सत्यमेव जयते

AESA BASED IPM PACKAGE BLACK PEPPER

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 – Black pepper, was compiled by the NIPHM working group under the Chairmanship of Dr. Satyagopal Korlapati, IAS, DG, NIPHM, and guidance of Shri. Utpal Kumar Singh 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.
5. Sri. D Chattopadhyaya, Assistant Director (PHM), Pathology 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. H. Narayanaswamy, Professor of Pathology, COA, Shimoga
2. Dr. C. M. Kalleshwaraswamy, Assistant Professor, COA, Shimoga.
3. Dr. Poonam Srivastava, Dept of Entomology, G.B. Pant University of Agriculture & Technology, Pantnagar
4. Dr. K. P. Singh, Dept of Plant Pathology, G.B. Pant University of Agriculture & Technology, Pantnagar
5. Dr. B. R. Patel, Professor & Head (Ento) C.P. College of Agriculture, S.D. Agriculture University, Sardarkrushinagar-385506
6. Dr. Surajit Khalko, Assistant professor (Plant pathology), Uttar Banga Krishi Viswavidyalaya Cooch Behar, West Bengal
7. Dr. Nripendra Laskar, Asst. Professor (Ento), Uttar Banga Krishi Viswavidyalaya Cooch Behar, West Bengal
8. Dr. Ayon Roy, Associate Professor (Plant Pathology), Uttar Banga Krishi Viswavidyalaya Cooch Behar, West Bengal
9. Prof. Tapan Kumar Hath, Prof (Ento), Uttar Banga Krishi Viswavidyalaya Cooch Behar, West Bengal

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 & Cooperati
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)

CONTENTS

AESA BASED IPM PACKAGE FOR BLACK PEPPER

Black pepper (*Piper nigrum* L.; Family: Piperaceae) is a flowering vine cultivated for its fruit, which is usually dried and used as a spice and seasoning. The pepper plant is a perennial woody vine growing up to 4 metres (13 ft) in height on supporting trees, poles, or trellises. It is a spreading vine, rooting readily where trailing stems touch the ground. 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. The fruit of the black pepper is called a drupe and when dried it is a peppercorn. The fruit, known as a peppercorn when dried, is approximately 5 millimetres (0.20 in) in diameter, dark red when fully mature, and, like all drupes, contains a single seed. Peppercorns, and the ground pepper derived from them, may be described simply as pepper, or more precisely as black pepper (cooked and dried unripe fruit), green pepper (dried unripe fruit) and white pepper (unripe fruit seeds).

Pepper is native to South Asia and Southeast Asia and has been known to Indian cooking since at least 2 BCE. Black pepper is native to south India confined in Kerala state, and is extensively cultivated there and elsewhere in tropical regions. Currently Vietnam is the world's largest producer and exporter of pepper, producing 34% of the world's *Piper nigrum* crop as of 2008.

Dried ground pepper has been used since antiquity for both its flavor and as a medicine. Black pepper is the world's most traded spice. It is one of the most common spices added to European cuisine and its descendants. The spiciness of black pepper is due to the chemical piperine, not to be confused with the capsaicin that gives fleshy peppers theirs. It is ubiquitous in the modern world as a seasoning, and is often paired with salt.

I. PESTS

A. Pests of Major Significance

1. Insect Pests

1.1 Pollu beetle: *Lanka ramakrishnae* (*Longitarsus nigripennis)* Mots. (Coleoptera: Chrysomelidae)

1.2 Top shoot borer: *Cydia hemidoxa* Meyr. (Lepidoptera: Tortricidae)

1.3 Leaf gall thrips: *Liothrips karnyi* Bagnall (Thysanoptera: Phaleothripidae)

1.4 Mussel scale insects: *Lepidosaphes piperis* Gr.*; Aspidiotus destructor* Sign. (Hemiptera: Diaspididae)

2. Diseases

2.1 Foot rot /quick wilt disease: *Phytophthora capsici* Leonian

2.2 Pollu disease /Anthracnose: *Colletotrichum gloeosporioides* Penz. and Sacc.

2.3 Slow decline /slow wilt: (*Phytophthora capsici*-fungi; *Meloidogyne incognita* & *Radopholus similis* - nematodes)

3. Weeds

Broadleaf

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

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

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

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

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

3.6 Little mallow, (cheese weed): *Malva parviflora* F. (Malvaceae)

Grasses

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

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

Sedges

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

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

Parasitic

3.11 Dodder: *Cuscuta* spp. (Convolvulaceae)

4. Nematodes

4.1 Root-knot nematode: *Meloidogyne incognita* Kofoid & White (Tylenchida: Heteroderidae)

4.2 Burrowing nematode: *Radopholus similis* Cobb (Tylenchida: Pratylenchidae)

B. Pest of Minor Significance

1. Insect pests

1.1 Leaf feeding caterpillar: *Synegia* sp. (Lepidoptera: Geometridae)

1.2 Mealybugs: *Planococcus* sp. / *Pseudococcus* sp. (Hemiptera: Pseudococcidae)

1.3 Soft scale: *Marsipococcus marsupiale* Gr. (Hemiptera: Coccidae)

2. Diseases

2.1 Basal wilt in nurseries: *Sclerotium rolfsii* Sacc.

2.2 Leaf rot and leaf blight: *Rhizoctonia solani* Kuhn

2.3 Stunt disease: *Cucumber Mosaic Virus* and *Pepper Yellow Mottle Virus*

2.4 Phyllody disease: Phytoplasma like organism

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

A. AESA:

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

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

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

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

- Climatic factors
- Farmers past experience

Principles of AESA based IPM:

AESA will be taken in all stages of the crop

- Observe the soil physical condition, moisture level, etc.
- Take representative soil sample and get the soil analysis report showing soil pH, electrical conductivity (EC), organic matter and nutrient status.
- Observe the number and species of weeds found in per square meter area in three randomly selected spots/acre.

Grow a healthy crop:

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

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

Farmers should:

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

Understand and conserve defenders:

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

Insect zoo:

In field various types of insects are present. Some are beneficial and some may be harmful. Generally farmers are not aware about it. Predators (friends of the farmers) which feed on pests are not easy to observe in crop field. Insect zoo concept can be helpful to enhance farmers' skill to identify beneficial and harmful insects. In this method, unfamiliar/unknown predators are collected in plastic containers with brush from the field and brought to a place for study. Each predator is placed inside a plastic bottle together with parts of the plant and some known insect pests. Insects in the bottle are observed for certain time and determined whether the test insect is a pest (feeds on plant) or a predator (feeds on other insects).

Pest: Defender ratio (P: D ratio):

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

Model Agro-Ecosystem Analysis Chart

Date:
Village:
Farmer:

Decision taken based on the analysis of field situations

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

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

Decision making:

Farmers become experts in crop management:

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

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

AESA methodology:

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

Data recording:

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

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

Data to be recorded:

- **Plant growth (weekly):** Length of plant; Number of leaves
- **Crop situation (e.g. for AESA):** Plant health; Pests, diseases, weeds; Natural enemies; Soil conditions; Irrigation; Weather conditions
- **Input costs:** Seeds; Fertilizer; Pesticides; Labour
- **Harvest:** Yield (Kg/acre); Price of produce (Rs./Kg)

Some questions that can be used during the discussion:

- Summarize the present situation of the vineyard.
- What crop management aspect is most important at this moment?
- Is there a big change in crop situation compared to last visit? What kind of change?
- Is there any serious pest or disease outbreak?
- What is the situation of the beneficial insects?
- Is there a balance in the field between pests and defenders?
- Were you able to identify all pests and diseases?

- Do you think the crop is healthy?
- What management practices are needed at this moment?
- When will it be done? Who will do it? Make sure that responsibilities for all activities are being discussed.
- Are you expecting any problems to emerge during the coming week such as congenial weather conditions for pest buildup?
- What are the problems. How can we avoid it? How can we be prepared?
- Summarize the actions to be taken.

Advantages of AESA over ETL:

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

AESA and farmer field school (FFS):

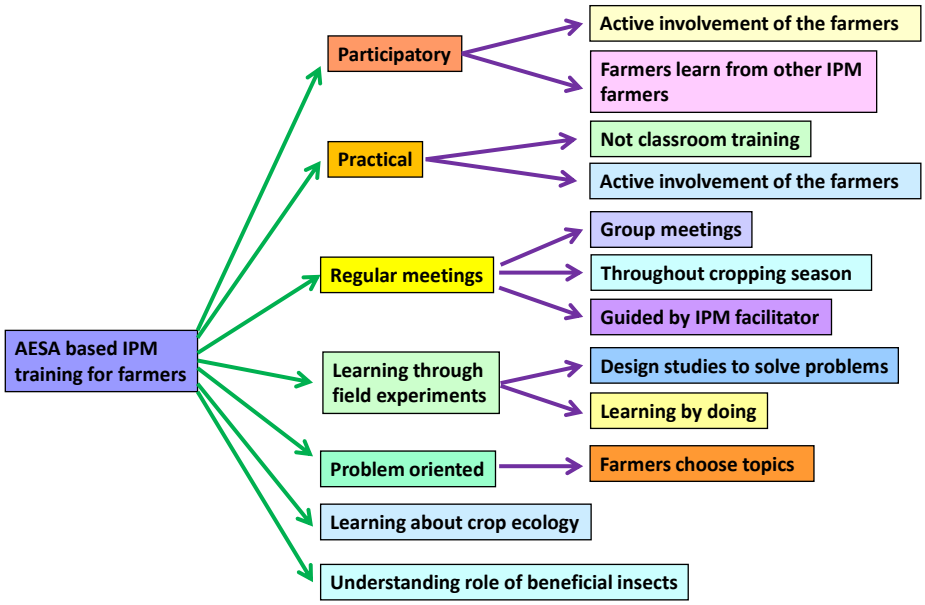
AESA is a season-long training activity that takes place in the farmer field. It is season-long so that it covers all the different developmental stages of the crop and their related management practices. The process is always learner-centered, participatory and relying on an experiential learning approach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

Farmers can learn from AESA:

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

- Role of natural enemies in pest management

FFS to teach AESA based IPM skills:



B. Field scouting:

AESA requires skill. So only the trained farmers can undertake 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 at the main field should commence soon after crop establishment and at weekly intervals thereafter. In each 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:

For mealybug: Count and record the number of both nymphs and adults on five randomly selected leaves per plant.

For 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.

C. Blue sticky traps:

Set up blue pan traps 15 cm above the canopy for monitoring thrips @ 4-10 traps (15 X 7.5 cm)/acre. Locally available empty tins can be painted blue/ coated with grease/ Vaseline/castor oil on outer surface may also be used as blue pan trap. Count the number of thrips on the traps daily and take the appropriate decision regarding management practices

D. Light traps:

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

E. Nematode extraction:

Collect 100 to 300 cm^3 (200-300 g) representative soil sample. Mix soil sample and pass through a coarse sieve to remove rocks, roots, etc. Take a 600 cc subsample of soil, pack lightly into a beaker uniformly. Place soil in one of the buckets or pans half filled with water. Mix soil and water by stirring with paddle; allow to stand until water almost stops swirling. Pour all but heavy sediment through 20-mesh sieve into second bucket; discard residue in first bucket; discard material caught on sieve. Stir material in second bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 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. The cultural practices are informed by ecological knowledge rather than on high technology approaches such as synthetic pesticides and genetically engineered crops (Gurr et al. 2004 a,b).

Natural enemies may require:

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

Ecological engineering for pest management – Above ground:

- Raise the flowering plants / compatible cash crops along the vineyard 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 vineyard
- Not to uproot weed plants those are growing naturally like *Tridax procumbens, Ageratum* sp, *Alternanthera* sp, 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.

Ecological engineering for pest management – Below ground:

- 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.
- Reduce tillage intensity so that hibernating natural enemies can be saved.
- Apply balanced dose of nutrients using biofertilizers.
- Apply mycorrhiza and plant growth promoting rhizobacteria (PGPR)
- Apply *Trichoderma viride/harzianum* and *Pseudomonas fluorescens* as seed/ cutting, and soil application (If Commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).

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

Ecological Engineering Plants

Attractant plants

Ageratum

Carrot

Sunflower

Buckwheat

French bean

Alfaalfa

Mustard

Cosmos

Anise

Caraway

Dill

***Chrysanthemum* sp.**

Eupatorium

Theobroma

Cowpea

Maize

Terminalia

Repellent plants

***Ocimum* sp**

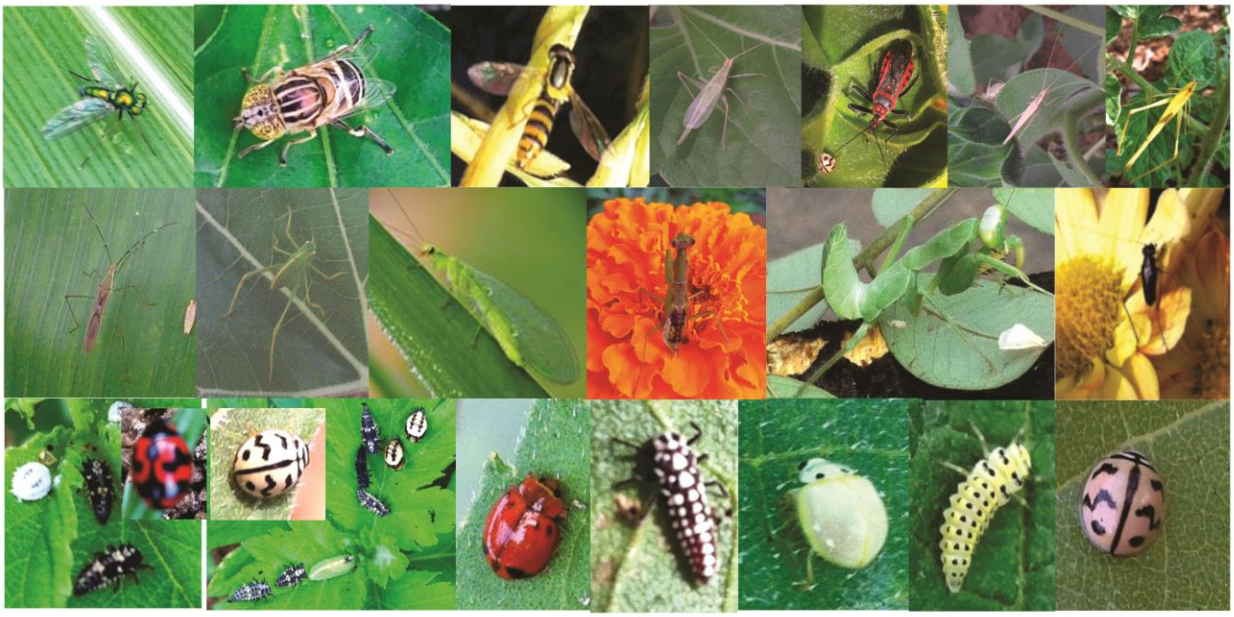
Peppermint/Spearmint

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

Biodiversity of natural enemies observed in Ecological Engineering field at NIPHM

Biodiversity of natural enemies: Parasitoids

Biodiversity of natural enemies: Predators



Biodiversity of natural enemies: Spiders

A. Resistant/ tolerant varieties:

- Panniyur-1, Panniyur-2, Panniyur-3, Panniyur-4, Panniyur-5, Panniyur-6, Panniyur-7, Subhakara, Sreekara, Karimunda, Panchami, Pournami, Kottanadan, Kuthiravally, Arakulam Munda, Balankotta and Kalluvally are the commonly cultivated varieties. Of these, Panniyur-1 is to be grown in comparatively open areas.

IV: CROP STAGE-WISE IPM

Management	Activity
Pre-sowing*	
	Common cultural practices: • Deep ploughing of fields during summer to control nematodes population, to expose pupae and popagules of soil borne pathogens. • Soil solarization can be done for sterilizing the nursery mixture • Timely sowing should be done. • Field sanitation, rogueing. • Destroy the alternate host plants • Crop rotation with non-cereals. • Adopt ecological engineering by growing the attractant, repellent, and trap crops around the field bunds.
Nutrients	• Prepare pits of the size 50 x 50 x 50 cm before the onset of the monsoon at a spacing of 2 to 3 m in either direction. Slopes facing West and South should be avoided. • Fill it up after the onset of monsoon with FYM @10 Kg + Neem cake1 Kg + bone meal and Rock phosphate 70 g + top soil. Wherever possible a large pit filled with alternate layers of coconut husk and the above mixture is preferable. This will help in conserving soil moisture and help the young plants to survive the hot summer. Plant rooted cuttings in June – July.
Weeds	• Destroy all the weeds from planting area by ploughing during summer. • Remove all the perennial weds and their rhizomes/suckers before onset of monsoon.
Soil and seed borne pathogens, Pests and nematodes	**Cultural control:** • Planting material must be collected from disease free garden or nursery raised preferably in fumigated soil. • Well drained level land and hill slopes are suitable for growing pepper, slopes facing south and south western side should be avoided and north and north eastern slopes should be preferred. • Cultivated varieties such as Naryankodi, kalluvally, Uthirankotta and Balancotta which are tolerant to quick wilt • Press the soil around the cutting to form a small mound slopping outward and away from cuttings to prevent water stagnation around the plants • Adequate mulch with green leaf saw dust or coir dust or organic matter should be given towards the end of the north-eastern

	monsoon. • Injury to root system to be avoided at any cost. • About 10 Kg of well rotten cattle manure or compost to be given in April may in order to support antagonistic fungi. • Growing cover crops like Calapogonium muconoides, Mimosa invisa are also recommended under west coast conditions to provide an effective soil cover to prevent soil erosion as well as spread of soil borne pathogens in rainy seasons and for thick organic mulch during summer. • Planting materials must be collected from disease free garden and nurseries raised preferably in fumigated soil. **Mechanical control:** • The affected cutting along with defoliated leaves should be removed from nursery and destroyed. **Biological control:** • Alternatively, Rhizobacteria like IISR 853 can be applied @ 1 g (formulations containing 108 - 1010 cfu/g) at monthly intervals. • Apply neem /mustard/castor cake
Sowing/planting*	
Nutrients	• In addition, organic manure application before planting, apply 50 g *Azospirillum* + 50 g PSB + 200 g VAM per plant at the time of planting.
Weeds	• Hand weeding around the plants is to be done according to necessity • Adequate mulch with green leaf or organic matter should be given towards the end of north east monsoon. • Recommended dose of fertilizers is to be applied. Care should be taken to avoid direct contact of fertilizers with the roots of pepper. • Water logging is to be avoided.
Nematodes/Borers	**Cultural control:** • With the receipt of the first rain in May-June, primary stem cuttings of *Erythrina* sp.(Murukku) or *Garuga pinnata* (kilinjil) or *Grevillea robusta* (silver oak) are planted in pits of 50 cm x 50 cm x 50 cm size filled with cow dung and top soil, at a spacing of 3 m x 3 m which would accommodate about 1110 standards per hectare (Seedlings of *Alianthus malabarica* (Matti) can also be planted and the black pepper vines can be trailed on it after 3 years when they attain sufficient height). • Pits of 50 cm 3 at a distance of 30 cm away from the base, on the northern side of supporting tree are taken with the onset of monsoon. • The pits are filled with a mixture of top soil, farmyard manure @ five Kg/pit and 150 g rock phosphate. With the onset of monsoon, two-three rooted cuttings of black pepper are planted individually in the pits on the northern side of each standard. At least one node of the cutting Should be kept below the soil for better anchorage. • Follow the spacing recommended 3 m X 3 m in plain lands and 2 m X 4 m in sloppy lands.

<table>
<tr><td></td><td><u>Botanical control:</u>
Neem cake @ 1 Kg /vine may be mixed with the soil at the time of planting.</td></tr>
<tr><td colspan="2">** Apply Trichoderma viride/harzianum and Pseudomonas fluorescens as 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
<u>Common mechanical practices:</u>
Collection and destruction of eggs, and larvae
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).
Collect and destroy diseased and insect infected plant parts
Use yellow sticky trap for aphid vector control and blue sticky traps for thrips @ 4-5 traps/acre.
Use light trap @ 1/acre and operate between 6 pm and 10 pm
Erecting of bird perches @ 20/acre for encouraging predatory birds such as King crow, common mynah etc.
Set up bonfire during evening hours at 7-8 pm
<u>Common biological practices:</u>
Conserve natural enemies through ecological engineering
Augmentative release of natural enemies.</td></tr>
<tr><td>Nutrients</td><td>Fertilizers should be applied on the basis of soil test report and recommendation for the particular area. In general, fertilizers may be applies as mentioned in Table 1.
Table 1. Fertilizers requirement of black pepper<table><tr><th>Age of plants (year)</th><th>N (g/vine/year)</th><th>P_2O_5 (g/vine/year)</th><th>K_2O (g/vine/year)</th></tr><tr><td>1st</td><td>17</td><td>17</td><td>50</td></tr><tr><td>2nd</td><td>34</td><td>34</td><td>100</td></tr><tr><td>3rd and above</td><td>50</td><td>50</td><td>150</td></tr></table>
Fertilizer should be applied 10-15 days after pruning of the living supports.</td></tr>
</table>

	• If soil is highly acidic 500g lime per vine also is to be applied in alternate years. • During the first year,1/3rd of the dosage recommended for the adult vines should be applied during September. • During the second year, two thirds of the dosage recommended for the adult vines should be applied in two equal instalments, one during May-June, and the other during September-October. • The manures and fertilizers are applied around the vine at a distance of 30 cm from the base and incorporated into the soil.
Weeds	• Pull out weeds before flowering by 2-3 rounds of hand 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 @ 10Kg should be given to control weed growth and to prevent sun scorching of young vines during summer.
Phytophthora foot rot (quick wilt), basal wilt	**Cultural control:** • 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. **Chemical control:** **For foot rot:** • Metalaxyl M 4% + Mancozeb 64% WP @ 0.25%, 2 or 3 l/vine • Metalaxyl 8% + Mancozeb 64% WP @ 0.125 %, 2 or 5 l/vine
Slow wilt	**Cultural control:** • Nematode free root cutting raised in fumigated nursery mixture should be used for fresh planting. • Remove the severely affected vines which are beyond recovery.
Pollu beetle, Top shoot borer, Leaf gall thrips	**Cultural control:** • Regulation of shade in the plantation reduces the population of the pest in the field. • For others follow common practices. **Biological control:** • Spraying Neemgold (0.6 per cent) (neem-based insecticide) during August, September and October is effective for the management of

	the pest. The underside of leaves (where adults are generally seen) and spikes are to be sprayed thoroughly. • For biological control follow common practices.
Mealybugs	**<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, Minor pests	**<u>Cultural control:</u>** • Follow common practices. **<u>Biological control:</u>** • In nurseries spraying neem oil 0.3 per cent or Neem gold 0.3 per cent or fish oil rosin three per cent is also effective in controlling the pest infestation. • Follow common biological practices.
Spike formation/flowering stage	
Nutrients	• Apply deficient micronutrient if any.
Weeds	• Keep the orchard weed free.
Pollu disease /Anthracnose, leaf rot	**<u>Cultural control:</u>** • Eradication of affected vine from vineyard. • Apply Phytosanitation process. **<u>Chemical control:</u>** • Same as Phytophthora foot rot.
Spike shedding, Stunt disease, Phyllody disease	**<u>Cultural control:</u>** • Use virus free healthy planting material • Regular inspection and removal of infected plants; the removed plants may be burnt or buried deep in soil. • Insects such as aphids and mealy bugs on the plant or standards should be controlled with insecticide spray.
Pollu beetle	• Same as vegetative stage.
Mealy bug	• Same as vegetative stage.
Berry formation stage	
Pollu disease, Spike shedding, Stunt disease, Phyllody	• Same as vegetative and flowering stage.

disease, Foot rot (quick wilt)	
Pollu beetle, Top shoot borer, Leaf gall, thrips Scale insects, Minor pests	• Same as vegetative and flowering stage

**The chemical dosage and spray fluid volumes are based on high volume sprayer.

Source of Nutrient and weeds:
http://www.indianspices.com/html/spices_spfarm_blkpepper.html,http://agritech.tnau.ac.in/agriculture/plant_nutri/cashew_potassium.html
APHU (2010). Package of practices of important Horticultural Crops.Venkattrientaramannagudem, West Godavari District – 534 101 (A.P.).

V. INSECTICIDE RESISTANCE AND ITS MANAGEMENT

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

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

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

1) **Monitor pests:** Monitor insect population development in 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.

VI. NUTRIENT DEFICIENCIES

Potassium: Reduced growth. Leaves develop characteristic bronzing followed by necrotic lesions along the veins and leaf fall.
Correction measure: Foliar spray of K_2SO_4 @1% at weekly intervals.

Magnesium: Interveinal chlorosis of immature and recently matured leaves. Necrotic lesions develop within the chlorotic areas.
Correction measure: Foliar spray of $MgSO_4$ @ 1% at fortnightly intervals.

Boron: Young leaves become small and malformed.
Correction measure: Foliar application of borax@0.2%.

Iron: Inter-veinal chlorosis of young leaves veins remain green and leaf size reduced. In severe cases, whole leaf become chlorotic and yellow and fall.
Correction measure: Foliar spray of $FeSO_4$ @1.0% at fortnightly intervals.

Manganese: Yellowing of young leaves; veins remain green.
Correction Measure:
Foliar application of $MnSO_4$ @ 0.5% solution in water.

VII. COMMON WEEDS

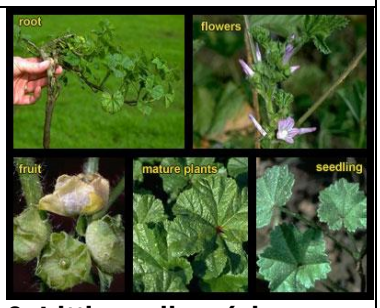
1. Pigweed: *Amaranthus viridis* Hook. F. (Amaranthaceae)

2. Common purselane: *Portulaca oleracea* L. (Portulacaceae)

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

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

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



6. Little mallow (cheese weed): *Malva parviflora F*. (Malvaceae)

 **7. Barnyard grass: *Echinochloa crusgalli* (L.) Beauv. (Poaceae)**	 **8. Bermuda grass: *Cynodon dactylon* (L.) Pers. (Poaceae)**	 **9. Purple nutsedge: *Cyperus rotundus* L. (Cyperaceae)**
 **10. Flat sedge: *Cyperus iria* L. (Cyperaceae)**	 **11. Dodder: Cuscuta spp. *(*Convolvulaceae*)***	

APHU (2010). Package of practices of important Horticultural Crops. Venkataramannagudem, West Godavari District – 534 101 (A.P.).
http://agritech.tnau.ac.in/agriculture/plant_nutri/cashew_potassium.html

VIII. DESCRIPTION OF INSECT AND NEMATODE PESTS

1. Pollu beetle*:*

Biology:

- **Egg:** Eggs are laid on the berries and lays 1-2 eggs in each hole, egg period 5-8 days.
- **Grub:** Grub period 30-32 days.
- **Pupa:** Pupation occurs in soil in a depth of 5.0 - 7.5 cm. Pupal period 6-7 days. Life cycle completed in 40 - 50 days. Four overlapping generations in a year.
- **Adult:** Adult is a bluish yellow shining flea beetles.

.

Adults

http://www.kissankerala.net:8080/KISSAN-CHDSS/English/pepper/pests/images/50.jpg

Damage symptoms:

- The pollu beetle is a serious in black pepper plantations in the plains and at lower altitudes.
- The adults feed on tender shoots, spikes and berries.
- The infested shoots and spikes turn black and drop.
- The grub on emergence bore into the berries, feed on the internal contents and make them hollow.
- The infested berries turn yellow initially and then black and crumble when pressed.
- The pest population is more severe in shaded areas.
- During the period from January to April the adults do not breed but remain in the field feeding on older leaves.

1. **2.** **3.**

Damage symptoms

1,2,3:
http://www.kissankerala.net:8080/KISSAN_CHDSS/English/pepper/pests/images/50.jpg

Natural enemies od pollu beetle:

Predators: Spider (Araneae), *Oecophylla smaragdina* (weaver ant)

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

2. Top shoot borer:

Biology:

- **Egg:** Eggs are small colourless.
- **Larva:** Larva grayish green, 12-14 mm long, larval period 10 -15 days. Pupates inside shoots.

- **Pupa:** Pupal period 8 – 10 days.
- **Adult:** Adult moth is tiny, forewing black with distal half red, hind wing greyish. Life cycle completed in a month.

1. Adults

Damage symptoms:

- The adult is a fine moth with basal half of the forewing black and distal half orange red.
- The top shoot borer is found more in younger plantations.
- The caterpillars of the moth bore into tender shoots which turn black and dry up.
- When successive new shoots are attacked, the growth of the vine is affected.
- The pest infestation is higher during July-November when numerous new shoots are available on the vines.

2. Damage symptoms

Source: 1, 2:http://www.kissankerala.net:8080/KISSAN-CHDSS/English/pepper/pests/images/50.jpg

Natural enemies od top shoot borer:

Parasitoid: *Apanteles cypris, Eudederus* sp. (Hymenoptera)*, Goniozus* sp.

Parasitic mite: *Clinotrombium* sp.(on larvae).

Entomopathogenic nematode: *Hexamermis* sp.

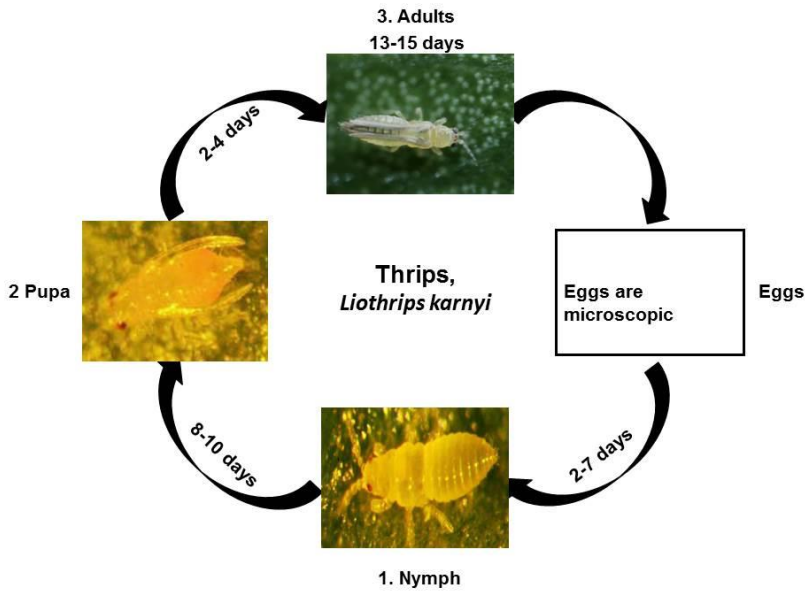
*For management refer to page number----------

3. Leaf gall thrips:

Biology:

- **Egg:** Eggs are laid in single within the marginal leaf folds or on the leaf surface, egg period6-8 days.
- **Nymph:** Nymphs whitish and sluggish, nymphal period 9-13 days
- **Pupa:** Pupal period, 2 to 3 days
- **Adult:** Adults with heavily fringed wings. Adult longevity is 7-9 days.

Life cycle:



http://entnemdept.ufl.edu/creatures/orn/thrips/_thrips.htm

Damage symptoms:

- Infestation by leaf gall thrips is more serious at higher altitudes, especially in younger vines and also in the nurseries.
- The feeding of thrips on tender leaves causes the leaf margins to curl down and inwards resulting in the formation of marginal leaf galls.
- The infested leaves become thick, malformed and crinkled
- Life stages of the insect can be seen within the gall.
- In severe cases of infestation, the growth of young vines is affected

Damage Symptoms

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

- **Parsitoids:** *Aphytis* sp., *Pseudoscymcus* sp., *Chilocorus circumdatus*
- **Predators:** *Montandoniola moraguesi, Androthrips flavipes, Geogarypus* sp*., Lestodiplosis* sp*., Rhodesiella* sp*,* Predatory mites, Hoverflies, Thrips, Mirids

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

4. 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 moult 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.
- **Pepper mussel scale:** *Lepidosaphes piperis* **:** Scale is small, dark, boat shaped.
- **Coconut scale:** *Aspidiotus destructor* : Circular (about 1 mm in diameter) and yellowish brown.

1. Aspidiotus destructor 2. Lepidosaphes piperis

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:

- Scale insects appear as encrustations on stems, leaves and berries
- They feed on plant sap resulting in yellowing and drying of infested portions of the vines.

1. 2. 3.

Damage symptoms

1,2,3:

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

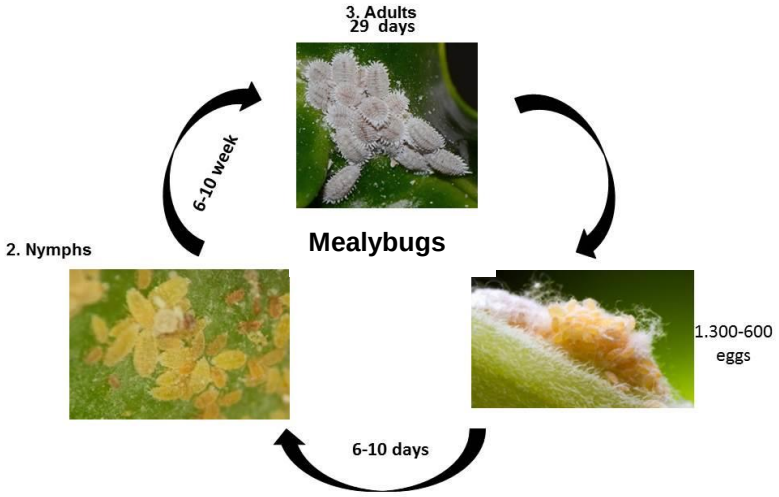
Natural enemies of Scale insects:
Parasitoids: *Encarsia lounsburyi, Aphytis* sp. etc.
Predators: Mite: *Bdella* sp., Thrips: *Karnyothrips melaleucus, Aleurodothrips fasciatus*, Beetle: Ladybird beetle, *Chilocorus circumdatus, C.nigrita,* Lacewings, *Pseudoscymnus dwikalpa, Pharoscymna shorni, Sticholotisex anguis, Cybocephalus* sp. etc.
*For management refer to page number----------

5. Mealybugs*:*

Biology:

- **Egg:** These eggs are yellowish to orange in colour
- **Nymph:** The first instar nymphs are also called as crawlers, which are mobile. The total nymphal period is 19 days for male and 21 days for female. The male nymph forms a cottony cocoon in which the pupal stage is found mainly in the winter season
- **Adult:** The adult female mealybugs are pinkish white and sparsely covered with white wax. The male and female mealybugs are similar in early stages.
- The female passes through three nymphal instars while male passes through four nymphal instars.
- The adult male has a pair of wings and a pair of halters. Males are very rare and female mealybugs are commonly found causing the damage in the field.
- Mealybug completes the life cycle in about 30 days. Without mating, they are known to reproduce partheno-genetically throughout the year.

Life cycle:



Damage symptoms:

- Large number of mealy bugs colonise the roots of the vine (Plate 59)
- As a result of sap sucking, the plant turns yellow, leaves and branches dry and drop
- Many of the vines infested by root mealy bugs are also likely to be infected with *Phytophthora* and nematodes

Damage symptoms

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

Natural enemies of mealy bugs:

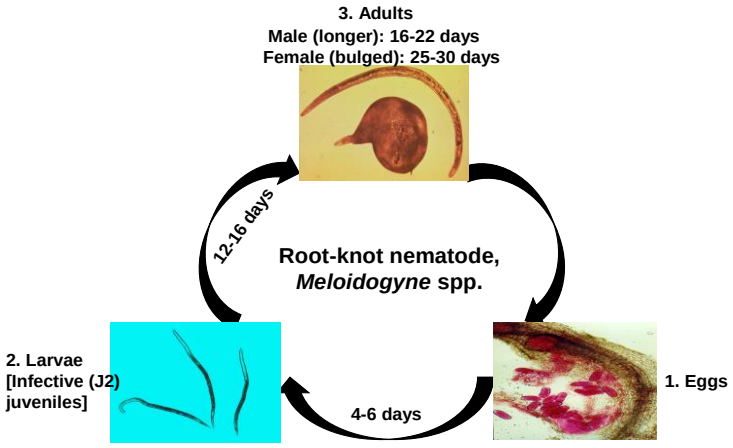
Parasitoid: Parasitic wasps,
Predators: Hover flies, coccinellid (*Cryptolaemus montrouzieri*), praying mantis
*For management refer to page number----------

6. 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

Damage symptom

https://www.google.co.in/search?q=damage+symptoms+of+wheat+by+nematode&espv=210&es_sm=122&source=lnms&tbm=isch&sa=X&ei=xs8BU9DHGoOJ

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:

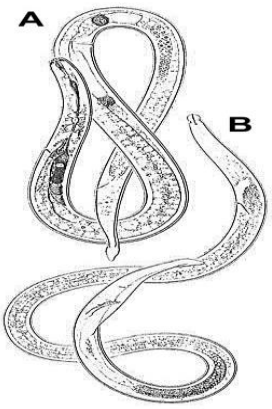
Loamy light soils.

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

7. Burrowing nematode:

Biology:

- Burrowing nematode is an endoparasitic migratory nematode, meaning it completes its life cycle within root tissue.
- Adults and juveniles are vermiform in shape. Adults are sexually dimorphic. The male has a poorly developed stylet, a knob-like head, and a sharp, curved spicule enclosed in a sac.
- The male is 500 to 600 µm in length, while the female is about 550 to 880 µm long. The female has a well-developed stylet. Both male and female have long, tapered tails with rounded or indented ends.
- The nematode completes its life cycle in about 21 days at 25°C.
- Females and juveniles feed inside roots, especially near the tips. Males with their weak stylets do not feed. Females lay two to six eggs per day.
- The nematode causes a disease condition called toppling or blackhead disease in plants



1. **Female (A) and male (B)**

2. Damage Symptoms

1,2: http://entnemdept.ufl.edu/creatures/NEMATODE/Radopholus_similis.htm

Natural Enemies of Black Pepper Pests

Parasitoids

Larval parasitoids

***1. Apanteles* cypris**

2. *Goniozus*

3. *Clinotrombium*

Nymphal/Adult parasitoids

4. ***Chilocorus circumdatus***

5. Encarsia sp

6. Scale

7. Parasitic wasp

1. https://www.google.co.in/search?q= Apanteles+cypris+ aqs=chrome..69i57j0l5.1065j0j9&sourceid=chrome&espv=210&es_sm=122&ie=UTF-
2. https://www.google.co.in/search?q=Goniozus&oq=Goniozus&aqs=chrome..69i57j0l5.1065j0j9&sourceid=chrome&espv=210 &es_sm=122&ie=UTF-8#q=Clinotro
3. https://www.google.co.in/search?q= Clinotrombium &oq Clinotrombium =&aqs=chrome..69i57j0l5.1065j0j9&sourceid=chrome&espv=210&es_sm=122&ie=UTF-8#q=Clinotro
4. https://www.google.co.in/search?q= chilocorus+ circudatus& espv =210& es_sm= 122 & source= lnms
5. https://www.google.co.in/search?q=encarsia+formosa&espv=210&es_sm=122&source=lnms&tbm=isch&sa=X&ei=LjcYU6qQG8bnrAfI1 oDAAQ&ved=0CAkQ_AUoAQ&biw=1242&bih=585#facrc=_&imgdii=_&imgrc=PHem7BhlBs6FMM%253A%3BHkcuogaJYUpWJM%3Bhttp
6. http://www.buglogical.com/aphytis-melinus/aphytis-melinus-red-scale-parasite/
7. http://www.insectimages.org/browse/detail.cfm?imgnum=5195078

Predators

1. Lacewing

2. Ladybird beetle

3. Spider

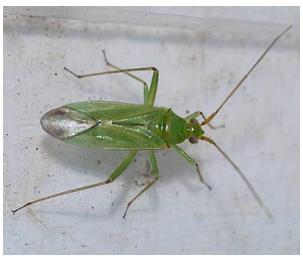
4. Weaver ant

1. *Montandoniola* sp.

2. *Androthrips* sp.

3. *Geogarypus* sp.

4. *Lestodiplosis* sp.



5. Mirid bug **6. Hover fly** **7. Predatory mite** **8. Bdella**




9. *Chilocorus* sp. **10. *Cybocephalus*** **11. *Cryptolaemus* sp.** **12. Praying mantis**

1.https://www.google.co.in/search?q=Montandoniola+moraguesi&espv=210&es_sm=12
2. https://www.google.co.in/search?q= androthrips+ flavipes
3.https://www.google.co.in/search?q=geogarypus&espv=210&es_sm=122&source=lnm
4.https://www.google.co.in/search?q= Lestodiplosis + &espv =210 &es_sm =122&source
5. http://www.britishbugs.org.uk/heteroptera/Miridae/blepharidopterus_angulatus.html
7. http://www.dragonfli.co.uk/natural-pest-control/natural-enemies\
8. http://www.dragonfli.co.uk/natural-pest-control/natural-enemies
9. http://www.fugleognatur.dk/forum/show_message.asp?MessageID=560188&ForumID
10.http://en.wikipedia.org/wiki/File:Orius_insidiosus_from_USDA_2_(cropped).jpg

11. http://spirit-animals.com/praying-mantis/

IX. DESCRIPTION OF DISEASES

1. Foot rot /quick wilt disease:

Disease symptoms:

- One or more black spots appear on the leaves which have a characteristic fine fibre like projections at the advancing margins which rapidly enlarge and cause defoliation.
- The tender leaves and succulent shoot tips of freshly emerging runner shoots trailing on the soil turn black when infected. The disease spreads to the entire vine, from these infected runner shoots and leaves, during intermittent showers due to rain splash.
- If the main stem at the ground level or the collar is damaged, the entire vine wilts followed by shedding of leaves and spikes with or without black spots. The branches break up at nodes and the entire vine collapses within a month.
- If the damage is confined to the feeder roots, the expression of symptoms is delayed till the cessation of rain and the vine starts showing declining symptoms such as yellowing, wilting, defoliation and drying up of a part of the vine.

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:

- Rainy season during October-November onwards favour the development of disease.

Disease symptoms

https://www.google.co.in/search?q=Foot+rot+/quick+wilt+disease+of+pepper&espv=210&es_sm=122&source=lnms&tbm=isch&sa=X&ei=Sf8WU8WOCoWWrAeD4YCgAQ&ved=0CAcQ_AUoAQ&biw=

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

2. Pollu disease /anthracnose:

Disease symptoms:

- It can be distinguished from the pollu (hollow berry) caused by the beetle by the presence of characteristic cracks on the infected berries.
- The disease appears towards the end of the monsoon.
- The affected berries show brown sunken patches during early stages and their further development is affected.
- In later stages, the discolouration gradually increases and the berries show the characteristic cross splitting.
- Finally, the berries turn black and dry. The fungus also causes angular to irregular brownish lesions with a chlorotic halo on the leaves.

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.

1. 2. 3.

Disease symptoms

1,2:
https://www.google.co.in/search?q=pollu+disease+of+black+pepper&espv=210&es_sm=122&tbm=isch&tbo=u&source=univ&sa=X&ei=LQQXU7GYM4a_rgfkq4DYAg&ved=0CEoQsAQ&biw=1366

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

3. Slow decline /slow wilt:

Disease symptoms:

- Foliar yellowing, defoliation and die-back are the aerial symptoms of this disease. The affected vines exhibit varying degrees of root degeneration due to infestation by **plant parasitic nematodes**.
- The diseased vines exhibit foliar yellowing from October onwards coinciding with depletion of soil moisture.
- With the onset of south west monsoon during May/June, some of the affected vines recover and put forth fresh foliage.
- The symptoms reappear in subsequent seasons after the cessation of the monsoon and the diseased vines gradually lose their vigour and productivity.
- The affected vines show varying degrees of feeder root loss and the expression of symptoms on the aerial parts occur after a considerable portion of the feeder roots are lost.
- The root system of diseased vines show varying degrees of necrosis and presence of root galls due to infestation by plant parasitic nematodes such as *Radopholus similis* and *Meloidogyne* incognita leading to rotting of feeder roots. The damage to feeder roots is caused by these nematodes and *P. capsici* either independently or together in combination.

Survival and spread:

- Fungus survives in disease plant debris.
- 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 inoculums.
- Autonomous second stage juveniles that may also be water dispersed.

Favourable conditions:

- Rainy seasons and loamy light soils favours the development of disease.



1. 2. 3.

DIsease symptoms

1,2,3:https://www.google.co.in/search?q=slow+wilt+of+black+pepper&espv=210&es_sm=122&tbm=isch&tbo=u&source=univ&sa=X&ei=LQQXU7GYM4a_rgfkq4DYAg&ved=0CEoQsAQ&biw=1366

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

4. Stunt disease:

Disease symptoms:

- This disease which is caused by viruses is noticed in parts of Kannur, Kasargod, Kozhikode, Wayanad and Idukki Districts of Kerala and Kodagu, Hassan and Uthara Kannada districts of Karnataka.
- The vines exhibit shortening of internodes to varying degrees.
- The leaves become small and narrow with varying degrees of deformation and appear leathery, puckered and crinkled.
- Chlorotic spots and streaks also appear on the leaves occasionally. The yield of the affected vines decreases gradually.
- Two viruses namely **Cucumber Mosaic Virus** and a **Badna virus** are associated with the disease.

Transmission and favorable conditions:

- The major means of spread of the virus is through the use of infected stem cuttings. The disease can also be transmitted through insects like aphids and mealy bugs.

Disease symptoms

https://www.google.co.in/search?q=stunt+disease+of+pepper&espv=210&es_sm=122&source=lnms&tbm=isch&sa=X&ei=Sf8WU8WOCoWWrAeD4YCgAQ&ved=0CAcQ_AUoAQ&biw=

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

5. Phyllody disease:

Disease symptoms:

- This disease which is caused by ***Phytoplasma*** is noticed in parts of Wayanad and Kozhikode districts of Kerala.
- The affected vines exhibit varying stages of malformation of spikes. Some of the floral buds are transformed into narrow leaf like structures.
- Such malformed spikes show leafy structures instead of floral buds, exhibiting Phyllody symptoms.
- In advanced stages, the leaves become small and chlorotic, and the internodes are also shortened.
- The affected fruiting laterals give a witches broom appearance. Severely affected vines become unproductive.
- In severely affected vines the entire spike is converted into small branches which appear chlorotic and the vines decline rapidly.
- The infected vine becomes unproductive within two to three years.

Transmission and favourable conditions:

- The infected vines are to be destroyed to prevent the further spread of the disease.
- Phytoplasmadisease is spread by leaf hoppers and plant hoppers besides spread by vegetative propagation through cuttings, storage tubers, rhizomes or bulbs.

1. **2.**

Disease symptoms

1,2:
https://www.google.co.in/search?q=phyllodi+disease+of+pepper&espv=210&es_sm=122&source=lnms&tbm=isch&sa=X&ei=Sf8WU8WOCoWWrAeD4YCgAQ&ved=0CAcQ_AUoAQ&biw=

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

6. Basal wilt:

Symptoms

- Grayish lesions appear on stems and leaves.
- On the leaves white mycelium are seen at the advancing edges of the lesions.
- The mycelial threads later girdle the stem resulting in drooping of leaves beyond the point of infection and in advanced stages the rooted cuttings dry up.
- Small whitish to cream coloured grain like sclerotial bodies appear on the mature lesions.

Survival and spread:

- Disease is soil born 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

https://www.google.co.in/search?q=basal+wilt+of+black+pepper&espv=210&es_sm=122&tbm=isch&tbo=u&source=univ&sa=X&ei=LQQXU7GYM4a_rgfkg4DYAg&ved=0CEoQsAQ&biw=1366

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

7. Leaf rot and blight:

Symptoms:

- Greyish sunken spots and mycelial threads appear on the leaves and the infected leaves are attached to one another with the mycelial threads.
- Leaf spots caused by *Colletotrichum* sp. are characterized by yellow halo surrounding the necrotic spots.
- On stems, the infection occurs as dark brown lesions which spread both upwards and downwards. The new flushes subtending the points of infection gradually droop and dry up.

Survival and spread:

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

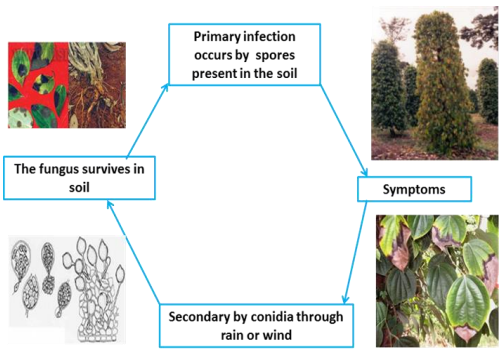
Favourable conditions:

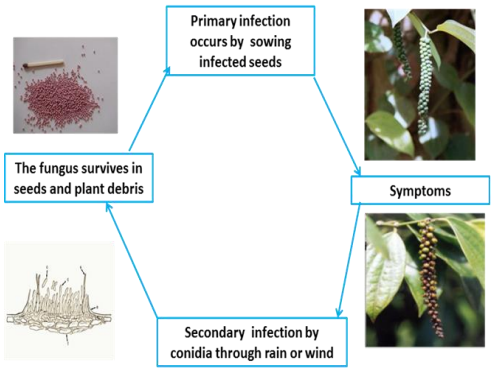
- The disease is caused by *Rhizoctonia solani* Kühn and is often serious in nurseries during April- May when warm humid conditions prevail. The fungus infects both leaves and stems.

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

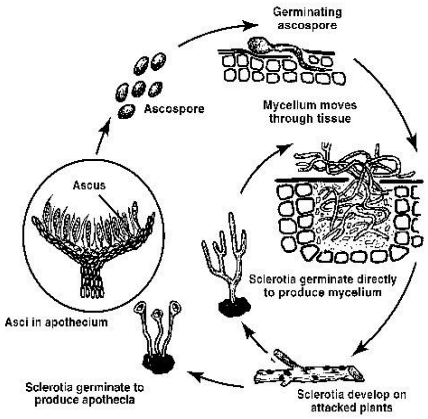
Disease cycles:

1. Foot rot /quick wilt disease: **2. Pollu disease /Anthracnose:**





3. Basal wilt by *Sclerotium rolfsii:*



X. SAFETY MEASURES

A. Pre-harvest:

- The crop takes about 6-8 months from flowering to harvest. The harvest season extends from November to January in the plains and January to March in the hills. When one or two berries in the spike turn bright orange or purple it is time for harvest. However, pepper berries are harvested at different maturity levels depending on the intended use or product preparation.
- Pepper powder is best made from berries with maximum starch content and therefore has to be fully mature when harvested. The extraction industry prefers berries which contain the highest level of oleoresin and essential oils.
- High levels of both are usually found when the berries are picked couple of weeks before full maturity.
- The following describes the intended use of pepper berries and the maturity level at which berries should be harvested for ensuring best results.

Products	Maturity at harvest
Pepper in brine/ Canned pepper	Green and tender (4-5 months)
White pepper	Fully matured (ripened)

Black pepper	Fully mature and near ripe
Dehydrated Green pepper	10-15 days before full maturity
Oil and Oleoresin	15-20 days before maturity
Pepper powder	Fully matured with maximum starch

- Start harvesting when one or two berries in few spikes turn orange or red.
- Follow selective harvesting method to harvest only fully matured spikes.
- Care should be taken to avoid damage to vine during harvest.
- If any spike falls on ground during harvesting, it should be mixed along with other lot only after thorough washing.
- If chemical measures are adopted to prevent ants while harvesting the lot should be thoroughly washed before mixing with the main lot.

B. During post-harvest:

Points to be observed in the storage of pepper
1. Pepper should be stored in bags after the moisture content is reduced to 10-11% .The bags should be preferably new, clean, dry and free from any contamination.
2. Other substances should not be stored in storerooms of godowns where pepper is kept.
3. Graded or garbled pepper should be kept separately.
4. While stacking pepper-filled bags in godowns, wooden planks should be used on the floor as dunnage. This is to prevent moisture from the affecting pepper. The bags should be kept at least 30 cms. away from the walls.
5. Doors, windows and ventilators of rooms in which pepper is kept should always be kept closed. The entry of rats and other pests should be completely avoided. Rodent repellent devices can be used in the godowns.
6. Pest control practices should be followed systematically. Use of pesticides and chemical fumigants should be limited to the correct dosage and should be applied only under the supervision of experts.

XI. DO'S AND DON'TS IN IPM

S. No.	Do's	Don'ts

1.	Deep ploughing is to be done on bright sunny days during the months of May and June. The field should be kept exposed to sun light at least for 2-3 weeks.	Do not plant or irrigate the field after ploughing, at least for 2-3 weeks, to allow desiccation of weed's bulbs and/or rhizomes of perennial weeds.
2.	Grow only recommended varieties.	Do not grow varieties not suitable for the season or the region.
3.	Plant early in the season	Avoid late planting as this may lead to reduced yields and incidence of pests and diseases.
4.	Apply only recommended herbicides with recommended dose at proper time, with flat fan or flat jet nozzle(s) on sprayer	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.
5.	Maintain optimum and healthy crop stand	Crops should not be exposed to moisture deficit stress at their critical growth stages.
6.	Use NPK fertilizers as per the soil test recommendation.	Avoid imbalanced use of fertilizers.
7.	Use micronutrient mixture after soil based test recommendations or nutrient deficiency symptoms on the crop.	Do not apply any micronutrient mixture after sowing without test recommendations.
8.	Conduct weekly AESA in the morning preferably before 9 a.m. Take decision on management practice based on AESA and P: D ratio only.	Do not take any management decision without considering AESA and P: D ratio
9	Spray pesticides thoroughly to treat the undersurface of the leaves, particularly for sucking pests	Do not spray pesticides only on the upper surface of leaves.
10	Apply short persistent pesticides to avoid pesticide residue in the soil and produce.	Do not apply pesticides during preceding 7 days before harvest.
11	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.

XII. SAFETY PARAMETERS IN PESTICIDE USAGE

S. No.	Pesticide; Classification as per insecticide rules; Colour of toxicity triangle	WHO classification of hazard	Symptoms poisoning	First Aid measures;	Waiting period from last application to harvest (days)
Fungicides					
1.	Metalaxyl MZ Moderately toxic 	Class III Slightly hazardous	Headache, palpitation, nausea, vomiting, flushed face, irritation of nose, throat, eyes and skin etc.	**Treatment of poisoning**: No specific antidote. Treatment is essentially symptomatic	-
2.	Mancozeb Slightly toxic 	Unlikely produce acute hazard	Headache, palpitation, nausea, vomiting, flushed face, irritation of nose, throat, eyes and skin etc.	**Treatment of poisoning**: No specific antidote. Treatment is essentially symptomatic	-

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.
   3. Do not purchase pesticides without proper/approved labels.
   4. While purchasing insist for invoice/bill/cash memo

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

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

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

E. 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
   3. Do not apply just before the rains and after the rains.
   4. Do not apply against the windy direction
   5. Emulsifiable concentrate formulations should not be used for spraying with battery operated ULV sprayer
   6. Wash the sprayer and buckets etc. with soap water after spraying

7. Containers buckets etc. used for mixing pesticides should not be used for domestic purpose
8. Avoid entry of animals and workers in the field immediately after spraying
9. Avoid tank mixing of different pesticides

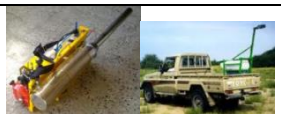
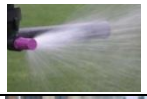
G. Disposal

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.

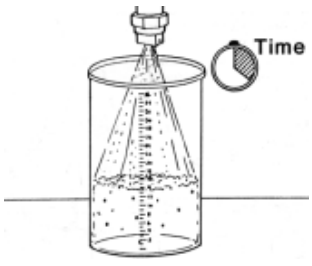
XIV. PESTICIDE APPLICATION TECHNIQUES

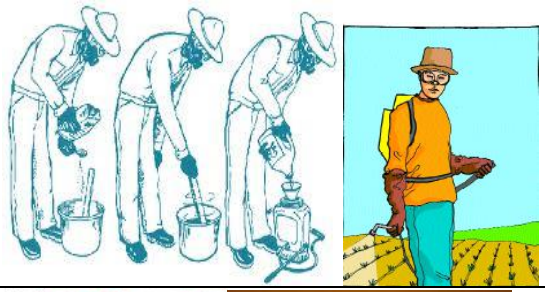
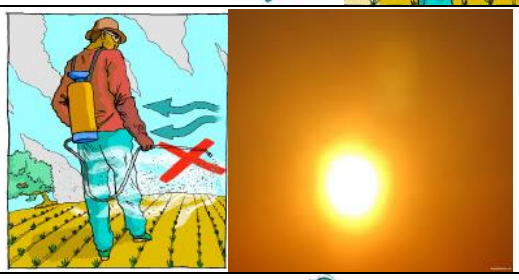
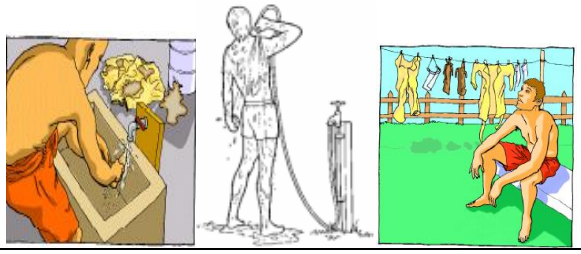
<table>
<tr><td colspan="4">Equipment</td></tr>
<tr><td colspan="4">Category A: Stationary, crawling pest/disease</td></tr>
<tr><td rowspan="2">Vegetative stage
i) For crawling and soil borne pests

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>
<tr><td>Reproductive stage</td><td>Insecticides and fungicides</td><td>• Lever operated knapsack sprayer (Droplets of big size)
• Hollow cone nozzle @ 35 to 40 psi
• Lever operating speed = 15 to 20 strokes/min</td><td>  </td></tr>
<tr><td colspan="4">Category B: Field flying pest/airborne pest</td></tr>
<tr><td>Vegetative stage
Reproductive stage
(Field Pests)</td><td>Insecticides and fungicides</td><td>• Motorized knapsack sprayer or mist blower (Droplets of small size)
• Airblast nozzle
• Operating speed: 2/3rd throttle
Or
• Battery operated low volume sprayer (Droplets of small size)
Spinning disc nozzle</td><td> 
  </td></tr>
</table>

Mosquito/ locust and spatial application *(migratory* Pests)	Insecticides and fungicides	• Fogging machine and ENV (Exhaust nozzle vehicle) (Droplets of very small size) • Hot tube nozzle	
Category C: Weeds			
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 **properbath with soap** after completing spraying	
9.	Do not blow the nozzle with mouth for any blockages. Clean with water and a soft brush.	

XVI. REFERENCES

1. https://www.google.co.in/search?q=oecophylla
2. http://www.eduwebs.org/bugs/predatory_mites.htm
3. http://www.kissankerala.net:8080/KISSAN CHDSS /English /pepper/ pests/ images /50.jpg

4. https://www.google.co.in/search?q=oecophylla+smaragdina&aqs=chrome..69i57j0l5.1065j0j9&sourceid=chrome&espv=210&es_sm=122&ie=UTF-8#q=Clinotro
5. https://www.google.co.in/search?q= Apanteles+cypris+ aqs= chrome.. 69i57j0l5. 1065j0j9 & sourceid=chrome & espv=210&es_sm=122&ie=UTF-
6. https://www.google.co.in/search?q=Goniozus&oq=Goniozus&aqs=chrome..69i57j0l5.1065j0j9&sourceid=chrome&espv=210&es_sm=122&ie=UTF-8#q=Clinotro
7. https://www.google.co.in/search?q= Clinotrombium &oq Clinotrombium =&aqs=chrome..69i57j0l5.1065j0j9&sourceid=chrome&espv=210&es_sm=122&ie=UTF-8#q=Clinotro
8. http://entnemdept.ufl.edu/creatures/orn/thrips/_thrips.htm
9. http://www.kissankerala.net:8080/KISSAN-CHDSS/English/pepper/pests/2.htm
10. https://www.google.co.in/search?q= chilocorus+ circudatus& espv =210& es_sm= 122 & source= lnms
11. https://www.google.co.in/search?q=Montandoniola+moraguesi&espv=210&es_sm=122&sou
12. https://www.google.co.in/search?q= androthrips+ flavipes &espv=210&es_sm=122&source=lnms&tbm=isch&sa=X&ei=6_IWU6TaOoSIrgfX1oHoBQ&v
13. https://www.google.co.in/search?q=geogarypus&espv=210&es_sm=122&source=lnms&tbm=isch&sa=X&ei=6_IWU6TaOoSIrgfX1oHoBQ&ved=0CAcQ_AUoAQ&biw=1366&bih=643#q
14. https://www.google.co.in/search?q= Lestodiplosis + &espv =210 &es_sm =122&source =lnms &tbm isch&sa =X&ei=6_IWU6TaOoS IrgfX1oHoBQ &ved=0CAcQ_ AUoAQ&biw=13
15. http://www.britishbugs.org.uk/heteroptera/Miridae/blepharidopterus_angulatus.html
16. 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
17. 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
18. http://www.dragonfli.co.uk/natural-pest-control/natural-enemies
19. http://biocontrol.ucr.edu/hoddle/persea_mite.html
20. http://www.fugleognatur.dk/forum/show_message.asp?MessageID=560188&ForumID
21. http://en.wikipedia.org/wiki/File:Orius_insidiosus_from_USDA_2_(cropped).jpg
22. http://www.kissankerala.net:8080/KISSAN-CHDSS/English/pepper/pests/2.htm
23. http://www.insectimages.org/browse/detail.cfm?imgnum=5195078
24. http://www.tiptopbio.com/hob_c_montrouzieri.html
25. https://www.google.co.in/search?q=damage+symptoms+of+wheat+by+nematode&espv=210&es_sm=122&source=lnms&tbm=isch&sa=X&ei=xs8BU9DHGoOJ
26. http://keys.lucidcentral.org/keys/sweetpotato/key/Sweetpotato%20Diagnotes/Media/Html/TheProblems/Nematodes/RootKnotNematode/Root-knot.htm
27. http://nematology.umd.edu/rootknot.html
28. http://www.cals.ncsu.edu/pgg/dan_webpage/Introduction/Images/pyroform.htm
29. https://www.google.co.in/search?q=damage+symptoms+of+wheat+by+nematode&esp =210&es_sm=122&source=lnms&tbm=isch&sa=X&ei=xs8BU9DHGoOJ
30. http://entnemdept.ufl.edu/creatures/NEMATODE/Radopholus_similis.htm
31. https://www.google.co.in/search?q=Foot+rot+/quick+wilt+disease+of+pepper&espv=210&es_sm=122&source=lnms&tbm=isch&sa=X&ei=Sf8WU8WOCoWWrAeD4YCgAQ&ved=0CAcQ_AUoAQ&biw=
32. https://www.google.co.in/search?q=slow+wilt+of+black+pepper&espv=210&es_sm=122&tbm=isch&tbo=u&source=univ&sa=X&ei=LQQXU7GYM4a_rgfkq4DYAg&ved=0CEoQsAQ&biw=1366
33. https://www.google.co.in/search?q=stunt+disease+of+pepper&espv=210&es_sm=122&source=lnms&tbm=isch&sa=X&ei=Sf8WU8WOCoWWrAeD4YCgAQ&ved=0CAcQ_AUoAQ&biw=
34. https://www.google.co.in/search?q=phyllodi+disease+of+pepper&espv=210&es_sm=122&source=lnms&tbm=isch&sa=X&ei=Sf8WU8WOCoWWrAeD4YCgAQ&ved=0CAcQ_AUoAQ&biw=
35. https://www.google.co.in/search?q=basal+wilt+of+black+pepper&espv=210&es_sm=122&tbm=isch&tbo=u&source=univ&sa=X&ei=LQQXU7GYM4a_rgfkq4DYAg&ved=0CEoQsAQ&biw=1366.
36. Gurr Men SD, Altieri MA (2004) Ecological Engineering for Pest Management Advances in Habitat Manipulation for Arthropods. CSIRO PUBLISHING, Collingwood, Australia.
37. http://www.indianspices.com/html/spices_spfarm_blkpepper.html
38. http://agritech.tnau.ac.in/agriculture/plant_nutri/cashew_potassium.html
39. APHU (2010). Package of practices of important Horticultural Crops.Venkattrientaramannagudem, West Godavari District – 534 101 (A.P.).
40. http://www.ipm.ucdavis.edu/PMG/WEEDS/dodder.html
41. http://www.ipm.ucdavis.edu/PMG/WEEDS/IMAGES/little_mallow-1.jpg
42. http://agritech.tnau.ac.in/agriculture/plant_nutri/cashew_potassium.html