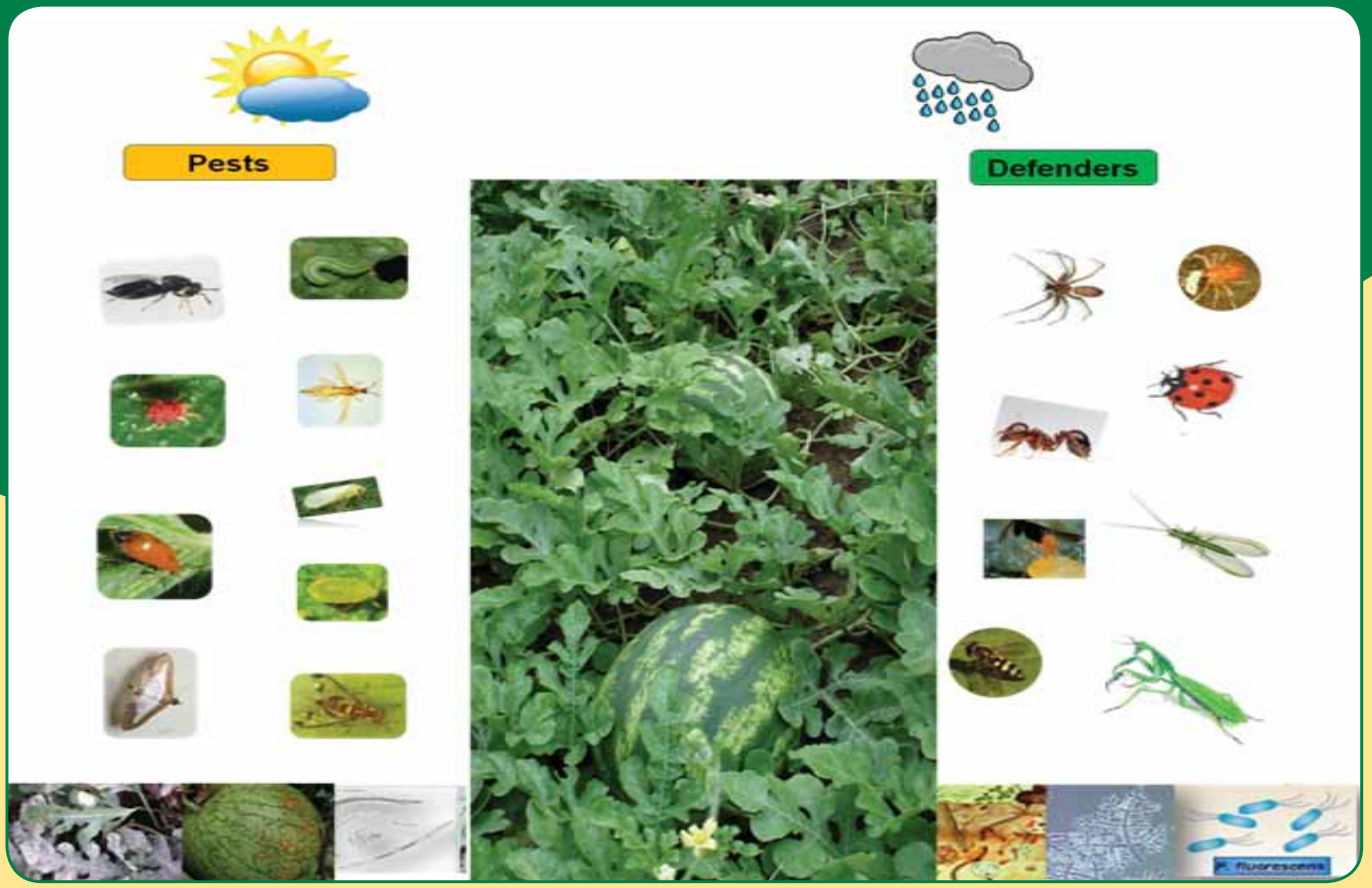
AESA BASED IPM PACKAGE

AESA based IPM – Watermelon



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National Institute of
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Department of Agriculture and Cooperation
Ministry of Agriculture
Government of India

Important Natural Enemies of Watermelon Insect Pests

Parasitoids

***Trichogramma* spp.**

***Campoletis* spp.**

Chrysocharis pentheus

***Bracon* spp.**

***Apanteles* sp**

***Brachymeria* sp**

Predators

Lacewing

Ladybird beetle

Spider

Reduviid bug

Preying mantis

Common mynah

The AESA based IPM - Watermelon, was compiled by the NIPHM working group under the Chairmanship of Dr. Satyagopal Korlapati, IAS, DG, NIPHM, and guidance of Shri. Utpal Kumar Singh, IAS, JS (PP). The package was developed taking into account the advice of experts listed below on various occasions before finalization.

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Front cover picture Model AESA chart for Watermelon

Back cover picture Watermelon field

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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.

Date : 6.3.2014

(Avinash K. Srivastava)

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FOREWORD

IPM as a holistic approach of crop protection based on the integration of multiple strategies viz., cultural, physical, mechanical, biological, botanical 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, through 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 sine show 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 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, through cannot be eliminated altogether, can be minimized through development, dissemination and promotion of sustainable biointensive approaches.

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

(K. SATYAGOPAL)

CONTENTS

AESA BASED IPM PACKAGE FOR WATERMELON

Watermelon plant description:

Watermelon (*Citrullus lanatus* (Thunb.) Matsum & Nakai; Family : Cucurbitaceae) is a vining annual plant grown for its fleshy fruit. Watermelon vines are thin, grooved and covered in tiny hairs. Vines are branching and possess deeply lobed pinnate leaves. The plant produces solitary yellow flowers and a large spherical to oblong fruit. The fruit is a 'pepo' - a fleshy fruit protected by a thick leathery rind. The fruit is smooth, light to dark green in color and can be striped, marbled or solid green. The flesh of the fruit is usually red in color but some cultivars produce green, orange or white flesh and contain numerous seeds which are usually black or dark brown in color. Watermelon vines can reach a length of 3 m (10 ft) and as an annual, survives only one growing season. Watermelon originates from Africa.

Watermelon is a warm season crop and can be grown year round in the tropics. Worldwide production of watermelon was 95,211,432 metric tones (MT) in 2012 season. Watermelon is produced commercially with the top five countries in the order of decrease in the production are China (70,000,000 t), Turkey (4,044,184 t), Iran (3,800,000 t), Brazil (2,079,547 t) and Egypt (1,874,710). Watermelon is thought to have originated in southern Africa, where it is found growing wild, because it reaches maximum genetic diversity resulting in sweet, bland and bitter forms there.

Watermelon contains about 6% sugar and 92% water by weight. As with many other fruits, it is a source of vitamin C. Notable is the inner rind or the watermelon which is usually a light green or white color. This area is edible and contains many hidden nutrients that most people avoid eating due to its unique flavor. The amino acid citrulline was first extracted from watermelon and analysed. Watermelons contain a significant amount of citrulline and after consumption of several Kg an elevated concentration is measured in the blood plasma; this could be mistaken for citrullin anemia or other urea cycle disorder. Watermelon rinds are also edible, and sometimes used as a vegetable.

I. PESTS

A. Pests of National Significance

1. Insect and mite pests

1.1 Red pumpkin beetle: *Raphidopalpa foveicollis* Lucas (Coleoptera: Chrysomelidae)

1.2 Fruit fly: *Bactrocera cucurbitae* Coquillett (Diptera: Tephritidae)

1.3 Thrips: *Thrips tabaci* Linderman (Thysanoptera: Thripidae)

1.4 Whitefly: *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae)

1.5 Aphid: *Aphis gossypii* Glover (Hemiptera: Aphididae)

1.6 Leaf eating caterpillar: *Diaphania indica* Saunders (Lepidoptera: Pyralidae)

1.7 Serpentine leaf miner: *Liriomyza trifolii* Burgess (Diptera: Agromyzidae)

1.8 Red spider mite:*Tetranychus urticae* Koch (Acarina: Tetranychidae)

2. Diseases

2.1 Downy mildew: *Pseudoperonospora cubensis* Berkeley & Curtis

2.2 Powdery mildew: *Erysiphe cichoracearum* DC, *Sphaerotheca fuliginea* (Schltdl.) Pollacci)

2.3 Anthracnose: *Colletotrichum orbiculare* Berk. & Mont. Arx, & *C. lagenarium* Pass. Ell. & Halst

2.4 *Alternaria* leaf spot: *Alternaria cucumerina* Elliot

2.5 *Fusarium* wilt: *Fusarium oxysporum* f.sp. *niveum* (E.F. Sm.) W.C. Snyder & H.N. Hans

2.6 Bud necrosis diseases: *Tomato spotted wilt virus* (Tospo virus)

2.7 Cucumber mosaic disease: *Cucumber mosaic virus*

3. Nematode

3.1 Root - knot nematode: *Meloidogyne* sp.

4. Weeds

Broad leaf

4.1 Lamb's quarter: *Chenopodium album* L. (Chenopodiaceae)

4.2 Scarlet pimpernel: *Anagallis arvensis* (Primulaceae)

4.3 Sweet clover: *Melilotus indica* L. (Fabaceae)

4.4 Swine cress: *Coronopus didymus* L. Sm. (Brassicaceae)

4.5 Fine leaf fumitory: *Fumaria parviflora* Lam. (Papaveraceae)

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

4.7 Pigweed: *Amaranthus viridis* Hook (Amranthaceae)

4.8 Black nightshade: *Solanum nigrum* L. (Solanaceae)

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

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

4.11Carrot grass: *Parthenium hysterophorus* L. (Asteraceae)

Grasses

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

4.13 Rabbit/crow foot grass: *Dactyloctenium aegyptium* L. Willd. (Poaceae)

4.14 Crab grass: *Digitaria sanguinalis* L. Willd (Poaceae)

Sedges

4.15 Purple nut sedge: *Cyperus rotundus* L. (Cyperaceae)

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

A. AESA:

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

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

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

- Plant health at different stages
- Built-in compensation abilities of plants
- Pest and defender population dynamics
- Soil conditions
- Climatic factors
- Farmers past experience

Principles of AESA based IPM:

Grow a healthy crop:

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

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:

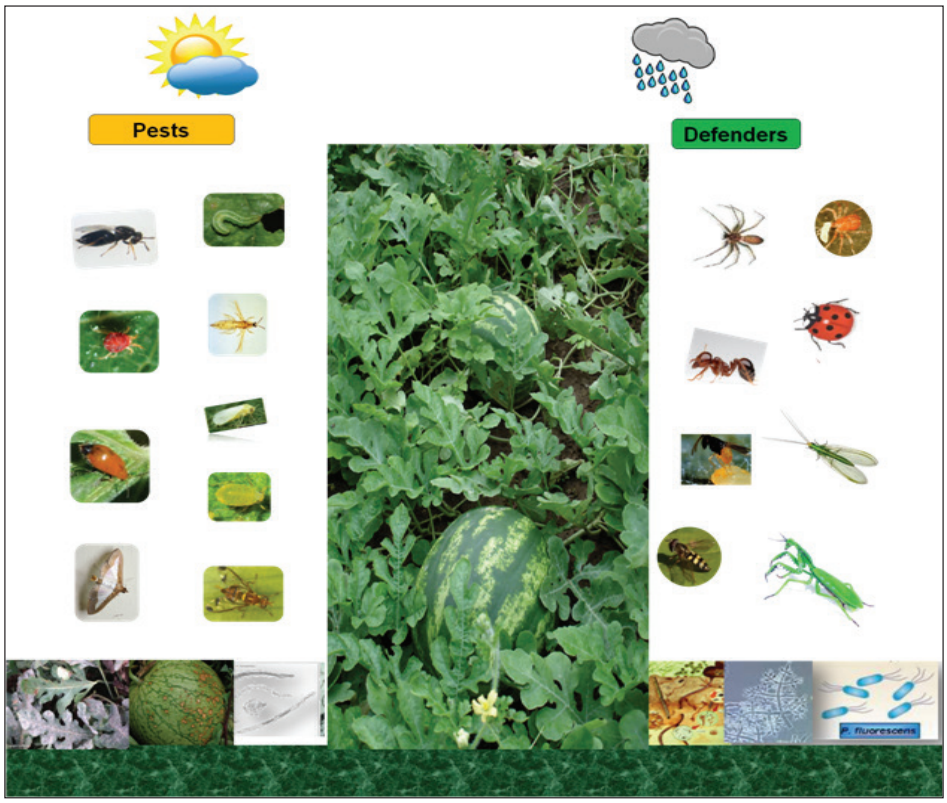
In field various types of insects are present. Some are beneficial and some may be harmful. Generally farmers are not aware about it. Predators (friends of the farmers) which feed on pests are not easy to observe in crop field. Insect zoo concept can be helpful to enhance farmers' skill to identify beneficial 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 watermelon 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 & damage severity	**:**
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 length, number of leaves, crop stage, deficiency symptoms, no of fruits etc.
    - Insect pests: Observe and count insect pests at different places on the plant.
    - Defenders (natural enemies): Observe and count parasitoids and predators.
    - Diseases: Observe leaves and stems and identify any visible disease symptoms and severity.
    - Weeds: Observe weeds in the field and their intensity.
    - Water: Observe the water situation of the field.
    - Weather: Observe the weather condition.
- While walking in the field, manually collect insects in plastic bags. Use a sweep net to collect additional insects. Collect plant parts with disease symptoms.
- Find a shady place to sit as a group in a small circle for drawing and discussion.
- If needed, kill the insects with some chloroform (if available) on a piece of cotton.
- Each group will first identify the pests, defenders and diseases collected.
- Each group will then analyze the field situation in detail and present their observations and analysis in a drawing (the AESA drawing).
- Each drawing will show a plant representing the field situation. The weather condition, water level, disease symptoms, etc. will be shown in the drawing. Pest insects will be drawn on one side. Defenders (beneficial insects) will be drawn on another side. Write the number next to each insect. Indicate the plant part where the pests and defenders were found. Try to show the interaction between pests and defenders.
- Each group will discuss the situation and make a crop management recommendation.
- The small groups then join each other and a member of each group will now present their analysis in front of all participants.
- The facilitator will facilitate the discussion by asking guiding questions and makes sure that all participants (also shy or illiterate persons) are actively involved in this process.
- Formulate a common conclusion. The whole group should support the decision on what field management is required in the AESA plot.
- Make sure that the required activities (based on the decision) will be carried out.
- Keep the drawing for comparison purpose in the following weeks.

Data recording:

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

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

Data to be recorded:

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

Some questions that can be used during the discussion:

- Summarize the present situation of the field.
- 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.

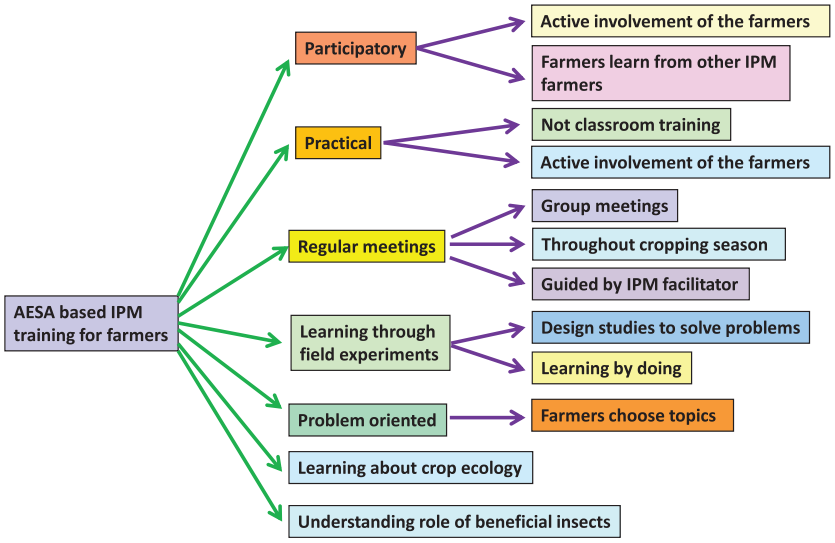
AESA and farmer field school (FFS):

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
- Decision making process.

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

For insect pests:

Aphids, whiteflies, jassids and mites: Count and record the number of both nymphs and adults on five randomly selected leaves per plant.

Thrips: Count and record the number of nymphs and adults of thrips present on five terminal leaves per plant (tapping method also can be used to count thrips).

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). Always check plants that appear unhealthy. It is often necessary to wash the roots with water to examine them properly. If the roots are well developed, cut into 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 on each plant for lesions and determine the amount area of leaf infection. 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. Count the number of leaves (leaf area diameter)/plant infected due to disease and incidence should be recorded.

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

C. Surveillance through pheromone trap catches:

Pheromone traps for caterpillars and fruit fly @ 4-5 per acre have to be installed. Install the traps for each species separated by a distance of >75 feet in the vicinity of the selected field, if available. Fix the traps to the supporting pole at a height of one foot above the plant canopy. Change of lures should be made once a month. 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/blue pan water/ sticky traps 15 cm above the canopy for monitoring whiteflies, aphids and blue sticky trap for thrips @ 4-5 traps/acre. Locally available empty tins can be painted yellow/blue 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 insects. Light traps with exit option for natural enemies of smaller size should be installed and operate around the dusk time (6 to 10 pm).

F. Nematode extraction:

Collect 100 to 300 cm^3 (200-300 g) representative soil sample. Mix soil sample and pass through a coarse sieve to remove rocks, roots, etc. Take a 600 cc subsample of soil, pack lightly into a beaker uniformly. Place soil in one of the buckets or pans half filled with water. Mix soil and water by stirring with paddle; allow to stand until water almost stops swirling. Pour all but heavy sediment through 20-mesh sieve into second bucket; discard residue in first bucket; discard material caught on sieve. Stir material in second bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 60 mesh sieve to collect cysts into first bucket; discard residue in second bucket. Stir material in first bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 325-mesh sieve into second bucket; discard residue in first bucket. Backwash material caught on 325-mesh sieve (which includes small to mid-sized nematodes and silty material) into 250-ml beaker. More than 90% of the live nematodes are recovered in the first 5-8 mm of water drawn from the rubber tubing and the sample is placed in a shallow dish for examination.

III. ECOLOGICAL ENGINEERING FOR PEST MANAGEMENT

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

Natural enemies may require:

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

Ecological engineering for pest management – Above ground:

- 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.

Ecological engineering for pest management – Below ground:

- Keep soils covered year-round with living vegetation and/or crop residue.
- Add organic matter in the form of farm yard manure (FYM), vermicompost, crop residue which enhance below ground biodiversity.
- Reduce tillage intensity so that hibernating natural enemies can be saved.
- Apply balanced dose of nutrients using biofertilizers.
- Apply *Mycorrhiza* and plant growth promoting rhizobacteria (PGPR)
- Apply *Trichoderma viride/harzianum* and *Pseudomonas fluorescens* as seed/seedling/planting material 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).

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

Ecological Engineering Plants

Attractant plants


Cluster bean


Cowpea


Carrot


Sunflower


Buckwheat


French bean


Alfalfa


Mustard


Parsley


Coreopsis spp.


Cosmos


Dandelion


Anise


Caraway


Dill

Marigold

Repellent plants

Ocimum spp

Peppermint

Border plants

Sorghum

Maize

Bajra

Trap plants

Tomato

Marigold

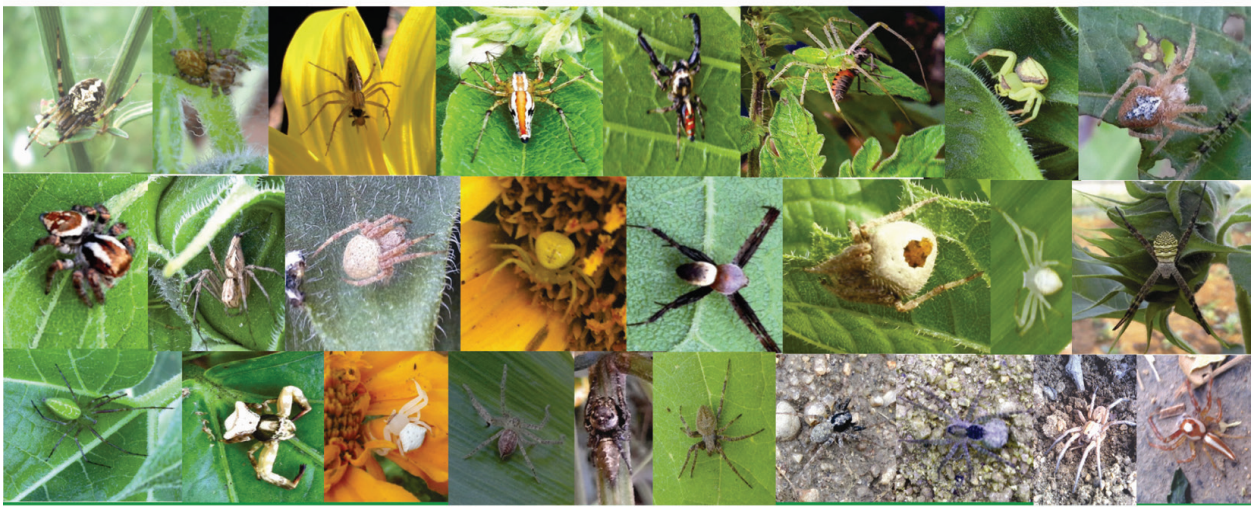
The flowering plants suggested under Ecological Engineering for pest management strategy are known as attractant plants to the natural enemies of the selected pests. The information is based on published research literature. However, the actual selection of flowering plants could be based on availability,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

Biodiversity of natural enemies observed in Ecological Engineering field at NIPHM

Biodiversity of natural enemies: Parasitoids

Biodiversity of natural enemies: Predators

Biodiversity of natural enemies: Spiders



A. Resistant/tolerant varieties*:

Pest/disease	Tolerant/ Resistant Variety
Wilt	Watermelon-F1 sweet sensation, watermelon –F1 big guy
Anthracnose and wilt	Watermelon-F1 midnight, watermelon F1 bengal tiger, watermelon-F1 sweet dragon, watermelon-F1 wonder hybrid.
Alternaria leaf spot	Sugar baby', 'Fairfax', and 'Calhoun gray
Powdery mildew	Arka Manik
Aphid	PI 299563
Spider mite	'Congo' and 'Giza 1'
	'Durgapura Kesar' (RW 187-2), Mithila, Suganthi, Kiran, Simran, Vishal

***For detailed and updated information nearest KVK, State Department, SAU / ICAR Institute may be contacted.**

IV. CROP STAGE-WISE IPM

Management	Activity
Pre sowing*	
	Common cultural practices: • Timely sowing should be done. • Field sanitation, rogueing • Destroy the alternate host plants and weeds. • 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. • Sow/plant tall border crops such as maize/sorghum/bajra all around watermelon field as guard crop. • Rotate crop with non-host crops.
Nutrients	• Nutrients should be applied based on the soil test report and recommendations for the particular agro-climatic zone. • Apply FYM @ 16 t/acre and incorporate in the soil 2 to 3 weeks before sowing. • If crop is planted in pit a mixture of soil and 4-5 Kg of FYM or compost, 30-40 g urea, 40-50 g SSP (single super phosphate) and 80 or 100 g of MOP (muriate of potash) should be added.
Weeds	• Deep ploughing during summer or adopt stale bed technique. • Harrowing and ploughing before sowing.
Soil borne pathogens, nematodes, resting stages of insects	**Biological control:** • Apply neem cake/pongamia cake @ 100 Kg/acre or press mud @ 2 t /acre in soil at the time of last ploughing for reducing nematodes and soil dwelling pests.

Management	Activity
Sowing*	
	Common cultural practices: • Use tolerant/resistant varieties. • Select healthy, certified and weed seed free seed. • Avoid overlapping sowings of susceptible crops and sequential plantings side by side to minimise virus spread from one crop to the next.
Nutrients	• Basal application of 10 Kg Nitrogen (N), 15 Kg Phosphorus and 8-10 Kg Potash should be done.
Weeds	• Adopt the recommended agronomic practices like timely sowing, method of sowing and proper spacing etc.
*Apply *Trichoderma viride/harzianum* and *Pseudomonas fluorescens* as seeds/seedling/planting materials treatment and soil application (If commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).	
Vegetative stage	
	Common cultural practices: • Collect and destroy the crop debris • Provide irrigation at critical stages of the crop • Avoid water stress and water stagnation conditions. • Enhance parasitic activity by avoiding chemical spray, when 1-2 larval parasitoids are observed **Common mechanical practices:** • Collect and destroy disease infected and insect infested plant parts • Collect and destroy eggs and early stage larvae • Handpick the older larvae during early stages • Handpick the gregarious caterpillars and the cocoons which are found on stem and destroy them in kerosene mixed water. • Use yellow sticky traps for whitefly and aphids and blue sticky trap for thrips @ 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) • Erect of bird perches @ 20/acre for encouraging predatory birds such as king crow, common mynah etc. • Set up bonfire during evening hours at 7-8 pm **Common biological practices:** • Conserve natural enemies through ecological engineering • Augmentative release of natural enemies
Nutrients	• Apply 14 Kg of N/acre at 25 days after sowing as top dressing. • Micronutrient deficiency should be corrected by foliar spray of particular nutrient. • To maintain the sex ratio (more number of female flowers), spray borax @ 3-4 g/l at 2-4 leaf stage

Management	Activity
Weeds	• Regular hoeing by power hand tillar and/ or hand tools to keep the field weed free up to 30 days crop stage.
Serpentine leaf miner	**Biological control:** • Foliar spray with neem oil @ 10-20 ml/l or NSKE 5%
Red pumpkin beetle	• See common cultural, mechanical and biological practices. • Spray NSKE 4%
Aphid	**Cultural control:** • High levels of nitrogen fertilizer favor aphid reproduction, so never use more nitrogen than necessary. **Biological control:** • Release 1st instar larvae of green lacewing (*Chrysoperla zastrowi sillemi*) @ 4,000 Nos/acre. • Spraying with tobacco decoction (1 Kg tobacco boiled in 10 l of water for 30 minutes and making up to 30 l + 100 g soap).
Whitefly	• See common cultural, mechanical and biological practices.
Leaf eating caterpillar	**Cultural control:** • Soil application of neem cake (immediately after germination and again at flowering) followed by spraying of NSKE @ 4% with sticker (0.5 ml/l of water) at 10-15 days interval.
Thrips	**Cultural control:** • Keep plants well irrigated, and avoid excessive applications of nitrogen fertilizer, which may promote higher populations of thrips. **Biological control:** • Soil application of neem cake (once immediately after germination and second at flowering) followed by spraying of NSKE @ 4% with sticker (0.5 ml/l of water) at 10-15 days interval.
Red spider mite	• See common cultural practices. **Biological control:** • Spray neem or pongamia soap at 1% on lower surface thoroughly.
Powdery mildew	**Cultural control:** • Bower system (maintain gapping) of cropping reduces the disease incidence.
Downy mildew, Anthracnose	**Cultural control:** • Trellising (provide support system) watermelon. • Control alternate weed hosts (wild cucumber, golden creeper and volunteer cucumbers) in neighbouring fence rows and field edges. • Bower system of cropping reduces the disease incidence. • Seed production should be preferably carried out in summer season because summer crop is often free from diseases.

Management	Activity
***Alternaria* Leaf spot**	• See common cultural and mechanical practices.
Bud necrosis	**Cultural control:** • Maintaining a clean buffer zone free of weeds of at least 25 m between a virus source and a susceptible crop can considerably reduce virus levels. • Control the thrips as given above in thrips management.
***Fusarium* wilt**	**Cultural control:** • Uproot and burn the infected plants.
Cucumber mosaic disease	**Cultural control:** • Raise 4 rows of barrier crop such as maize/sorghum/bajra. • Avoid planting tomatoes next to cucurbits, spinach, or other vegetables and flowers susceptible to these diseases. • Control of aphid vectors as given in aphid management.
Reproductive stage	
Nutrients	• Micronutrient deficiency should be corrected by foliar spray of particular micronutrient.
Weeds	• Left over weeds should be removed from the field before shedding of seeds to avoid further spread of weed seeds.
Fruit fly	**Cultural control:** • Put fly traps in the field @4-8 traps/acre. Kill the collected fruit flies. • Raking of soil during fruiting time and after the harvest to expose pupae to the predators and sunlight. **Biological control** • Spray neem based products
Other pests and diseases	• Same as vegetative stage

Note: The pesticide dosages and spray fluid volumes are based on high volume sprayer.

V. INSECTICIDE RESISTANCE AND ITS MANAGEMENT

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

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

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

1) Monitor pests: Monitor insect population development in fields to determine if and when control measures are warranted. Monitor and consider natural enemies when making control decisions. After treatment, continue monitoring to assess pest populations and their control.

2) Focus on AESA: Insecticides should be used only as a last resort when all other non-chemical management options are exhausted and P: D ratio is above 2: 1. Apply biopesticides/chemical insecticides judiciously after observing unfavourable P: D ratio and when the pests are in most vulnerable life stage. Use application rates and intervals as per label claim.

3) Ecological engineering for pest management: Flowering plants that attract natural enemies as well as plants that repel pests can be grown as border/intercrop.

4) Take an integrated approach to managing pests: Use as many different control measures as possible viz., cultural, mechanical, physical, biological etc. Select insecticides with care and consider the impact on future pest populations and the environment. Avoid broad-spectrum insecticides when a narrow-spectrum or more specific insecticide will work. More preference should be given to green labeled insecticides.

5) Mix and apply carefully: While applying insecticides care should be taken for proper application of insecticides in terms of dose, volume, timing, coverage, application techniques as per label claim.

6) Alternate different insecticide classes: Avoid the repeated use of the same insecticide, insecticides in the same chemical class, or insecticides in different classes with same mode of action and rotate/alternate insecticide classes and modes of action.

7) Preserve susceptible genes: Preserve susceptible individuals within the target population by providing unsprayed areas within treated fields, adjacent "refuge" fields, or habitat attractions within a treated field that facilitate immigration. These susceptible individuals may outcompete and interbreed with resistant individuals, diluting the resistant genes and therefore the impact of resistance.

VI. NUTRITIONAL DEFICIENCY

Manganese:

Fine network of green veins as a light green background on young leaves. Leaf remains fairly green. Dark green irregular bands on mature leaves, along the midrib.

Management: Foliar spray of 0.5% $MnSO_4$.

Source: http://agritech.tnau.ac.in/agriculture/plant_nutri/watermelon_manganese.html

VII. COMMON WEEDS

1. Lamb's quarter: *Chenopodium album* L. (Chenopodiaceae)

2. Scarlet pimpernel: *Anagallis arvensis* (Primulaceae)

3. Sweet clover: *Melilo tusindica* L. (Fabaceae)

4. Swine cress: *Coronopus didymus* L. Sm.(Brassicaceae)

5. Fine leaf fumitory: *Fumaria parviflora* Lam. (Papaveraceae)

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

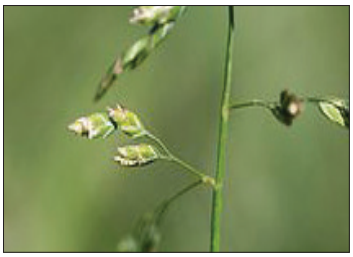
7. Pigweed: *Amaranthus viridis* Hook (Amranthaceae)

8. Black nightshade: *Solanum nigrum* L. (Solanaceae)

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

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

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



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

13. Rabbit/crow foot grass: *Dactyloctenium aegyptium* L. Willd. (Poaceae)

14. Crab grass: *Digitaria sanguinalis* L. Willd (Poaceae)

15. Purple nut sedge: *Cyperus rotundus*L. (Cyperaceae)

VIII. DESCRIPTION OF INSECT, MITE AND NEMATODE PESTS

1) Red pumpkin beetle:

Biology:

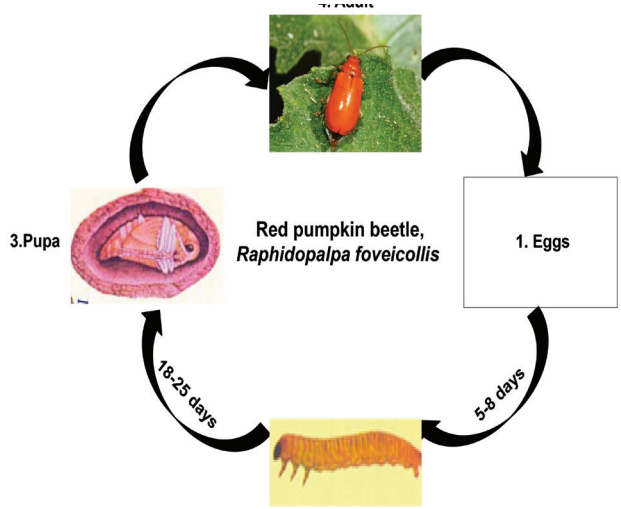
Egg: Eggs are brownish-yellow in colour, elongated, laid singly or in batches in moist soil near rhizosphere. Incubation period is 5-8 days after which tiny larvae hatch out and enter the soil.

Larva: Grubs grow by feeding on the debris and on roots and stems of plants. There are four larval instars and larvae must enter the soil each time before to moult. Larval period is 18-25 days, which is spent mostly in soil. Fully grown grubs are 10-12 mm in length.

Pupa: Pupation also takes place in the soil in a waterproof cocoon up to a depth of 25 cm. Adults emerge and make their way out of the soil.

Adult: Adults are small bright reddish beetles, 4-7 mm long, active beetles, flying from plant to plants and feeding on leaves. Hibernation takes place in adult stage from November to March in northern India, usually in debris or under stones or other hiding places. Longevity of adult is more than a month. Fecundity is 150-300 eggs per female.

Life cycle:



Damage symptoms:

- Seedlings may be completely destroyed by adult feeding.
- Older plants have foliage riddled with holes or completely defoliated, and the floral parts, including anthers are nibbled.
- Feeding by larvae causes rotting and withering of the roots and stems.
- The surface of young fruit may show feeding marks caused by the adults and the undersurface of fruits where they touch the soil surface may have indications of larval tunnels in the surface.

http://www.indianaturewatch.net/displayimage.php?id=226432; http://www.iaszoology.com/raphidopalpa-foveicollis/

Natural enemies of red pumpkin beetle:

Parasitoids: Braconid wasp, *Celatoria cetosa* (tachinid fly)

Predators: Pennsylvania leatherwing beetle, ground beetle, spider, earwig etc.

*For the management please refer page number 16

2) Fruit fly:

Biology:

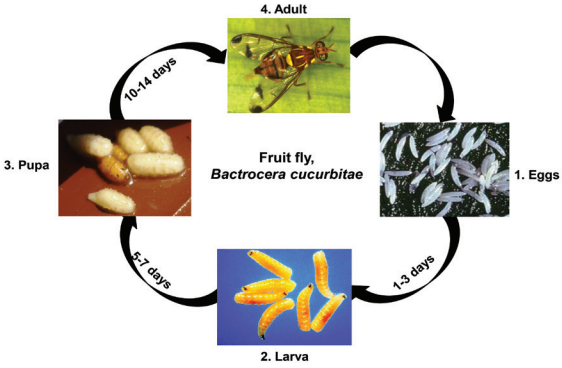
Egg: The egg is elliptical, pure white and about 2 mm long. It is almost flat on the ventral surface, and more convex on the dorsal. Eggs are often somewhat longitudinally curved.

Larva: The maggot is cylindrical cigar shaped. It has anterior mouth hooks, ventral fusiform areas and a flattened caudal end. Last instar larvae range from 7.5 to 11.8 mm in length.

Pupa: The puparium ranges in color from dull red or brownish yellow to dull white, and is about 5 to 6 mm in length. Pupation takes place in soil.

Adult: The adult melon fly is 6 to 8 mm in length. Distinctive characteristics include its wing pattern, its long third antennal segment, the reddish yellow dorsum of the thorax with light yellow markings, and the yellowish head with black spots. Total life cycle completes 14-34 days depending on weather conditions.

Life cycle:



http://gzrm.pl/poczta/fruit-flies-eggs-pictures&page=7

Natural enemies of fruit fly:

Parasitoid: *Opius fletcheri*

Predators: Ants, dragon fly, spider, robber fly

*For management refer to page number 17

Damage symptoms:

- Newly hatched maggots bore into the fruit pulp by forming serpentine galleries and contaminating them with its frassy excreta and providing entry points for saprophytic fungi and bacteria resulting rotting of fruits.
- Due to feeding, there is pre-mature dropping of fruits and make them unfit for consumption.
- Formations of galls are also rarely seen on stems.

Fruit fly maggots in rotting produce

http://www.ppdl.purdue.edu/PPDL/images FruitFlyMaggotsRotClosePencil.jpg

3) Thrips:

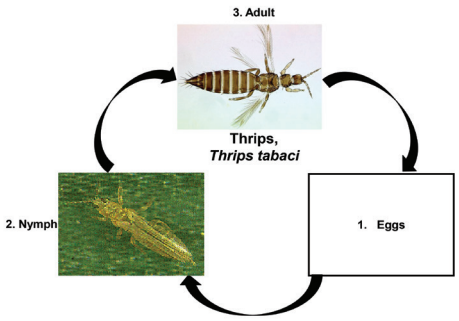
Biology:

Egg: Eggs are microscopic and white or yellow in colour. Eggs are inserted one by one by the gravid females in the plant tissue. Only one end of the egg will be near the surface of the tissue to allow the immature to emerge. Adults prefer to lay their eggs in leaf, cotyledon, or flower tissues.

Nymph: Nymphs are tiny, small and pale yellow to brownish colour. Nymphs are similar to adults except wing and are smaller in size.

Adult: The adult are slender, pale yellow to dark brown in colour and measures up to 1.5-2mm. Adults have fully developed fringe things. There are several overlapping in generations of this pests in a year.

Life cycle:



Damage symptoms:

- Thrips have a very peculiar feeding behavior as they are typical xylem-feeder.
- They start the feeding by rasping the leaf surface with their mouth parts to release the liquids from the plant cells and suck the plant juice.
- The plant loses more water than normal through the damaged tissues and plant pathogens penetrate the injured plant cells easily.

1,2, http://web.entomology.cornell.edu/shelton/veg-insects-global/english/thrips.html

Natural enemies of thrips:

Parasitoid: *Ceranisus menes*

Predators: Predatory mite, predatory thrips, *Oligota* spp., *Orius* spp. (pirate bug), mirid bug

*For management refer to page number 16

4) Whitefly:

Biology:

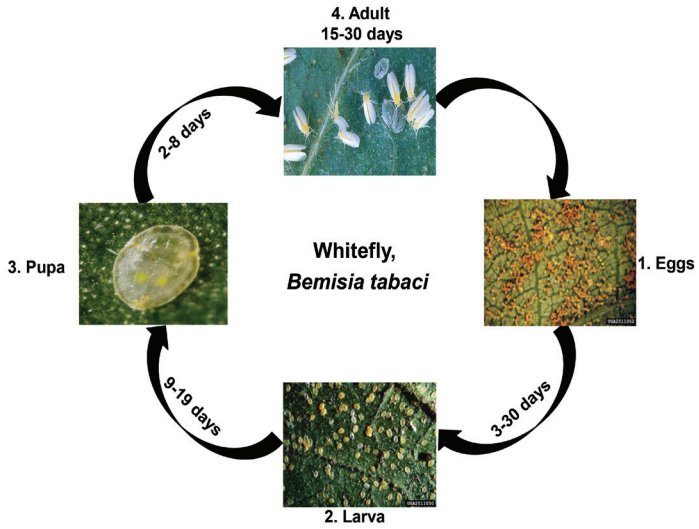
It is polyphagous pest and occurs almost throughout the country.

Egg: Eggs are stalked, sub-elliptical and light yellow to light brown in colour. Gravid female lays eggs singly on under side of the leaves. Incubation period varies 3-7 days during summer season.

Nymph: Nymphs are louse like, pale yellow coloured and clustered together underside of the leaves.

Adult: Adults are winged, tiny (1-1.5 mm long), yellowish body covered with white waxy powder. Several overlapping generations are completed in a year.

Life cycle:



Damage symptoms:

- Affected plant lose its vitality due to sap sucking by both nymph and adult whiteflies resulting yellowing, downward curling and finally drying of leaves.
- Normal photosynthesis is restricted due to growth of black sooty mould on the honeydew excreted by the whitefly.

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://www.fera.defra.gov.uk/plants/publications/documents/factsheets/bemisia.pdf; 4. http://www.entomology.umn.edu/cues/inter/inmine/Whitefg.html

Natural enemies of whitefly:

Parasitoids: *Encarsia formosa, Eretmocerus* spp., *Chrysocharis pentheus*

Predators: *Dicyphus hesperus*, lacewing, ladybird beetle, big-eyed bugs (*Geocoris* sp), mirid bug, spider, reduviid bug, robber fly, dragon fly, *Orius* spp.

*For management refer to page number 16

5) Aphid:

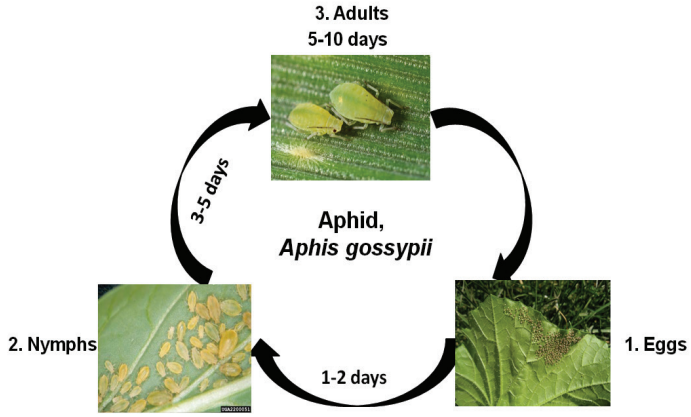
Biology:

Egg: Eggs are very tiny, shiny-black, and are found in the crevices of bud, stems, and barks of the plant. Aphids usually do not lay eggs in warm parts of the world.

Nymph: Nymphs look like the wingless adults but are smaller. They become adults within 7 to 10 days.

Adult: Adults are small, 1 to 4 mm long, soft-bodied insects with two long antennae that resemble horns. Most aphids have two short cornicles (siphunculi) protruding from 5th or 6th abdominal segment of the body. They complete their life cycle 9-21 days depending upon weather conditions.

Life cycle:



Damage symptoms:

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

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

Natural enemies of aphid:

Parasitoids: *Aphidius colemani, Aphelinus* sp

Predators: Red ant, robber fly, big-eyed bug (*Geocoris* sp), earwig, ground beetle, cecidomyiid fly, dragon fly, praying mantis, lacewing, ladybird beetle, spider etc.

*For management refer to page number 16

6) Leaf eating caterpillar:

Biology:

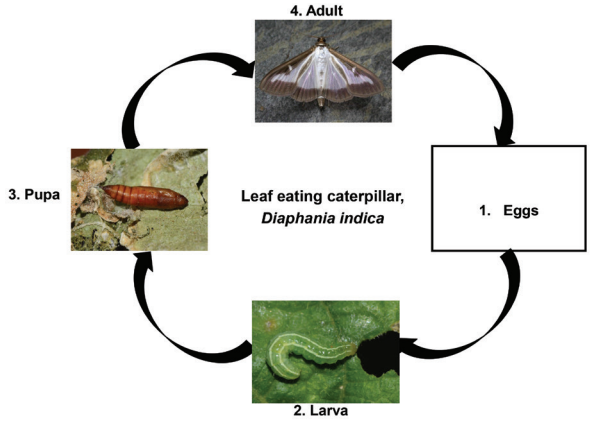
Egg: A female can lay upto 350 eggs, mostly singly or some time in groups on the lower surface of the leaves. Incubation period is 306 days.

Larva: Elongate bright green caterpillar with two narrow longitudinal white stripes dorsally.

Pupa: The pupa color is dull red or brownish yellow to dull white, and is about 5 to 6 mm in length. Pupation takes place in the silken cocoon formed in the leaf fold.

Adult: The wingspan is about 30 mm. Adults have translucent whitish wings with broad dark brown borders. The body is whitish below, and brown on top of head and thorax as well as the end of the abdomen. There is a tuft of light brown "hairs" on the tip of the abdomen, vestigial in the male but well-developed in the female.

Life cycle:



Damage symptoms:

- Larva folds the leaves and scrapes the green matter. As a result the leaves get dried up.
- It can also feed on ovaries of flower; sometimes bore into young developing fruits.

1,2,3: http://www.nbaii.res.in/insectpests/Diaphania-indica.php

Natural enemies of leaf eating caterpillar:

Parasitoids: *Trichogramma* spp., *Apanteles taragamae, A. machaeralis, Bracon hebetor, Phanerotoma hendecasisella, Chelonus* sp., *Campoletis chlorideae, Goniozus sensorius, Elasmus brevicornis, Xanthopimpla punctata, Brachymeria lasus, B. margaroniae* etc.

Predators: Reduviid, predatory bird, wasps, ground beetle, spiders, ants, earwig etc.

*For management refer to page number 16

7) Serpentine leaf miner:

Biology:

Egg: Eggs are minute in size and orange yellow in colour. The egg hatches in 3-5 days.

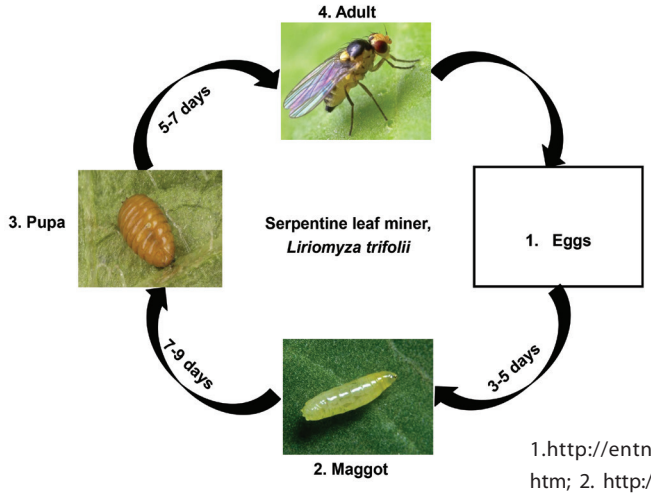
Larva: Apodous maggot feeds on chlorophyll mining in between epidermal layers. Full grown maggot measures 3 mm. Larval duration is about 7-9 days.

Pupa: Pupation is in soil. Some pupae are found in leaves. Pupation takes place inside a thin loose mesh of silken cocoon. Pupal period is about 5-7 days.

Adult: It is a pale yellowish fly, measuring 1.5 mm in length. The female fly punctures upper surface of leaf to lay eggs singly

Total life cycle takes 3 weeks.

Life cycle:



Damage symptoms:

- Leaves with silvery serpentine mines
- Drying and dropping of pre-matured leaves in severe cases

1.http://entnemdept.ufl.edu/creatures/veg/leaf/aserpentine_leafminer.htm; 2. http://www.nbaii.res.in/insectpests/images/Liriomyza-trifolii3.jpg; 3. http://www.nbaii.res.in/insectpests/images/Liriomyza-trifolii8.jpg

Favourable conditions:

Warm weather conditions are favourable for multiplication.

Natural enemies of serpentine leaf miner:

Parasitoids: *Gronotoma micromorpha* (larva and pupa), *Diglyphus* sp (larva), *Halticoptera circulus* and *Opius* sp (pupal) *Chrysocharis* sp, *Neochrysocharis formosa*.

Predators: Lacewings, ladybird beetle, spiders, red ants, dragonfly, robber fly, praying mantis etc.

*For management refer to page number 16

8) Red spider mite:

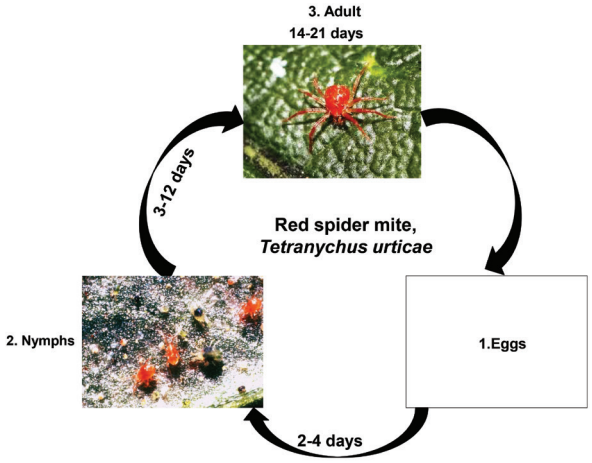
Biology:

Egg: Eggs reddish, spherical, provided with a small filament. Incubation period is 2-4 days, before hatching becomes light orange colour.

Nymph: Upon hatching, it will pass through a larval stage and two nymphal stages before becoming adult. Developmental stages include six legged larva, protonymph and deutonymph.

Adult: Adult female elliptical in shape, bright crimson anteriorly and dark pruplish brown posteriorly. Mites spin a web of silken threads on the leaf. Each developmental stage is followed by a quiescent stage and life cycle completed in 10-14 days.

Life cycle:



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

Damage symptoms:

- Spider mites usually extract the cell contents from the leaves using their long, needle- like mouthparts. This results in reduced chlorophyll content in the leaves, leading to the formation of white or yellow speckles on the leaves.
- In severe infestations, leaves 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 mite:

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

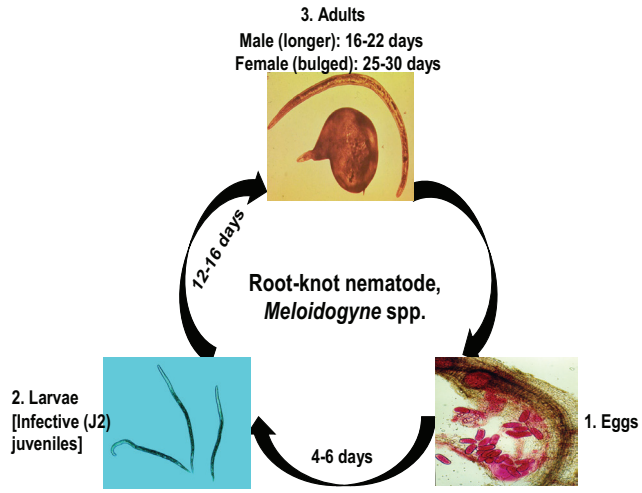
*For management refer to page number 16

9) Root-knot nematode:

Biology:

- Most species of plant parasitic nematodes have a relatively simple life cycle consisting of the egg, four larval stages and the adult male and female. 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.

1.

2.

1. http://utahpests.usu.edu/htm/utah-pests-news/up-summer12-newsletter/root-knot-nematodes/; 2. http://extension.entm.purdue.edu/nematology/melonnems.html

Survival and spread:

Primary: Egg masses survive 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 14

Natural Enemies of Watermelon Insect Pests

Parasitoids

Egg parasitoid

1. *Trichogramma* spp.

Egg-larval parasitoid

2. *Chelonus* spp.

Larval parasitoids

3. *Bracon* spp.

4. *Campoletis* spp.

5. Braconid wasp

6. Tachinid fly

7. *Apanteles* sp

8. *Goniozus* sp

9. *Elasmus* sp

10. *Phanerotoma* sp

Pupal parasitoids

11. *Brachymeria* sp

12. *Xanthopimpla punctata*

Nymphal parasitoids

13. *Ceranisus menes*

14. *Opius fletcheri*

Nymphal/larval and adult parasitoids

15. *Chrysocharis* sp

16. *Aphidius* sp

17. *Diglyphus isaea*

18. *Gronotoma micromorpha*

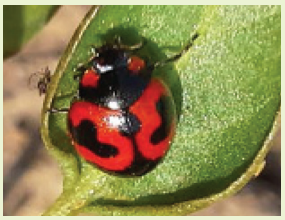
19. *Encarsia formosa*

20. *Eretmocerus* spp.

2. http://www.nbaii.res.in/Featured%20insects/chelonus.htm; 4. http://www.nbaii.res.in/Featured%20insects/Campoletis.htm; 5. http://nathistoc.bio.uci.edu/hymenopt/Braconid2.htm; 6. http://www.hr-na.com/RNA/Other%20insect%20pages/Eastern%20Tachinids.htm; 7. http://www.european-lepidopteres.fr/Videos-parasites-Apanteles.html; 8. http://www.pbase.com/tmurray74/bethylid_wasp__bethylidae; 9. http://species.wikimedia.org/wiki/Elasmus; 10. http://www.pbase.com/tmurray74/image/136622361; 11.http://www.nhm.ac.uk/researchcuration/research/projects/chalcidoids/database/media.dsml?IMAGENO=chalc519&VALGENUS=Brachymeria&VALSPECIES=euploeae; 12. http://cse.naro.affrc.go.jp/konishi/mokuroku/Xanthopimpla%20punctata/Xanthopimpla%20punctata.html; 13. http://cache.ucr.edu/~heraty/Eulophidae/Ceranisus_page.html; 14. http://mx.speciesfile.org/projects/8/public/public_content/show/13297; 15. http://baba-insects.blogspot.in/2012/05/blog-post_; 16. http://biobee.in/products-and-services/solutions/bio-aphidius/; 17: http://www.evergreengrowers.com/diglyphus-isaea-114.html; 18. http://www.ento.csiro.au/science/Liriomyza_ver3/key/Eucoilidae_Key/Media/Html/ gronotoma_sp.html; 19. http://www.buglogical.com/whitefly-control/encarsia-formosa/; 20. http://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. Red ant

7. Black drongo

8. Common mynah

9. Big-eyed bug

10. Earwig

11. Ground beetle

12. Pentatomid bug

13. Preying mantis

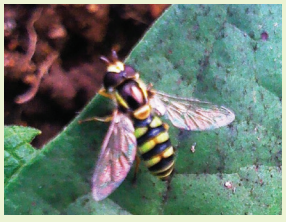
14. Wing beetle

15. Predatory mite

16. Predatory thrips

17. *Oligota* spp.

18. *Orius* spp.



19. Hover fly

20. Mirid bug

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

IX. DESCRIPTION OF DISEASES

1) Downy mildew:

Disease symptoms:

- Yellow, angular spots restricted by veins resembling mosaic mottling appear on upper surface of leaves.
- The corresponding lower surface of these spots shows a purplish downy growth in moist weather.
- The spots turn necrotic with age. The diseased leaves become yellow and fall down. Diseased plants get stunted and die. Fruits produced may not mature and have a poor taste.

Host range: Musk melon, watermelon, sponge gourd and bitter gourd etc.

Survival and spread:

- The pathogen survives in disease plant debris. Primary spread occurs by means of oospores in soil and sporangia from perennial collateral weed hosts in the vicinity. Secondary spread occurs by wind and rain splashes.

Favourable conditions:

- Relative humidity > 85%, high soil moisture, frequent rains.



1. 2. 3.

Leaves showing disease symptoms

1.http://msue.anr.msu.edu/news/downy_mildew_outbreak_on_cucumbers_in_southwest_michigan;2.http://www.cals.ncsu.edu/plantpath/extension/fact_sheets/Cucurbits_-_Downy_Mildew.htm; 3. http://agdev.anr.udel.edu/weeklycropupdate/?tag=basil-downy-mildew

*For management refer to page number 16

2) Powdery mildew:

Disease symptoms:

- Whitish powdery growth on upper foliage, stems and young growing parts. The superficial growth ultimately covers the entire leaf area.
- The diseased areas turn brown and dry leading to premature defoliation and death. Fruits remain underdeveloped and are deformed.

Host range: Pumpkins, watermelon, bottle gourd, coccinia, cucumber, ridge gourd, bitter gourd.

Survival and spread:

- The fungus overwinters in dormant buds or plant parts. Primary infection occurs by dormant mycelium or cleistothecia in infected plant debris or conidia from collateral hosts. Secondary infection occurs by means of wind borne conidia.

Favourable conditions:

- Morning relative humidity > 50%, cool and dry weather.


1. 2.

Leaves showing disease symptoms

1.http://www.clemson.edu/extension/hgic/pests/plant_pests/veg_fruit/hgic2206.html;2.http://aggie-horticulture.tamu.edu/vegetable/watermelon/foliar-diseases/powdery-mildew/

*For management refer to page number 16

3) Anthracnose:

Disease symptoms:

- Water soaked lesions are seen on the leaf which later become yellowish irregular spots.
- Foliage spots are irregular and turn dark brown or black. Stem lesions can girdle the stem and cause vines to wilt.
- The most striking diagnostic symptoms are produced on the fruit, where circular, black, sunken cankers appear. The spots may measure 1/4 to 1/2 in (6 to 13 mm) in diameter and up to 1/4 in (6 mm) deep.
- When moisture is present, the black center of the lesion is covered with a gelatinous mass of salmon colored spores.

Host range: Common on watermelon, muskmelon and cucumber.

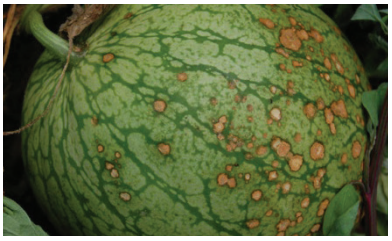
Survival and spread:

- Fungus survives in disease plant debris and overwinters on diseased residue from the previous vine crop in the form of resting spore. Secondary infection occurs by means of wind borne conidia.

Favorable conditions:

- 24-30°C and high relative humidity up to 100% for 24 h is optimum for fungal growth and infection with a thin film of water on leaf.





1. 2. 3.

Leaves and fruit showing disease symptoms

1.http://vegetablemdonline.ppath.cornell.edu/DiagnosticKeys/CucurLeaf/Anthrac/Anth_wtrmln.htm;2.http://vegetablemdonline.ppath.cornell.edu/DiagnosticKeys/CucurFrt/Anthracnose/Anth_wtrmln.htm;3. http://www.omafra.gov.on.ca/IPM/english/cucurbits/diseases-and-disorders/anthracnose.html

*For management refer to page number 16

4) *Alternaria* leaf spot:

Disease symptoms:

- The symptoms are first observed at the top of the portion of the plant.
- Round to irregular target board spots on older leaves are seen.

Survival and spread:

- Fungus survives in soil, and may persist in plant debris.
- Primary infection occurs by infected soil or inoculum present in plant debris
- Secondary spread is through rain or wind borne conidia.

Favourable conditions:

- The disease is favored by continuous wet conditions.

Leaves showing disease symptoms

http://aggie-horticulture.tamu.edu/vegetable/watermelon/foliar-diseases/alternaria-leaf-spot/

*For management refer to page number 17

5) *Fusarium* wilt:

Disease symptoms:

- The first symptom appears as chlorosis of the leaves.
- Wilting of leaves from bottom to top occur.
- Brown vascular discolouration inside infected stem or root leads to the death of plants.

Survival and spread:

- Pathogen survives in soil in the form of Chlamydospore (resting spore) for many years and primary infection occurs through inoculum present in the soil.

Favourable conditions:

- Relatively high soil moisture and soil temperature are favourable for the infection.

1. 2.

Leaves showing disease symptoms

1. http://www.plantmanagementnetwork.org/pub/php/research/2006/watermelon/; 2. http://extension.entm.purdue.edu/CAPS/pestInfo/fusariumWilt.htm

*For management refer to page number 17

6) Bud necrosis disease:

Disease symptoms:

- Chlorotic rings, mottling, crinckling on leaves are seen, on stunted plants.
- These spots turn brownish black, and leaves become brown and distorted.
- The surface of the fruits having ring spots which later turn to tan, necrotic or scab like lesions.

Transmission and favourable conditions:

- Thrips are the main vector for the transmitting the virus. Dry and hot periods when thrips population increase rapidly favours the spread of the disease.

1. 2.

Leaves and fruit showing disease symptoms

http://aaqua.persistent.co.in/aaqua/forum/viewthread?thread=23006

*For management refer to page number 17

7) Cucumber mosaic disease:

Disease symptoms:

- Symptoms of mosaic appear on the youngest leaves when infection occurs at 6 – 8 leaves stage
- Leaves curl downwards and become mottled, distorted, wrinkled and reduced in size
- Veins appear bunchy because of shortening of internodes
- Fruit set is very less if infection occurs early in crop growth
- Fruits are often misshapen, mottled, warty and reduced in size

Wide host range: Cucumber, pumpkin, gourds, cowpea, tomato, chilli, etc. Cucumovirus with spherical particles having ssRNA, banana, clover, corn, passion fruit, safflower, spinach, sugarbeet, wild cucumber, *Commelina communis, C. diffusa, C. nudiflora, Solanum elaegnifolium, Phytolacca* sp., *periwinkle, Gladiolus* sp., *Impatiens* sp. and Phlox.

Survival and spread:

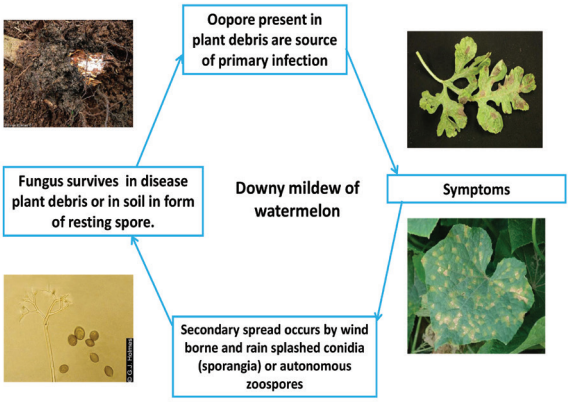
- Primary: Virus particles on collateral and other weeds, ornamentals or crops.
- Secondary: Virus particles transmitted by aphids (*Aphis craccivora*, *Myzus persicae*) and spotted and striped cucumber beetles.

*For management refer to page number 17

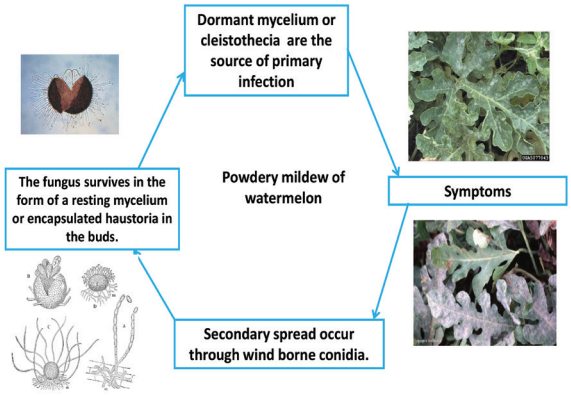
Leaves showing disease symptoms

Disease cycles:

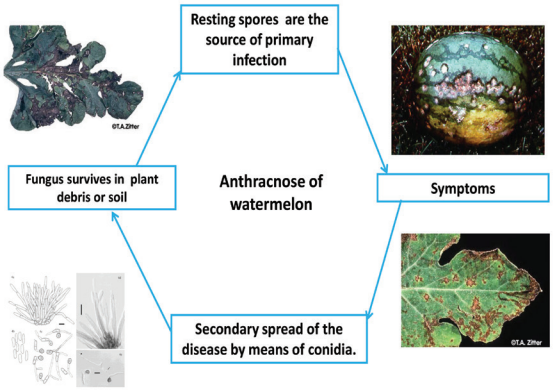
1. Downy mildew:



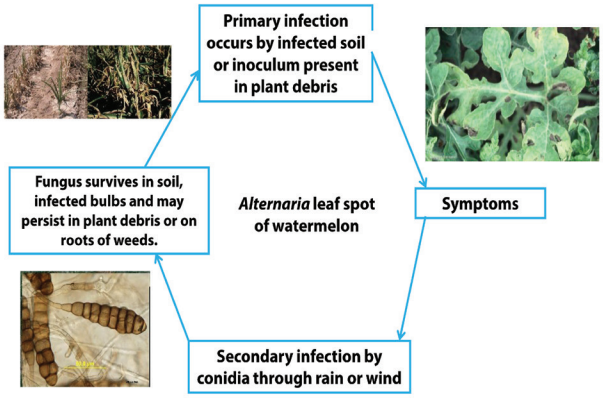
2. Powdery mildew:



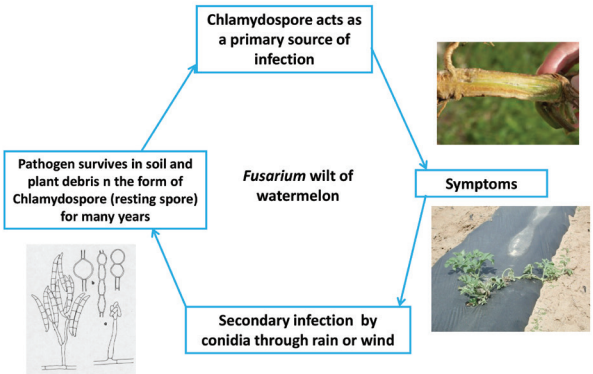
3. Anthracnose:



4. *Alternaria* leaf spot:



5. *Fusarium* wilt:



X. SAFETY MEASURES

A. At the time of harvest:

- The watermelon is ready for harvest about 45-60 days after sowing, depending on cultivars and growing conditions. The fruits take about 7–10 days from setting to reach marketable stage.
- Fruit size during harvesting depends on the purpose of use or market requirement.
- Fruits are harvested when it produces dull sound upon tapping or the fruits surface on the ground level produces light yellow colour (harvest index for water melon).

B. During post-harvest storage:

- Storage of watermelon is generally less than 14 days as visual and sensory quality deteriorate rapidly. Shriveling, yellowing, and decay are likely to increase following storage beyond two weeks, especially after removal to typical retail conditions. Short term storage or transit temperatures below this range (such as 7.2°C (45°F) are commonly used but will result in chilling injury after 2-3 days.
- Watermelons are chilling sensitive at temperatures below 10°C (50°F) if held for more than a day to 3 days depending on temperature and cultivar. Consequences of chilling injury are water-soaked areas, pitting and accelerated decay. Chilling injury is cumulative and may be initiated in the field prior to harvest.

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/ biopesticides for the control of seed borne diseases/pests.	Do not use seeds without seed treatment with biopesticides/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 weekly AESA in the morning preferably before 9 a.m. Take decision on management practice based on AESA and P: D ratio only.	Do not take any management decision without considering AESA and P: D ratio
12	Install pheromone traps at appropriate period.	Do not store the pheromone lures at normal room temperature (keep them in refrigerator).
13	Release parasitoids only after noticing adult moth catches in the pheromone trap or as pheromone trap or as per field observation	Do not apply chemical pesticides within seven days of release of parasitoids.
14	Spray pesticides thoroughly to treat the undersurface of the leaves, particularly for mites, whiteflies, etc.	Do not spray pesticides only on the upper surface of leaves.
15	Apply short persistent pesticides to avoid pesticide residue in the soil and produce.	Do not apply pesticides during preceding 7 days before harvest.
16	Follow the recommended procedure of trap crop technology.	Do not apply long persistent pesticides on trap crop, otherwise it may not attract the pests and natural enemies.

XII. BASIC PRECAUTIONS IN PESTICIDE USAGE

A. Purchase

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

B. Storage

1. Avoid storage of pesticides in house premises.
2. Keep only in original container with intact seal.
3. **Do not** transfer pesticides to other containers; **Do not** store expose to sunlight or rain water; **Do not** 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. Equipments

1. Select right kind of equipment.
2. **Do not** use leaky and defective equipments
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

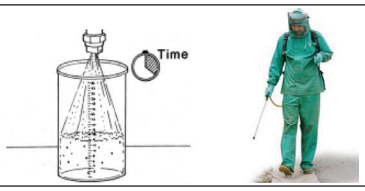
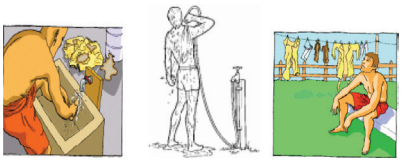
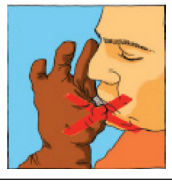
G. Disposal

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

Equipment			
Category A: Stationary, crawling pest/disease			
Vegetative stage i) For crawling and soil borne pests ii) For small sucking leaf borne pests	Insecticides and fungicides	• Lever operated knapsack sprayer (droplets of big size) • Hollow cone nozzle @ 35 to 40 psi • Lever operating speed = 15 to 20 strokes/min *or* • Motorized knapsack sprayer or mist blower (droplets of small size) • Airblast nozzle • Operating speed: 2/3rd throttle	 
Reproductive stage	Insecticides and fungicides	• Lever operated knapsack sprayer (droplets of big size) • Hollow cone nozzle @ 35 to 40 psi • Lever operating speed = 15 to 20 strokes/min	
Category B: Field flying pest/airborne pest			
Vegetative stage Reproductive stage *(Field Pests)*	Insecticides and fungicides	• Motorized knapsack sprayer or mist blower (droplets of small size) • Airblast nozzle • Operating speed: 2/3rd throttle *Or* • Battery operated low volume sprayer (droplets of small size) • Spinning disc nozzle	 
Mosquito/ locust and spatial application *(migratory* Pests)	Insecticides and fungicides	• Fogging machine and ENV (exhaust nozzle vehicle) (droplets of very small size) • Hot tube nozzle	 
Category C: Weeds			
Post-emergence application	Weedicide	• Lever operated knapsack sprayer (droplets of big size) • Flat fan or floodjet nozzle @ 15 to 20 psi • Lever operating speed = 7 to 10 strokes/min	 
Pre-emergence application	Weedicide	• Trolley mounted low volume sprayer (droplets of small size) • Battery operated low volume sprayer (droplets of small size)	 

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

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Ecological Engineering Plants for Watermelon

Dill

Sunflower

Carrot

***Ocimum* sp**

Cluster bean

Mustard

Parsley

Alfalfa

French bean

Cowpea

Buckwheat

Maize

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