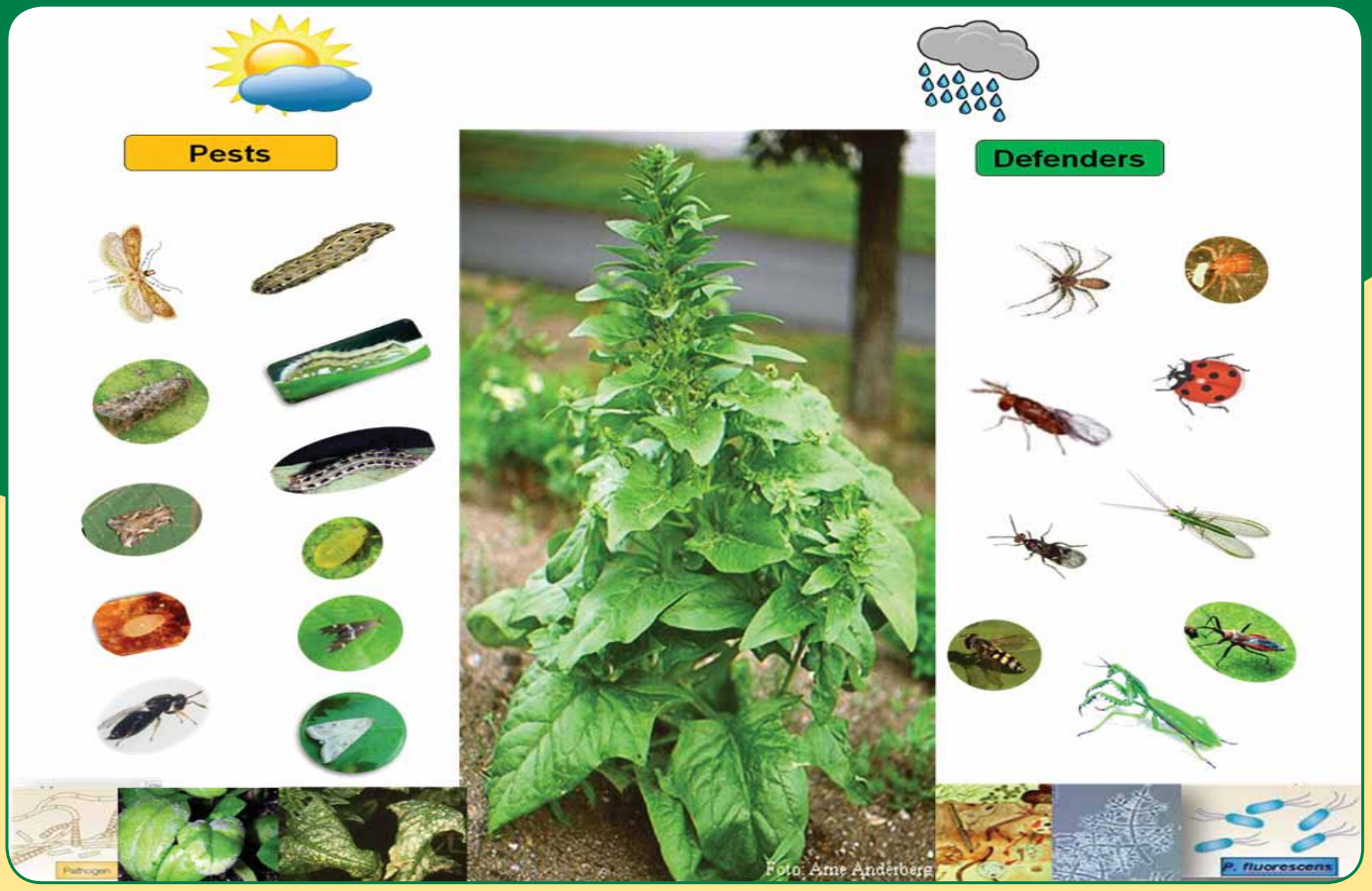
AESA BASED IPM PACKAGE

AESA based IPM – Spinach



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N. H. IV, Faridabad, Haryana

National Institute of Plant Health Management
Rajendranagar, Hyderabad, Telangana

Department of Agriculture and Cooperation
Ministry of Agriculture
Government of India

Important Natural Enemies of Spinach Insect Pests

Parasitoids

***Trichogramma* spp.**

***Tetrastichus* spp.**

***Ichneumon* sp**

***Bracon* spp.**

***Apanteles* sp**

***Brachymeria* sp**

Predators

Lacewing

Ladybird beetle

Spider

Reduviid bug

Preying mantis

Common mynah

The AESA based IPM - Spinach, 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 Spinach

Back cover picture Spinach 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 SPINACH

Spinach plant description:

Spinach (*Spinacia oleracea* L.; Family: Amaranthaceae) is an edible flowering plant. It is native to central and southwestern Asia. It is an annual plant (rarely biennial), which grows to a height of up to 30 cm. Spinach may survive over winter in temperate regions. The leaves are alternate, simple, ovate to triangular-based, very variable in size from about 2–30 cm long and 1–15 cm broad, with larger leaves at the base of the plant and small leaves higher on the flowering stem. The flowers are inconspicuous, yellow-green, 3–4 mm diameter, maturing into a small, hard, dry, lumpy fruit cluster 5–10 mm across containing several seeds.

Worldwide production of spinach was 20,793, 353 metric tones (MT) in 2011 season. Spinach is produced commercially with the top nine countries in the order of decrease in the production are China (18,782,961 mt), USA (409,360 t), Japan (263,500 t), Turkey (221,632 t), Indonesia (160,513 t), France (110,473t), South Korea (104,532), Pakistan (103,446), Belgium (99,750). Arab traders carried spinach into India, and then the plant was introduced into ancient China, where it was known as "Persian vegetable". The earliest available record of the spinach plant was recorded in Chinese, stating it was introduced into China via Nepal (probably in 647 AD).

Spinach, along with other green leafy vegetables is considered to be rich in iron. Spinach has a high nutritional value and is extremely rich in antioxidants, especially when fresh, steamed, or quickly boiled. It is a rich source of vitamin A (and especially high in lutein), vitamin C, vitamin E, vitamin K, magnesium, manganese, folate, betaine, iron, Vitamin B_2, calcium, potassium, vitamin B_6, folic acid, copper, protein, phosphorus, zinc, niacin, selenium and omega-3 fatty acids. Recently, opioid peptides called rubiscolins have also been found in spinach. Spinach is sold loose, bunched, packaged fresh in bags, canned, or frozen. Fresh spinach loses much of its nutritional value with storage of more than a few days.

I. PESTS

A. Pests of National Significance

1. Insect and mite pests

1.1. Leaf miner: *Liriomyza trifolii* Burgess (Diptera: Agromyzidae)

1.2. Spinach crown mite: *Rhizoglyphus* sp (Sarcoptiformes: Acaridae)

1.3. Beet armyworm: *Spodoptera exigua* Hubner (Lepidoptera: Noctuidae)

1.4. Tobacco caterpillar: *Spodoptera litura* Fab. (Lepidoptera: Noctuidae)

1.5. Leaf eating caterpillar/gram pod borer: *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae)

1.6. Cutworm: *Agrotis ipsilon* Hufnagel (Lepidoptera: Noctuidae)

1.7. Amaranthus weevil: *Hymenia recurvalis* Fab. syn. *Spoladea recurvalis* Fab. (Lepidoptera: Crambidae)

1.8. Aphid: *Aphis gossypii* Glover (Hemiptera: Aphididae)

2. Diseases

2.1. Downy mildew: *Peronospora farinosa* f.sp. *spinaceae* Fr.

2.2. Anthracnose: *Colletotrichum dematium* (Pers.) Grove

2.3. *Cladosporium* leaf spot: *Cladosporium variabile* (Cooke) de Vries

2.4. *Stemphylium* leaf spot: *Stemphylium botryosum* Wallr

2.5. Damping off and root rot: *Pythium* sp. and *Rhizoctonia* sp.

3. Weeds

Broad leaf

3.1. Dock's: *Rumex dentatus* L. (Polygonacae)

3.2. Sweet clover: *Melilotus alba* Medik., *M. indicus* (L.) All. (Fabaceae)

3.3. Wild pea: *Lathyrus aphaca* L. (Fabaceae)

3.4. Pig weed: *Amaranthus viridis* L. (Amaranthaceae)

Grasses

3.5. Burmuda grass: *Cynodon dactylon* L. (Poaceae)

3.6. Darnel: *Lolium temulantum* L. (Poaceae)

3.7. Polypogon: *Polypogon monspeliensis* (L.) Desf. (Poaceae)

Sedges

3.8. Nut grass: *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 situations and Pest: Defender ratio (P: D ratio)
- Take direct action when needed (e.g. collect egg masses, remove infested plants etc.)

Plant compensation ability:

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

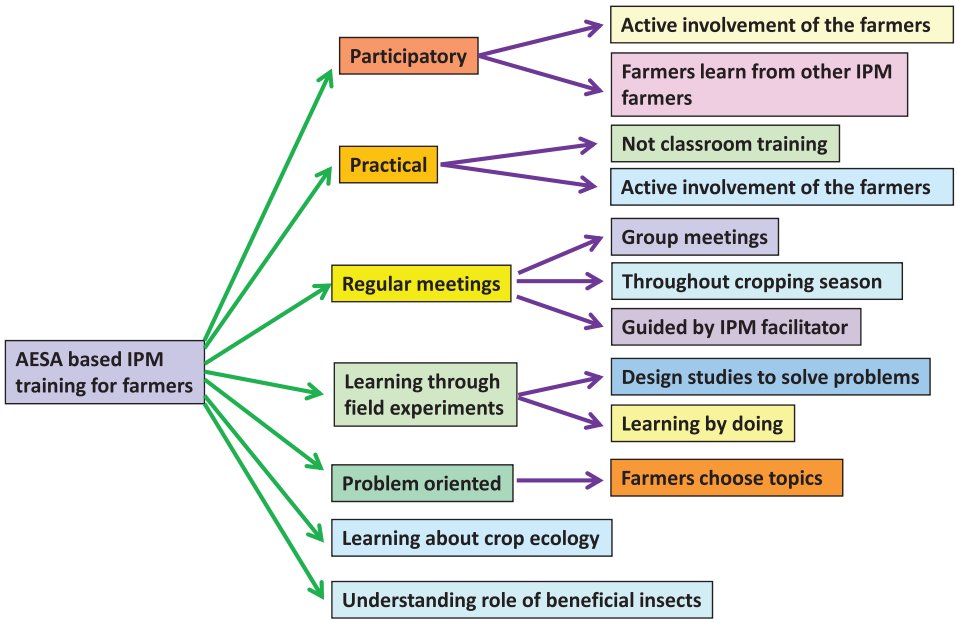
AESA and farmer field school (FFS):

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

For insect pests:

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

Leaf miner: Only the number of live mines on five randomly selected leaves per plant should be counted and recorded.

***Helicoverpa and Spodoptera*:** Total number of leaves damaged due to *Helicoverpa* and *Spodoptera* and number of larvae on individual plants 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 of each plant for lesions. Leaf diseases cause most damage during the seedling and flowering stages of plant growth. Observe for the symptoms and signs on the infected plant parts. Determine the percent area of leaf infection by counting the number of leaves (leaf area diameter)/plant infected due to disease and incidence should be recorded.

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

C. Surveillance through pheromone trap catches:

Pheromone traps for caterpillars viz., *Helicoverpa armigera*, *Spodoptera litura, S. exigua, Agrotis ipsilon, Hymenia recurvalis* @ 4-5 traps/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 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 pan water/ sticky traps:

Set up yellow pan water/sticky traps 15 cm above the canopy for monitoring aphids @ 4-5 traps (15 X 7.5 cm)/acre. Locally available empty tins can be painted yellow and coated with grease/vaseline/castor oil on outer surface may also be used as yellow sticky trap. Count the number of aphids on the traps daily and take the appropriate decision regarding management practices.

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 pm to 10 pm).

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, beetle bank 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 like *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:

- 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.
- Reduce tillage intensity so that hibernating natural enemies can be saved.
- Apply balanced dosage of nutrients using biofertilizers.
- Apply mycorrhiza and plant growth promoting rhizobacteria (PGPR).
- Apply *Trichoderma viride/harzianum* and *Pseudomonas fluorescens* as seed/seedlings/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).

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

Castor

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*

Insect/disease	Resistant/tolerant varities
Downy mildew	Tyee, Olympia, Melody, Regal
Cercospora leaf spot	Ooty (Sp) 1
Aphids	Ooty (Sp) 1

***For more information contact nearest KVK/State Department/SAU/CIPMC/ICAR institute**

IV. CROP STAGE-WISE IPM

Management	Activity
Pre sowing*	
	Common cultural practices: • Deep summer ploughing • Timely sowing should be done. • Field sanitation, rogueing • Sow the ecological engineering plants • Sow/plant sorghum/maize/bajra in 4 rows all around spinach field as guard crop • Destroy the alternate host plants • Follow crop rotation with non-host spinach crop • Grow trap crops such as castor for *S. litura*, marigold *for H. armigera.* and tomato for leaf miner
Nutrients	• Apply manures and fertilizers as per soil test recommendations and agro-climatic zone • Apply FYM @ 10 t/ acre and incorporate in the soil 2 to 3 weeks before sowing.
Weeds	• At the time of field preparation, adopt stale seed bed technique to minimize the weeds menace in field or • Soil solarization with transparent polyethylene sheet may be adopted
Soil borne pathogens, nematodes, resting stages of insects and weeds	**Cultural control:** • Excessive watering and poorly drained areas of field should be avoided and use raised beds: more than 35 cm height is better for water drainage for the management of damping off. **Biological control:** • Apply neem cake/pongamia cake @ 100 Kg/acre or press mud @ 2 t /acre

Management	Activity
Sowing *	
	Common cultural practices: • Use resistant/tolerant varieties • Select healthy, certified, and weed seed free seeds
Nutrients	• Apply 8 Kg Nitrogen, 16 Kg Phosphorus and 8 Kg Potash/acre as basal dose.
Weeds	• Adopt recommended agronomic practices with respect to timely sowing, seed rate, row spacing, fertilizer application, irrigation management etc. to have healthy crop.
Soil borne disease	**Cultural control:** • Seeds are soaked in water overnight before sowing • Line spacing is at 20 cm and thinning within lines at 10-12 cm. • Irrigation at 4-5 days interval in summer and 8-10 days interval in winter.
Leaf miner and other insect pests	**Cultural control:** • Avoid excess use of nitrogen. • Inter-planting with beans to reduce attack. **Biological control:** • Spray NSKE 4%.
*Apply *Trichoderma viride/harzianum* and *Pseudomonas fluorescens* as seed 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 crop debris • Judicious use of fertilizers • Provide irrigation at critical stages of the crop • Avoid water logging • Avoid any stress to the crop as much as possible • 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 • Collection and destruction of eggs and early stage larvae • Handpick the older larvae during early stages of crop • Handpick the gregarious caterpillars and the cocoons which are found on stem and destroy them in kerosene mixed water.

Management	Activity
	• Use yellow sticky traps @ 4-5 trap/acre • Use light trap @ 1/acre and operate between 6 pm and 10 pm • Install pheromone traps @ 4-5/acre for monitoring adult moths activity (replace the lures with fresh lures after every 2-3 weeks) • Erecting of bird perches @ 20/acre for encouraging predatory birds such as king crow, common mynah etc. • Set up bonfire during evening hours at 7-8 pm **Common biological practices:** • Conserve natural enemies through ecological engineering • Augmentative release of natural enemies
Nutrients	• Apply 12 Kg N/acre as top dressing at 30 days after sowing. • In case of slow growth of the crop top dressing of the N may be done after each cutting. • Micronutrient deficiency should be corrected by foliar spray of particular micronutrient.
Weeds	• Hand tool weeding/hoeing should be done to keep the field weeds free up to 30 days crop stage.
Leaf miner	• See common cultural, mechanical and biological practices. **Biological control:** • Spray neem oil @ 5 ml/l of water + 0.5 ml/l sticker
Spinach crown mite	• See common cultural, mechanical and biological practices.
Caterpillars, beet army worm	• See common cultural, mechanical and biological practices. **Biological control:** • Release egg parasitoids viz., *Trichogramma chilonis* and *T. pretiosum* @ 25,000/acre • Spraying NSKE 4% against eggs and first instar larva.
Cutworm	• See common cultural, mechanical and biological practices. **Biological control:** • Release of *Trichogramma* spp. @ 20,000/acre.
Amaranthus weevil	• See common cultural practices.

Management	Activity
Aphid	**Cultural control:** • Reflective mulches such as silver colored plastic can deter aphids from feeding on plants. • For others see common cultural practices. **Mechanical control:** • If aphid population is limited to just a few leaves or shoots then the infestation can be pruned out. **Biological control:** • Release 1st instar larvae of green lacewing bug (*Chrysoperla zastrowi sillemi*) @ 4,000/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).
Downy mildew	**Cultural control:** • See common cultural, mechanical and biological practices.
Anthracnose	**Cultural control:** • Harvesting and cutting of leaves at regular intervals to reduce spread of diseases. • Reduce leaf moisture by avoiding sprinkler irrigation. • See common cultural, mechanical and biological practices.
***Cladosporium* and *Stemphylium* leaf spot**	**Cultural control:** • After harvest of spinach seed crops, incorporate residues into the soil to prevent the sexual/asexual stage of the fungus from forming fruiting bodies on residues that remain on the soil surface. • Plough (disk) volunteer plants and residue to reduce the disease inoculum. • See common cultural, mechanical and biological practices.
Damping off & root rot	• See common cultural, mechanical and biological practices.
Reproductive stage (for seed production purpose only)	
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.
Pests and diseases	• Same as in vegetative stage.

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:

Manganese deficiency leads to severe chlorosis in plants.

http://customers.hbci.com/~wenonah/min-def/plate154.jpg

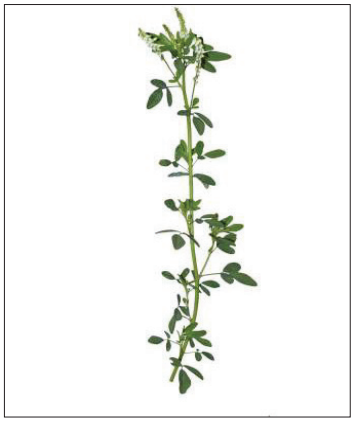
VII. COMMON WEEDS

1. Burmuda grass:
***Cynodon dactylon* L.**
(Poaceae)

2. Darnel:
***Lolium temulantum* L.**
(Poaceae)

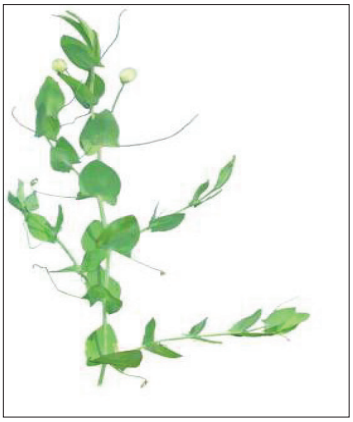
3. Polypogon:
***Polypogon monspeliensis* (L.)**
Desf. (Poaceae)

4. Dock's:
***Rumex dentatus* L.**
(Polygonacae)



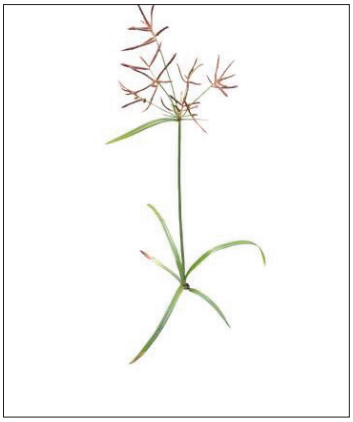
5. Sweet clover:
***Melilotus alba* Medik.,**
(Fabaceae)

6. Sweet clover:
***M. indicus* (L.) All.**
(Fabaceae)



7. Wild pea:
***Lathyrus aphaca* L.**
(Fabaceae)

8. Pig Weed:
***Amaranthus viridis* L.**
(Amaranthaceae)



9. Nut grass:
***Cyperus rotundus* L.,**
(Cyperaceae)

VIII. DESCRIPTION OF INSECT AND MITE PESTS

1) Leaf eating caterpillar/gram pod borer:

Biology:

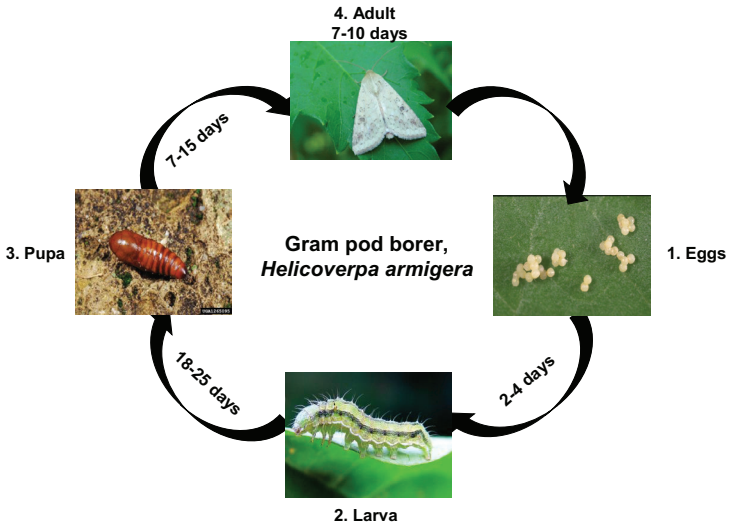
Egg: The spherical, yellowish eggs are laid singly on tender parts and buds of plants. The egg period lasts for 2-4 days.

Larva: Caterpillars are of varying colour, initially brown and later turn greenish with darker broken lines along the side of the body. Body covered with radiating hairs. When full grown, they measure 3.7 to 5 cm in length. The full grown caterpillar pupates in the soil in an earthen cell. The larval period lasts for 18-25 days.

Pupa: Pupation takes place inside the soil, pupal stage lasts 7-15 days.

Adult: Moth is stout, medium sized with brownish/greyish forewings with a dark cross band near outer margin and dark spots near costal margins, with a wing expanse of 3.7cm.

Life cycle:



Damage symptoms

- Young larva feeds on the leaves. Internal tissues are eaten severely and completely hollowed out.
- While feeding, the caterpillar thrust its head inside leaving the rest of the body outside. Fed leaves, shoots and buds.

1. http://www7.inra.fr/hyppz/RAVAGEUR/6helarm.htm; 2. http://www.infonet-biovision.org/default/ct/120/crops;
3. http://www.invasive.org/browse/subinfo.cfm?sub=9408; 4. http://en.wikipedia.org/wiki/Helicoverpa_armigera

Natural enemies of leaf eating caterpillar/gram pod borer:

Parasitoids: *Trichogramma chilonis, Tetrastichus* spp., and *Telenomus* spp., Braconid wasp, *Ichneumon* spp., *Bracon hebetor, Goniophthalmus halli, Carcelia* spp., *Campoletis chlorideae; Lissopimpla excels, Ichneumon promissorius*

Predators: Lacewings, king crow, dragonfly, spider, robber fly, reduviid bug, praying mantis, red ant etc.,

Entomopathogenic nematode: *Ovomermis albicans*

*For management refer to page number 16

2) Tobacco caterpillar:

Biology:

It is found throughout the tropical and sub tropical parts of the world, wide spread in India.

Besides tobacco, it feeds on cotton, castor, groundnut, tomato, cabbage and various other cruciferous crops.

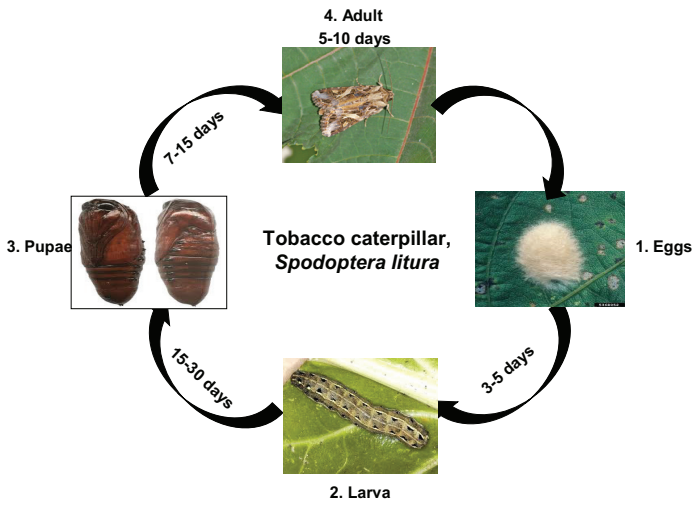
Egg: Female lays about 300 eggs in clusters. The eggs are covered over by brown hairs and they hatch in about 3-5 days.

Larva: Caterpillar measures 35-40 mm in length, when full grown. It is velvety, black with yellowish – green dorsal stripes and lateral white bands with incomplete ring – like dark band on anterior and posterior end of the body. It passes through 6 instars. Larval stage lasts 15-30 days

Pupa: Pupation takes place inside the soil, pupal stage lasts 7-15 days.

Adult: Moth is medium sized and stout bodied with forewings pale grey to dark brown in colour having wavy white crisscross markings. Hind wings are whitish with brown patches along the margin of wing. Pest breeds throughout the year. Moths are active at night. Adults live for 7-10 days. Total life cycle takes 32-60 days. There are eight generations in a year.

Life cycle:



Damage symptoms:

- In early stages, the caterpillars are gregarious and scrape the chlorophyll content of leaf lamina giving it a papery white appearance. Later they become voracious feeders making irregular holes on the leaves.
- Irregular holes on leaves initially and later skeletonization leaving only veins and petioles
- Heavy defoliation.

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

Favourable conditions:

Maximum *S. litura* built up at temperature ranges from 26.0°C to 35.1°C, relative humidity ranges from 89 and 62 per cent, zero rainfall, total sunshine hours (64.6 hrs/week), *S. litura* population shows a positive correlation with relative humidity, sunshine hours, whereas negatively correlated with wind velocity .

Parasitoids and predators same as in *Helicoverpa armigera*

*For management refer to page number 16

3) Beet armyworm:

Biology:

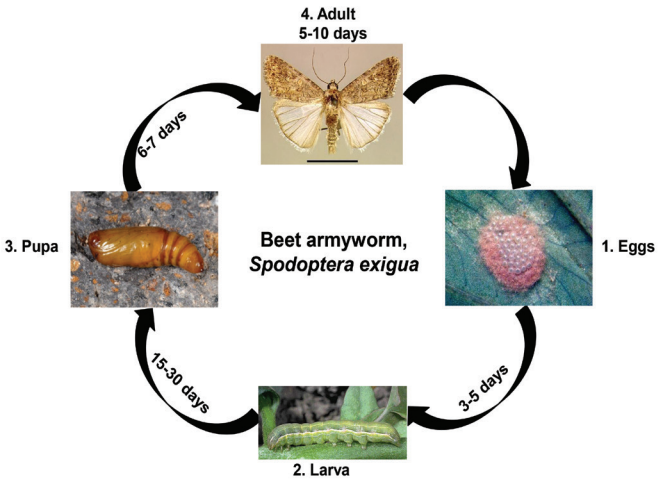
Egg: Eggs are laid in clusters of 50 to 150 eggs per mass. Normal egg production is about 300 to 600 per female. Eggs are usually deposited on the lower surface of the leaf, and often near blossoms and the tip of the branch. The eggs are greenish to white in color, and covered with a layer of whitish scales that gives the egg mass a fuzzy or cottony appearance. Eggs hatch in 2-3 days during warm weather.

Larva: There normally are five instars, although additional instars are sometimes reported. Duration of the instars under warm (summer) conditions is reported to be 2.3, 2.2, 1.8, 1.0, and 3.1 days, respectively. The larvae are pale green or yellow in color during the first and second instars, but acquire pale stripes during the third instar. Larvae during the fifth instar are quite variable in appearance, tending to be green dorsally with pink or yellow color ventrally and a white stripe laterally. A series of dark spots or dashes is often present dorsally and dorsolaterally. The body is practically devoid of hairs and spines.

Pupa: Pupation occurs in the soil. The chamber is constructed from sand and soil particles held together with an oral secretion that hardens when it dries. The pupa is light brown in color and measures about 15 to 20 mm in length. Duration of the pupal period 6-7 days during warm weather.

Adult: The moths are moderately sized, the wing span measuring 25 to 30 mm. The forewings are mottled gray and brown, and normally with an irregular banding pattern and a light colored bean-shaped spot. The hind wings are a more uniform gray or white color, and trimmed with a dark line at the margin. Moths usually live for 9-10 days.

Life cycle:



Damage symptoms:

- Larvae feed on foliage. Young larvae feed gregariously and skeletonize foliage.
- As they mature, larvae become solitary and eat large irregular holes in foliage.
- They also burrow into the crown or center of the head on lettuce, or on the buds of cole crops.

1. https://www.flickr.com/photos/koppert/2412866727/; 2,3. http://www.pyrgus.de/Spodoptera_exigua_en.html; 4. http://www.discoverlife.org/mp/20q?search=Spodoptera+exigua

Natural enemies of beet armyworm:

Parasitoids: *Telenomus remus, Trichogramma* spp.

Predators: Pentatomid bugs, earwigs, red ants, spiders, reduviid bug, wasps, *Bracon* spp., *Chelonus* spp. etc.

*For management refer to page number 16

4) Cutworm:

Biology:

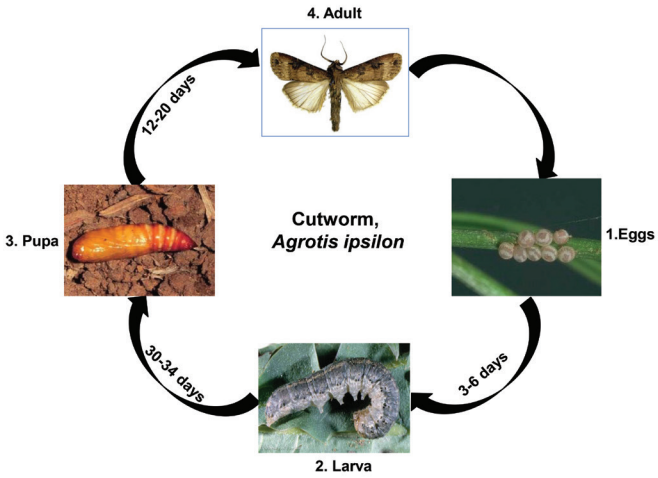
Egg: The egg is white in color initially, but turns brown with age. It measures 0.43 to 0.50 mm height and 0.51 to 0.58 mm wide and is nearly spherical in shape, with a slightly flattened base. The eggs normally are deposited in clusters on foliage. Females may deposit 1200 to 1900 eggs. The egg period is 3-6 days.

Larva: There are five to nine instars, with a total of six to seven instars most common.

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. 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:



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.

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

Natural enemies of cutworm:

Parasitoids: *Apanteles merginiventris, Chelonus insularis, Hyposoter exigua, Lespesia archippivora.*

Predators: Spider, ground beetle, lacewing, reduviid bug, pentatomid bug, predatory bug, praying mantis, wasps, ants etc.

Entomopathogenic nematode: *Hexameris arvalis*

*For management refer to page number 16

5) Amaranthus weevil:

Biology:

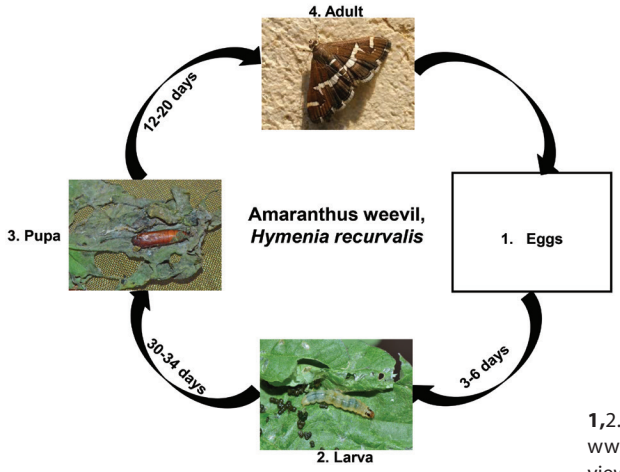
Egg: The eggs are yellowish in colour and normally are deposited in clusters on foliage. Duration of the egg stage is 3-6 days.

Grub: Body brownish-green with sparse white hairs; thin black dorsal line, broad dark subdorsal stripes, and paler yellowish sides and bottom.

Pupa: The pupa is 17 to 22 mm long and 5 to 6 mm wide, and dark brown.

Adult: Wingspan 19-21 mm, forewing dark brown or gray with broad white median band beginning at inner margin and terminating in "fish-hook" shape before reaching costa. Hindwing dark brown with broad white median band across wing; band is fairly straight with smooth margins outlined in black.

Life cycle:



Damage symptoms:

- Larvae feed on beets, chard, spinach, and various other crops.

1,2.http://www.norfolkmoths.co.uk/micros.php?bf=14040;3.http://www.gabi-krumm.de/wickler.htm;4.http://animal.memozee.com/view.php?tid=5&did=762&lang=kr

Natural enemies of amaranthus weevil:

Predators: Spider, ground beetle, lacewing, reduviid bug, pentatomid bug, predatory bug, praying mantis, wasps, ants etc.

*For management refer to page number 16

6) Aphid:

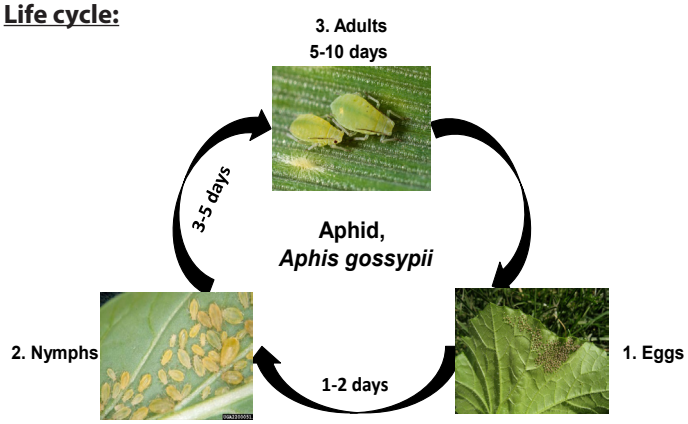
Biology:

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 (immature stages) are young aphids, they look like the wingless adults but are smaller. They become adults within 7 to 10 days.

Adult: Adults are small, 1 to 4 mm long, soft-bodied insects with two long antennae that resemble horns. Most aphids have two short cornicles (horns) towards the rear of the body.

Life cycle:



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* spp. and *Diaeretiella* sp

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

*For management refer to page number 17

7) Leaf miner:

Biology:

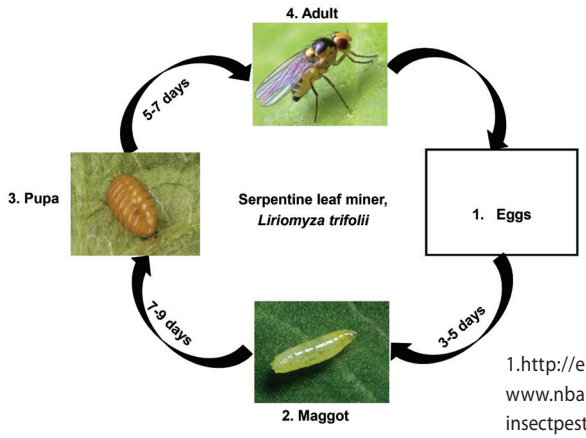
Egg: Minute orange yellow, apodous maggot feeds on chlorophyll mining in between epidermal layers. Egg period is 4 days.

Larva: Full grown maggot measures 3 mm. Larval duration is about 7 days.

Pupa: Pupation takes place inside a thin loose mesh of silken cocoon. Pupal period is about 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 serpentine mines. The maggot punctures the epidermal layers and scraps the chlorophyll content between the layers.
- In severe cases the photosynthetic activity reduced and leads to death of the plant.
- Drying dropping of leaves in severe cases.

Favourable conditions:

Warm weather conditions are favourable for multiplication.

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

Natural enemies of leaf miner:

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

Predators: Robber fly, spider, red ants etc.

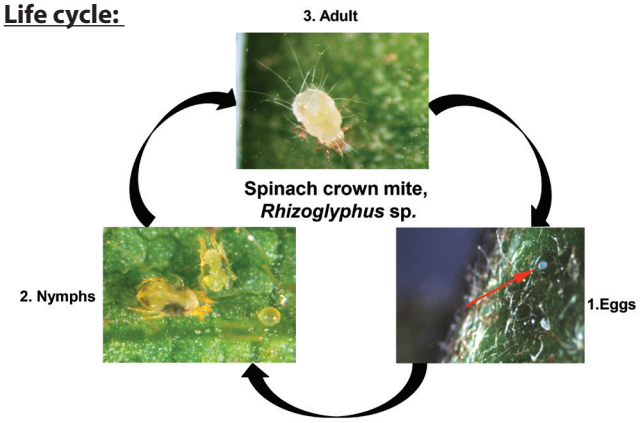
*For management refer to page numbers15, 16

8) Spinach crown mite:

Biology:

Crown mite eggs are transparent and spherical and are laid in the innermost parts of the plant. Immature are similar to adults except smaller in size known as protonymph. Adults are tiny, almost transparent mites with prominent long hairs. They can be found in both the soil and in the crowns of susceptible plants. They live deep in the crown of the spinach plant and lay eggs on the new growth.

Life cycle:



http://plant-pest-advisory.rutgers.edu/might-be-mites/

Damage symptoms:

- Crown mites may damage sprouting seeds, seedlings before or after emergence, or older plants.
- They feed primarily on newly expanding leaves at the heart of the plant.
- Their ability to injure the crop decreases as plants get larger and as plants grow rapidly.
- The damage appears as deformed leaves or as small holes in expanding leaves.
- Vector for plant pathogens - *Pythium* sp and *Rhizoctonia* sp

Natural enemies of crown mite:

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

*For management refer to page number 16

Natural Enemies of Spinach Insect Pests

Parasitoids

Egg parasitoids

1. *Trichogramma* spp.

2. *Tetrastichus* spp.

3. *Telenomus* spp.

Egg-larval parasitoid

4. *Chelonus* spp.

Larval parasitoids

5. *Bracon* spp.

6. *Ichneumon* spp.

7. *Carcelia* spp.

8. *Campoletis* spp.

9. *Apanteles* sp

10. *Hyposoter exiquae*

11. *Lespesia* sp

12. *Microgaster* sp

Pupal parasitoids

13. *Brachymeria euploeae*

14. *Gronotoma micromorpha*

Nymphal/larval/adult parasitoids

15. *Chrysocharis* sp

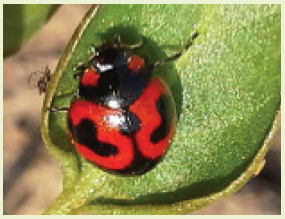
16. *Aphidius* sp

17. *Diglyphus isaea*

2. http://www.pbase.com/image/135529248; 3. http://baba-insects.blogspot.in/2012/02/telenomus.html; 4. http://www.nbaii.res.in/Featured%20insects/chelonus.htm; 6. http://www.organicgardeninfo.com/ichneumon-wasp.html; 7. http://72.44.83.99/forum/viewthread.php?thread_id=40633&pid=178398; 8. http://www.nbaii.res.in/Featured%20insects/Campoletis.htm; 9. http://www.european-lepidopteres.fr/Videos-parasites-Apanteles.html; 10. http://www.biologie.uni-hamburg.de/lehre/bza/molnews/jasmon/jasmonate.htm; 11. http://www.wright.edu/~john.stireman/research%20interests.html; 12. http://www.commanster.eu/commanster/Insects/Bees/SuBees/Microgaster.rufipes.html; 13. http://www.nhm.ac.uk/researchcuration/research/projects/chalcidoids/database/media.dsml?IMAGENO=chalc519&VALGENUS=Brachymeria&VALSPECIES=euploeae; 14. http://www.ento.csiro.au/science/Liriomyza_ver3/key/Eucoilidae_Key/Media/Html/ gronotoma_sp.html; 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

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

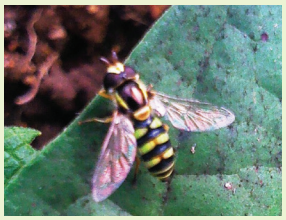

14. Wing beetle


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:

- The initial stage: Dull to bright yellow spots that form on cotyledons and leaves of all ages.
- The late stage: Enlarged spots and become browning and dry. Close inspection of the underside of the leaf often reveals the purple growth of the fungus.
- If disease development is extensive, leaves appear curled and distorted and may take on a blighted effect as a result of numerous infection sites.

Host range: Spinach, *Chenopodium* weed, *Beta* sp.

1. 2. 3.

Leaves showing disease symptoms

1.http://www.uark.edu/ua/jcorrell/spinach%20diseases.htm;2.3.http://pnwhandbooks.org/plantdisease/spinach-spinacia-oleracea-downy-mildew

Survival and spread:

- Fungus survives in disease plant debris or in soil in form of resting spore.
- **Primary:** The heavy canopy of densely planted spinach retains much moisture and creates ideal conditions for infection and disease development.
- **Secondary:** Spores (sporangia/zoospores) are dispersed in the air from plant to plant and field to field by winds and splashing water.

Favourable conditions:

- Heavy canopy of densely plantations, relative humidity > 90%, high soil moisture and frequent rains favour the development of diseases.

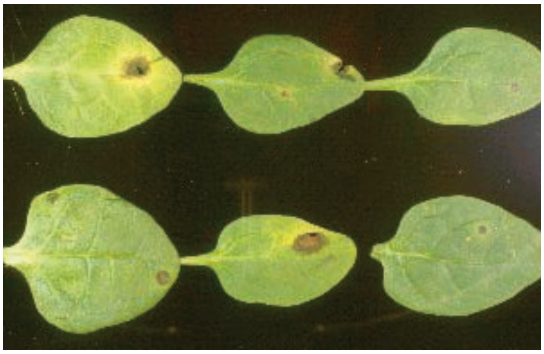
*For management refer to page number 17

2) Anthracnose:

Disease symptoms:

- In initial stage: Small, circular, water-soaked lesions on both young and old leaves.
- In late stage: Lesion turns brown to brownish in color, and become thin and papery.
- Tiny black fruiting bodies (acervuli) form profusely in diseased tissue and are a characteristic feature of the disease.

Host range: Cowpea (*Vigna unguiculata*), bean (*Phaseolus vulgaris*) and betel vine (*Piper* sp)



1. **2.**

Leaves showing disease symptoms

1. http://ag.arizona.edu/plp/plpext/diseases/vegetables/spinach/spinanth; 2.http://mtvernon.wsu.edu/path_team/newsaug03.htm

Survival and spread:

- Fungus survives in plant debris or soil.
- **Primary:** Seed borne inoculum and dormant mycelium in infected plant debris.
- **Secondary:** Spores are spread from plant-to-plants by splashing water from rains or sprinklers

Favourable conditions:

- Relative humidity > 90%, High soil moisture and frequent rains favour the development of disease.

*For management refer to page number 17

3) *Cladosporium* leaf spot:

Disease symptoms:

- Round, brownish leaf spots that rarely exceed 0.2 inch in diameter.
- Dark green spores and mycelium later develop in the centers of the spots.
- The presence of dark green sporulation distinguishes *Cladosporium* leaf spot from anthracnose and *Stemphylium* leaf spot diseases, both of which also form circular lesions.

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

Leaves showing disease symptoms

1.http://mtvernon.wsu.edu/path_team/DiseaseGallery/spinach-cladosporium-leaf-spot;2.http://mtvernon.wsu.edu/path_team/DiseaseGallery/spinach-cladosporium-leaf-spot-2.htm; 3. http://bumperscollege.uark.edu

Survival and spread:

- Pathogen survives in seeds and these seeds are source of primary inoculums. The secondary spread occurs by means of conidia.

Favourable conditions:

- Heavy rain in spring favours the development of diseases.

*For management refer to page number 17

4) *Stemphylium* leaf spot:

Disease symptoms:

- Initial stage: Small (0.1 to 0.2 inch diameter), circular to oval, gray-green leaf spots.
- Late stage: Leaf spots enlarge, remain circular to oval in shape, and turn brownish in color. Older spots coalesce, dry up, and become papery in texture.
- Visual signs of fungal growth are generally absent from the spots; hence this symptoms is readily differentiated from foliar diseases in which purple growth (downy mildew), green spores (*Cladosporium* leaf spot), or acervuli (anthracnose) develop within circular lesions.
- Overall, symptoms resemble the brownish, circular spots caused by pesticide or fertilizer toxicity.

1. **2.**

Leaves showing disease symptoms

1,2: http://mtvernon.wsu.edu/path_team/newsaug03.htm

Survival and spread:

- Fungus survives in seeds and infected seeds are the source of primary inoculums. Secondary infection occurs by means of conidia.

Favourable conditions:

- High humidity and moisture conditions favour the development of disease.

*For management refer to page number 17

5) Damping off and root rot:

Disease symptoms:

- Symptoms of damping-off and root rot consist of poor seed germination, pre-emergence death of seedlings, postemergence death of newly emerged seedlings, stunted plants, yellowed lower leaves, general poor growth, wilting, and eventual collapse and death of older plants.
- Roots of infected plants can appear water-soaked or brown to black in color. The upper taproot may be girdled by a necrotic lesion, or the tip of the taproot may be necrotic. In severe cases, nearly all roots may be girdled or rotted off.
- Severity is influenced by cultivar, soil texture, irrigation, and pathogen populations. Severe damping-off is associated with clay or poorly draining soils with a history of frequent spinach production. While all stages of spinach can be infected by root rot organisms, newly emerging plants and young seedlings are very susceptible.

Host range: Spinach, tomato, brinjal

Survival and spread:

- The fungus survives in soil and inoculum present in the soil is source of primary infection. Secondary infection occurs by means of conidia through rain splash or wind.

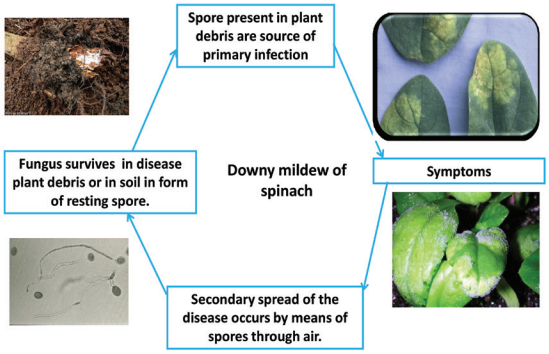
Favourable conditions:

- 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.

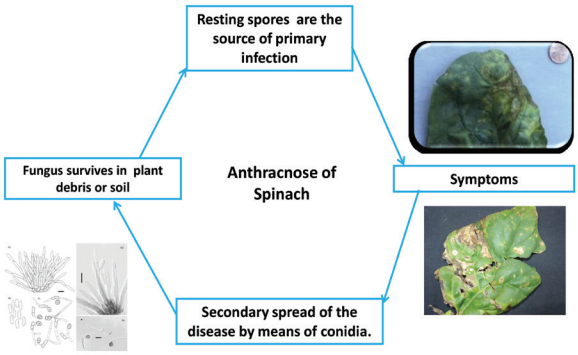
*For management refer to page number 17

Disease cycles:

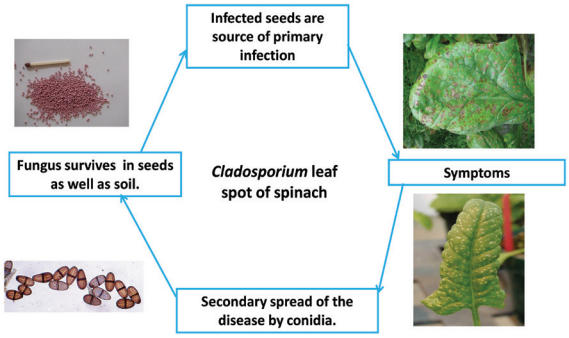
1. Downy mildew:



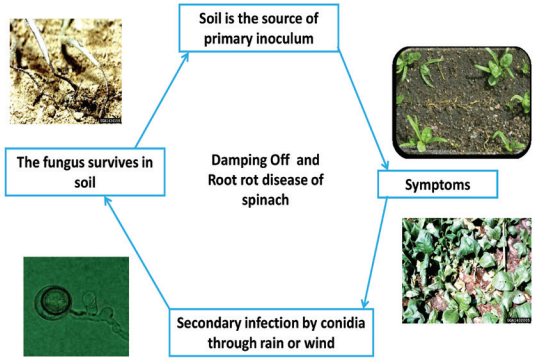
2. Anthracnose:



3. *Cladosporium* leaf spot:



4. Damping off and root rot:



X. SAFETY MEASURES

A. At the time of harvest:

Choosing when to pick spinach depends on whether you want baby leaves or full grown. Picking spinach as needed is called "cut and come again" and is a good way to harvest this highly perishable vegetable. When to Pick Spinach: When to pick spinach is an important consideration in order to get the best tasting leaves and prevent bolting. Spinach is a cool season crop that will flower or bolt when the sun is high and temperatures are warm. Most varieties mature in 37 to 45 days and can be harvested as soon as it is a rosette with five or six leaves. Baby spinach leaves have a sweeter flavor and more tender texture. Spinach leaves should be removed before they get yellow and within a week of full leaf formation. There are a few methods on how to harvest spinach as a complete harvest or continuous harvest. Small spinach leaves can be harvested with scissors by simply cutting the leaves at the stem. One way to do this is start harvesting the outer, older leaves first and then gradually working your way in to the center of the plant as those leaves mature. You can also just cut the whole plant off at the base. Harvesting spinach by this method will often allow it to re-sprout and give you another partial harvest. When considering how to pick spinach, decide if you will use the entire plant immediately or just need a few leaves. Picking spinach will accelerate its decay since the leaves do not keep well. There are ways to preserve the vegetable but it needs a proper cleaning first. Spinach should be soaked or rinsed several times to remove the dirt and any discolored or damaged leaves taken out of the harvest.

B. During post-harvest storage:

Fresh spinach can be kept in the refrigerator for ten to fourteen days. The best temperature to keep spinach is 41 to 50 degrees Fahrenheit. Bundle the stems together lightly and place them in a paper towel in a plastic bag. Handle spinach leaves gently as they are prone to bruising. After harvesting spinach, use what leaves you can as a fresh vegetable. In a bumper crop you can steam or sauté the extra leaves and chop them. Freeze the resulting product in sealed containers or bags. Plant a fall crop in early August for harvest all the way into October or until freezing temperatures arrive.

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 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.	Adopt proper spacing in the field.	Do not damage the seedling while uprooting and transplanting.
7.	Maintain optimum and healthy crop stand which would be capable of competing with weeds at a critical stage of crop weed competition	Crops should not be exposed to moisture deficit stress at their critical growth stages.
8.	Use NPK fertilizers as per the soil test recommendation.	Avoid imbalanced use of fertilizers.
9.	Use micronutrient mixture after sowing based on test recommendations.	Do not apply any micronutrient mixture after sowing without test recommendations.
10.	Conduct 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
11.	Install pheromone traps at appropriate period.	Do not store the pheromone lures at high temperature and preferably store 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.	Apply HaNPV or SINPV at recommended dose when a large number of egg masses and early instar larvae are noticed. Apply NPV only in the evening hours after 5 pm.	Do not apply NPV on late instar larva and during day time.
15.	In case of pests which are active during night such as *Spodoptera* spray recommended biopesticides/ chemicals at the time of their appearance during evening time.	Do not spray pesticides at midday since, most of the insects are not active during this period.
16.	Spray pesticides thoroughly to treat the undersurface of the leaves, particularly for mites and *Spodoptera*.	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 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

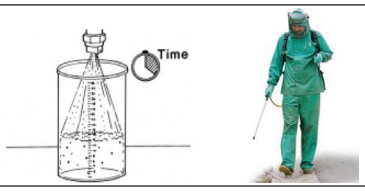
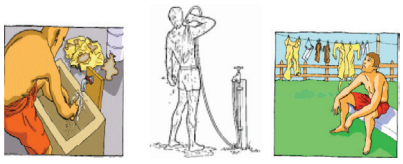
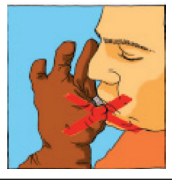
G. Disposal

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 Spinach

Dill

Sunflower

Carrot

***Ocimum* sp**

Cluster bean

Mustard

Parsley

Alfalfa

French bean

Cowpea

Buckwheat

Maize

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