 2-3 years the desirable cropping sequence has to be worked to minimize the population of soil borne pathogens
• Neem cake @ one Kg/pit may be mixed with the mixture at the time of planting.</td></tr>
<tr><td colspan="2">Note: Apply Trichoderma viride/harzianum and Pseudomonas fluorescens as seed 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).</td></tr>
<tr><td colspan="2">Vegetative</td></tr>
<tr><td></td><td><u>Common cultural practices:</u>
• Provide irrigation at critical stages of the crop
• Avoid water stress and water stagnation conditions.
• Enhance parasitic activity by avoiding chemical spray, when larval parasitoids are observed

• The soil used for earthing up should be either sun dried or disinfested by chemical.
<u>Common mechanical practices:</u>
• Collection and destruction of visible eggs, and larvae of inset pests.
• Collect and destroy diseased and insect infected plant parts
• Use yellow sticky traps for aphids and whitefly and blue sticky traps for thrips @ 4-5 traps/acre.
• 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.</td></tr>
<tr><td>Nutrients</td><td>Table 1. Fertilizers requirement of betelvine
<table><tr><th rowspan="2">Time of application</th><th>N</th><th>P</th><th>K</th></tr><tr><th colspan="3">(kg/acre)</th></tr><tr><td>Basal dressing</td><td>15</td><td>40</td><td>20</td></tr><tr><td>Top dressing @ 3 split doses</td><td>45</td><td>0</td><td>0</td></tr><tr><td>Total</td><td>60</td><td>40</td><td>20</td></tr></table>• Apply N as top dressing @ 45 kg / acre in three split doses first at 15 days after lifting the vines while second and third dose at 40 - 45 days intervals as mentioned in Table 1.
• The manures and fertilizers are applied around the vine at a distance of 30 cm from the base and incorporated into the soil.</td></tr>
</table>

Weeds	• Pull out weeds before flowering by 2-3 rounds of hand tool weeding. • Slash weeding is a cost-effective method and to keep a cover always over the soil. • Mulching with dry/green leaves or organic matter @ 10 Kg should be given to control weed growth and to prevent sun scorching of young vines during summer. • Mulching by black polyethylene sheet or organic matter between the rows be adopted to manage the weeds.
Phytophthora* foot rot, *Sclerotial* wilt or collar rot or *Fusarial* wilt*	**Cultural control:** • Removal and destruction of dead vines along with root system from the garden is essential as this reduces the build up of inoculum (fungal population). • Planting material must be collected from disease free gardens and the nursery preferably raised in fumigated or solarized soil. • Adequate drainage should be provided to reduce water stagnation. • Injury to the root system due to cultural practices such as digging should be avoided. • The freshly emerging runner shoots should not be allowed to trail on the ground. They must either be tied back to the standard or pruned off. • The branches of support trees must be pruned at the onset of monsoon to avoid build up of humidity and for better penetration of sunlight. • Reduced humidity and presence of sunlight reduces the intensity of leaf infection. **For foot rot:** **Chemical control:** • Copper oxychloride 50% WP @ 1 Kg in 300-400 l of water/acre
Leaf spot or anthracanose	**Cultural control:** • Eradication of affected vine from vineyard. • Apply phytosanitation process. • Irrigation by rose can.
Powdery mildew	**Cultural control:** • Cultural practices that reduce humidity within the vineyard, enable good air circulation through the canopy, and provide good light exposure to all leaves and clusters aid in managing powdery mildew. • Use an under vine irrigation system and manage it carefully, excess can favour the disease
Bacterial leaf spot	**Cultural control:** • Collecting and burning the infected plant parts minimizes the spread of the disease. • Increase air circulation in the vineyard. • Remove disease cane from the vineyard during normal pruning operations in the dormant season. • Follow up hand pruning.
Thrips**	**Cultural control:** • The recommendation on shade management, if adopted, will help to

	prevent the excessive built up of thrips and mites • Regular field assessment **<u>Biological control:</u>** • See common practices.
Aphids**	**<u>Cultural control:</u>** • Reflective mulches such as silver colored plastic can deter aphids from feeding on plants. • Sturdy plants can be sprayed with a strong jet of water to knock aphids from leaves • For other follow common practices. **<u>Biological control:</u>** • See common biological practices.
Mealy bug	**<u>Cultural control:</u>** • Removal of weeds and alternate host plants like hibiscus, bhindi, custard apple, guava etc in and nearby vineyards throughout the year. • Deep ploughing in summer or raking of soil in vineyards helps to destroy its nymphal stages and minimizing the incidence. **<u>Biological control:</u>** • Release exotic predator, *Cryptolaemus montrouzieri* @ 10 beetles/vine. **<u>Physical control:</u>** • Detrash the crop on 150 and 210 DAP.
Scale insects	**<u>Cultural control:</u>** • Initiate control measures during early stages of pest infestation. • Select scale free seed vines. • For other follow common practices. **<u>Biological control:</u>** • In nurseries spraying neem oil 0.3 per cent or fish oil rosin 3.0 per cent is also effective in controlling the pest infestation. • Conserve the natural enemies.
Whitefly	**<u>Cultural control:</u>** • Field sanitation and rogueing of alternate hosts. • A regularly maintained program of hedging and topping can help avoid whitefly problems • For others see common practices. **<u>Biological control:</u>** • See common biological practices.
Spike formation/flowering stage	
Nutrients	• Apply deficient micronutrient if any.
Weeds	• Left over weeds may be removed before shedding of their seeds.
Leaf spot, powdery mildews	• Same as in vegetative stage.
Mites (red and yellow)**	**<u>Cultural control:</u>** • The recommendation on shade management, if adopted, will help to prevent the excessive built up of mites • Grow nurseries away from infested crops and avoid planting next

	to infested fields • Apply mulch and incorporate organic matter into the soil to improve the water holding capacity and reduce evaporation • Keep perennial hedges such as pigeon peas, they are said to encourage predatory mites • Uproot and burn infested plants. This can be successful during the early stages of infestation when the mites concentrate on a few plants • Keep the field free of weeds • Remove and burn infested crop residues immediately after harvest **Biological control:** • Conserve the natural enemies.
Betelevine bugs, black fly**	**Mechanical control:** • See common practices.
Aphids, Thrips, Whitefly, Mealybugs	• Same as vegetative stage.

Note: The dosages of pesticides usage are based in high volume sprayer.

****Regional pests**

V. RODENT PEST MANAGEMENT

Small bandicoot, Black rat:	**Cultural control:** • Practice clean cultivation/maintain weed free orchards which reduces the harboring/hiding points for rodents. • Practice trapping with locally available traps using lure @ 20-25 traps/ac. In areas, where bandicoot is a problem, wonder traps/multi-catch traps work better and enable to trap more animals in a single trap. • Identify live rodent burrows and smoke the burrows with burrow smoker for 2-3 minutes • Erect owl perches @ 12-15/ac to promote natural control of rodents **Chemical control:** • 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 orchards, orchard 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.

VI. INSECTICIDE RESISTANCE AND ITS MANAGEMENT

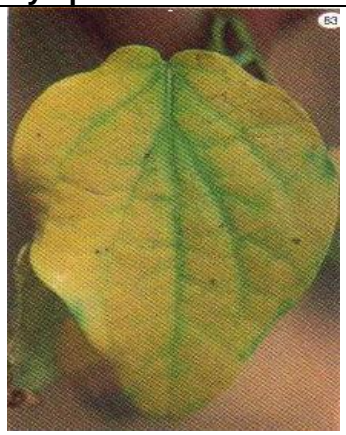
Insecticide resistance: Resistance to insecticides may be defined as ‘a heritable change in the sensitivity of a pest population that is reflected in the repeated failure of a product to achieve the expected level of control when used according to the label recommendation for that pest species’ (IRAC). 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. Nutrient deficiencies

Nutrient	Symptoms
Nitrogen Deficiency: Reduced plant growth with yellowish green to yellow leaves. Lower leaves senesces and drop. Apply N as top dressing as per recommended dose. Apply 2 % urea as foliar spray.	 http://www.indiakisan.net/web/pest/betelvine/betp24dtinf_system.jsp
Chloride Toxicity: It can be prominently seen when betelvine crop is grown in salty soils or when water containing high salt level is used for irrigation.	

VIII. Common weeds

 **1. Batthal: *Launea nudicaulis* (L.) Hook.f. (Asteraceae)**	 **2. Creeping wood sorrel: *Oxalis corniculata* L. (Oxalidaceae)**	 **3. Joyweed: *Alternenthera sessiles* (L.) R.Br. *ex* DC. (Amaranthaceae)**

		
4. Punarnava: *Boerhavia diffusa* L. (Nyctaginaceae)	**5. Common puruselene: *Portulaee oleraceae* L. (Portulacaceae)**	**6. Lambs quarter: *Chenopodium album* L. (Chenopodiaceae)**
		
7. Horse purslane: *Trianthema portulacastrurn* L. (Aizoaceae)	**8. Common sorrel: *Rumex dentatus* L. (Polygonaceae)**	**9. Yellow sweet clover: *Melilotus indica* (L.) All. (Fabaceae)**
		
10. Creeping Thistle: *Cirsium arvense* (L.) Scop (Asteraceae)	**14. Bermuda Grass: *Cynodon dactylon* (L.) Pears.(Poaceae)**	**15. Blue grass: *Poa annua* L. (Poaceae)**

		
16. Flat sedge: *Cyperus iria* L. (Cyperaceae)	**17. Purple nutsedge: *Cyperus rotundus* L. (Cyperaceae)**	

IX. DESCRIPTION OF INSECT, MITES AND NEMATODES PESTS

1. Scale insect:

Biology:

- Scales have unusual life cycles.
- The eggs are laid underneath the waxy covering and hatch over a period of one to three weeks.
- The newly hatched scales (called crawlers) move about over the plant until they locate succulent new growth.
- They insert their piercing-sucking mouthparts into the plant and begin feeding. Female scales lose their legs and antennae during the first molt.
- They molt a second time before reaching maturity and do not pupate.
- The cast skins (exuviae) are incorporated in the scale cover.
- Male scales go through two additional molts and pupate underneath the wax. Adult males are tiny two-winged, gnat-like insects without mouthparts.
- *Lepidosaphes* is small, dark, boat shaped.

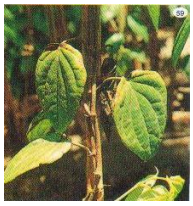
***Lepidosaphes* sp.**

1,2:
https://www.google.co.in/search?q=scale+insect+of+black+pepper&espv=210&es_sm=122&tbm=isch&tbo=u&source=univ&sa=X&ei=RTgYU7mXB8SFrQePj4HwAg&ved=0CDoQsAQ&biw=1242&bih=585#facrc

Damage symptoms:

Both nymph and adults infest the leaves, petioles and main veins. The scale infested leaves loose their colour, exhibit warty appearance, crinkle and dry up ultimately. The affected vines

present a sticky appearance and wilt in due course.



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

https://www.google.co.in/search?q=encarsia+formosa&espv=210&es_sm=122&source=lnms&tbm=isch&sa=X&ei=LjcYU6qQG8bnrAfI1oDAAQ&ved=0CAkQ_AUoAQ&biw=1242&bih=585#facrc=_&imgdii=_&imgrc=PHem7BhlBs6FMM%253A%3BHkcuogaJYUpWJM%3Bhttp%2

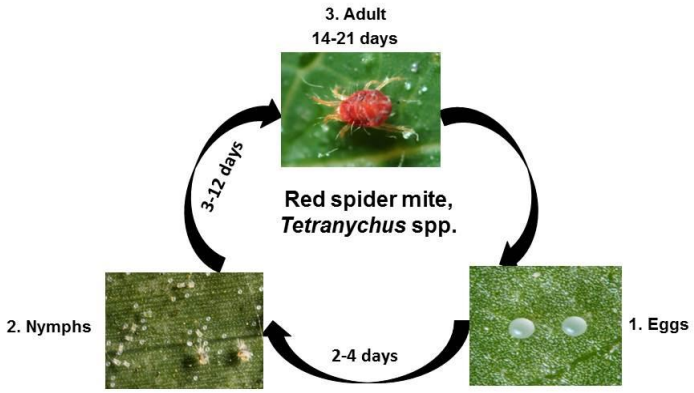
Natural enemies of scales:

Parasitoids: *Encarsia citrine*, *Aphytis* sp.
Predators: *Bdella* sp*. Aleurodothrips jasciatus, Karnyothrips melaleucus, Chilocorus circumdatus, C. nigrita, Pharoscymnus horn; Pseudoscymnus, Lacewings, mirids, Pytoseiids* beetles
*For the management refer page no……..

2. Red spider mite:

Biology:

Egg: Eggs are reddish, spherical, provided with a small filament. Incubation period is 4-6 days, before hatching becomes light orange colour.
Nymph: Upon hatching, it will pass through a larval stage and two nymphal stages before becoming adult. Developmental stages include six legged larva, protonymph and deutonymph.
Adult: Adult female is elliptical in shape, bright crimson anteriorly and dark pruplish brown posteriorly. Mites spin a web of silken threads on the leaf. Each developmental stage is followed by a quiescent stage and life cycle completed in 10-14 days.
Life cycle:



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

Damage symptoms:

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

Natural enemies of mites:

Predators: Anthocorid bugs (*Orius* spp.), mirid bugs, syrphid/hover flies, green lacewings (*Mallada basalis* and *Chrysoperla zastrowi sillemi*), predatory mites (*Amblyseius alstoniae*, *A. womersleyi, A. fallacies* and *Phytoseiulus persimilis*), predatory coccinellids (*Stethorus punctillum*), staphylinid beetle (*Oligota* spp.), predatory cecidomyiid fly (*Anthrocnodax occidentalis*), predatory gall midge (*Feltiella minuta*), spiders etc.

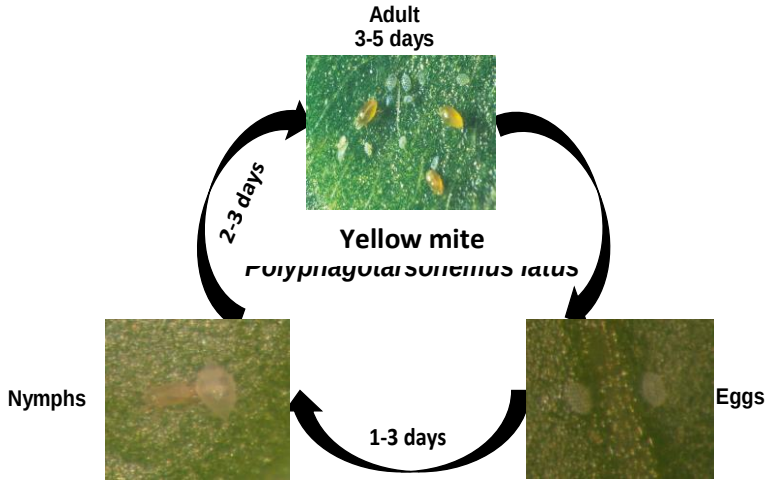
*For the management refer page no……..

3. Yellow mite:

Biology:

- **Egg:** Eggs are oval shaped large, obovate, flattened at the bottom and white in colour. Eggs are glued firmly on the leaf surface and hatches after 27-32 hours
- **Nymph:** Nymphs white in colour.
- **Adult:** Adults large, oval and broad and yellowish in colour. Females are yellowish and bigger than the males and they carrying the “female nymphs” on their back.

Life cycle:



Damage symptoms:

- Mite is seen on young leaves especially the top two to three leaves and the bud.
- Affected leaves become rough and brittle and with corky lines.
- Downward curling.

- Internodes get shortened

*For management refer to page number----------
Predators same as red spider mite.

4. Thrips:

Biology:

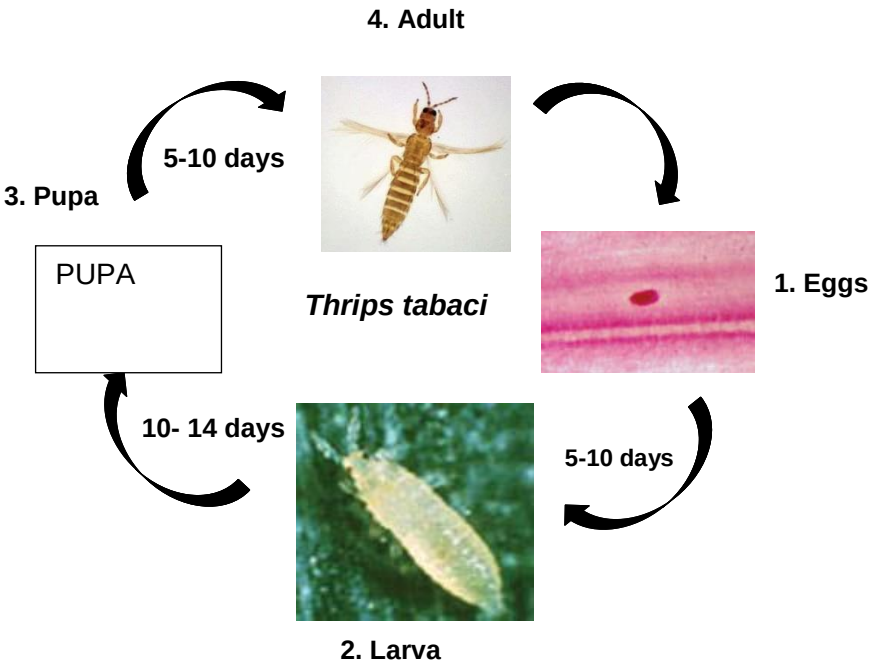
Egg: White to yellow, kidney-bean shaped, microscopic in size. Develop within leaf tissue with one end near the leaf surface. Egg stage is 5-10 days.

Larva: Instars I and II are active, feeding stages. White to pale yellow, elongate and slender body. Resemble adult, but without wings. Antennae are short and eyes are dark in color. Feed on new leaves in the center of the onion neck. Crawl quickly when disturbed. Larval stage is 10-14 days.

Pre-pupa and pupa: Instars III and IV are inactive, non-feeding stages called pre-pupa and pupa. Pale yellow to brown; body more stout than younger instars. Antennae are bent to head; wing buds are visible. Found in the soil, at the base of the onion plant neck, or underneath bulb scales. Lasts 5-10 days.

Adult: About 1.5 mm long; elongate, yellow and brown body with two pairs of fringed (hairy) wings. Mouthparts are beak-like and antennae are 7-segmented. Spend the winter in protected sites under plants and debris in onion, alfalfa and small grain fields, and other plant habitats. In the spring when temperatures warm, adults fly to new onion fields. Parthenogenic (asexually reproducing) females; males are extremely rare. Feed on young leaves in center of onion neck and insert eggs individually into leaves. Fly readily when disturbed. Adult life span is about 1 month; pre-oviposition period (time before egg-laying begins) is 1 week and females will lay eggs for about 3 weeks.

Life cycle:



1,2,4. http://extension.usu.edu/files/publications/factsheet/ENT-117-08PR.pdf

Damage symptoms:

Thrips prefer to feed on the newly emerged leaves. Under crowded conditions, they will move toward leaf tips to feed. Both adult and larval thrips feed within the mesophyll layer using a punch-and suck motion. The beak and mandible is thrust forward to puncture the leaf epidermis and sap released from injured plant cells is sucked up. Removal of chlorophyll causes the feeding area to appear white to silvery in color. Areas of leaf injury can occur as patches and streaks. When feeding injury is severe, leaves take on a silvery cast and can wither. Tiny black "tar" spots of thrips excrement are evident on leaves with heavy feeding injury.

Natural enemies of thrips:
Parasitoids: *Ceranisus menes* (nymph).
Predators: Syrphid flies, minute pirate bug/anthocorid bug (*Blaptosthethus* sp, *Buchananiella whitei, Orius tantilus*), praying mantis, predatory thrips (*Aeolothrips fasciatum*), damsel bug, lace wings, coccinellids (*Menochilus sexmaculatus*), spiders etc.

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

5. Shoot bug

Biology:

- The adult is reddish brown bug. It thrusts its eggs singly within the tender plant parts. Egg period 8 - 16 days. Fecundity 72 eggs/female. Nymphal period 12 - 18 days. The incidence of this pest is severe in June to October.

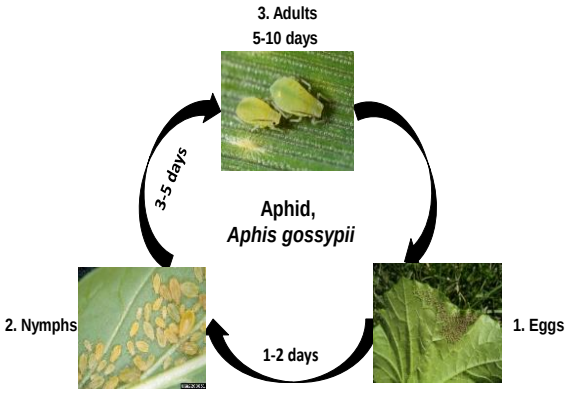
Damage symptoms:

- Both nymph and adults suck the sap from the tender leaves causing leaf blotches leading to ultimate drying.

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

6. Aphids:

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



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

Damage symptoms:

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

Natural enemies of aphids:

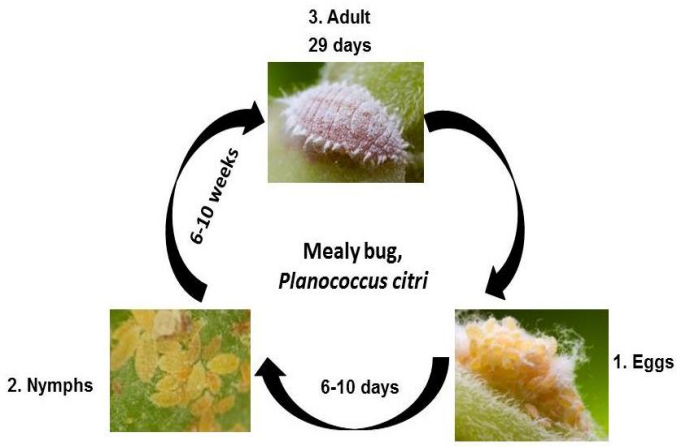
Parasitoids: *Aphelinus* spp. *Aphytis* spp., *Diaeretiella rapae*
Predators: Ladybird beetles viz., *Coccinella septempunctata, Menochilus sexmaculatus, Hippodamia variegata* and *Menochilus vicina*, Syrphid fly: *Sphaerophoria* spp., *Eristallis* spp., *Metasyrphis* spp., *Xanthogramma* spp. and *Syrphus* spp.Lacewing: *Chrysoperla zastrowi sillemi*, Aphid midge: *Aphidoletes aphidimyza*, Predatory bird: *Motacilla cospica*
Entomopathogenic fungi : *Cephalosporium* spp., *Entomophthora* and *Verticillium lecanii*

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

7. Mealybug

Biology:

Egg: Eggs are deposited as white cottony masses called ovisacs. The glossy, light yellow eggs are oval and approximately 0.3 mm long. A female lay 300 to 600 eggs in a life period, which are deposited in groups of 5 to 20.
Nymph: Nymphs emerge from the ovisacs and typically settle along midribs and veins on the underside of leaves and young twigs. Wax and honeydew secreted by crawlers are visible indicators of infestations. The nymphs are yellow, oval-shaped with red eyes, and covered with white waxy particles The female nymphs resemble the adult female in appearance, while male nymphs are more elongated. Female nymphs have four instars.
Adult: Adult size ranges in length from 3 mm (females) to 4.5 mm (males). The females are wingless, white to light brown in color, with brown legs and antennae. The body of adult females is coated with white wax and bears a characteristic faint gray stripe along their dorsal side. Short waxy filaments can be seen around the margins of their oval body with a slightly longer pair of filaments present at the rear end of their body.
Life cycle:



1.http://www.alexanderwild.com/keyword/planococcus%20citri/2. http://cals.arizona.edu/crops/citrus/photos/figure21.jpg\

Damage symptoms:

- Young plants – susceptible for heavy infestation.
- Infest tender branches, nodes, leaves, spikes, berries and roots
- Both nymphs and adults suck the sap from the leaves.
- Severe infestation - Chlorotic leaves, aborted flower buds and small berries
- Honey dew excrete – development of sooty mould fungus (affects photosynthesis)

http://agritech.tnau.ac.in/crop_protection/crop_prot_crop_insectpest%20Coffee.html#7

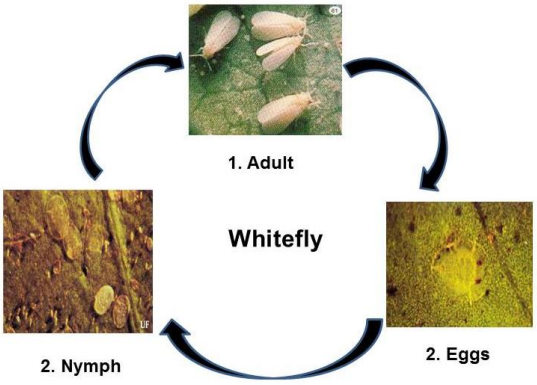
Natural enemies of mealybugs:
Parasitoid: *Leptomastix dactylopii* etc.
Predators: Ladybird beetle *Cryptolaemus montrouzieri*, spider, reduviid etc.
*For the management refer page no….

8. Whitefly:

Biology:
Egg: The whitefly lays yellow eggs with a nearly smooth surface, distinguishing them from eggs of the cloudy winged whitefly, which are yellow when freshly laid, but soon turn black and have a surface that is netted with a system of ridges.
Nymph: The nymph is a flat, elliptical, scale-like object, closely fastened to the underside of a leaf. It becomes fixed after the **first** molt. The nymphs, after the first instar, are flattened, oval, and are similar in appearance to the early instars of the unarmored scale insects.

Like the scale insects, whiteflies lose their normal legs and antennae after the first molt (they are kept, but are abbreviated), but unlike the scale insects, the females gain them back in the adult stage.
The nymphs of the whitefly lack a fringe of conspicuous, white, waxy plates or rods extending out from the margin of the body, which characterizes some species of whiteflies. Nymphs of both species are translucent, oval in outline, and very thin. Because the green color of the leaf shows through the body, nymphs are difficult to see. Pupae are similar but are thickened and are somewhat opaque, and eye spots of the developing adult may show through the pupal skin.
Adult: The adult is a tiny, mealy-white insect with four mealy-white wings that expand less than 1/8 of an inch. The adults of both sexes have two pairs of wings covered with a white, powdery wax which gives the insects their common name. In the middle of each wing, cloudy winged whitefly adults have a darkened area which is lacking in the wings of the whitefly, and the wings fold to a flatter position than those of the whitefly.

Life cycle:



1,2,3: http://entnemdept.ifas.ufl.edu/creatures/citrus/citrus_whitefly.htm

Damage symptoms:
Both nymph and adults suck the sap from the tender leaves causing yellowing, chlorotic spots and shooty mould development on leaves.

Natural enemies of whitefly:
Parasitoids: *Cryptognatha* spp. (egg), *Encarsia* sp, *Eretmocerus* sp, *Chrysocharis pentheus* (nymphal)
Predators: Mirid bug (*Dicyphus hesperus*), dragonfly, spider, Ladybird beetle, lacewings, mites, ants, and a species of thrips, *Aleurodothrips fasciapennis.*

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

9. Root-knot nematode:

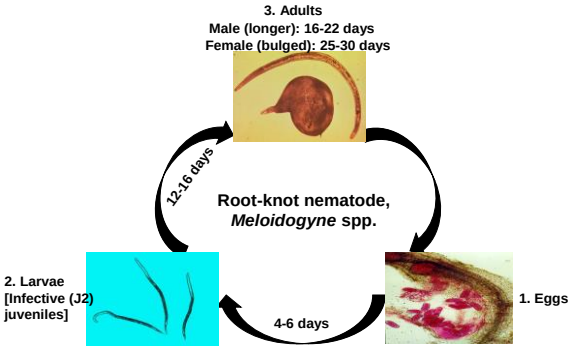
Biology:

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

foliar tissues.

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

Life cycle:



1.http://keys.lucidcentral.org/keys/sweetpotato/key/Sweetpotato%20Diagnotes/Media/Html/TheProblems/Nematodes/RootKnotNematode/Root-knot.htm
2. http://nematology.umd.edu/rootknot.html
3. http://www.cals.ncsu.edu/pgg/dan_webpage/Introduction/Images/pyroform.htm

Damage symptoms:

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

Survival and spread:

Primary: Egg masses in infected plant debris and soil or collateral and other hosts like Solonaceous, Malvaceous and Leguminaceous plants act as sources of inoculums.
Secondary: Autonomous second stage juveniles that may also be water dispersed.
Favourable conditions:
Loamy light soils.

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

Natural Enemies of Betelvine Insect and Mite Pests

Parasitoids

Nymphal/larval and adult parasitoids

9. *Chrysocharis* sp

10. *Aphidius*

11. *Encarsia formosa*

12. *Aphytis* sp..

13. *Aphelinus*

14. *Ceranisus menes*

2 http://www.pbase.com/image/135529248
3 http://baba-insects.blogspot.in/2012/02/telenomus.html
4 http://www.nbaii.res.in/Featured%20insects/chelonus.htm
6 http://www.organicgardeninfo.com/ichneumon-wasp.html
7 http://72.44.83.99/forum/viewthread.php?thread_id=40633&pid=178398
8. http://www.nbaii.res.in/Featured%20insects/Campoletis.htm
9 http://baba-insects.blogspot.in/2012/05/blog-post_21.html
10 http://biobee.in/products-and-services/solutions/bio-aphidius/
11 http://www.buglogical.com/whitefly-control/encarsia-formosa/
12 http://www.dongbufarmceres.com/main/mboard.asp?strBoardID=c_product01_en

13 http://australianmuseum.net.au/image/Aphelinus-wasp-stings-aphid-Denis-Crawford/
14 http://biocontrol.ucr.edu/hoddle/avocadothrips.html

Predators

1. Lacewing

2. Ladybird beetle

3. Reduviid bug

4. Spider

5. Robber fly

6. Fire ant

7. Black drongo

8. Common mynah

9. Big-eyed bug

10. Earwig

11. Ground beetle

12. Pentatomid bug

13. Preying mantis

14. Predatory mite

15. Predatory thrips

16. Bdella

17. *Oligota* spp.

18. *Orius* spp.

19. Hover fly

20. Mirid bug

21. Chilocorrus sp **22. *Cybocephalus* sp.**

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

X. DESCRIPTION OF DISEASES

1. Leaf stem and foot rot:

Disease symptoms:

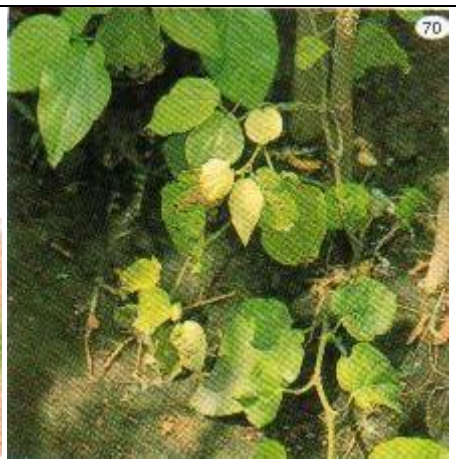
- Most destructive fungal disease that produces both a wet rot symptom on leaves and wilting due to foot rot.
- At first circular, dark brown spots appear which become wet and rot under continuous high humid conditions
- Otherwise dark brown necrotic spots with alternate light brown zonations appear.
- Loss of lustre of the leaves in the foot rot condition followed by total wilting and drying of the vines occur in a quick sequence
- Root system of the affected plant is damaged. Lateral roots are completely destroyed. Disease occurs mostly in patches and the vines wilt and die. In a week's time, 80 to 90 per cent of the vines wilt and die.

Survival and spread:

- Fungus survives in disease plant debris as well as soil. These vines may recover after the rains and survive for more than two seasons till the root infection culminates in collar rot and death of the vine.

Favourable conditions:

- Rains during July onwards favour the development of disease.



http://mrgoutham.blogspot.in/2011/05/betelvine-disease-gallery_23.html

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

2. Leaf spot or anthracnose:

Disease symptoms:

- Leaf spots are irregular in shape and size, light to dark brown surrounded by diffuse chlorotic yellow halo.
- Marginal leaf tissue becomes black, necrotic and gradually spreads towards the leaf centre.
- Occasionally diffused yellow halo also develops.
- In the anthracnose stage circular, black lesions that occur rapidly increase in size and girdle the stem culminating in the death of the vine.

Survival and spread:

- The primary infection by sowing infected seeds and secondary by wind.

Favourable conditions:

- Rain and high humidity are responsible for the development of disease.

Disease symptoms:


1. 2. 3.

1: http://mrgoutham.blogspot.in/2011/05/betelvine-disease-gallery_23.html
2,3: http://www.indiakisan.net/web/pest/betelvine/betp16dtinf_system.jsp

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

3. *Fusarium* wilt:

Disease symptoms:

- Plants show the yellowing of leaves and wilts gradually. Often sudden wilting and drying up entire plant takes place. Vascular discoloration of plant.

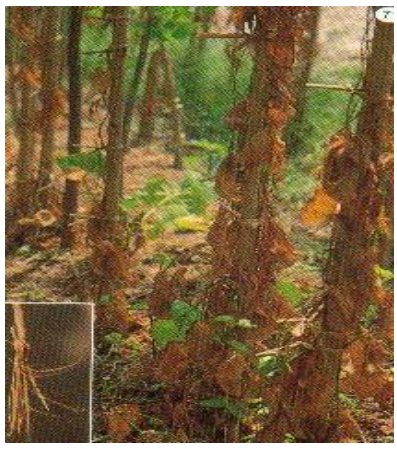
Survival and spread:

- Chlamydospores survive in soil, conidia spread through irrigation water.
- Secondary infection by conidia through rain or wind

Favourable conditions:

- High temperature and high relative humidity favour the development of disease.

Disease symptoms:



http://www.indiakisan.net/web/pest/betelvine/ANSadv_system_dises.jsp?defectid=2&qid=156

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

4. Sclerotial wilt or collar rot:

Disease symptoms:

- Darkening of the stem at the foot of the plant, near ground level. The leaves turn yellow, become flaccid and droop off.
- Ultimately the whole vine wilts and dries up.
- The darkened portion of the stem becomes shrinked , soft and turn black.
- On the affected stem portion, white ropy fan shaped mycelial strands developed.
- Brown to dark brown sclerotia appears on the infected portion

Survival and spread:

- Disease is soil borne and pathogen survives in soil which is the source of primary infection.

Favourable conditions:

- The disease is mainly noticed in nurseries during June- September and is caused by *Sclerotium rolfsii.*

Disease symptoms:

1. 2.

1,2: http://www.indiakisan.net/web/pest/betelvine/betp16dtinf_system.jsp

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

5. Powdery mildew or Basal rot:

Symptoms:

- White to light brown powdery patches appears on lower surface of the leaves, later these increases in size.
- Early leaf infection appears as light grey spots which gradually enlarge and soon powdery mass of fungal growth covers the lower surface of the leaf.
- Under ideal conditions both the leaf surface gets covered by the white floury mass of fungal growth resulting in early leaf fall.

Survival and spread:

- The fungus survives in the form of a resting mycelium or encapsulated haustoria in the crop debris.
- Secondary spread occurs through wind borne conidia.

Favourable conditions:

- Cool weather coupled with mild temperature favour the development of disease.

Disease symptoms:

http://www.indiakisan.net/web/pest/betelvine/betp16_2dtinf_system.jsp

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

6. Bacterial leaf spot/Bacterial stem rot:

Disease symptoms:

- Minute water soaked lesions appear on all over the leaf blade which delimited by veins.
- These coalesce to form large irregular brown spots.
- The affected leaves defoliate prematurely.

http://www.indiakisan.net/web/pest/betelvine/betp18dtinf_system.jsp

Survival and spread:

- The pathogens survive in soil, Bacteria spread through irrigation water.

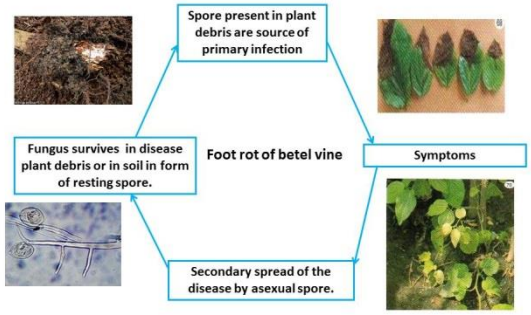
Favourable conditions:

- High temperature and high relative humidity favour the development of disease.

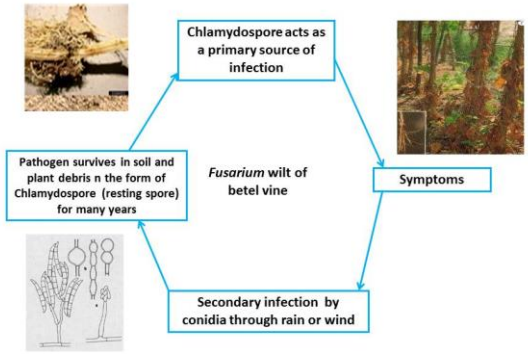
*For management refer to page number----------

Disease cycle:

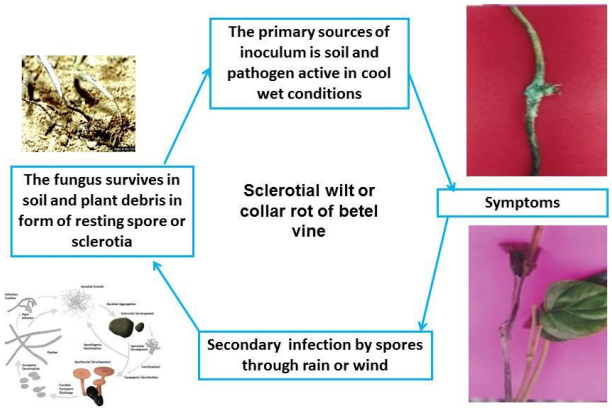
1. **Foot rot:**



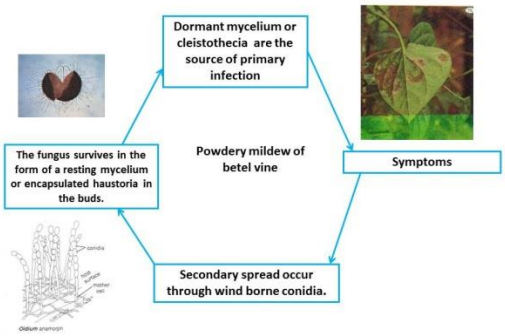
2. ***Fusarium* wilt:**



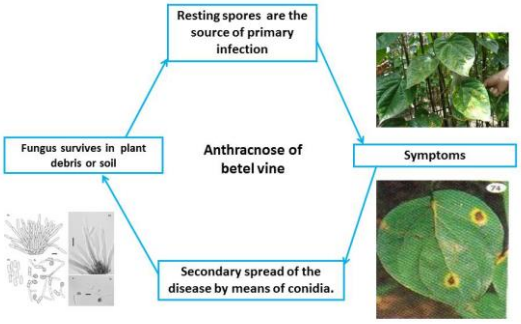
3. **Sclerotial wilt or collar rot:**



4. Powdery mildew:



5. Anthracnose:



XI. SAFETY MEASURES

A. During pre-harvest:

As vines reach to a certain height, leaves are harvested from the lower portion of the stem. Harvesting is done during March–April in Uttar Pradesh, Madhya Pradesh and Bihar, during May–June in Andhra Pradesh; during January–February or April–May in Tamil Nadu. Mature leaves are plucked along with a portion of petiole. They are plucked by hand. In Karnataka and Tamil Nadu, leaves are plucked from side shoots. In south India, comparatively tender leaves are preferred in the market. After plucking, they are washed thoroughly and made into bundles according to the prevailing custom of the area. On an average, 60–80 lakh leaves are harvested annually from one hectare plantation.

B. During post-harvest:

Harvested leaves are washed, cleaned and graded according to their size and quality. Then they are packed after cutting a portion of the petiole and rejecting the damaged leaves. The picked leaves are sorted into different grades according to size, colour,

texture and maturity. After that, they are arranged in numbers for packing. For packing mostly bamboo baskets are used and in many places straw, fresh or dried banana leaves, wet cloth etc. are used for inner lining. Usually betel leaves are used for chewing as fresh unprocessed. But in certain areas, leaves are subjected to processing known as bleaching or curing. There is a good, demand for such leaves which fetch higher prices in the markets. Bleaching is done by successive heat treatments at 60°–70°C for 6–8hr.

XII. DO'S AND DON'TS IN IPM

S. No.	Do's	Don'ts
1.	Deep ploughing is to be done on bright sunny days during the months of May and June. The field should be kept exposed to sun light at least for 2-3 weeks	Do not plant or irrigate the field after ploughing, at least for 2-3 weeks, to allow desiccation of weed's bulbs and/or rhizomes of perennial weeds.
2.	Grow only recommended varieties.	Do not grow varieties not suitable for the season or the region.
3.	Sow early in the season	Avoid late sowing as this may lead to reduced yields and incidence of white grubs and diseases.
4.	Always treat the seeds with approved chemicals/bio products for the control of seed borne diseases/pests.	Do not use seeds without seed treatment with biocides/chemicals.
5.	Sow in rows at optimum depths under proper moisture conditions for better establishment.	Do not sow seeds beyond 5-7 cm depth.
6.	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.
7	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.
8.	Use NPK fertilizers as per the soil test recommendation.	Avoid imbalanced use of fertilizers.
9	Use micronutrient mixture after sowing based on test recommendations.	Do not apply any micronutrient mixture after sowing without test recommendations.
10.	Conduct AESA weekly in the morning preferably before 9 a.m. Take decision on management practice based on AESA and P: D ratio only.	Do not take any management decision without considering AESA and P: D ratio
11	Install pheromone traps at appropriate period.	Do not store the pheromone lures at normal room temperature (keep them in refrigerator).
12	Release parasitoids only after noticing adult moth catches in the pheromone trap or as pheromone trap or as per field observation	Do not apply chemical pesticides within seven days of release of parasitoids.

13	Spray pesticides thoroughly to treat the undersurface of the leaves.	Do not spray pesticides only on the upper surface of leaves.
14	Apply short persistent pesticides to avoid pesticide residue in the soil and produce.	Do not apply pesticides during preceding 7 days before harvest.
15	Follow the recommended procedure of trap crop technology.	Do not apply long persistent on trap crop, otherwise it may not attract the pests and natural enemies.

XIII. BASIC PRECAUTIONS IN PESTICIDES USAGE

A. Purchase

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

B. Storage

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

C. Handling

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

D. Precautions for preparing spray solution

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

E. Equipment

1. Select right kind of equipment.

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

F. Precautions for applying pesticides

1. Apply only at recommended dose and dilution
2. **Do not** apply on hot sunny day or strong windy condition; **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

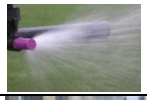
G. Disposal

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.

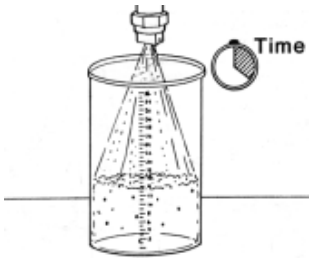
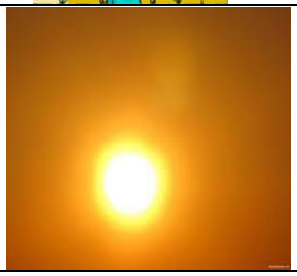
XIV PESTICIDE APPLICATION TECHNIQUES

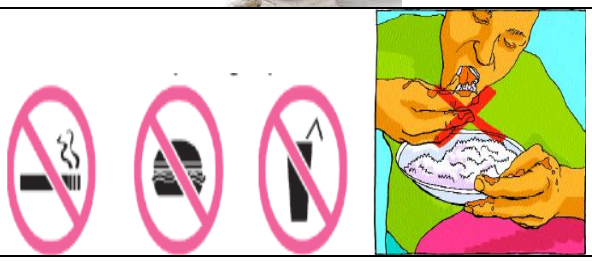
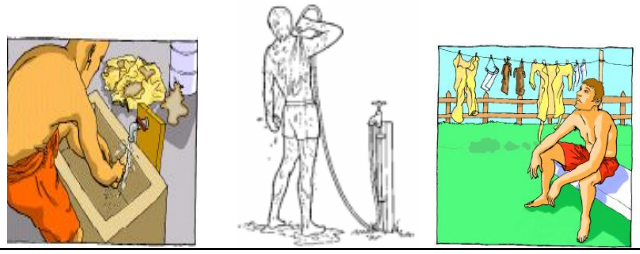
<table>
<tr><td colspan="4">Equipment</td></tr>
<tr><td colspan="4">Category A: Stationary, crawling pest/disease</td></tr>
<tr><td rowspan="2">Vegetative stage
i) for crawling and soil borne pests

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>  </td></tr>
</table>

Reproductive stage	Insecticides and fungicides	• Lever operated knapsack sprayer (Droplets of big size) • Hollow cone nozzle @ 35 to 40 psi • Lever operating speed = 15 to 20 strokes/min	
Category B: Field flying pest/airborne pest			
Vegetative stage Reproductive stage *(Field Pests)*	Insecticides and fungicides	• Motorized knapsack sprayer or mist blower (Droplets of small size) • Airblast nozzle • Operating speed: 2/3rd throttle ***Or*** • Battery operated low volume sprayer (Droplets of small size) Spinning disc nozzle	   
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)	  

XV. 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 **proper bath with soap** after completing spraying	
9.	Do not blow the nozzle with mouth for any blockages. Clean with water and a soft brush.	

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