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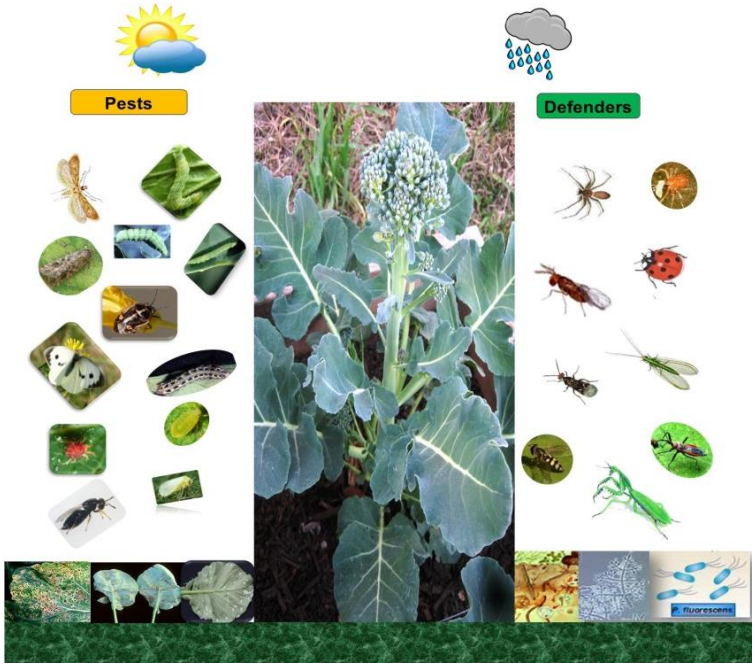
AESA BASED IPM PACKAGE

BROCCOLI



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FOREWORD

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

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

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

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(Avinash K. Srivastava)

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FOREWORD

IPM is a holistic approach of crop protection based on the integration of multiple strategies viz., cultural, physical, mechanical, biological, botanicals and chemical. Over the years IPM underwent several changes, shifting its focus from damage boundary, economic injury to economic threshold. Currently most stake holders rely upon economic threshold levels (ETL) and tend to apply chemical pesticides at the first instance in the event of a pest attack, though Government of India has advocated need based and judicious application of chemicals. This approach is likely to cause adverse effects on agro-ecosystems and increase the cost of agricultural production due to problems of pest resurgence, insecticide resistance and sustainability.

During the late 90s FAO started advocating Agro-Ecosystem Analysis (AESA) based IPM. Experience in different countries have since shown that AESA, which takes into account ecological principles and relies on the balance that is maintained by biotic factors in an ecosystem has also resulted in reduction in cost of production and increase in yields. AESA based IPM also takes into account the need for active participation of farmers and promotes experiential learning and discovery based decision making by farmers. AESA based IPM in conjunction with ecological engineering for pest management promotes bio-intensive strategies as against current chemical intensive approaches, while retaining the option to apply chemical pesticides judiciously as a measure of last resort.

The resource persons of NIPHM and DPPQ&S have made sincere efforts in revising IPM packages for different crops by incorporating agro-ecosystem analysis, ecological engineering, pesticide application techniques and other IPM options with the active cooperation of crop based plant protection scientists working in State Agricultural Universities and ICAR institutions. I hope this IPM package will serve as a ready reference for extension functionaries of Central/ State Governments, NGOs and progressive farmers in adopting sustainable plant protection strategies by minimizing the dependence on chemical pesticides.

(Utpal Kumar Singh)

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PREFACE

Need for environmentally sustainable agricultural practices is recognised worldwide in view of the wide spread ecological imbalances caused by highly intensive agricultural systems. In order to address the adverse impacts of chemical pesticides on agro-ecosystems, Integrated Pest Management has evolved further from ETL based approach to Agro-ecosystem Analysis based Integrated Pest Management (IPM).

In AESA based IPM the whole agro-ecosystem, plant health at different stages, built-in-compensation abilities of the plant, pest and defender population dynamics, soil conditions, climatic factors and farmers' past experience are considered. In AESA, informed decisions are taken by farmers after field observation, AESA chart preparation followed by group discussion and decision making. Insect zoo is created to enable the farmer understand predation of pests by Natural Enemies. AESA based PHM also results in reduction of chemical pesticide usage and conserves the agro-ecosystems.

Ecological Engineering for Pest Management, a new paradigm, is gaining acceptance as a strategy for promoting Biointensive Integrated Pest Management. Ecological Engineering for Pest Management relies on cultural practices to effect habitat manipulation and enhance biological control. The strategies focus on pest management both below ground and above ground. There is a growing need to integrate AESA based IPM and principles of ecological engineering for pest management.

There is a rising public concern about the potential adverse effects of chemical pesticides on the human health, environment and biodiversity. The intensity of these negative externalities, though cannot be eliminated altogether, can be minimized through development, dissemination and promotion of sustainable biointensive approaches.

Directorate of Plant Protection Quarantine and Storage (DPPQS), has developed IPM package of practices during 2001 and 2002. These packages are currently providing guidance to the Extension Officers in transferring IPM strategies to farmers. These IPM package of practices, have been revised incorporating the principles of AESA based IPM in detail and also the concept of Ecological Engineering for Pest Management. It is hoped that the suggested practices, which aim at enhancing biodiversity, biointensive strategies for pest management and promotion of plant health, will enable the farmers to take informed decisions based on experiential learning and it will also result in use of chemical pesticides only as a last resort & in a safe and judicious manner.

(K. SATYAGOPAL)

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AESA BASED IPM PACKAGE FOR BROCCOLI

Broccoli, *Brassica oleracea*, is an herbaceous annual or biennial grown for its edible flower heads which are used as a vegetable. The broccoli plant has a thick green stalk, or stem, which gives rise to thick, leathery, oblong leaves which are gray-blue to green in color. The plant produces large branching green flower heads covered with numerous white or yellow flowers. Broccoli can be annual or biennial depending on the variety. The first leaves produced are ovate to oblong (egg-shaped) with a lobed petiole. Plants are 40–60 cm (16–24 in) tall in their first year at the mature vegetative stage, and 1.5–2.0 m (4.9–6.6 ft) tall when flowering in the second year. Most of the plants have thick, alternating leaves, with margins that range from wavy or lobed to highly dissected. Plants have root systems that are fibrous and shallow. About 90 percent of the root mass is in the upper 20–30 cm (8–12 in) of soil; some lateral roots can penetrate up to 2 m (6.6 ft) deep. The inflorescence is an un-branched and indeterminate terminal raceme measuring 50–100 cm (20–40 in) tall, with flowers that are yellow or white. Each flower has four petals set in a perpendicular pattern, as well as four sepals, six stamens, and a superior ovary that is two-celled and contains a single stigma and style. Two of the six stamens have shorter filaments. The fruit is a silique that opens at maturity through dehiscence to reveal brown or black seeds that are small and round in shape. Broccoli is high in vitamin C and dietary fiber. It also contains multiple nutrients with potent anti-cancer properties, such as diindolylmethane and small amounts of selenium. A single serving provides more than 30 mg of vitamin C and a half-cup provides 52 mg of vitamin C. Broccoli has the highest levels of carotenoids in the brassica family. It is particularly rich in lutein and also provides a modest amount of beta-carotene.

I. PESTS

1. Insect and mite pests

1.1 Diamondback moth:*Plutella xylostella* L. (Lepidoptera: Plutellidae)

1.2 Leaf webber: *Crocidolomia binotalis* Zeller (Lepidoptera: Pyralidae)

1.3 Cabbage butterfly: *Pieris brassicae* L. (Lepidoptera: Pieridae)

1.4 Mustard Sawfly: *Athalia lugens proxima* Klug (Hymenoptera: Tenthredinidae)

1.5 Aphid: *Aphis* spp. (Hemiptera: Aphididae)

1.6 Painted bug: *Bagrada cruciferarum* Kirkaldy (Hemiptera: Pentatomidae)

1.7 Cabbage Head borer: *Hellula undalis* Fab. (Lepidoptera: Pyralidae)

1.8 Termites: *Microtermes obesi* Holmgren (Isoptera:Termitidae)

1.9 Cutworm: *Agrotis ipsilon* Hufnagel (Lepidoptera: Noctuidae)

1.10 Leaf eating weevil: *Tanymecus circumdatus* Wiedemann (Coleoptera: Curculionidae)

1.12 Leaf eating caterpillar/Semilooper: *Trichoplusia ni* Hübner (Lepidoptera: Noctuidae)

1.13 Leaf miner: *Chromatomyia horticola* Goureau (Diptera: Agromyzidae)

1.14 Whitefly: *Bemesia tabaci* Gennadius (Hemiptera: Aleyrodidae)

1.15 Red spider mites: *Tetranychus urticae* Koch (Acari: Tetranychidae)

2. Diseases

2.1 White blister: *Albugo candida* (Lev.) Kunze

2.2 Leaf blight: *Alternaria* spp.

2.3 Damping off: *Pythium aphanidermatum* (Eds.) Fitz ; *Rhizoctonia solani* Kuhn

2.4 Club root: *Plasmodiophora brassicae* Wor.

2.5 Black rot : *Xanthomona scampestris* pv. *campestris* (Dowson) Dye, et al.

2.6 Mosaic disease: *Cauliflower mosaic virus*

2.7 Root rot: *Pythium* spp.

2.8 Downy mildew: *Hyaloperonospora parasitica* (Pers.) Constant.

3. Nematodes

3.1 Root-knot nematode: *Meloidogyne incognita* Kofoid & White

3.2 Reniform nematode: *Rotylenchulus reniformis* Linford and Oliveira

4. Weeds

Broadleaf

4.1.1 Lamb's quarter: *Chenopodium album* L. (Amaranthaceae)
4.1.2 Scarlet Pimpernel: *Anagallis arvensis*L. (Primulaceae)
4.1.2 Yellow Sweet clover: *Melilotus indica*(L.) All. (Fabaceae)
4.1.4 Fine leaf fumitory: *Fumaria parviflora* Lam. (Fumariaceae)
4.1.5 Corn spurry: *Spergula arvensis* L. (Caryophyllaceae)
4.1.6 Common purselane: *Portulaca oleracea* L. (Portulacaceae)
4.1.7 Yellow pea: *Lathyrus aphaca* L. (Fabaceae)

Grassy

4.1.8 Blue grass: *Poa annua* L. (Poaceae)
4.1.9 Canary grass: *Phalaris minor* Retz. (Poaceae)
4.1.10 Bermuda grass: *Cynadon dactylon* L. (Poaceae)
4.1.11 Wild oat: *Avena ludoviciana* Thell (Poaceae)

Sedges

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

5. Rodents:

5.1 Bandicoot rat: *Bandicota bengalensis* Gray
5.2 Indian gerbil: Tatera indica Hardwicke
5.2 Striped squirrel: *Funambulus* spp.

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. sun, rain, wind and soil nutrients) and biological factors (i.e. sun, rain, sunshine hours, wind etc.). 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
- Pests and defenders population dynamics
- Soil conditions
- Climatic factors
- Farmers past experience

Principles of AESA based IPM:

Grow a healthy crop

- Select a variety resistant/tolerant to major pests
- Select healthy seeds and seedlings
- Treat the seed with recommended pesticides especially biopesticides
- 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
- Crop rotation

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

Farmers should

- Monitor the field situations 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.)

Plant Compensation ability

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

Understand and conserve defenders

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

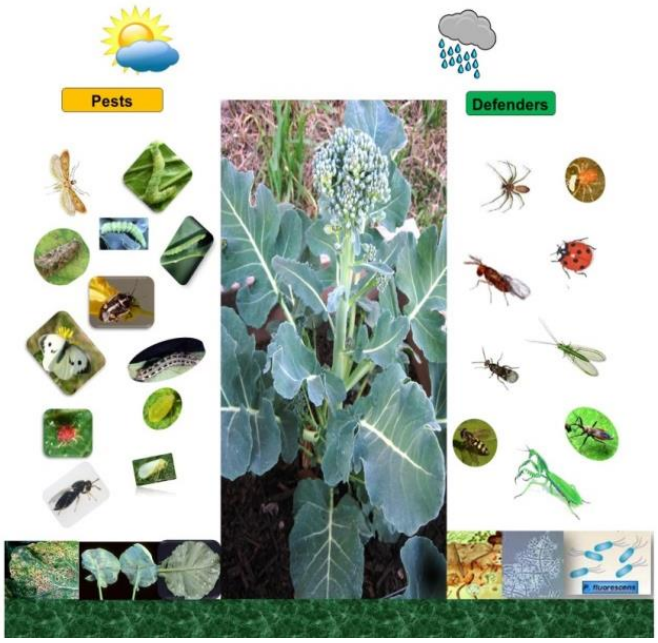
Insect zoo

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

Pest: Defender ratio (P: D ratio):
Identifying the number of pests and beneficial insects helps the farmers to make appropriate pest management decisions. Sweep net, visual counts etc. can be adopted to arrive at the numbers of pests and defenders. The P: D ratio can vary depending on the feeding potential of natural enemy as well as the type of pest. The natural enemies of broccoli 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 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 field in groups (about 5 farmers per group). Walk across the field and choose 20 plants/acre randomly. Observe keenly each of these plants and record your observations:

    - Plant: Observe the plant height, number of 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.
    - Rats: Count number of plants affected by rats.
    - Weeds: Observe weeds in the field and their intensity.
    - Water: Observe the water situation of the field.
    - Weather: Observe the weather condition.

- While walking in the field, manually collect insects in plastic bags. Use a sweep net to collect additional insects. Collect plant parts with disease symptoms.
- Find a shady place to sit as a group in a small circle for drawing and discussion.
- If needed, kill the insects with some chloroform (if available) on a piece of cotton.
- Each group will first identify the pests, defenders and diseases collected.
- Each group will then analyze the field situation in detail and present their observationsand 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 whatfield management is required in the AESA plot.
- Make sure that the required activities (based on the decision) will be carried out.
- Keep the drawing for comparison purpose in the following weeks.

Data recording

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

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

Data to be recorded

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


Advantages of AESA over ETL

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

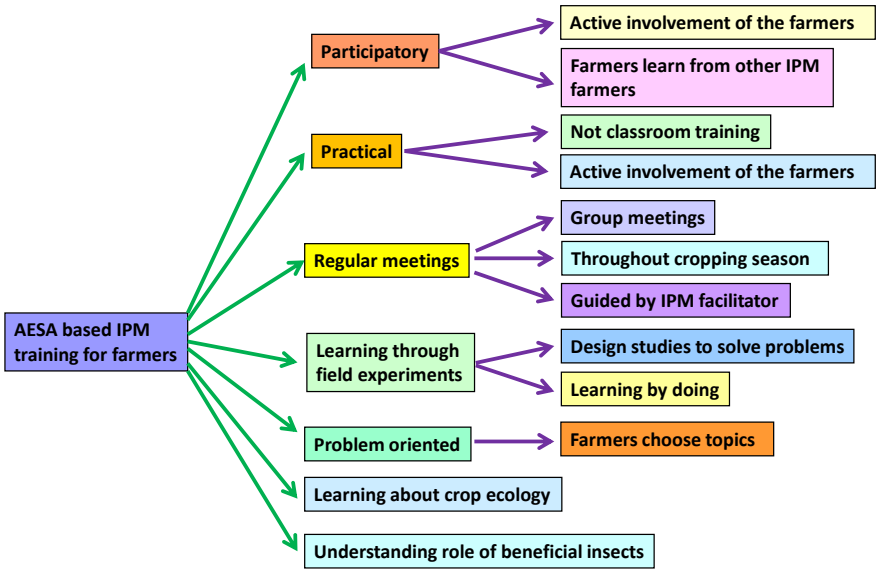
AESA and farmer field school (FFS)

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

Farmers can learn from AESA

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

FFS to teach AESA based IPM skills



B. Field Scouting:

AESA requires skill. So only the trained farmers can undertake 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 field 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 pest:

Aphids, mites and whitefly: Count and record the number of both nymphs and adults on five randomly selected leaves per plant.
Leaf webber: Count the number of webs formed in each direction, thus covering the whole plant.
For defoliator/ borers: Count the number of young and grown up larvae on each plant and record.
Leaf miner: Only the number of live mines on five randomly selected leaves per plant should be counted and recorded.

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.

Heads sampling: Carefully examine the heads of plants for symptoms and signs of fungal or bacterial diseases. The heads should be split or taken apart and examined for discoloration caused by fungi and bacteria. Count the number of heads infected due to disease and percent disease incidence should be recorded.

C. Surveillance through pheromone trap catches for diamondback moths:

Pheromone traps for DBM @ 4-5 traps/acre have to be installed, if available. Install the traps for each species separated by a distance of >75 feet in the vicinity of the selected field. Fix the traps to the supporting pole at a height of one foot above the plant canopy. Change of lures should be made at 2-3 week interval (regular interval). During each week of surveillance, the

number of moths/trap should be counted and recorded. The trapped moths should be removed and destroyed after each recording.

D. Yellow/blue pan water/sticky traps:
Set up yellow pan water trap/sticky traps 15 cm above the crop canopy for monitoring aphids and whiteflies @ 4-5 traps/acre. Locally available empty tins can be painted yellow and coated with grease/Vaseline/castor oil on outer surface may also be used.

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

F. Nematode extraction:
Collect 200-300 g representative soil sample. Mix soil sample and pass through a coarse sieve to remove rocks, roots, etc. Take a 600 cc subsample of soil, pack lightly into a beaker uniformly. Place soil in one of the buckets or pans half filled with water. Mix soil and water by stirring with paddle; allow to stand until water almost stops swirling. Pour all but heavy sediment through 20-mesh sieve into second bucket; discard residue in first bucket; discard material caught on sieve. Stir material in second bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 60 mesh sieve to collect cysts into first bucket; discard residue in second bucket. Stir material in first bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 325-mesh sieve into second bucket; discard residue in first bucket. Backwash material caught on 325-mesh sieve (which includes small to mid-sized nematodes and silty material) into 250-ml beaker. More than 90% of the live nematodes are recovered in the first 5-8 mm of water drawn from the rubber tubing and the sample is placed in a shallow dish for examination.

III. ECOLOGICAL ENGINEERING FOR PEST MANAGEMENT

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

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

Yarrow

Marigold

Repellent plants

***Ocimum* spp**

Peppermint/Spearmint

Barrier plant

Rye grass

Border plants

Maize

Sorghum

Crop rotation plants

***Sesbania* sp.**

***Crotalaria* sp.**

***Gaillardia* sp.**

Castor

Desmodium

Potato

Trap plants

Tomato

Marigold

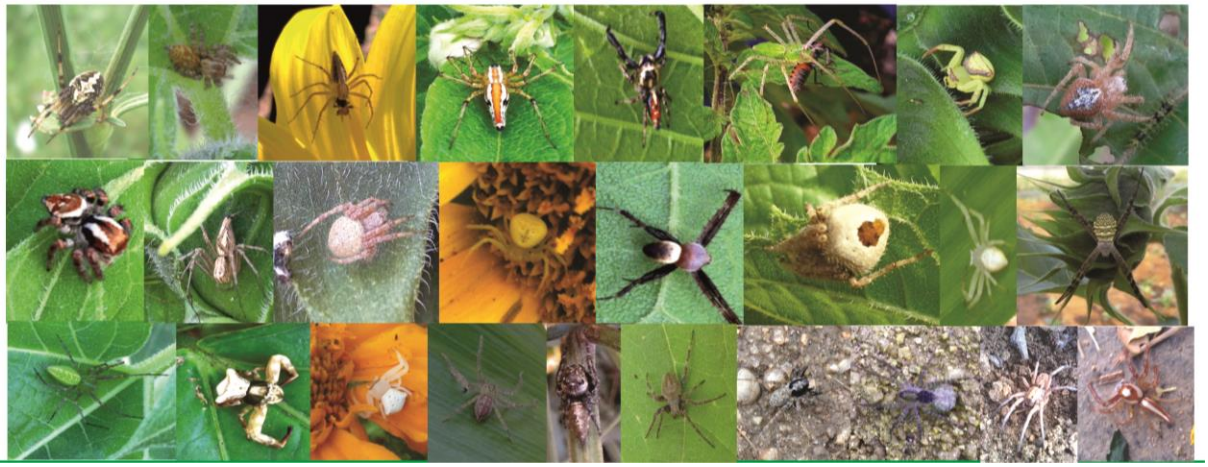
Pearl millets

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: Parasitoids

Biodiversity of natural enemies: Predators

Biodiversity of natural enemies: Spiders



IV. CROP STAGE-WISE IPM

Management	Activities
Pre-sowing and nursery stage*	
	<u>Common cultural practices:</u> • Deep ploughing of fields during summer. Three summer ploughings at 10 days interval reduces pests population. • Timely sowing should be done. • Use straw mulch in the nursery for better germination. • Field sanitation, rogueing • Destroy the alternate host plants • Apply manures and fertilizers as per soil test recommendations. • Grow the attractant, repellent, and trap crops around the field bunds. • Growing tomato or marigold as a trap crop for the management of leaf miner. • Plant tall border crops like maize, sorghum for the management of aphids. • Crop rotation with non-host crops (non-cruciferous).
Nutrients	• Broccoli grows best on a well-drained, medium to heavy soil with high organic matter content. Apply nutrients based on soil test report. It requires moist soil for fast and proper growth. The shoots become more fibrous under dry soil. It does well in pH range of 5.0 to 6.5. Plough the nursery beds thoroughly and mix with well rotten FYM @ 8 t per acre.
Weeds	• At the time of field preparation, adopt stale seed bed technique to minimize the weeds menace in field. • Soil solarization of nursery beds with transparent polyethylene sheet • Keep the nursery weeds free by hand weeding
Soil borne pathogens, insects and nematodes	• Raised nursery beds. • **<u>Soil solarization:</u>** Cover the beds with transparent polythene sheet of 100gauge thickness for three weeks before sowing for soil solarization which will help in reducing the **soil borne pests.** • Apply neem cake @ 180 Kg/acre at the time of transplanting for reducing nematodes..
Termites	**<u>Cultural control:</u>** • Apply well rotten farm yard manure only to discourage termite infestation. • Take 4 number earthen pots/acre around the hole and put 500 maize gully without seed or keep 1 kg of raw cow dung at 10 places in fields if the earlier crop is wheat. Destroy the crop residues which form the sources of infestation. • Use of crude oil emulsion to destroy the termite colony in the termitorium. **<u>Mechanical control:</u>**

	• Dismantle termitoria (termite mounds) around field and kill the termite queen by fumigation. **<u>Biological control:</u>** • Apply neem cake@ 80 kg/acre.
DBM	**<u>Cultural control:</u>** • After land preparation leave two ridges at the beginning and then after every 25 rows and at the end. • Removal and destruction of stubbles and plant debris after harvest and ploughing the field. • Grow intercrops such as tomato, garlic, coriander and carrot in alternate rows with broccoli. • Growing of 2 rows Indian mustard as trap crop after every 16 rows of broccoli (Sowing of first row of Indian mustard 15 days prior to broccoli planting and second row 25 days after broccoli planting).
Sowing/ Transplanting*	
Nutrients	• Apply 16-20kg N, 32kg P and 24 kg K per acre at the time of sowing.
Weeds	• Avoid weed seedlings along with broccoli seedlings transplanting. • Transplant the seedling in weed free beds. • Follow the row transplanting with recommended rows and plants spacing.
Black rot, root rot	**<u>Cultural control:</u>** • Use resistant/tolerant varieties, if any. • Crop sanitation • Use of disease free certified seed. • Appropriate drainage system to avoid movement of pathogens from plant to plant. • Treat the seed in hot water (58 °C) for 30 min.
Damping off	**<u>Cultural control:</u>** • Excessive watering and poorly drained are as should be avoided for sowing/transplanting. • Use raised beds: more than 15cm height is better for water drainage or use pro-trays for raising seedlings
***Alternaria* leaf blight**	**<u>Cultural control:</u>** • Crop rotation for 3 years without cruciferous crops or cruciferous weeds such as wild mustard. • Allow for good aeration (i.e. wide spacings, rows parallel to prevailing winds, not close to hedgerows). • Adequate drainage for avoiding excessive soil moisture. • Avoid low land for cropping.
Termites	• Same as pre-sowing stage
Club root of crucifer	• Soil solarization and soil fumigation (vapam). • Maintain soil pH 7 by adding lime.

	• Eradication of cruciferous weeds.
***** Apply *Trichoderma viride/harzianum* and *Pseudomonas fluorescens* for seed, nursery treatment and soil application (if commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).	
Vegetative	
	<u>Common cultural practices:</u> • Collect and destroy diseased and insect infected plant parts. • Provide irrigation at critical stages of the crop • Avoid water stagnation. • Enhance parasitic activity by avoiding chemical spray, when 1-2 larval parasitoids are observed **<u>Common mechanical practices:</u>** • Collection and destruction of eggs and early stage larvae • Handpick the older larvae during early stages • The infested curd and seed capsules may be collected and destroyed • Handpick the gregarious caterpillars and the pupae which are found on leavesand destroy them in kerosene mixed water. • Use yellow sticky traps for aphids @ 4-5 trap/acre. • Use light trap @ 1/acre and operate between 6 pm and 10 pm • Install pheromone traps @ 4-5/acre for monitoring adult moths activity (replace the lures with fresh lures after every 2-3 weeks) • Erecting of bird perches @ 20/acre for encouraging predatory birds such as King crow, common mynah etc. • Set up bonfire during evening hours at 7-8 pm **<u>Common biological practices:</u>** • Conserve natural enemies through ecological engineering • Augmentative release of natural enemies
Nutrients	• Apply remaining half dose of N in 2 equal split doses i.e. 8-10 kg N per acre at 4 – 5 weeks after transplanting and 8 – 10kg N per acre before head formation
Weeds	• Tool weeding and hoeing should be done once within 20-25 days after transplanting and second time 45 days after transplanting. Deep hoeing should be avoided. • Mulching with black Low Density Polyethylene (LDPE) sheets of 30micron thickness by burying both the ends into the soil to a depth of 10 cm will avoid weed growth.
DBM	• See common cultural practices. **<u>Biological control:</u>** • Release egg parasitoid, *Trichogramma chilonis/pretiosum* @ 20,000/acre 4-6 times at weekly interval. • Release larval parasitoids, *Diadegmasemi clausum*@ 1,00,000/acre (Hills – below 25 –27ºC) or *Cotesia plutellae* (plains) @ 20,000/acre from 20 days after planting
Cabbage borer, cabbage leaf webber, Cabbage	• See common cultural and biological practices.

Aphid	
Cutworm	**Cultural control:** • Use of ovipositional trap crops such as castor @ 250 plants/acre and collection of larvae from leaves and soil clods. • For other cultural and biological practices see common practices.
Painted bug	**Cultural control**: • Remove weed hosts in and around planting areas. • Removal of plant residue after harvest can reduce carryover between crops. • In gardens where the painted bug is present in very high densities, it may be advisable to remove very attractive host plants and replace them with non-cruciferous plants. **Mechanical control:** • Hand picking the bugs when populations are very low. • When infestations are heavy, it may be possible to collect the bugs with a portable vacuum cleaner. It is often easier to tap the plant onto a sheet and collect/vacuum the bugs rather than removing them individually. • Pyramid traps baited with crushed sweet alyssum, inside polypropylene bags, can also be used to catch and destroy bugs, particularly when numbers are high. **Biological control:** • See common biological practices.
Leaf eating weevil	• Adopt common cultural and biological practices.
White fly	**Cultural control:** • Clipping of infested leaves. • Avoid water log conditions. • Avoid planting in low land areas • For others follow common practices. • Follow common mechanical practices. **Biological Control:** • See common practices.
Leaf miner	• See common cultural and biological practices.
Red spider mite	**Cultural Control:** • Regular field monitoring for pest and defender population, barrier crops like mustard crop around the field. • Attractant plants like French bean are helpful for attraction of Predator. • Frequent irrigation deters the red spider mite population. **Biological control:** • Release 8 days old Anthocorid bug, *Blaptostethuspallescens.*
Caterpillars	**Cultural control:** • See common cultural practices.

	Biological control: • Spray NSKE 5% against eggs and first instar larvae. • Spray SlNPV @ 40LE/ac in combination with jaggery 1 kg, sandovit 100 ml or Robin Blue 50 g thrice at 10-15 days interval on observing the eggs or first instar larvae in the evening hours.
Cabbage butterfly	**Cultural control:** • Fine-mesh netting in nursery will stop butterflies from reaching the crop and lay eggs. Collect and destroy eggs or caterpillars mechanically by hand- usually on the underside of the leaves. • Intercropping cabbages with *Nasturtium* results in fewer egglaying on cabbage by the butterflies. **Biological control:** • See common biological control.
Club rot diseases	**Cultural control:** • A pH slightly above neutral (usually about pH 7.2) helps to minimize disease • Add hydrated lime to soil to increase pH to 7.2 (6 weeks before planting) as per soil test recommendation. • Avoid excess irrigation
White blister	**Cultural control:** • Sanitary measures and destruction of weeds • Crop rotation with non-cruciferous crops
/Downy mildew	**Cultural control:** • Soil solarization, burning of infected plant debris, deep ploughing, well-drained soil. • Restricted irrigation.
Mosaic disease	• Control insect vector
Black rot	• Same as in sowing stage
***Alternaria* leaf blight**	• Pruning of diseased leaves and burn it. • Others are same as sowing stage.
Other Lepidopteran insects	• Same as in vegetative stage
Head stage	
Nutrients	• Apply deficient micronutrients in standing crop.
Weeds	• Remove the weeds before shedding of their seeds in the field.
Mustard Saw fly	**Cultural control:** • Summer ploughing to destroy the pupae. • Early sowing should be done. • Maintain clean cultivation. • Apply irrigation in seedling stage for sawfly management because most of the larvae die due to drowning effect. **Mechanical control:** • Collection and destruction of larvae of saw fly in morning and

	evening. **Biological control:** • Conserve *Perilissuscingulator* (parasitoids of the larvae), and the bacterium *Serratiamarcescens* which infect the larvae of sawfly. • Use of bitter gourd seed oil emulsion as an anti-feedant.
Other insect pests and diseases	• Same as sowing and vegetative stage.

V. RODENT PEST MANAGEMENT

Common/Scientific name	Damage symptoms	Management
Bandicoot rat, Indian gerbil, Tatera indica	• Active burrow in the field • Presence of damaged fruits in dug out rodent burrows and in premises	**Cultural control:** • Practice clean cultivation/maintain weed free fields which reduces the harboring/hiding points for rodents. • Practice trapping with locally available traps using lure @ 20-25 traps/ac. In areas, where *Rattus rattus* 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 fields, field bunds, canal bunds and surrounding barren lands etc. Day 2: Count the re-opened burrows and practice pre-baiting @ 20 g/burrow (98 parts of broken rice + 2 parts of edible oil) Day 4: Observe the re-opened burrows and treat the burrow with zinc phosphide poison bait (96 parts of broken rice + 2 parts of edible oil + 2 parts of zinc phosphide) @ 10g/ burrow. Collect the dead rats, if found any

		outside and bury them.

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 DEFICIENCY/ PHYSIOLOGICAL DISORDERS

Magnesium: Symptoms seen in old leaves; leaves turn into yellow color. Correction Measure: Foliar spray of MgSO4@0.5%	
Whiptail: Deficiency of molybdenum cause whiptail in which the lamina of the newly-formed leaves become leathery, irregular and consisting of only the mid-rib. Control: In Boron deficient soils apply 1-1.5 kg molybdenum before planting. In standing crop the disorder can be corrected by foliar spray of 0.01% solution of Ammonium molybdate.	

Browning Head: It results from boron deficiency. First water-soaked areas appear on bud clusters which in turn pinkish or rusty-brown in advanced stages resulting in rotting. Control: Soil application of Borax or Sodium Borate @ 20 kg/ha will prevent the disorder. In standing crop, foliar spray of 0.25-0.5% solution of borax should be applied.	

VIII. COMMON WEEDS

Major *rabi* weeds

1. Lambs quarter: *Chenopodium album* L. Chenopodiaceae

2.Scarlet pimpernel: *Anagalli sarvensis* L (Primulaceae)

3. Sweet clover: *Melilotus indica*(L.) All. Fabaceae

4.Fine leaf fumitory: ***Fumaria parviflora* Lam. (Fumariaceae)**

5.Corn spurry: *Spergula arvensis* L. (Caryophyllaceae)

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

 **7 Yellow pea: *Lathyrus aphaca* L. (Fabaceae)**	 **8. Canary grass: *Phalaris minor* Retz. (Poaceae)**	 **9. Bluegrass: *Poa annua* L. (Poaceae)**
 **10 Bermuda grass: *Cynadon dactylon* L. (Poaceae)**	 **11 Wild oat: *Avena ludoviciana* Thell (Poaceae)**	 **9. Purple nutsedge: *Cyperusrotundus* L. (Cyperaceae)**

IX. DESCRIPTION OF INSECT, MITE AND NEMATODE PESTS

1. Diamondback moth:

Biology:

Egg: Each female lays 50-300 small whitish eggs singly along the veins on underside of leaves at night times. Egg hatches in about 3-10 days.

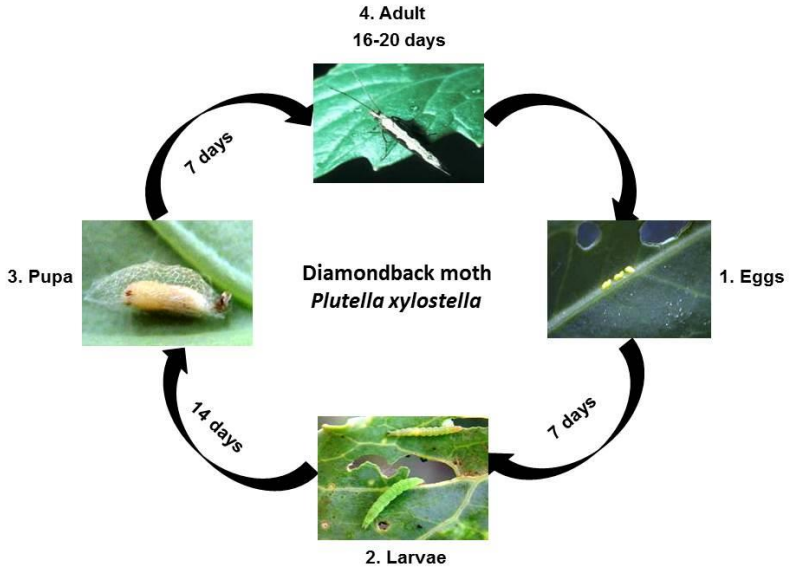
Larva: Larva is greenish with short thin hairs on the body. Full grown caterpillar measures 1-1.5 cm and its body tapers towards both ends. Larval period is 14 days.

Pupa: Pupation takes place inside a barrel shaped thin loose mesh of silken cocoon. Pupal period is about 7 days.

Adult: The moth is greyish brown with narrow wings having pale white triangular markings on inner margin of each forewing which form three diamond shaped white patches dorsally when wings are folded over back at rest. Hence the name, diamondback moth.

The pest is active throughout the year. There are 8-12 generation in a year.

Life cycle:



http://www.infonet-biovision.org/default/ct/90/pests

Damage symptoms:

- Caterpillars feed on undersurface of leaves and bite holes in leaves and cause serious damage
- Withered appearance of affected leaves.
- Skeletonized leaves.
- Growing tip damaged no head/curd formation.
- In severe infestation, under-sized curds are formed, and head formation does not take place when infestation is very severe during primordial stage.

http://www.extension.umn.edu/garden/diagnose/plant/vegetable/broccoli/leavesholes.html

Natural enemies of Diamondback moth:

Parasitoids:*Trichogramma* sp (egg) *Apantele sglomeratus* (larval), *Bracongelechiae* (larval), *Bracon* sp, (larval), *Mesochorus* spp. (larval), *Brachymeria* spp. (larval), *Eriborus*spp. (larval), *Diadegmasemi clausum*, (larval) *D. fenestralis* (larval), *Tetrastichus sokolowskii* (larval) and *Cotesia vestalis* (larval), *Diadromus collaris* (pupal), *Diadromus* spp. (pupal), *Brachymeria excarinata* (pupal) etc.

Predators:*Chrysoperla zastrowi sillemi*, coccinellids, King crow, common mynah, wasp, dragonfly, spider, robber fly, reduviid bug, praying mantis, fire ants, big eyed bugs (*Geocoris* sp), pentatomid bug (*Eocanthecona furcellata*), earwigs, ground beetles, rove beetles etc.

Fungal pathogens: *Paecilomyces* spp., *Zoophthora radican* etc.

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

2. Leaf webber:

Biology:

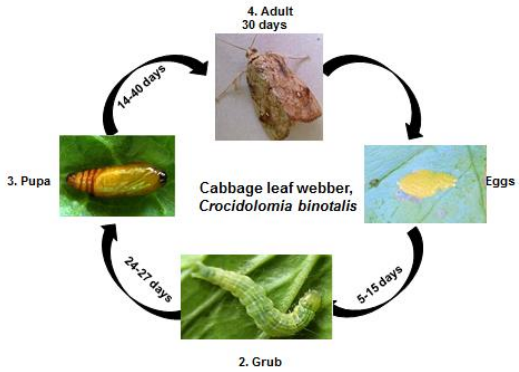
Egg: Female moth lays eggs in masses of 40 -100 on underside of leaves. They hatch in 5 -15 days

Larva: Caterpillar webs together the foliage and feeds on leaves. It also feeds on flowers and pods in the case of mustard and flower heads in cabbage and cauliflower. Caterpillar bears red head with brown longitudinal stripes and rows of tubercles on the body. Larval period is 24-27 days.

Pupa: Pupation takes place in a cocoon within the webbed leaves. Pupal period is 14-40 days.

Adult: Adult is small with light brownish forewings. The total life cycle is completed in 42-84 days.

Life cycle:



1. http://ecoport.org/ep?SearchType=pdb&PdbID=38333
2,3,4http://infohamapenyakittumbuhan.blogspot.in/2012/04/crocidolomia-binotalis-zell.html

Damage symptoms:

- Webbed leaves with fecal matter
- Skeletonized leaves

https://www.plantvillage.com/en/topics/broccoli/infos/diseases_and_pests_description_uses_propagation

Natural enemies of leaf webber:

Parasitoids:*Trichogramma* sp (egg), *Bracon hebetor* (larval), *Cotesia crocidolomiae*(larval), *Palexorista solennis*(larval), *Microbracon nudlus* etc.
Predators:*Chrysoperla zastrowi sillemi*, coccinellids, King crow, common mynah, wasp, dragonfly, spider, robber fly, reduviid bug, praying mantis, fire ants, big eyed bugs (*Geocoris* sp), pentatomid bug (*Eocanthe conafurcellata*), earwigs, ground beetles, rove beetles etc.
Fungal pathogens: *Paecilomyces* spp., *Zoophthora radican* etc.

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

3. Cabbage butterfly:

Biology:

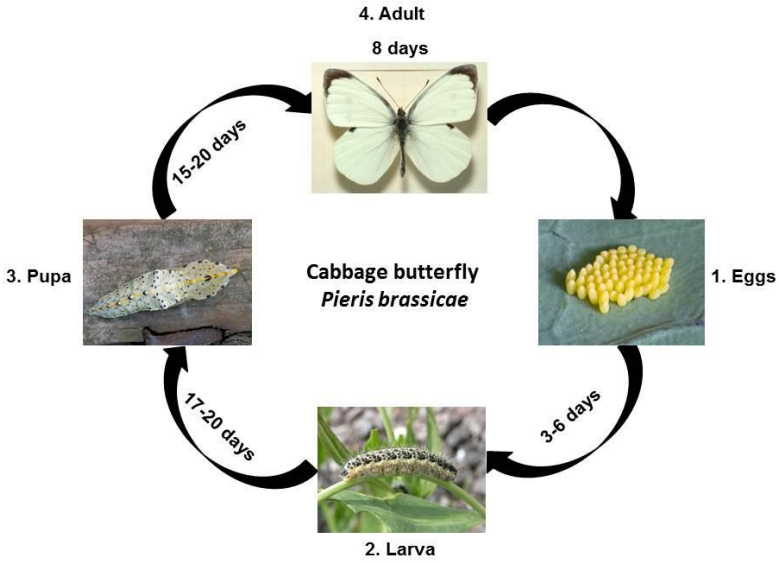
Egg: Adult butterfly after mating lays about 100-150 yellowish cigar-shaped eggs in batches. The eggs hatch in 10-16 days in winter and 307 days in summer.

Larva: The caterpillar is velvety green and measures about 4.2 cm in length. The caterpillars are gregarious initially but disperse as they grow.

Pupa: Pupation is in damaged leaves.

Adult: Adult is a butterfly with its fore wings snow white having black distal margins. Hind wings pure white with black apical spots.

Life cycle:



Symptoms of damage:

- They skeletonise leaves and bore into heads of broccoli

http://extension.entm.purdue.edu/radicalbugs/default.php?page=pests/cabbage_butterfly

Natural enemies of cabbage butterfly:

Parasitoids:*Trichogramma chilonis* (egg)*, T. japonicum* (egg), *Cotesia glomeratus* (larval), *Phryxe vulgaris* (larval) and *Pteromalus puparum* (pupal)
Predators: Lacewings (*Chrysoperla zastrowii sillemi*), coccinellids*,* King crow, common mynah, wasp, dragonfly, spider, robber fly, reduviid bug, praying mantis, fire ants, big eyed bugs (*Geocoris* sp), pentatomid bug (*Eocanthecona furcellata*), earwigs, ground beetles, rove beetles etc.

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

4. Mustard Sawfly:

Biology:

Egg: Eggs are spherical, about 0.5 mm in diameter, light bluish green in colour, inserted singly into leaf tissues.

Larva: Larva is greenish black with wrinkled body and eight pairs of pro-legs. On slightest touch the larva falls to round and feigns death. The larvae had 6 instars, feed on the leaves, and pupated after 14-16 days.

Pupa: Pupae look like sand particle and have salivary secretions; the pupal stage lasted 11-12 days. Pupation takes place in thick silken cocoon in soil.

Adult: Adults are orange bodied with smoky transparent wings. The pest is active during seedling stage of the crop i.e. October - November.

1. Larva **2. Adult**

1,2: https://www.google.co.in/search?q=mustard+saw+fly&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=fJf4U

Damage symptoms:

- Initially the larva nibbles leaves, later it feeds from the margins towards the midrib.
- The larvae cause numerous shot holes and even riddle the entire leaves by voracious feeding.
- They devour the epidermis of the shoot, resulting in drying up of seedlings and failure to bear seeds in older plants.
- The yield losses up to 5 to 18 %. In severe case at the seedling stage, the crop have to be resown.

Natural enemies of mustard sawfly:

Parasitoids:*Perilissus cingulator* (larval)

Entomopathogen: *Bacterium serratiamarcescens*

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

5. Aphid:

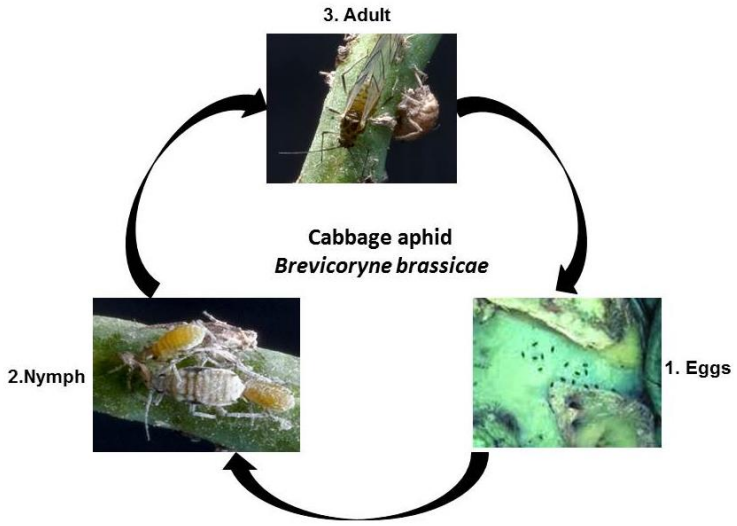
Biology:

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

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

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

Life cycle:



1,2,3: http://whatcom.wsu.edu/ipm/manual/blue/aphid.html

Damage symptoms: This pest infests crucifers in cold season. Both the nymphs and adults suck sap from plant causing loss of vigour. Sooty mould develops on excreted honeydew reducing the photosynthesis

http://hubpages.com/hub/Organic-Aphid-Control-Methods#

Natural ennemies of cabbageaphids:

Parasitoids: *Aphidius colemani* (adult and nymphal), *Diaeretiella* spp. (adult and nymphal), *Aphelinus* spp. (adult and nymphal) etc.
Predators: Anthocorid bugs/pirate bugs (*Orius* spp.), mirid bugs, syrphid/hover flies, green lacewings (*Mallada basalis* and *Chrysoperla zastrowi sillemi*), predatory coccinellids (*Stethorus punctillum*), staphylinid beetle (*Oligota* spp.), predatory cecidomyiid fly (*Aphidoletis aphidimyza*)

and predatory gall midge, (*Feltiella minuta*), earwigs, ground beetles, rove beetles, spiders, wasps etc.

6. Painted bug:

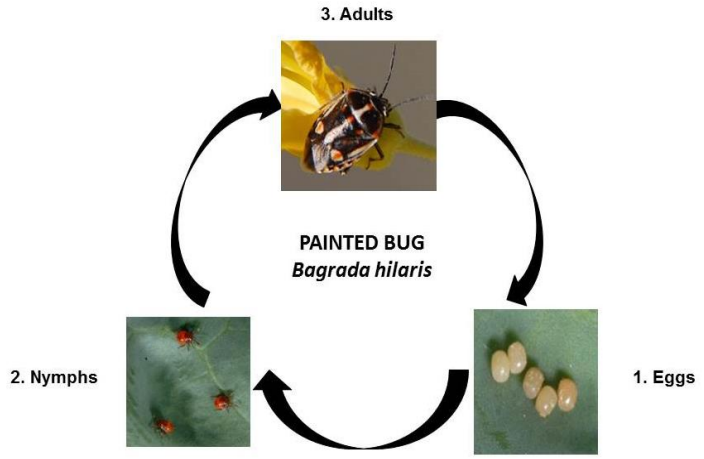
Biology:

Egg: Bagrada bug lays its eggs in clusters on leaves or on the soil underneath host plants. Eggs are barrel shaped, initially white and turn orange with age. A single female can lay as many as 100 eggs within 2 to 3 weeks. The incubation period is 5 to 8 days

Nymph: Nymph passes through five stages changing colour from bright orange to red with dark markings, gradually acquiring the colouration of the adult. Initially they do not have wings; wings are gradually developed as the nymphs grow. Wing pads are visible in the last instar nymph.

Adult: The adult bug is typically shield-shaped, 5 to 7 mm long and 3 to 4 mm broad at its widest area. The upper surface has a mixture of black, white and orange markings, which gives the insect its common names harlequin bug or painted bug. The life cycle lasts 3 to 4 weeks and several generations may occur in a year. Period of activity of painted bug starts from September.

Life cycle:



https://www.google.co.in/search?q=painted+bug+of+mustard&oq=painted+ bug+of+mustard&aqs=chrome.

Damage symptoms:

- Adults and nymphs suck sap from all parts of the plant.
- Young plants wilt and wither as a result of the attack.
- Quality and quantity (31% losses) of yield is affected when grown up plants are infected.
- Harvested crop in threshing floor is also infested.

Natural enemies of painted bug:

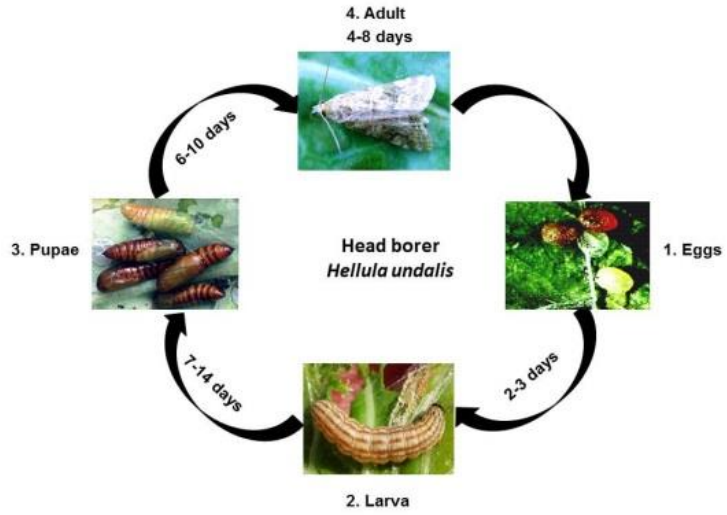
Parasitoid: *Alophora* spp. (Tachinid fly) (eggs).

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

7. Cabbage Head borer:

Egg: Female moth lays yellowish shiny eggs on underside of the leaves. Eggs hatch in about 2-4 days.
Larva: The caterpillar becomes full grown in about 9 days. Full grown caterpillar is 12-15 mm, greyish yellow with seven purplish brown longitudinal stripes on the body, dark brown head with 'V' shaped marking.
Pupa: Full grown larva pupates in the larval burrow itself or in the soil. Pupal period is about 6 days.
Adult: Adult is pale yellowish-brown moth having grey wavy lines on the forewing.

Life cycle:



1 http://www.extento.hawaii.edu/kbase/view/files/pictures/h_undal1.jpg
2 http://www.ent.uga.edu/veg/colecrops/images/cabbagewebworm2.jpg
3 http://www.malaeng.com/blog/tmp/2010/08/4hellula.jpg
4 http://www.infonet-biovision.org/default/ct/106/pests

Damage symptoms:

- Caterpillars web the leaves and bore into stem, stalk or leaf veins.
- They bore into the head also making it unfit for consumption. The damage results in Webbed leaves
- Holes in cabbage head with fecal matter

Natural enemies of cabbage head borer:
Parasitoids:*Trichogramma* spp. (egg), *Bracon gelechiae* (larval), *B. hebetor* (larval) etc.
Predators:*Chrysoperla zastrowi sillemi*, coccinellids, King crow, common mynah, wasp, dragonfly, spider, robber fly, reduviid bug, praying mantis, fire ants, big eyed bugs (*Geocoris* sp), pentatomid bug (*Eocanthecon afurcellata*), earwigs, ground beetles, rove beetles etc.
Fungal pathogens:*Paecilomyces* spp., *Zoophthora radican* etc.

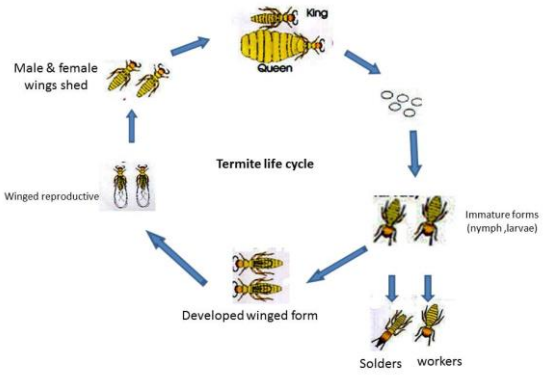
*For the management refer page no……..

8. Termites:

Biology:

Egg: Dull, kidney shaped and hatches in 30-90 days.
Nymph: Moult 8-9 times and are full grown in 6-12 months.
Adult: Creamy coloured tiny insects resembling ants with dark coloured head.

Life cycle:



http://www.termitenewyorkcity.com/more-about-termites/life-cycle/

Damage symptoms:

- Termites damage the crop soon after sowing and sometimes near maturity. They feed on roots, stem of growing plants, even dead tissues of plant feeding on cellulose. The damaged plants dry up completely and are easily pulled out. The plants damaged at later stages give rise to white ears. Infestation is heavy under unirrigated conditions and in the fields where un-decomposed farm yard manure is applied before sowing.

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

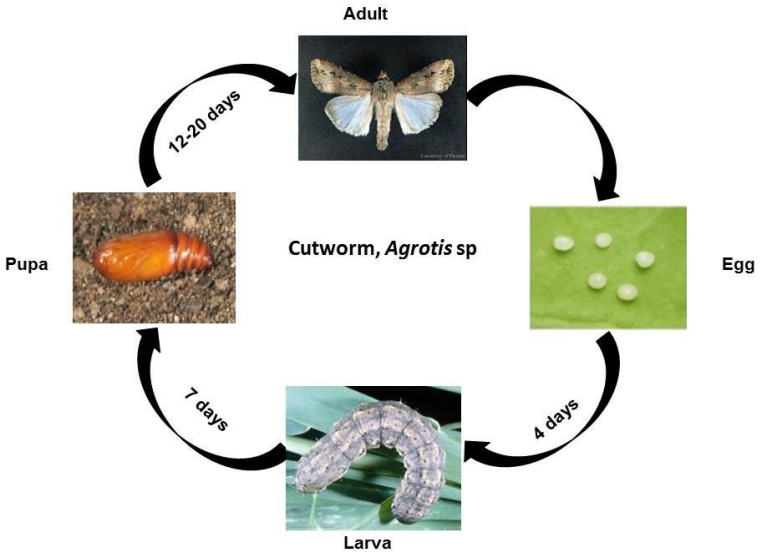
9. Cutworm:

Biology:

Egg: The egg is white in color initially, but turns brown with age. It measures 0.43 to 0.50 mm high and 0.51 to 0.58 mm wide and is nearly spherical in shape, with a slightly flattened base. The eggs normally are deposited in clusters on foliage. Females may deposit 1200 to 1900 eggs. Duration of the egg stage is three to six days.
Larva: Neonate larvae are yellow in colou whereas the full grown larvae is dark brown with greasy body. There are five to nine instars, with a total of six to seven instars most common. Head capsule widths are very similar for instars one through four, but thereafter those individuals that display eight or nine instars show only small increments in width at each molt and eventually attain head capsule sizes no larger than those displaying only six or seven instars.
Pupa: Pupation occurs belowground at a depth of 3 to 12 cm. The pupa is 17 to 22 mm long and 5 to 6 mm wide, and dark brown. Duration of the pupal stage is normally 12 to 20 days.

Adult: The adult is fairly large in size, with a wingspan of 40 to 55 mm. The forewing, especially the proximal two-thirds, is uniformly dark brown. The distal area is marked with a lighter irregular band, and a small but distinct black dash extends distally from the bean-shaped wing spot. The hind wings are whitish to gray, and the veins marked with darker scales. The adult pre-oviposition period is about seven to 10 days. Moths select low-growing broadleaf plants preferentially for oviposition, but lacking these will deposit eggs on dead plant material. Soil is an unsuitable oviposition site.

Life cycle:



http://en.wikipedia.org/wiki/Agrotis_ipsilon

Damage symptoms:

Larvae can consume over 400 sq cm of foliage during their development, but over 80% occurs during the terminal instar, and about 10% in the instar immediately preceding the last. Thus, little foliage loss occurs during the early stages of development. Once the fourth instar is attained, larvae can do considerable damage by severing young plants, and a larva may cut several plants in a single night. Plants tend to outgrow their susceptibility to injury.

Natural enemies of cutworm:

Parasitoids: *Apanteles merginiventris, Chelonis insularis*, *Hyposoter exigua, Lespesia archippivora, Cotesia* sp, *Meterorus* sp., *Campoleti* sp, *Bracon kitcheneri*, *Fileanta ruficanda*

Predators: *Broscus punctatus*, *Liogryllus bimaculatus,* lacewings (*Chrysoperla zastrowii sillemi*), coccinellids*,* King crow, common mynah, wasp, dragonfly, spider, robber fly, reduviid bug etc.

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

9. Leaf eating caterpillars/cabbage looper:

Biology:

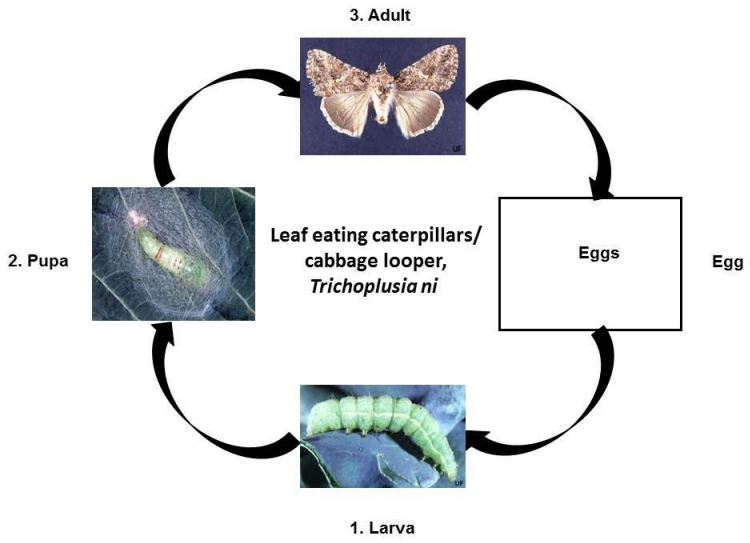
Egg: Eggs are hemispherical in shape, with the flat side affixed to foliage. They are deposited singly on either the upper or lower surface of the leaf, although clusters of six to seven eggs are not uncommon. The eggs are yellowish white or greenish in color, bear longitudinal ridges, and measure about 0.6 mm in diameter and 0.4 mm in height. Eggs hatch in about two, three, and five days at 32, 27, and 20°C, respectively, but require nearly 10 days at 15°C.

Larva: Young larvae initially are dusky white, but become pale green as they commence feeding on foliage. They are somewhat hairy initially, but the number of hairs decreases rapidly as larvae mature. Larvae have three pairs of prolegs, and crawl by arching their back to form a loop and then projecting the front section of the body forward. The mature larva is predominantly green, but is usually marked with a distinct white stripe on each side. The thoracic legs and head capsule are usually pale green or brown. Dorsally, the larva bears several narrow, faint white stripes clustered into two broad white bands. In some cases the mature larva is entirely green. The body is narrower at the anterior end, and broadens toward the posterior. It measures 3 to 4 cm in length at maturity. The number of instars is four to seven, but many authors indicate only five. Larval development required 17.8 and 19.9 days when reared on bean and held at 23 and 32°C, respectively.

Pupa: At pupation, a white, thin, fragile cocoon in formed on the underside of foliage, in plant debris, or among clods of soil. The pupa contained within is initially green, but soon turns dark brown or black. The pupa measures about 2 cm in length. Duration of the pupal stage is about four, six, and 13 days at 32, 27, and 20°C, respectively.

Adult: The forewings of the cabbage looper moth are mottled gray-brown in color; the hind wings are light brown at the base, with the distal portions dark brown. The forewing bears silvery white spots centrally: a U-shaped mark and a circle or dot that are often connected. The forewing spots, although slightly variable, serve to distinguish cabbage looper from most other crop-feeding noctuid moths. The moths have a wingspan of 33 to 38 mm.

Life cycle:



http://entnemdept.ufl.edu/creatures/veg/leaf/cabbage_looper.htm

Damage symptoms:

- Cabbage loopers are leaf feeders, and in the first three instars they confine their feeding to the lower leaf surface, leaving the upper surface intact.
- The fourth and fifth instars chew large holes, and usually do not feed at the leaf margin. In the case of cabbage, however, they feed not only on the wrapper leaves, but also may bore into the developing head.
- Larvae consume three times their weight in plant material daily.
- Feeding sites are marked by large accumulations of sticky, wet fecal material. Despite their voracious appetite, larvae are not always as destructive as presumed.

Natural enemies of leaf eating caterpillars of cabbage looper:

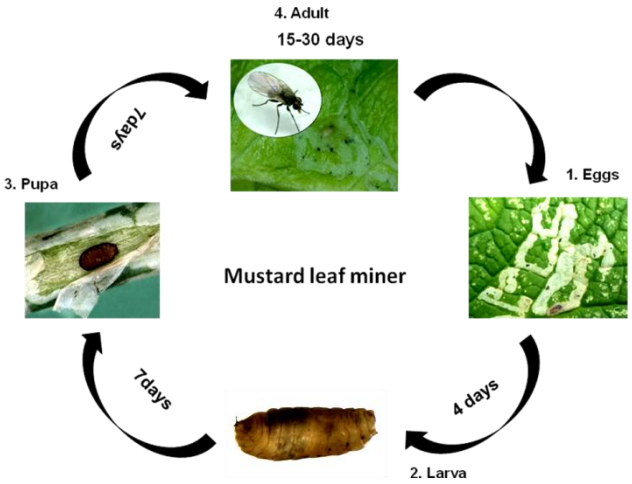
Parasitoids:*Trichogramma,* tachinid, *Copidosoma truncatellum*
Predators: Lacewings (*Chrysoperla zastrowii sillemi*),coccinellids*,* King crow, common mynah, wasp, dragonfly, spider, robber fly, reduviid bug etc.

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

10. Leaf miner:

Biology:
Egg: Eggs are laid singly mostly on leaf tissues. More than one egg may be laid in a single leaf. Incubation period varies from 2-6 days depending upon the weather conditions.
Larva: Larvae are minute, apodous and yellowish in colour.
Pupa: Pupation takes place with in galleries and pupal period last for 4-6 days.
Adult: Adults are small two winged flies with grayish black meso notum and yellowish forms.

Life cycle:



https://www.google.co.in/search?q=mustard+leaf+minor+ &espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=dq

Damage symptoms:

- Leaves with mines; the attacked leaves wither; vigour of the plant gets reduced. Its damage is often more prominent on the older leaves.

Natural enemeis of leaf miner:

Parasitoids:*Gronotoma micromorpha* (larval and pupal), *Diglyphus isaea* (larval), *Halticoptera circulus,Opius phaseoli* (pupal) *Chrysocharis pentheus* (larval), *Neochrysocharis formosa* (larval).

Predators: Lacewings, ladybird beetle, spiders, fire ants.

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

11. Whitefly:

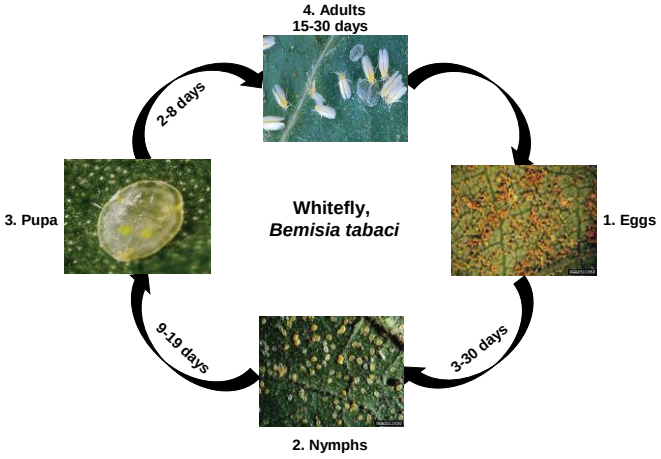
Biology:

Egg: The gravid females mostly lay eggs near the veins on the underside of leaves. They prefer hairy leaf surfaces to lay more eggs. Each female can lay about 300 eggs in its lifetime. Eggs are small (about 0.25 mm), pear-shaped, and vertically attached to the leaf surface through a pedicel. Newly laid eggs are white and later turn brown. The eggs are not visible to the naked eye, and must be observed under a magnifying lens or microscope. Egg period is about three to five days during summer and 5 to 33 days in winter.

Nymph: Upon hatching, the first instar larva (nymph) moves on the leaf surface to locate a suitable feeding site. Hence, it is commonly known as a "crawler." It then inserts its piercing and sucking mouthpart and begins sucking the plant sap from the phloem. The first instar nymph has antennae, eyes, and three pairs of well-developed legs. The nymphs are flattened, oval-shaped, and greenish-yellow in color. The legs and antennae are atrophied during the next three instars and they are immobile during the remaining nymphal stages. The last nymphal stage has red eyes. This stage is sometimes referred to puparium, although insects of this order (Hemiptera) do not have a perfect pupal stage (incomplete metamorphosis). Nymphal period is about 9 to 14 days during summer and 17 to 73 days in winter. Adults emerge from pupariathrough a T-shaped slit, leaving behind empty pupal cases or exuviae.

Adult: The whitefly adult is a soft-bodied, moth-like fly. The wings are covered with powdery wax and the body is light yellow in color. The wings are held over the body like a tent. The adult males are slightly smaller in size than the females. Adults live from one to three weeks.

Life cycle:



1.http://m.animal.memozee.com/m.view.php?q=%EB%8B%B4%EB%B0%B0%EA% B0%80%EB%A3%A8%EC%9D%B4&p=3

2. http://www.forestryimages.org/browse/detail.cfm?imgnum=2511050
3. http://agspsrv34.agric.wa.gov.au/ento/pestweb/Query1_1.idc?ID=955595135
4. http://www.entomology.umn.edu/cues/inter/inmine/Whitefg.html

Damage symptoms:

Both the adults and nymphs suck the plant sap and reduce the vigor of the plant. In severe infestations, the leaves turn yellow and drop off. When the populations are high they secrete large quantities of honeydew, which favors the growth of sooty mould on leaf surfaces and reduces the photosynthetic efficiency of the plants.

Natural enemies of whitefly:

Parasitoids: *Encarsia* sp, *Eretmocerus* sp, *Chrysocharis pentheus*

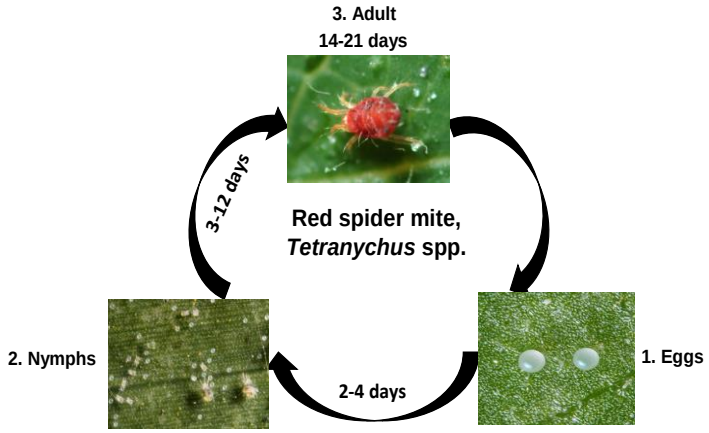
Predators: Mirid bug (*Dicyphus hesperus*), dragonfly, spider, robber fly, praying mantis, fire ants, coccinellids, lace wings, big eyed bugs (*Geocoris*sp) etc.

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

12. Mites:

Biology:

Tetranychus urticae is commonly known as red spider mite or two spotted spider mite. They are minute in size, and vary in color (green, greenish yellow, brown, or orange red) with two dark spots on the body. Eggs are round, white, or cream-colored; egg period is two to four days. Upon hatching, it will pass through a larval stage and two nymphal stages (protonymph and deutonymph) before becoming adult. The lifecycle is completed in one to two weeks. There are several overlapping generations in a year. The adult lives up to three or four weeks.



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 red spider mites:

Predators: Anthocorid bugs (*Orius* spp.), mirid bugs, syrphid/hover flies, green lacewings (*Mallada basalis* and lacewing), predatory mites (*Amblyseius alstoniae*, *A. womersleyi, A. fallacies* and *Phytoseiulusper similis*), predatory coccinellids (*Stethorus punctillum*), staphylinid beetle (*Oligota* spp.), cecidomyiid fly (*Anthrocnoda xoccidentalis*), gall midge (*Feltiella minuta*) etc.

Entomopathogen: *Beauveria bassiana* (entomo pathogen)

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

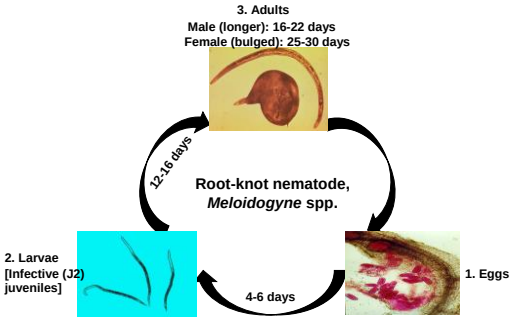
13. Nematodes:

Biology:

- Most species of plant parasitic nematodes have a relatively simple life cycle consisting of the egg, four larval stages and the adult male and female. They are microscopic in size.
- Development of the first stage larvae occurs within the egg where the first moult occurs. Second stage larvae hatch from eggs to find and infect plant roots or in some cases foliar tissues.
- Under suitable environmental conditions, the eggs hatch and new larvae emerge to complete the life cycle within 4 to 8 weeks depending on temperature.
- Nematode development is generally most rapid within an optimal soil temperature range of 70 to 80°F.

Life cycle:

Life stages are microscopic in size



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
- Seedlings infected in nursery do not normally survive transplanting and those surviving have reduced flowering and fruit production
- Nematode infection predisposes plants to fungal and bacterial root pathogens

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 inoculum
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 Insect Pests of broccoli vegetables

Parasitoids

Egg parasitoids

***1. Trichogramma* sp**

2. *Tetrastichus* spp.

Egg-larval parasitoid

3. *Chelonus* spp.

Larval parasitoids

4. *Bracon* spp.

5. *Campoletis* spp.

6. *Apanteles sp*

7. Cotesia

8. *Microplitis*

9.*Hyposoter*

10. *Lespesia* sp.

11. *Microgaster* sp.

Pupal parasitoid

12. *Brachymeria euploeae*

13.*Diadegma insulare*

Nymphal/larval and adult parasitoids


14. *Chrysocharis* sp


15. *Aphidius*


16.*Diglyphus isaea*


17. *Gronotoma micromorpha*


18. *Chrysocharis* sp


19. *Aphidius*

2 http://www.pbase.com/image/135529248
3 http://www.nbaii.res.in/Featured%20insects/chelonus.htm
4. http://72.44.83.99/forum/viewthread.php?thread_id=40633&pid=178398
5. http://www.nbaii.res.in/Featured%20insects/Campoletis.htm
6. http://www.european-lepidopteres.fr/Videos-parasites-Apanteles.html
7. http://www.biofac.com/Fruit_-_Vegetables/fruit_-_vegetables.html
8.https://www.google.co.in/search?q=Microplitis+plutellae&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=vKf4Up
9. http://www.biologie.uni-hamburg.de/lehre/bza/molnews/jasmon/jasmonate.htm
10http://www.wright.edu/~john.stireman/research%20interests.html
11. http://www.commanster.eu/commanster/Insects/Bees/SuBees/Microgaster.rufipes.html
12.http://www.nhm.ac.uk/researchcuration/research/projects/chalcidoids/database/media.dsml?IMAGENO=chalc519&VALGENUS=Brachymeria&VALSPECIES=euploeae
13.https://www.google.co.in/search?q=Diadegma+insulare,&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=R6f
14. http://baba-insects.blogspot.in/2012/05/blog-post_21.html
15 http://biobee.in/products-and-services/solutions/bio-aphidius/
16 http://www.evergreengrowers.com/diglyphus-isaea-114.html
17 http://www.ento.csiro.au/science/Liriomyza_ver3/key/Eucoilidae_Key/Media/Html/_gronotoma_sp.html
18 http://www.buglogical.com/whitefly-control/encarsia-formosa/
19http://www.dongbufarmceres.com/main/mboard.asp?strBoardID=c_product01_en

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. Wasp

15.*Oligota* spp.

16. *Orius* spp.

17. Hover fly

18. Mirid bug

19.*Broscus*

20.*Liogryllus*

21. Predatory mite

22. Predatory thrips

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/
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X. DESCRIPTION OF DISEASES

1) Damping Off:

Disease symptoms:

- Damping off occurs in two stages, i.e. the pre-emergence and the post-emergence phase.
- In the pre-emergence phase the seedlings are killed just before they reach the soil surface.
- The young radical and the plumule are killed and there is complete rotting of the seedlings.
- The post-emergence phase is characterized by the infection of the young, juvenile tissues of the collar at the ground level.
- The infected tissues become soft and water soaked. The seedlings topple over or collapse.


Favourable Conditions:

- High humidity, high soil moisture, cloudiness and low temperatures below 24° C for few days are ideal for infection and development of disease.
- Crowded seedlings, dampness due to high rainfall, poor drainage and excess of soil solutes hamper plant growth and increase the pathogenic damping-off.

Survival and spread:

Primary: Soil, Seed, Water
Secondary: Zoospore through rain splash or wind
*For management refer to page number----------

2) Club root of crucifers or Finger and toe disease:

Disease symptoms:

- Stunting and yellowing of plants
- Leaves become yellowish and wilt on hot days.

- Club like swelling of root and rootlets
- Club root is particularly prevalent on soils with a pH below 7, whereas it has been observed that the disease is often less serious on heavy soils and on soils containing little organic matter

http://www.moaf.gov.bt/moaf/wp-content/uploads/2011/09/DSC04222.jpg

Survival and spread:

- **Primary**: Soil borne resting spores, which survive for longer periods in soil (10yrs.) Collateral hosts: Broccoli, Brussels sprout, cabbage, cauliflower, Chinese cabbage, mustard, raddish, turnip
- **Secondary**: Resting spores or zoospores carried through irrigation water or by root contact.

Favourable conditions:

- It occur at a temperature range of 12-27^0 C.
- High soil moisture
- Neutral to acidic soils 5-7.0 pH

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

3) *Alternaria* leaf spot*:*

Common on cabbage, cauliflower and mustard.

Disease symptoms:

- Spots are small, dark coloured
- They enlarge, soon become circular with a 1mm in diameter
- Under humid conditions groups of conidiophores will be formed in the spot
- Spots develop concentric rings
- Finally the spots coalesce leading to blighting of leaves.
- Shriveling of seeds and poor germination occurs.
- Linear spots also appear on petioles, stems, pods and seeds

http://www.clemson.edu/extension/hgic/graphics/cabbagedis/altern.jpg

Survival and spread:

Primary: Mycelium persisting in the seed or as spores on seed or from debris

Secondary: Wind or insect borne conidia

Favourable conditions:

- Soil temperature of around 28^0 C
- High humidity or persistent dew
- Moist weather with intermittent showers

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

4) Black rot:

Serious on cabbage, cauliflower, knol-khol and radish

Disease symptoms:

- First appear as chlorotic or yellow (angular) areas near the leaf margins
- Yellow area extends to veins and midrib forming characteristic 'v' shaped chlorotic spotswhich later turn black
- Veins and veinlets turn brown and finally black
- Vascular blackening extend beyond affected veins to midrib, petiole and stem
- In advanced stages, infection may reach the roots system and blackening of vascular bundles occurs. Bacterial ooze can also be seen on affected parts
- If the infection is early, the plants wilt and die
- If the infection is late plants succumb to soft rot and die.

Survival and spread:

Primary : Bacterial cells internally seed borneand soil borne
Secondary: Bacterial cells dispersed through irrigation water and rain splashes.

Favourable conditions:

- Relative humidity more than 90%
- High soil moisture
- Frequent rains

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

5) Downy mildew:

Severe in radish, cabbage, cauliflower, mustard and knol-khol.

Disease symptoms:

- Small purplish brown spots on under surface of leaves
- Small, pale yellow angular spots on upper surface of leaves, with downy growth on the under surface. The spots coalesce and the leaves shrivel and dries up prematurely
- In cabbage, these spots expose the heads to soft rot
- Cauliflower curds look brownish
- Stems show dark brown and depressed lesions or streaks which later develop downy growth of fungus.

http://extension.umass.edu/vegetable/sites/vegetable/files/diseases/broccoli_downey_mildew_leaf.

Survival and spread:

Primary: Oospores in infected plant debris or in soil
Secondary: Wind borne and rain splashed sporangia

Favourable conditions:

- It occur at a moderate temperature range of 12-27^{0}C
- High soil moisture
- Neutral to acidic soils, pH 5-7.o

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

7)White rust:

Disease symptoms:

- White, shiny raised blisters (pustules) on the lower surfaces of leaves, stems and flowers
- Pustules coalesce to form irregular patches
- The epidermis ruptures exposing white spore mass which gives the pustule a powdery appearance
- Distortion of the floral parts including petals, pistils and anthers due to hypertrophy and hyperplasia
- Plants are malformed.

http://www.uoguelph.ca/~gbarron/MISC2006/march22.jpg

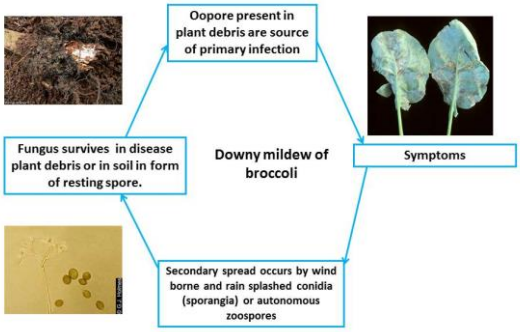
Survival and spread:
Primary: Oospores in soil and sporangia from perennial weed hosts in the vicinity
Secondary: Wind borne and rain splashed conidia (sporangia) or autonomous zoospores
Favourable conditions:

- Relative humidity more than 90%
- High soil moisture
- Frequent rains

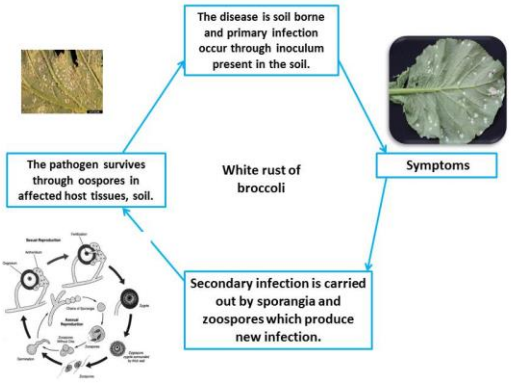
*For management refer to page number----------

Disease cycles:

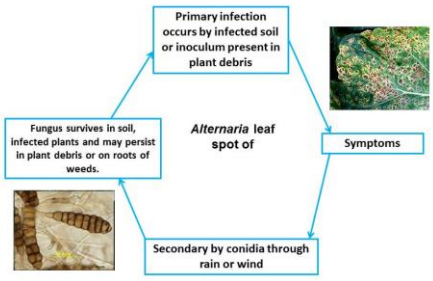
1. Downy mildew:



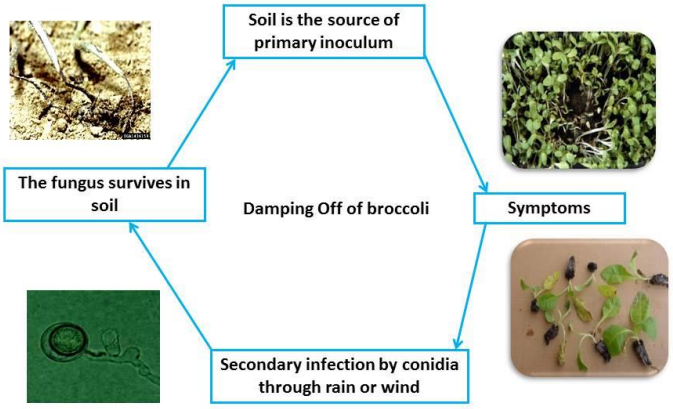
2. White rust:



3. *Alternaria* leaf spot:



4. Damping off:



X. SAFETY MEASURES

A. At the time of the harvest

Heads should be firm-to-hard at harvest, but delaying harvest may increase the risk of splitting mature heads if soil moisture increases suddenly. Heads are cut at the base and the outer leaves are trimmed off. For the fresh market, fields may be cut 3 to 5 times. When hybrid varieties are used, a higher percentage of the plants can be harvested at one time.

B. During post-harvest storage

Heads must be cooled immediately after harvest. Broccoli can be stored at 0-2 °C and 95% relative humidity for 3 to 6 weeks (early crop) or 5 to 6 months (late crop). Storage life can be prolonged even further at low O2 (2%) and high CO2 (5%) and with controlled atmosphere storage systems, where available.

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.	Adopt crop rotation.	Avoid monocropping.
3.	Grow only recommended varieties.	Do not grow varieties not suitable for the season or the region.
4	Sow early in the season	Avoid late sowing as this may lead to reduced yields and incidence of white

		grubs and diseases.
5	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.
6.	Sow in rows at optimum depths under proper moisture conditions for better establishment.	Do not sow seeds beyond 5-7 cm depth.
7.	Apply only recommended herbicides at recommended dose, proper time, as appropriate spray solution with standard equipment along with flat fan or flat jet nozzles.	Pre-emergent as well as soil incorporated herbicides should not be applied in dry soils. Do not apply herbicides along with irrigation water or by mixing with soil, sand or urea.
8.	Maintain optimum and healthy crop stand which would be capable of competing with weeds at a critical stage of crop weed competition.	Crops should not be exposed to moisture deficit stress at their critical growth stages.
9	Use NPK fertilizers as per the soil test recommendation.	Avoid imbalanced use of fertilizers.
10	Use micronutrient mixture after sowing based on test recommendations.	Do not apply any micronutrient mixture after sowing without test recommendations.
11	Conduct 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
12	Install pheromone traps at appropriate period.	Do not store the pheromone lures at normal room temperature (keep them in refrigerator).
13	Release parasitoids only after noticing adult moth catches in the pheromone trap or as pheromone trap or as per field observation	Do not apply chemical pesticides within seven days of release of parasitoids.
16	Spray pesticides thoroughly to treat the undersurface of the leaves.	Do not spray pesticides only on the upper surface of leaves.
17	Apply short persistent pesticides to avoid pesticide residue in the soil and produce.	Do not apply pesticides during preceding 7 days before harvest.
18	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. 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

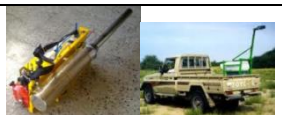
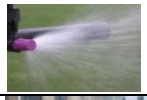
G. Disposal

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.

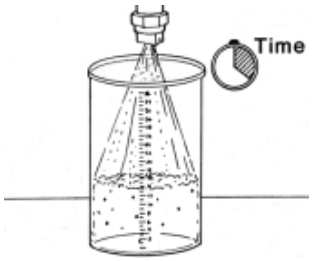
XIII. PESTICIDE APPLICATION TECHNIQUES

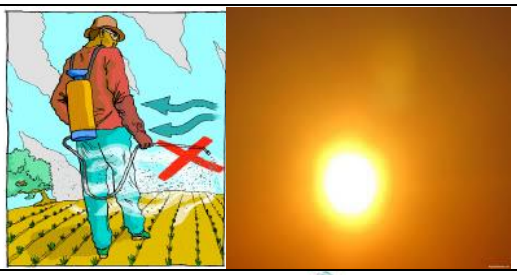
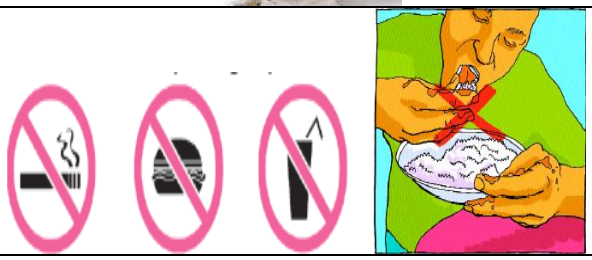
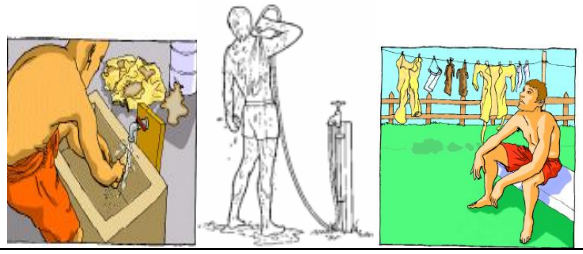
<table>
<tr><td colspan="4">Equipment</td></tr>
<tr><td colspan="4">Category A: Stationary, crawling pest/disease</td></tr>
<tr><td rowspan="2">Vegetative stage
i) for crawling and soil borne pests

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

Reproductive stage *(Field Pests)*	fungicides	(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)	 

XIV. OPERATIONAL, CALIBRATION AND MAINTENANCE GUIDELINES IN BRIEF

1.	For application rate and dosage see the label and leaflet of the particular pesticide.	 
2.	It is advisable to check the output of the sprayer (calibration) before commencement of spraying under guidance of trained person.	 
3.	Clean and wash the machines and nozzles and store in dry place after use.	
4.	It is advisable to use protective clothing, face mask and gloves while preparing and applying pesticides. Do not apply pesticides without protective clothing and wash clothes immediately after spray application.	 

5.	Do not apply in hot or windy conditions.	
6.	Operator should maintain normal walking speed while undertaking application.	
7.	Do not smoke, chew or eat while undertaking the spraying operation	
8.	Operator should take **properbath with soap** after completing spraying	
9.	Do not blow the nozzle with mouth for any blockages. Clean with water and a soft brush.	

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