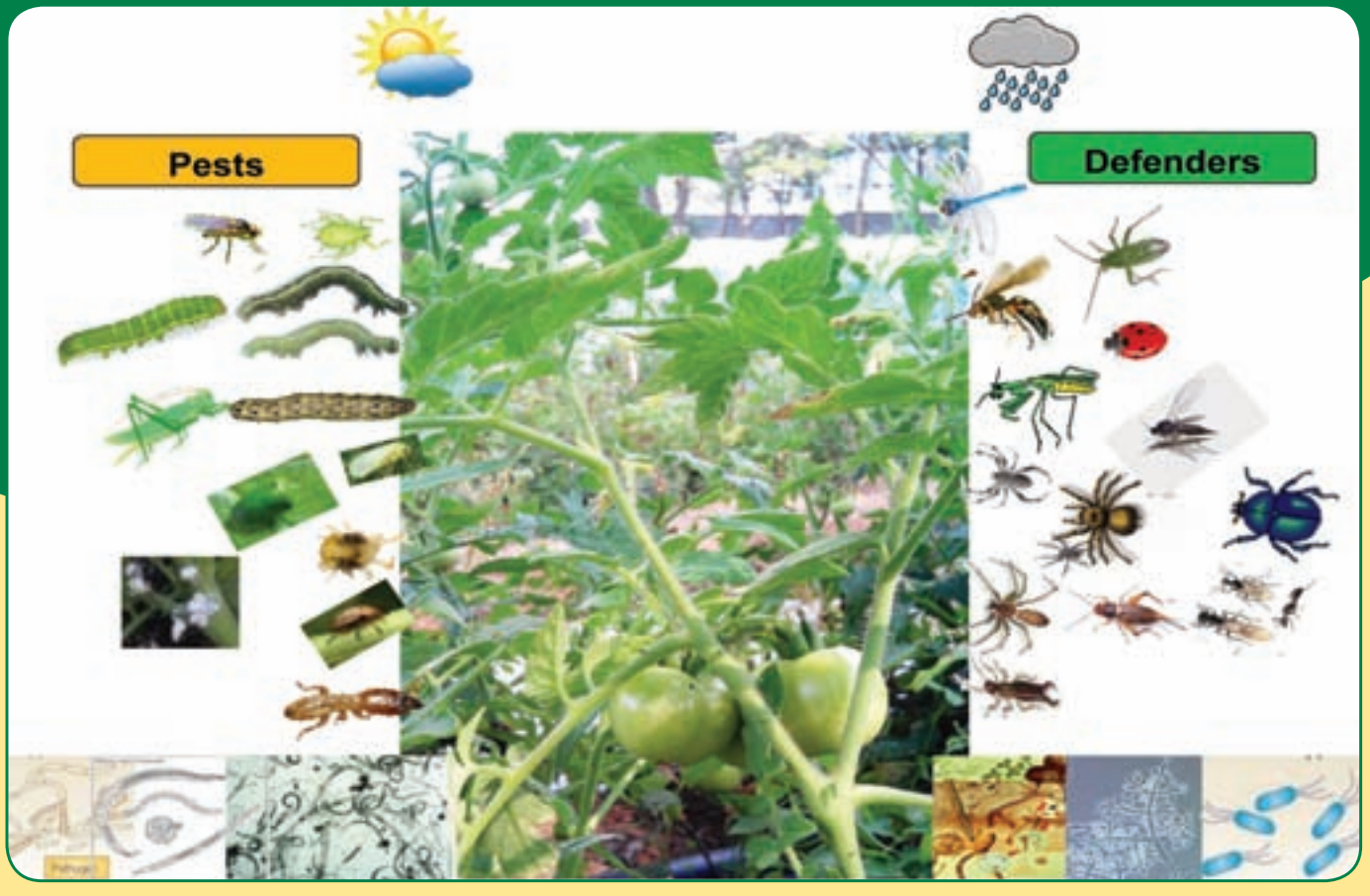
AESA BASED IPM PACKAGE

TOMATO



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Department of Agriculture and Cooperation
Ministry of Agriculture
Government of India

Important Natural Enemies of Tomato Insect Pests

Parasitoids

***Trichogramma* spp.**

***Campoletis* spp.**

Chrysocharis pentheus

***Bracon* spp.**

***Chelonus* spp.**

Encarsia formosa

Predators

Lacewing

Ladybird beetle

Spider

Reduviid bug

Praying mantis

Common mynah

The AESA based IPM - Tomato, 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 tomato

Back cover picture NIPHM PGDPHM Students taking AESA observations in tomato 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 TOMATO

Tomato - Plant description:

Tomato (*Lycopersicon esculentum* L.; Family Solanaceae) is one of the most important protective food crops of India. It is grown in 0.458 M ha area with 7.277 M mt production and 15.9 mt/ha productivity. The plants typically grow to 1-3 meters in height and have a weak stem that often sprawls over the ground and vines over other plants. It is a perennial in its native habitat, although often grown outdoors in temperate climates as an annual.

The plant is herbaceous, annual have a basal or terminal group of leaves. The leaves are generally alternate or alternate to opposed (that is, alternate at the base of the plant and opposed towards the inflorescence). The leaves can be herbaceous, leathery and are generally petiolate or subsessile, rarely sessile. The leaves have reticulated venation and lack a basal meristem. The flowers are hermaphrodites. The flowers can be solitary or grouped into terminal, cymose, or axillary inflorescences. The flowers are usually actinomorphic. The flowers have a differentiated perianth with a calyx and corolla (with five sepals and five petals, respectively) an androecium with five stamens and two carpels forming a gynoecium with a superior ovary. The stamens are epipetalous and are typically present in multiples of four or five, most commonly four or eight. They usually have a hypogynous disk. The major tomato producing states are Bihar, Karnataka, Uttar Pradesh, Orissa, Andhra Pradesh, Maharashtra, Madhya Pradesh and West Bengal. Tomato is rich source of vitamins A, C, potassium, minerals and fibers. Tomatoes are used in the preparation of soup, salad, pickles, ketchup, puree, sauces and also consumed as a vegetable in many other ways.

I. PESTS

A. Pests of National Significance

1. Insect and mite pests

1.1 Gram pod borer: *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae)

1.2 Tobacco caterpillar: *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae)

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

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

1.5 Thrips: *Thrips tabaci* Lindeman; *Frankliniella schultzei* (Thysanoptera: Thripidae)

1.6 Red spider mite: *Tetranychus* spp. (Acarina: Tetranychidae)

2. Diseases

2.1 Damping off: *Pythium aphanidermatum* (Edson) Fitzp

2.2 Tomato leaf curl disease: *Tomato leaf curl virus* (ToLCV)

2.3 Early blight: *Alternaria solani* (Ell. & Mart.). *A. alternata* f.sp. *lycopersici* Grogan et al.

2.4 Late blight: *Phytophthora infestans* (Mont.) de Bary.

2.5 Bacterial wilt: *Ralstonia solanacearum* (Smith) Yabuuchi et al.

2.6 *Fusarium* wilt: *Fusarium oxysporum* f. sp. *lycopersici* (Sacc.) W.C. Snyder and H.N. Hans.

2.7 Bacterial stem and fruit canker: *Clavibacter michiganensis* sub sp. *michiganensis* (Smith) Davis et al.

2.8 Tomato mosaic disease: *Tomato mosaic virus*

2.9 Bacterial fruits and leaf spots: *Xanthomonas campestris* pv. *vesicatoria* (Doidge) Dye

2.10 Tomato spotted wilt disease: *Peanut bud Necrosis Virus (PbNV)* TSWV

3. Nematodes

3.1 Root-knot nematode: *Meloidogyne* spp.

3.2 Reniform nematode: *Rotylenchulus reniformis* (Linford & Oliveira)

4. Rodents

4.1 Lesser bandicoot: *Bandicota bengalensis* (Gray)

4.2 Palm rat/house rat: *Rattus rattus* (Linnaeus)

4.3 Indian gerbil: *Tatera indica* Hardwicke

5. Weeds

5.1 Major *Kharif*

Broadleaf

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

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

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

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

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

Grasses

5.1.6 Rabbit/crow foot grass: *Dactyloctenium aegyptium* (L.) Beauv. (Poaceae)

5.1.7 Crab grass: *Digiteria sanguinalis* (L.) Willd. (Poaceae)

5.1.8 Barnyard grass: *Echinochloa crusgalli* (L.) Scop. (Poaceae)

Sedges

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

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

5.2 Major *Rabi*

Broadleaf

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

5.2.2 Scarlet pimpernel: *Anagallis arvensis* L. (Primulaceae)

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

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

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

Grasses

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

5.2.7 Canary grass: *Phalaris minor* Retz. (Poaceae)

B. Pests of Regional Significance

1. Insect pests

1.1 Leafhopper: *Amrasca biguttula biguttula* Ishida (Hemiptera: Cicadellidae) (Madhya Pradesh, Rajasthan, Uttar Pradesh, Tamil Nadu)

1.2 Cut worm: *Agrotis ipsilon* (Hufnagel) (Hemiptera: Cicadellidae) (Jammu & Kashmir)

1.3 Aphids:

1.3.1 *Myzus persicae* (Sulzar) (Hemiptera: Aphididae) (Bihar, Rajasthan, Karnataka)

1.3.2 *Aphis gossypii* (Glover) (Hemiptera: Aphididae) (West Bengal, Punjab)

1.3.3 *Aphis fabae* Scopoli (Hemiptera: Aphididae) (Rajasthan)

1.3.4 *Aphis craccivora* Koch (Hemiptera: Aphididae) (Uttar Pradesh)

1.4 Mealybug: *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) (Andhra Pradesh, Utter Pradesh, Punjab)

2. Diseases

2.1 Buck eye rot: *Phytophthora nicontianae* var. *parasitica* (Dastur) Waterhouse (Himachal Pradesh, Punjab, Haryana, Karnataka)

2.2 Powdery mildew: *Leveillula taurica* (Lev.) Arnaud. (Maharashtra, Andhra Pradesh)

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 white 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 material
- Treat the seeds/seedlings/planting material 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

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):

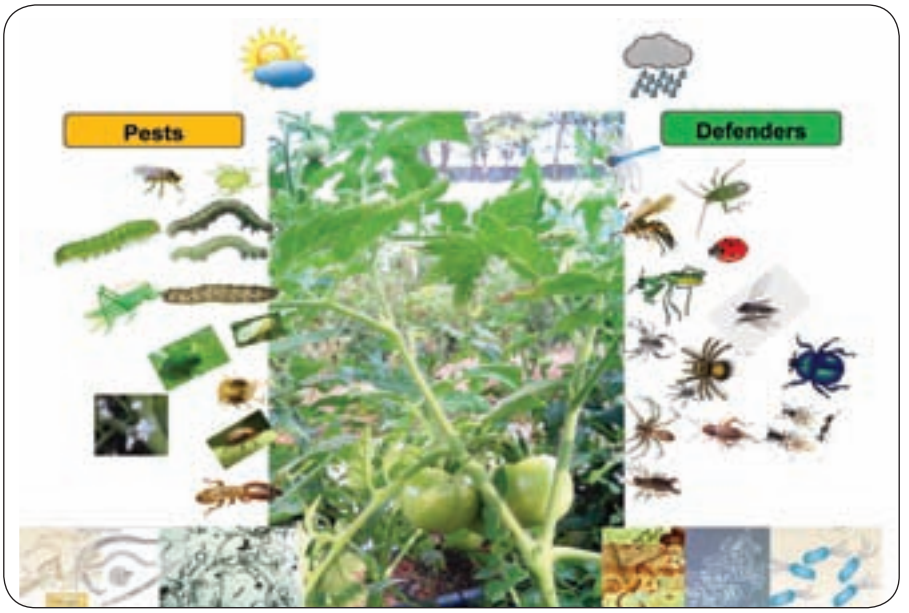
Identifying the number of pests and beneficial insects helps the farmers to make appropriate pest management decisions. Sweep net, visual counts etc. can be adopted to arrive at the numbers of pests and defenders. The P: D ratio can vary depending on the feeding potential of natural enemy as well as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

Model Agro-Ecosystem Analysis Chart

Date:

Village:

Farmer:



Decision taken based on the analysis of field situations

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

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

Decision making:

Farmers become experts in crop management:

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

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

AESA methodology:

- Go to the field in groups (about 5 farmers per group). Walk across the field and choose 20 plants/ acre randomly. Observe keenly each of these plants and record your observations:
    - Plant: Observe the plant height, number of branches, crop stage, deficiency symptoms etc.
    - Insect pests: Observe and count insect pests at different places on the plant.
    - Defenders (natural enemies): Observe and count parasitoids and predators.
    - Diseases: Observe leaves and stems and identify any visible disease symptoms and severity.
    - Rats: Count number of plants affected by rats.
    - Weeds: Observe weeds in the field and their intensity.
    - Water: Observe the water situation of the field.
    - Weather: Observe the weather conditions.
- 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:

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

Some questions that can be used during the discussion:

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

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

Advantages of AESA over ETL:

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

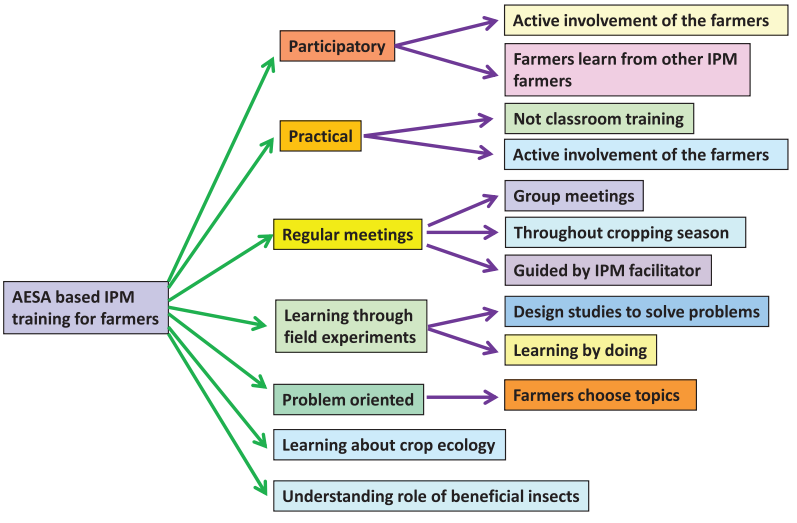
AESA and farmer field school (FFS):

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

Farmers can learn from AESA:

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

FFS to teach AESA based IPM skills:



B. Field scouting:

AESA requires skill. So only the trained farmers can undertake this exercise. However, other farmers also can do field scouting in their own fields at regular intervals to monitor the major pest situation.

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

For insect pests:

Aphids, whitefly 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.

***Helicoverpa* and *Spodoptera*:** Total number of fruits, damaged fruits 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, flower and fruit sampling: Carefully examine the stem, flower, and fruit of plants for symptoms and signs of fungal or bacterial diseases. The stem, flower, and fruit 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 percent disease incidence should be recorded.

C. Surveillance through pheromone trap catches for *Spodoptera* and *Helicoverpa*:

Pheromone traps for two insects viz., *Helicoverpa armigera* and *Spodoptera litura* @ 4-5/acre have to be installed, if available Install the traps for each species separated by a distance of >75 feet in the vicinity of the selected field. Fix the traps to the supporting pole at a height of one foot above the plant canopy. Change of lures should be made at 2-3 week interval (regular interval). During each week of surveillance, the number of moths/trap should be counted and recorded. The trapped moths should be removed and destroyed after each recording.

D. Yellow/blue pan water/sticky traps:

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

E. Light traps:

Set up light trap @ 1 trap/acre 15 cm above the crop canopy for monitoring and mass trapping 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).

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 200-mesh sieve into first bucket; discard residue in second bucket. Backwash material caught on 200-mesh sieve (which includes large nematodes) into 250-ml beaker. Stir material in first bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 325-mesh sieve into second bucket; discard residue in first bucket. Backwash material caught on 325-mesh sieve (which includes small to mid-sized nematodes and silty material) into 250-ml beaker. More than 90% of the live nematodes are recovered in the first 5-8 mm of water drawn from the rubber tubing and the sample is placed in a shallow dish for examination.

III. ECOLOGICAL ENGINEERING FOR PEST MANAGEMENT

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

Ecological Engineering for Pest Management – Below Ground:

There is a growing realization that the soil borne, seed and seedling borne diseases can be managed with microbial interventions, besides choosing appropriate plant varieties. The following activities increase the beneficial microbial population and enhance soil fertility.

- Crop rotations with leguminous plants which enhance nitrogen content.
- Keep soils covered year-round with living vegetation and/or crop residue.
- Add organic matter in the form of farm yard manure (FYM), vermicompost, crop residue which enhance below ground biodiversity of beneficial microbes and insects.
- Application of balanced dose of nutrients using biofertilizers based on soil test report.
- Application of biofertilizers with special focus on mycorrhiza and plant growth promoting rhizobia (PGPR)
- Application of *Trichoderma harzianum/viride* and *Pseudomonas fluorescens* for treatment of seed/seedling/ planting materials in the nurseries and field application (if commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).

Ecological Engineering for Pest Management – Above Ground:

Natural enemies play a very significant role in control of foliar insect pests. Natural enemy diversity contributes significantly to management of insect pests both below and above ground.

Natural enemies may require:

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

In order to attract natural enemies following activities should be practiced:

- Raise the flowering plants / compatible cash crops along the field border by arranging shorter plants towards main crop and taller plants towards the border to attract natural enemies as well as to avoid immigrating pest population
- Grow flowering plants on the internal bunds inside the field
- Not to uproot weed plants those are growing naturally such as *Tridax procumbens, Ageratum* sp, *Alternanthera* sp etc. which act as nectar source for natural enemies
- Not to apply broad spectrum chemical pesticides, when the P: D ratio is favourable. The plant compensation ability should also be considered before applying chemical pesticides.
- Reduce tillage intensity so that hibernating natural enemies can be saved.
- Select and plant appropriate companion plants which could be trap crops and pest repellent crops. The trap crops and pest repellent crops will also recruit natural enemies as their flowers provide nectar and the plants provide suitable microclimate.

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

Plants Suitable for Ecological Engineering for Pest Management

Attractant plants


Carrot


Sunflower


Buckwheat


French bean


Alfalfa


Berseem clover


Anise


Caraway


Dill


Parsley


Mustard


Bishop's weed


Sweet clover


Cowpea


Maize

Repellent plants


Ocimum spp.


Peppermint

Trap plants


Castor


Marigold

Border plant


Ryegrass

Barrier/guard plants


Bajra


Maize


Sorghum

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

Biodiversity of natural enemies observed in Ecological Engineering field at NIPHM

Biodiversity of natural enemies: Parasitoids

Biodiversity of natural enemies: Predators

Biodiversity of natural enemies: Spiders

IV. RESISTANT/TOLERANT VARIETIES

Pests	Tolerant/ resistant variety*
Root-knot nematode	Pusa-120, Pusa Hybrid-2, Pusa Hybrid-4, Arka Vardan, Hisar Lalit, TNAU Tomato Hybrid Co3
Tomato leaf curl virus	Arka Ananya, Kashi Vishesh, Kashi Amrit, COTH 2, TNAU Tomato Hybrid Co3
Bacterial wilt	Arka Ananya, Arka Abhijit, Arka Abha, Arka Alok

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

V. CROP STAGE-WISE IPM

Management	Activity
Pre-sowing*	
	Common cultural practices: • Deep summer ploughing • Follow crop rotation with non-host crops • Destroy the alternate host plants • Sow the ecological engineering plants • Sow sorghum/maize/ryegrass in 4 rows all around the main crop as guard/barrier crop
Nutrients	• Add well rotten FYM @ 8-10 t/ acre or vermicompost @ 5 t/acre. Incorporate at the time of field preparation at 1 week (vermicompost) or 2 to 3 weeks (FYM) before transplanting.
Weeds	• At the time of field preparation, adopt stale seed bed technique to minimize the weeds menace in field. • Keep the nursery weed free by hand pulling of the weeds.
Soil-borne fungus and nematodes, resting stages of insects	**Cultural control:** • Soil solarization: Cover the beds with polythene sheet of 45 gauge (0.45 mm) thickness for three weeks before sowing for soil solarization which will help in reducing the soil-borne pests including weeds. • Ecological engineering of tomato with raising African marigold nursery 15 days prior to tomato nursery serves as a trap crop for ovipositing females of *Helicoverpa*. **Biological control:** • Apply neem cake @ 100 Kg/acre. • *Pseudomonas fluorescens* 0.5% WP (TNAU, IPCC BE 0005) @ 10 g/Kg seeds
Damping off	• For resistant / tolerant varieties consult ICAR Institute / KVK's / SAU's. **Cultural control:** • Excessive watering and poorly drained areas of field should be avoided • Use raised beds: 15 cm height is better for water drainage or use pro-trays for raising seedlings **Biological control:** • Seed treatment with *Trichoderma viride* 1 % WP @ 9 g/Kg of seed. **Chemical control:** • Seed treatment with captan 75% WS @ 20-30 g/Kg seed • Soil drench with captan 75% WP @ 1Kg in 400 l of water/acre as soil drench in nursery
Seed sowing/ transplanting stage*	
	Common cultural practices: • Before sowing, soil testing should be done to find out the soil fertility status. • Based on soil test for micronutrients, the deficient micronutrient should be applied in soil at sowing/transplanting.

Nutrients	• Nutrients should be provided as per soil test recommendations. Generally, tomato needs 40: 24: 24 Kg N:P:K/ acre-for varieties and 60: 36: 36 Kg N:P:K/acre for hybrids. • In varieties- Apply 50% of N fertilizer dose as basal before transplanting. • Apply entire dose of phosphatic fertilizers at the time of last ploughing/transplanting in case of varieties. • For hybrids, apply nitrogen fertilizer in three equal split doses. First at the time of last ploughing. • For hybrids, apply potassic fertilizers in two equal splits, first at the time of last ploughing. • Biofertilizers: For seed/seedling treatment with *Azotobacter* and phosphorous solubilizing bacteria (PSB) cultures @ 8-10 g each/Kg seed • For seedling root dip treatment with *Azotobacter* and phosphorous solubilizing bacteria (PSB) cultures @ 250 g each/acre seedlings
Seed and Seedling*	
	Common cultural practices: • Grow resistant/tolerant varieties. • Use healthy, certified and weed seed free seeds. • Timely sowing should be done. • Avoid planting overlapping crops in adjacent area. • In the nursery all the infected plants should be removed carefully and destroyed.
Weeds	• Cultural practices such as crop rotation, line transplanting, intercropping should be adopted to avoid weeds spread and to suppress the weed growth.
Early blight	• For resistant / tolerant varieties consult ICAR Institute / KVK's / SAU's. **Cultural control:** • Change the nursery beds location every season, eradicate weeds and volunteer tomato plants, fertilize properly **Chemical control:** • Spray azoxystrobin 23% SC @ 200 ml in 200 l of water/acre or captan 50% WP @ 1000 g in 300-400 l of water/acre or captan 75% WP @ 666.8 g in 400 l of water/acre or copper oxy chloride 50% WP @ 1000 g in 300-400 l of water/acre or iprodione 50% WP @ 600 g in 200 l of water/acre or kitazin 48% EC @ 80 ml in 80 l of water/acre or mancozeb 35% SC @ 200 ml in 200 l water/acre or mancozeb 75% WG @ 400 g in 200 l of water/acre or pyraclostrobin 20% WG @ 150-200 g in 200 l of water/acre or zineb 75% WP @ 600-800 g in 300-400 l of water/acre or ziram 80% WP @ 600-800 g in 300-400 l of water/acre or famoxadone 16.6% + cymoxanil 22.1% SC @ 200 ml in 200 l of water/acre or metiram 55% + pyraclostrobin 5% WG @ 600-700 g in 200 l of water/acre, metriam 70% WG @ 1000 g in 200-300 l of water/acre
Bacterial wilt	• For resistant / tolerant varieties consult ICAR Institute / KVK's / SAU's. **Cultural control:** • Rotate with non-host crops, particularly with paddy • Restriction of irrigation water flowing from affected field to healthy field **Biological control:** • Neem cake @ 100 Kg/acre.
Bacterial leaf spot	• For resistant / tolerant varieties consult ICAR Institute / KVK's / SAU's. **Chemical control** • Spray streptomycin sulfate 9% + tetracycline hydrochloride 1% SP solution (streptocycline) 40-100 ppm in fields after the appearance of first true leaves. Two sprays, one before transplanting (seed beds) and another after transplanting (main field)

***Fusarium* wilt**	• For resistant / tolerant varieties consult ICAR Institute / KVK's / SAU's. **Biological control:** • Seed treatment with *Trichoderma viride* 1% WP @ 9 g/Kg seed • Root zone application: Mix thoroughly 2.5 Kg of the *T. viride* 1% WP in 150 Kg of compost or farmyard manure and apply this mixture in the field after sowing/ transplanting of crops
Leaf curl	• For resistant / tolerant varieties consult ICAR Institute / KVK's / SAU's. **Cultural control:** • Raising nursery in protected condition (with net of sufficient mesh size to prevent the entry of vector, whitefly) **Chemical control:** • Before transplanting dip the roots of seedlings for 15 minutes in imidacloprid 17.8 % SL @ 60-70 ml in 200 l of water/acre for management of leaf curl vector.
Nematodes	**Cultural control:** • Crop rotation with cereal crops • Ecological engineering of tomato with marigold/mustard as intercrops reduces nematode population • Nursery should be raised in nematode free sites or solarized beds. **Chemical control:** • Apply dazomet technical @ 12-16 g/acre (nursery)
Serpentine leaf miner	**Cultural control:** • Avoid excess use of nitrogen. • Ecological engineering of tomato with beans as intercrop reduces leaf miner attack. **Chemical control:** • Cyantraniliprole 10.26% OD @ 360 ml in 200 l water/acre
* Application of *Trichoderma harzianum/viride* and *Pseudomonas fluorescens* for treatment of seed/seedling/planting materials in the nurseries and field application (if commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).	
Vegetative stage	
	Common cultural practices: • Collect and destroy crop debris • Provide irrigation at critical stages of the crop • Avoid water logging • Avoid water stress during flowering stage • Judicious use of fertilizers • Enhance parasitic activity by avoiding chemical spray, when 1-2 larval parasitoids are observed • Field sanitation • Ecological engineering of tomato with growing intercrops such as cowpea, onion, maize, coriander, urdbean etc. • Grow 4 rows of maize/sorghum/bajra around the field as a gourd guard/barrier crop. **Common mechanical practices:** • Collection and destruction of eggs and early stages of larvae • Collect and destroy disease infected and insect damaged plant parts • Handpick the older larvae during early stages of plant • The infested shoots and seed capsules may be collected and destroyed • Handpick the gregarious caterpillars and the cocoons which are found on stem and destroy them in kerosene mixed water. • Use yellow/blue pan water / 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	• In varieties, apply the second dose of N i.e. 13.5 Kg N/acre, at 45 days after transplanting. • For hybrids, apply the second dose of N i.e. 20 Kg N/acre at 30 days after planting. • For hybrids, apply the second dose of potassic fertilizers at 30 days after planting. • Micronutrient deficiency should be corrected by foliar spray of particular micronutrient.
Weeds	• Field should be weed free before 30 days crop stage. Two hoeings between the rows plus hand weeding within the row at 15 and 30 days after planting. • Mulching with black Low Density Polyethylene (LDPE) sheets of 30 micron thickness by burying both the ends into the soil to a depth of 10 cm will avoid weed growth.
***Alternaria* blight and late blight**	• For resistant / tolerant varieties consult ICAR Institute / KVK's / SAU's. • Follow common cultural, mechanical and biological practices (See page no. 16). **Chemical control:** • Spray mancozeb 35% SC @ 200 ml in 200 l water/acre or mancozeb 75% WP @ 600-800 g in 300 l of water/acre or zineb 75% WP @ 600-800 g in 300-400 l of water/acre or famoxadone 16.6% + cymoxanil 22.1% SC @ 200 ml in 200 l of water/acre or cymoxanil 8% + mancozeb 64% WP @ 600 g in 200-300 l of water/acre or azoxystrobin 23% SC @ 200 ml in 200 l of water/acre or captan 50% WP @ 1000 g in 300-400 l of water/acre or captan 75% WP @ 666.8 g in 400 l of water/acre or copper oxy chloride 50% WP @ 1000 g in 300-400 l of water/acre or cyazafamid 34.5% SC @ 80 ml in 200 l of water/acre or metriam 75% WG @ 1000 g in 200-300 l of water/acre
Leaf curl disease (vector –whitefly)	• For resistant / tolerant varieties consult ICAR Institute / KVK's / SAU's. • Follow common cultural, mechanical and biological practices (See page no. 16). **Biological control:** • Spray neem seed kernel extract (NSKE) 5% or azadirachtin 5% W/W neem extract concentrate @ 80 g in 160 l of water/acre **Chemical control:** • Spray dimethoate 30% EC @ 396 ml in 200-400 l of water/acre or imidacloprid 17.8 SL @ 60-70 ml in 200 l of water/acre or thiamethoxam 25 WG @ 80 g in 200 l of water/acre or carbofuran 3% CG @ 16,000 g/acre or malathion 50% EC @ 600 ml in 200-400 l of water/acre or oxydemeton-methyl 25% EC @ 400 ml in 200-400 l of water/acre or phorate 10% CG @ 6,000 g/acre or spiromesifen 22.9% SC @ 250 ml in 200 l of water/acre, Cyantraniliprole 10.26% OD @ 360 ml in 200 l water/acre
***Septoria* leaf spot**	• For resistant / tolerant varieties consult ICAR Institute / KVK's / SAU's. • Follow common cultural, mechanical and biological practices (See page no. 16). **Chemical control:** • Spray with mancozeb 75% WP @ 600-800 g in 300 l of water/acre
Red spider mites	• Follow common cultural, mechanical and biological practices (See page no. 16). **Chemical control:** • Apply fenazaquin 10% EC @ 500 ml in 200 l of water/acre or spiromesifen 22.9% SC @ 250 ml in 200 l of water/acre
Serpentine leaf miner	• Follow common cultural, mechanical and biological practices (See page no. 16).

Tobacco caterpillar	• Follow common cultural, mechanical and biological practices (See page no. 16). **Biological control:** • Release egg parasitoid, *Trichogramma pretiosum* @ 20,000/acre/week four times. • Spray NSKE 5% against eggs and first instar larva or azadirachtin 5% W/W neem extract concentrate @ 80 g in 160 l of water/acre • Apply entomopathogenic nematodes (EPNs) @ 2,50,000 infective juveniles of *Steinernema feltiae*/sq mt area **Chemical Control:** • Apply trichlorfon 5% GR @ 300 g/acre or trichlorfon 5% DUST @ 300 g/acre or trichlorfon 50% EC @ 300 ml/acre or spray indoxacarb 14.5% SC @ 160 - 200 ml in 120-240 l of water/acre or flubendiamide 20% WG @ 40 g in 150–200 l of water/acre or flubendiamide 39.35% M/M SC @ 40 ml in 150-200 l of water/acre or carbaryl 50% WP @ 800 g in 200-400 l of water/acre or chlorantranilioprole 18.5% SC @ 60 ml in 200 l of water/acre or lambda-cyhalothrin 4.9% CS @ 120 ml in 200 l of water/acre or lambda-cyhalothrin 5% EC @ 120 ml in 160-200 l of water/acre or methomyl 40% SP @ 300-450 ml in 200-400 l of water/acre or novaluron 10 % EC @ 300 ml in 200-400 l of water/acre or phosalone 35% EC @ 514 ml in 200-400 l of water/acre or quinalphos 20% AF @ 600-700 ml in 300-400 l of water/acre or quinalphos 25% EC @ 400 ml in 200-400 l of water/acre or novaluron 5.25% + indoxacarb 4.5% SC @ 330-350 ml in 200 l of water/acre
Reproductive stage	
Nutrients	• In varieties, the third dose of N i.e. 13.5 Kg N/acre, to be applied at 60 days after transplanting. • For hybrids, third dose of N i.e. 20 Kg N/acre is applied at 60 days after planting. • Micronutrient deficiency, if any, should be corrected by application of particular nutrients.
Weeds	• Weeds should be removed from the field to avoid further spread of weed seeds.
Gram pod borer	• Follow common cultural, mechanical and biological practices in vegetative stage. **Biological control:** • Inundatively release *T. pretiosum* @ 40,000/acre 4-5 times from flower initiation stage at weekly intervals • Spray azadirachtin 1% (10000 ppm) neem based EC @ 400-600 ml in 200 l of water/acre or azadirachtin 5% W/W neem extract concentrate @ 80 g in 160 l of water/acre • Spray Ha NPV 0.43% AS @ 600 ml in 160-240 l of water/acre or Ha NPV 2% AS @ 100-200 ml in 200 l of water/acre in combination with jaggery @ 1 Kg in the evening hours at 10-15 days interval on observing the eggs or early instar larvae or Ha NPV 0.43% AS (Strain No. BIL/HV-9) @ 600 ml in 160-240 l of water/acre or NPV 2% AS Strain No. GBS/HNPV-01 (BIL/HV-9) @ 100-200 ml in 200 l of water/acre • Spray *Bacillus thuringiensis* var *gallariae* @ 400-600 g in 200 l of water/acre • Apply entomopathogenic nematodes (EPNs) @ 20-120 crore infective juveniles of *Steinernema feltiae*/acre. **Chemical control:** • Spray with indoxacarb 14.5% SC @ 160-200 ml in 120-240 l of water/acre or flubendiamide 20% WG @ 40 g in 150-200 l of water/acre or flubendiamide 39.35% M/M SC @ 40 ml in 150-200 l of water/acre or novaluron 10 % EC @ 300 ml in 200-400 l of water/acre or carbaryl 50% WP @ 800 g in 200-400 l of water/acre or chlorantranilioprole 18.5% SC @ 60 ml in 200 l of water/acre or lambda-cyhalothrin 4.9% CS @ 120 ml in 200 l of water/acre or lambda-cyhalothrin 5% EC @ 120 ml in 160-200 l of water/acre or methomyl 40% SP @ 300-450 ml in 200-400 l of water/acre or phosalone 35% EC @ 514 ml in 200-400 l of water/acre or quinalphos 20% AF @ 600-700 ml in 300-400 l of water/acre or quinalohos 25% EC @ 400 ml in 200-400 l of water/acre, cyantraniliprole 10.26% OD @ 360 ml in 200 l water/acre or trichlorfon 5% GR @ 300 g/acre or trichlorfon 5% DUST @ 200 g/acre or trichlorfon 50% EC @ 200 ml/acre or spray indoxacarb 14.5% SC @ 160 - 200 ml in 120-240 l of water/acre or novaluron 10 % EC @ 300 ml in 200-400 l of water/acre

Thrips	• Follow common cultural and biological practices (See page no. 16). **Chemical control:** • Cyantraniliprole 10.26% OD @ 360 ml in 200 l water/acre
Tobacco caterpillar	• Same as in vegetative stage
Bacterial leaf spot	• Same as in seed and seedling stage
Leaf curl disease	• For resistant / tolerant varieties consult ICAR Institute / KVK's / SAU's. **Cultural practices:** • Staking of plants to avoid touching fruits on ground. • Same as in seed and seedling and vegetative stages.
Mosaic	• For resistant / tolerant varieties consult ICAR Institute / KVK's / SAU's. • Follow common cultural, mechanical and biological practices (See page no. 16).

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

Management of regional pests:

Aphids:

- Install yellow sticky trap @ 4-5/acre
- Judicious use of nitrogenous fertilizers
- Spray azadirachtin 5% W/W neem extract concentrate @ 80 g in 160 l of water/acre
- Release 1st instar larvae of green lacewing @ 4000/acre
- Conserve predators such as ladybird beetles (*Coccinella septumpunctata* and *Menochilus sexmaculata*) and parasitoids such as *Aphidius colemani* etc.
- Spray dimethoate 30% EC @ 264 ml in 200-400 l of water/acre or cyantraniliprole 10.26% OD @ 360 ml in 200 l water/acre

Leafhoppers:

- Soil application of neem cake 100 Kg/acre
- Conserve predators such as ladybird beetles and green lacewings and parasitoids such as *Anagrus flaveolus* and *Stethynium triclavatum.*
- Spray NSKE 5%.

Cutworm:

- Deep summer ploughing.
- Use well decomposed organic manure.
- Tillage at least 2 weeks before planting will help to destroy plant residue that could harbor larvae.
- Flood the infested fields.
- On a small area, collection of caterpillars from soil around the plants can be done.
- Collection of moths in the light traps.
- Conserve biological control agents such as *Microgaster* sp, *Micropilitis dimilis, Bracon kitchener*, *Broscus punctatus* and *Liogryllus bimaculatus* (predator)

Buck eye rot or fruit rot:

- Use resistant varieties
- Seed treatment with *Trichoderma* spp.
- Staking and removal of the fruits and leaves touching the ground (up to 30 cm)
- Provision of good soil drainage
- Periodic clipping of lower leaves and mulching
- Spray mancozeb 75% WP @ 600-800 g in 300 l of water/acre or propineb 70% WP @ 120 g in 40 l of water/acre

Powdery mildew:

- Growing resistant varieties
- Adopt early planting, sprinkler irrigation
- Immediately remove and destroy diseased leaves to help prevent the disease from spreading.
- Proper plant spacing of about 3 feet apart to allow for proper air circulation, which helps the foliage dry faster.
- Periodic clipping of lower leaves and mulching
- Organic mulch added around the plants will protect roots while preventing fungal spores from splashing onto the plant.

Plant growth regulators:

The following plant growth regulators are recommended for improvement of crop growth in tomato

1. Triacontanol 0.05% min GR @ 10000 g/acre to be broadcasted and mixed in the soil 2-3 days before sowing or
2. Spray gibberellic acid 0.001% L @ 70.8 ml in 180-200 l of water/acre at 45 and 65 days after sowing or
3. Triacontanol 0.05% EC/Triacontanol 0.1% EW @ 100 ml in 160-200 l of water/acre at 25, 45, and 65 days after sowing.
4. Alpha nephthyl acetic acid 4.5% SL (Na Salt) @ 45 ppm at the time of flowering two spray
5. Ethephon 39% SL @ 2500 ppm for uniform ripening (postharvest dip treatment of fruits)

VI. RODENT PEST MANAGEMENT

Lesser bandicoot and palm rat/house rat,	**Cultural control:** • Practice clean cultivation/maintain weed free fields which reduces the harboring/hiding points for rodents. • Practice trapping with locally available traps using lure @ 8-10 traps/acre. In areas, where *Rattus rattus* is a problem, wonder traps/multi-catch traps work better and enable to trap more animals into a single trap. • Identify live rodent burrows and smoke the burrows with burrow smoker for 2-3 minutes • Erect owl perches @ 5-6/acre to promote natural control of rodents **Chemical control:** • In cases of high level of infestation (>50 live burrows/ac) practice poison baiting with zinc phosphide @ 2.0% on community approach. PRACTICE PRE-BAITING TO AVOID BAIT SHYNESS Day 1: Close all the burrows in the fields, field bunds, canal bunds and surrounding barren lands etc. Day 2: Count the re-opened burrows and practice pre-baiting @ 20 g/burrow (98 parts of broken tomato + 2 parts of edible oil) Day 4: Observe the re-opened burrows and treat the burrow with zinc phosphide poison bait (96 parts of broken tomato + 2 parts of edible oil + 2 parts of zinc phosphide) @ 10g/ burrow. Collect the dead rats, if found any outside and bury them.

VII. 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.

VIII. NUTRITIONAL DEFICIENCIES

Nitrogen: Under N deficiency, older leaves gradually change from green to paler green. As the deficiency progresses these older leaves become uniformly yellow (chlorotic). Leaves approach a yellowish white color under extreme deficiency. The young leaves at the top of the plant maintain a green but paler color and tend to become smaller in size. Branching is reduced resulting in short, spindly plants. The yellowing in nitrogen deficiency is uniform over the entire leaf including the veins.

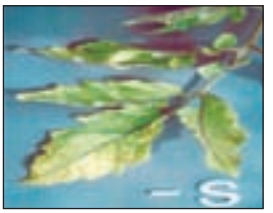
Correction measure: Recovery can be done by top dressing of urea of as recommended on soil test basis or apply 2 % urea solution. Recovery of deficient plants to applied nitrogen is immediate (days) and spectacular.

Phosphorus: The symptoms first develop on older leaves showing some necrotic spots and plants are dwarfed or stunted. Phosphorus deficient plants develop very slowly. Plants develop a distinct purpling of the stem, petiole and the under sides of the leaves. Under severe deficiency conditions there is a tendency for leaves to develop a blue-gray luster.

Correction measure: Soil application of recommended dose of phosphorous should be applied at the time of sowing or planting.

Potassium: Since potassium is very mobile within the plant, symptoms only develop on young leaves in the case of extreme deficiency. Some of the leaves show marginal necrosis (tip burn), and at a more advanced deficiency status show inter-veinal necrosis. This group of symptoms is very characteristic of K deficiency symptoms. As the deficiency progresses, most of the interveinal area becomes necrotic, the veins remain green and the leaves tend to curl and crinkle. In contrast to nitrogen deficiency, chlorosis is irreversible in potassium deficiency, even if potassium is given to the plants.

Correction measure: Foliar application of K_2SO_4 @ 1%.



Sulfur: This leaves show a general overall chlorosis. The veins and petioles show a very distinct reddish color. The yellowing is much more uniform over the entire plant including young leaves. The reddish color often found on the underside of the leaves. With advanced sulfur deficiency the leaves tend to become more erect and often twisted and brittle.

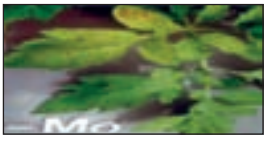
Correction measure: Foliar spray of K_2SO_4 or $CaSO_4$ 1% twice at fortnightly interval.

Magnesium: The Mg-deficient leaves show advanced interveinal chlorosis, In its advanced form, magnesium deficiency may superficially resemble potassium deficiency. The symptoms generally start with mottled chlorotic areas developing in the interveinal tissue.

Correction measure: Foliar spray of $MgSO_4$ @ 2%.

Manganese: The leaves show a light interveinal chlorosis developed under a limited supply of Mn. The early stages of the chlorosis induced by manganese deficiency are somewhat similar to iron deficiency. As the stress increases, the leaves develop dark necrotic areas along the veins.

Correction measure: Foliar spray of $MnSO_4$ @ 2%.



Molybdenum: The leaves show some mottled spotting along with some interveinal chlorosis. An early symptom for molybdenum deficiency is a general overall chlorosis, similar to the symptom for nitrogen deficiency but generally without the reddish

coloration on the undersides of the leaves.

Correction measure: Foliar spray of $NaMO_4$ 0.05% twice at weekly interval.

Zinc: The leaves show interveinal necrosis. In the early stages of zinc deficiency the younger leaves become yellow and pitting develops in the interveinal upper surfaces of the mature leaves. As the deficiency progress these symptoms develop into an intense interveinal necrosis but the main veins remain green, as in the symptoms of recovering iron deficiency.

Correction measure: Foliar spray of $ZnSO_4$ @ 0.5%.

Boron: These boron-deficient leaves show a light general chlorosis. Boron deficiency results in necrosis of meristematic tissues in the growing region, leading to loss of apical dominance and the development of a rosette condition. These deficiency symptoms are similar to those caused by calcium deficiency. The leaves are unusually brittle and tend to break easily. Also, there is often a wilting of the younger leaves even under an adequate water supply, pointing to a disruption of water transport caused by boron deficiency.

Correction measure: Foliar spray of borax @ 0.2%.

Calcium: The calcium-deficient leaves show necrosis around the base of the leaves. The very low mobility of calcium is a major factor determining the expression of calcium deficiency symptoms in plants. Classic symptoms of calcium deficiency include blossom-end rot of tomato. Symptoms show soft dead necrotic tissue at rapidly growing areas, which is generally related to poor translocation of calcium to the tissue rather than a low external supply of calcium. This ultimately results in the margins of the leaves growing more slowly than the rest of the leaf, causing the leaf to cup downward. Plants under chronic calcium deficiency have a much greater tendency to wilt than non-stressed plants.

Correction measure: Foliar spray of 2% Calcium sulphate twice at weekly intervals.

Copper: The copper-deficient leaves are curled, and their petioles bend downward. Copper deficiency may be expressed as a light overall chlorosis along with the permanent loss of turgor in the young leaves. Recently matured leaves show netted, green veining with areas bleaching to a whitish gray. Some leaves develop sunken necrotic spots and have a tendency to bend downward.

Correction measure: Foliar spray of 0.5% $CuSO_4$ twice at fortnightly interval.

Iron: The iron-deficient leaves show strong chlorosis at the base of the leaves with some green netting. The most common symptom for iron deficiency starts out as an interveinal chlorosis of the youngest leaves, evolves into an overall chlorosis, and ends as a totally bleached leaf. Because iron has a low mobility, iron deficiency symptoms appear first on the youngest leaves. Iron deficiency is strongly associated with calcareous soils, anaerobic conditions, and it is often induced by an excess of heavy metals.

Correction measure: Foliar spray of $FeSO_4$ @ 0.5%.

Source:

Epstein and Bloom (2004). *Plant Nutrition,* Sinauer Associates, Sunderland, MA.

http://5e.plantphys.net/images/ch05/wt0501d_s.jpg

http://agritech.tnau.ac.in/agriculture/agri_min_fldcrops_vegetables.html

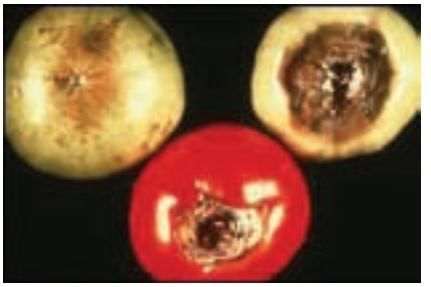
Physiological and nutritional disorders

Other than various pest' problems in tomato production, farmers are facing problems related to abiotic factors such as nutrient imbalance and environmental extremes. These factors affect plants fruits adversely resulting in poor quality of fruits fetching low market value. Some of the common disorders, possible causes and their remedies are briefly summerised here.

Blossom-end rot:

Blossom-end rot (BER) is caused by a localized Ca deficiency in the developing fruit. It begins with light tan, water-soaked areas that can then enlarge and turn black and leathery in appearance. Most often the problem occurs at the blossom end of the fruit. Factors like low soil Ca, high N rates, using ammoniacal sources of N, high concentrations of soluble K and Mg in the soil, high salinity, low humidity, inadequate or excess soil moisture, damage to root system by nematodes, diseases etc. increases the BER problem.

Correction measure: Soil applications of Ca materials, proper fertilization and good water management can prevent the problem.



Fruit showing symptoms of BER, top left fruit showing mild BER, others showing severe

Cat-face:

Cat-facing is a generic term used to describe a tomato fruit that has a gross deformity and is usually not marketable. The defect is usually located on the blossom end of the fruit. The deformity is starts occurring during the formation of the flower that results in the fruit not developing normally. Low temperatures, herbicide drifts, heavy thrips feeding and little leaf disease are some of the causes of cat-faced fruits.

Correction measure: Varieties should be selected that historically have had little problem with cat-facing, avoiding spray drift, water logging etc. can reduce the problem.

Fruit showing cat-facing into fruit

Cat-faced fruit with hole on blossom end

Cracking:

Cracking occurs when the internal expansion is faster than the expansion of the epidermis and the epidermis splits. Varieties differ greatly in their susceptibility to cracking.

Correction measure: Control is through selecting tolerant varieties or by reducing fluctuations in soil moisture. Cracking may also be reduced by maintaining good foliage cover, since exposed fruit are more susceptible.

Fruit showing both radial and concentric cracking

Gray wall (blotchy ripening):

Internally gray wall is characterized by dark necrotic areas usually in the vascular

tissue of the outer walls. Outward symptoms show up as grayish appearance caused by partial collapse of the wall tissue; hence the term gray wall is used to describe. It typically develops on green fruit prior to harvest but can develop later. Fruits affected are typically not marketable due to blotchy appearance as fruit ripens. Gray wall is more of a problem during cool and short days. There are variety differences in susceptibility. High N may increase the problem

Correction measure: Application of adequate Potassic may reduce the problem.

Fruit showing gray wall necrotic areas

Internal white tissue:

Fruit affected by this disorder usually show no outward symptoms. When ripe fruits are cut, white hard areas especially in the vascular region are present in the outer walls. Under severe conditions, fruit may also show white tissue in cross-wall and center of fruit. High temperatures during the ripening period in the field seem to trigger the symptoms.

Correction measure: Application of adequate Potassic fertilization may reduce it.

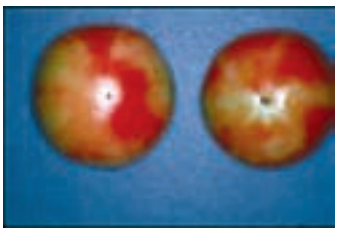
Fruit showing internal white tissue in walls and center

Irregular Ripening:

Irregular ripening is a fruit ripening disorder caused by feeding of nymphs of the silver leaf whitefly (*Bemisia argentifolii*) on the tomato foliage. Green fruit show no symptoms, but as fruit ripens, color fails to develop uniformly. Color often develops along locule walls with intermediate areas remaining green or yellow, producing a star-burst appearance.

Correction measure: This disorder can be controlled if nymphs of whitefly are controlled.

Adult silver leaf whiteflies feeding on collard leaf

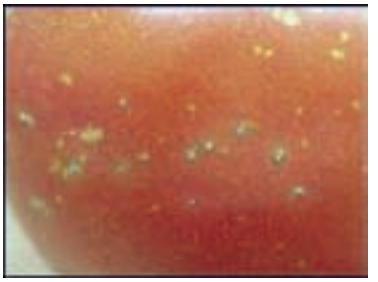


Fruit showing symptoms of irregular ripening

Pox and Fleck:

In most cases when a fruit is affected both disorders are found together but are considered separate problems. Pox is described as small cuticular disruptions found at random on the fruit surface. Fleck, develops as small irregular shaped green spots at random on the surface of immature fruit, which becomes gold in color as fruit ripens. Fruits severely affected with pox and fleck are not marketable. Both conditions seem to be genetic in nature, the disorders only show up under certain environmental conditions. There are differences between varieties as to susceptibility to pox and fleck.

Correction measure: Control is through selecting tolerant varieties.



Tomato fruit showing Pox and Fleck symptoms

Puffiness:

When this problem is slight, it may be impossible to detect puffiness until fruit are cut. When fruit are cut, open cavities are observed between the seed gel area and the outer wall. Fruits are also very light in relation to size. This problem is caused by any factor that affects fruit set, including inadequate pollination, fertilization, or seed development. Most common causes are too low or high temperatures during fruit set. Other factors such as high N, low light, or rainy conditions can also cause seed set problems.

Correction measure: Application of balanced Nitrogen doses may reduce the problem.

Note flattened areas on sidewalls of fruit caused by puffiness

Fruit severely affected by puffiness, note large open areas

Zebra Stripe:

Zebra stripe can be characterized as a series of dark green spots arranged in a line from the stem end to the bloom end. At times it seems the spots coalesce together and form elongated markings. Many times the dark green areas will disappear when fruit ripens. This problem seems to be variety related. It is probably a genetic defect that only develops under certain environmental conditions. Zebra stripe may be linked to pox and fleck.

Zebra stripe spots may form elongated areas

Zippering:

Zippering is described as a fruit having thin scars that extend partially or fully from the stem scar area to the blossom end. The longitudinal scar has small transverse scars along it. At times there may be open holes in the locules in addition to the zipper scar. Usually an anther that is attached to the newly forming fruit causes the zipper scar. Some people feel that a zipper is formed when the "blooms" stick to the fruit and do not shed properly but this may not be a cause.

Correction measure: The only control is to select varieties that are not prone to zippering.

Zippering with open hole in fruit

IX. COMMON WEEDS

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

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

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

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

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

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

7. Crabgrass: *Digiteria sanguinalis* (L.) Scop. (Poaceae)

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

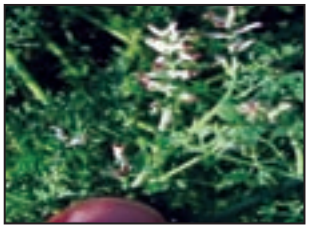
9. Purple nutsedge: *Cyperus rotundus* L. (Cyperaceae)

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

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

12. Scarlet pimpernel: *Anagallis arvensis* L. (Primulaceae)

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



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

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

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

17. Canary grass: *Phalaris minor* Retz. (Poaceae)

X. DESCRIPTION OF INSECT, MITE AND NEMATODE PESTS

1) Serpentine leaf miner:

Biology:

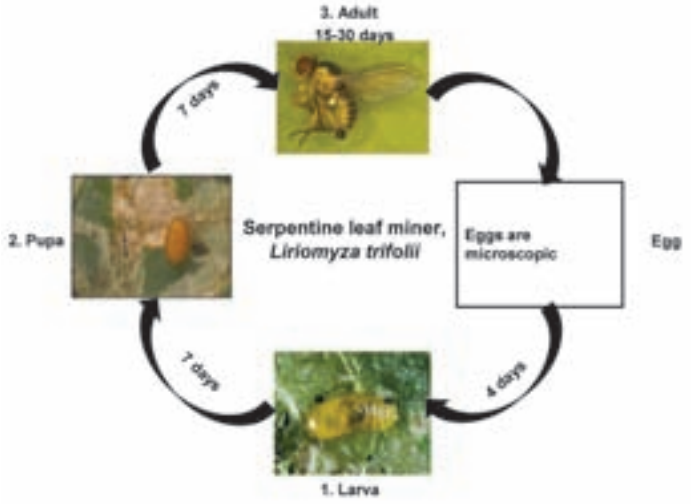
Egg: Eggs are minute in size and orange yellow in colour. The egg hatches in 4 days.

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

Life cycle:



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

Damage symptoms:

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

1. 2.

1,2. Mining on leaves

1. http://www.nbaii.res.in/insectpests/Liriomyza-trifolii.php
2. http://entnemdept.ufl.edu/creatures/veg/leaf/a_serpentine_leafminer.htm

Favourable conditions:

Warm weather conditions are favourable for multiplication.

Natural enemies of serpentine leaf miner:

Parasitoids: *Chrysocharis pentheus, Diglyphus isaea, Gronotoma micromorpha* etc.

Predators: Lacewing, ladybird beetle, spider, red ant etc.

*For management refer to page number 16

2) Gram pod borer:

Biology:

It is a polyphagous pest, infesting gram, lablab, safflower, chillies, groundnut, tobacco, cotton etc.

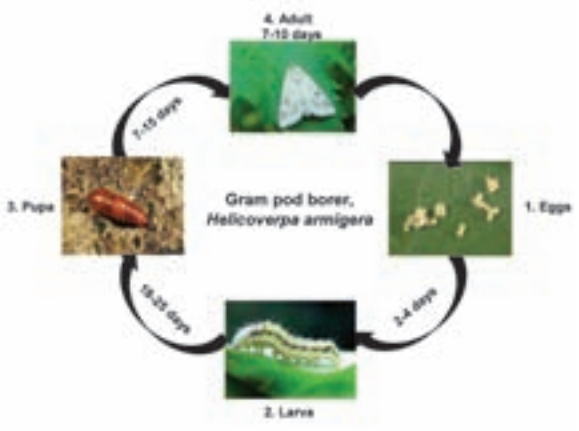
Egg: Spherical, yellowish eggs are laid singly on tender parts and buds of plants. The egg period lasts for 2-4 days.

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 larval period lasts for 18-25 days. The full grown caterpillar pupates in the soil.

Pupa: Pupation takes place inside the soil in an earthen cell. 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:



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

Damage symptoms:

- Young larva feeds on the leaves for some time and then attacks fruits. Internal tissues are eaten severely and completely hollowed out. While feeding the caterpillar thrust its head inside leaving the rest of the body outside.
- Bored fruits with round holes.
- Fed leaves, shoots and buds.
- The activity of *Helicoverpa* starts on green gram, summer vegetables and maize and continues their generation by Aug-Sept months synchronizing with main crop.

http://bppamongtani.blogspot.in/2013/01/penggunaan-pestisida-yang-baik-benar.html

Favourable conditions:

Warm weather conditions followed by light rains and dry spells are favourable for multiplication.

Natural enemies of gram pod borer:

Parasitoids: *Trichogramma* spp., *Tetrastichus* spp., *Chelonus* spp., *Telenomus* spp., *Bracon* spp., *Ichneumon* spp., *Carcelia* spp., *Campoletis* spp. etc.

Predators: Lacewing, ladybird beetle, spider, red ant, dragon fly, robber fly, reduviid bug, praying mantis, black drongo (King crow), wasp, common mynah, big-eyed bug (*Geocoris* sp), earwig, ground beetle, pentatomid bug (*Eocanthecona furcellata*) etc.

*For management refer to page number 18

3) Tobacco caterpillar:

Biology:

It is found throughout the tropical and subtropical 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:

1. http://commons.wikimedia.org/wiki/File:Spodoptera_litura_egg_mass.jpg
2. http://lepidoptera.butterflyhouse.com.au/lynf/lynf.html
3.http://www.ccs-hk.org/DM/butterfly/Noctuid/Spodoptera-litura.html
4. http://www.nbaii.res.in/insectpests/images/Spodoptera-litura11.jpg

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.
- Bored fruits with irregular holes

1

2

Damage symptoms

1. http://www.nbaii.res.in/insectpests/Spodoptera-litura.php
2. http://www.ncipm.org.in/nicra/NICRAPDFs/Manuals/Manual%20for%20Tomato%20Pest%20 Surveillance.pdf

Natural enemies of tobacco caterpillar:

Parasitoids: *Trichogramma* spp., *Tetrastichus* spp., *Chelonus* spp., *Telenomus* spp., *Bracon* spp., *Ichneumon* spp., *Carcelia* spp., *Campoletis* spp. etc.

Predators: Lacewing, ladybird beetle, spider, red ant, dragon fly, robber fly, reduviid bug, praying mantis, black drongo (King crow), wasp, common mynah, big-eyed bug (*Geocoris* sp), earwig, ground beetle, pentatomid bug (*Eocanthecona furcellata*) etc.

Favourable conditions:

Warm weather conditions and rainy conditions are favourable for multiplication.

*For management refer to page number 18

4) Whitefly:

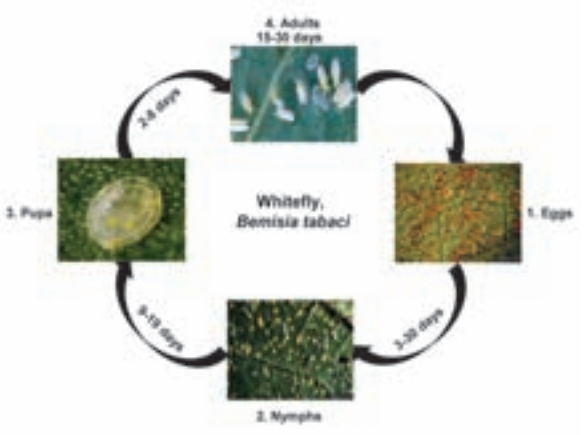
Biology:

Egg: Eggs are pear shaped, light yellowish, and stalked. Eggs are laid under side of leaves. Hatching occurs in 5-9 days

Nymph: On hatching first instar larvae are oval, scale-like, greenish white and moves to a suitable feeding site on the lower surface where it moults and becomes stationary through out the remaining stages.

Adult: White, tiny, scale-like adult. There are 10-15 generation in a year.

Life cycle:



Damage symptoms:

- Yellowing
- Downward curling and drying of leaves.
- Vector of tomato leaf curl disease.

1 **2**

Damage symptoms

1. http://www.kevinquinnmcguinness.com/dev/wp2/?p=87
2. http://ipm.illinois.edu/ifvn/contents.php?id=29

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* etc.

Predators: Mirid bug, lacewing, ladybird beetle, big-eyed bug (*Geocoris* sp) etc.

Favourable conditions:

Warm weather conditions are favourable for multiplication.

*For management refer to page number 17

5) Red spider mites:

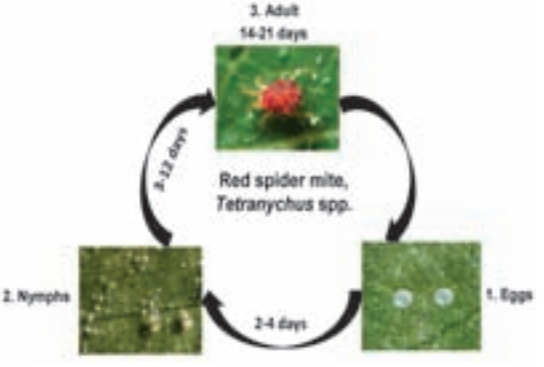
Biology: This polyphagous pest is known to feed on more than 100 species of plants including cucurbits, brinjal and okra.

Egg: Hyaline, globular laid in mass and hatch in 2-6 days

Nymphs: Yellowish in colour and feed on lower leaf surface

Adult: Red coloured small size

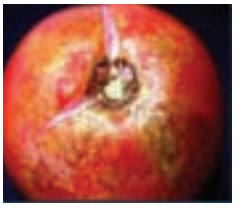
Life cycle:



1. http://www.simplepestcontrol.com/spider-mite-control.htm
2. http://entomology.k-state.edu/extension/insect-photo-gallery/Corn-Insects.html
3. http://www.al.gov.bc.ca/cropprot/grapeipm/spidermites.htm

Damage symptoms:

- Affected leaves become reddish brown and bronzy
- Severe infestation larvae silken webbing on the leaves
- Leaves wither and dry
- Flower and fruit formation affected

1. **2.**

Damage symptoms

1.http://www.pestsandcrops.com/index_files/Page3923.htm
2.http://gardeningnaturallywithclaudia.blogspot.in/2013/01/companion-plantsbenefits-in-garden.html

Natural enemies of spider mites:

Predators: Predatory mite, predatory thrips, *Oligota* spp., spider, *Orius* spp. (pirate/anthocorid bug), hover fly, mirid bug etc.

Favourable conditions:

Warm weather conditions are favourable for multiplication.

*For management refer to page number 17

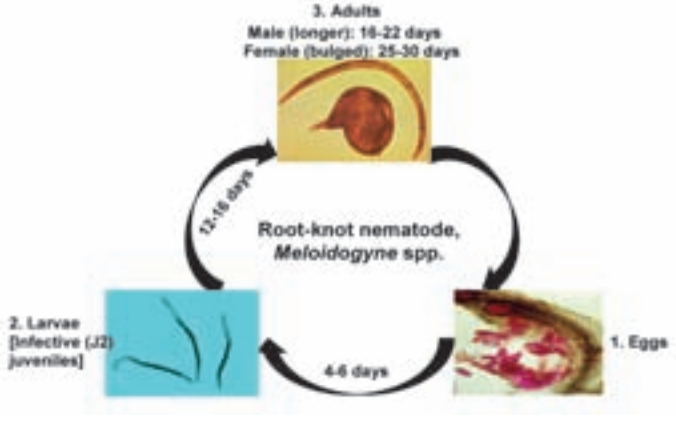
6) Root-knot nematode:

Biology:

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



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
- Plants wilt during the hot part of day, especially under dry conditions and are often stunted

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

- 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
- 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.**

Damage symptoms

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 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 etc.

Favourable conditions:

- Loamy light soils etc.

*For management refer to page number 14

Natural Enemies of Tomato Insect and Mite Pests

Parasitoids

Egg parasitoids

1. *Diglyphus isaea*

2. *Trichogramma* spp.

3. *Tetrastichus* spp.

4. *Telenomus* spp.

Egg larval parasitoid

5. *Chelonus* spp.

Larval parasitoids

6. *Bracon* spp.

7. *Ichneumon* spp.

8. *Campoletis* spp.

Larval and pupal parasitoids

9. *Gronotoma micromorpha*

10. *Carcelia* spp.

Nymphal and adult parasitoids

11. *Chrysocharis pentheus*

12. *Encarsia formosa*

13. *Eretmocerus* spp.

1. http://www.evergreengrowers.com/diglyphus-isaea-114.html; 3. http://www.pbase.com/image/135529248; 4. http://baba-insects.blogspot.in/2012/02/telenomus.html; 5. http://www.nbaii.res.in/Featured%20insects/chelonus.htm; 7. http://www.organicgardeninfo.com/ichneumon-wasp.html; 8. http://www.nbaii.res.in/Featured%20insects/Campoletis.htm 9. http://www.ento.csiro.au/science/Liriomyza_ver3/key/Eucoilidae_Key/Media/Html/ gronotoma_sp.html; 10. http://72.44.83.99/forum/viewthread.php?thread_id=40633&pid=178398; 11. http://baba-insects.blogspot.in/2012/05/blog-post_21.html; 12. http://www.buglogical.com/whitefly-control/encarsia-formosa/; 13. http://www.dongbufarmceres.com/main/mboard.asp?strBoardID=c_product01_en

Predators

1. Red ant

2. Dragonfly

3. Ladybird beetle

4. Spider

5. Praying mantis

6. Predatory thrips

7. *Oligota* spp.

8. Lacewing


9. Robber fly


10. King crow


11. Common mynah


12. Mirid bug


13. Reduviid bug

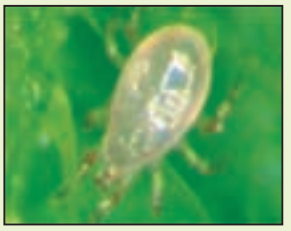

14. Big eyed bugs (*Geocoris* sp)


15. Pentatomid bug


16. Earwigs


17. Ground beetle


18. *Dicyphus hesperus*


19. Predatory mite


20. Hover fly

1. http://www.ants-kalytta.com/Oecophylla-smaragdina.fr.html; 2. http://littlegreenblog.com/green-home/gardening-and-pest-control/save-the-dragonflies/; 5. http://www.kimthompsonartist.com/SingleImages/PrayingMantis.html; 6. http://biocontrol.ucr.edu/hoddle/persea_mite.html; 7. http://www.fugleognatur.dk/forum/show_message.asp?MessageID=560188& ForumID=33; 9. http://www.visitingnature.com/promachusrufipes.htm; 10. http://en.wikipedia.org/wiki/Black_Drongo; 11. http://www.epnrm.sa.gov.au/AnimalPlantControl/DeclaredPestAnimals/ TheIndianMynaBird.aspx; 12. http://www.britishbugs.org.uk/heteroptera/Miridae/blepharidopterus_angulatus.html; 14. http://insectsgalore.blogspot.in/2010/08/big-eyed-bug-geocoris-ugilinosus.html; 15. http://www.malaeng.com/blog/?p=9646; 16. http://www.johnsonpestcontrol.com/pest-identification/earwigs/; 17. http://www.fcps.edu/islandcreekes/ecology/common_black_ground_beetle.htm; 18. http://nathistoc.bio.uci.edu/hemipt/Dicyphus.htm; 19. https://greenmethods.com/swirskii/

XI. DESCRIPTION OF DISEASES

1) *Fusarium* wilt:

Disease symptoms:

- The first symptom of the disease is clearing of the veinlets and chlorosis of the leaves.
- The younger leaves may die in succession and the entire may wilt and die in a course of few days. Soon the petiole and the leaves droop and wilt.
- In young plants, symptoms consist of clearing of veinlet and dropping of petioles. In field, yellowing of the lower leaves first and affected leaflets wilt and die.
- The symptoms continue in subsequent leaves. At later stage, browning of vascular system occurs. Plants become stunted and die.

Disease symptoms

http://www.apsnet.org/edcenter/K-12/NewsViews/Article%20Images/w/2003jul_jpg.

Survival and spread:

- Soil and implements

Favourable conditions:

- Relatively high soil moisture and soil temperature

*For management refer to page number 16

2) Damping off:

Disease symptoms:

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

1.

2.

Disease symptoms

1. http://http://thedxbgardener.blogspot.in/2012/11/seedlings-dying.html
2. http://afghanag.ucdavis.edu/a_horticulture/row-crops/tomato/pictures-tomato-pests/

Healthy nursery raising

1. Trays

2. Pro-trays

3. Raised bed

Photos by: SK Sain

Survival and spread:

Primary: Soil, Seed, Water

Secondary: Spores 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 14

3) *Septoria* leaf spot:

Disease symptoms:

- Less vigorous plants are usually affected
- Small, round to irregular spots with a grey center and dark margin on leaves
- Spots usually starts on lower leaves and gradually advance upwards
- Spots coalesce and leaves are blighted
- Complete defoliation of affected leaves
- Stems and flowers are sometimes attacked
- Fruits are rarely attacked

Disease symptoms

http://nuwildroots.files.wordpress.com/2010/06/septoria-leaf-spot2-copy.jpg

Survival and spread:

Primary: Mycelium or conidia in pycnidia in infected plant debris or on solanaceous weeds

Secondary: Conidia through rain splash or wind and also by slimy conidia sticking on to hands and clothing of tomato pickers

Favourable conditions:

- Poor vigour of plants due to nutrient inadequacy or in late season
- High humidity or persistent dew at 25° C
- Moist weather with intermittent showers

*For management refer to page number 17

4) Bacterial stem and fruit canker:

Disease symptoms:

- Disease appears as spots on leaves, stems and fruits and as wilting of leaves and shoots
- White blister like spots in the margins of leaves
- Spots become brown with age and coalesce, but leaves do not fall off
- Leaflets on one side of rachis show withering initially
- Light coloured streaks on stems and petioles at the joints
- Cracks develop in streaks and form cankers
- Slimy bacterial ooze through the cracks in humid weather
- Small, shallow, water soaked, spots with white halo develop on fruits
- The centers of spots become slightly raised, tan coloured and rough
- Vascular discolouration is seen in split open stems

Symptoms on leaves and fruit

Photo by: SK Sain

Survival and spread:

Primary: Bacterial cells survive on infected plant debris and seed (both internally and externally) and also on solanaceous weeds such as *Solanum nigrum*

Secondary: Bacterial cells transmitted through rain splash

Favourable conditions:

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

5) Early blight:

Disease symptoms:

- This is a common disease of tomato occurring on the foliage at any stage of the growth.
- The fungus attacks the foliage causing characteristic leaf spots and blight. Early blight is first observed on the plants as small, black lesions mostly on the older foliage.
- Spots enlarge, and by the time they are one-fourth inch in diameter or larger, concentric rings in a bull's eye pattern can be seen in the center of the diseased area.
- Tissue surrounding the spots may turn yellow. If high temperature and humidity occur at this time, much of the foliage is killed.
- Lesions on the stems are similar to those on leaves, sometimes girdling the plant if they occur near the soil line.
- Transplants showing infection by the late blight fungus often die when set in the field. The fungus also infects the fruit, generally through the calyx or stem attachment.
- Lesions attain considerable size, usually involving nearly the entire fruit; concentric rings are also present on the fruit.

Symptoms on foliage, leaf and fruit

Photos by: SK Sain

Survival and spread:

Primary: The fungus spends the winter in infected plant debris in or on the soil where it can survive at least one and perhaps several years. It can also be seed borne.

Secondary: The spores are transported by water, wind, insects, other animals including man, and machinery. Once the initial infections have occurred, they become the most important source of new spore production and are responsible for rapid disease spread.

Favourable conditions:

- Warm, rainy and wet weather

*For management refer to page number 15

6) Bacterial leaf spot:

Disease symptoms:

- Moist weather and splattering rains are conducive to disease development. Most outbreaks of the disease can be traced back to heavy rainstorms that occur in the area.
- Infected leaves show small, brown, water soaked, circular spots surrounded with yellowish halo.
- On older plants the leaflet infection is mostly on older leaves and may cause serious defoliation.
- The most striking symptoms are on the green fruit. Small, water-soaked spots first appear which later become raised and enlarge until they are one-eighth to one-fourth inch in diameter.
- Centers of these lesions become irregular, light brown and slightly sunken with a rough, scabby surface.
- Ripe fruits are not susceptible to the disease. Surface of the seed becomes contaminated with the bacteria, remaining on the seed surface for some time.
- The organism survives in alternate hosts, on volunteer tomato plants and on infected plant debris.

Disease symptoms

http://plantdoctor.pbworks.com/w/page/17167380/Tomato

Survival and spread:

Primary: Bacterial cells survive on infected plant debris and seed (both internally and externally) and also on solanaceous weeds such as *Solanum nigrum*

Secondary: Bacterial cells transmitted through rain splash

Favourable conditions:

- Moist weather and splattering rains
- High humidity or persistent dew

*For management refer to page number 15

7) Bacterial wilt:

Disease symptoms:

- Characteristic symptoms of bacterial wilt are the rapid and complete wilting of normal grown up plants.
- Lower leaves may drop before wilting. Pathogen is mostly confined to vascular region; in advantage cases, it may invade the cortex and pith and cause yellow brown discolouration of tissues.
- Infected plant parts when cut and immersed in clear water, a white streak of bacterial ooze are seen coming out from cut ends.

1.

2.

Disease symptoms

1. http://mobilebotanicalgardens.org/wordpress/wp-content/uploads/2012/01/bacterial-wilt-tomato.jpeg
2.http://mobilebotanicalgardens.org/wordpress/wp-content/uploads/ 2012/01/bacterial-wilt-2.jpg

Survival and spread:

- The bacteria spreads through wounds, soil and implements.

Favourable conditions:

- Relatively high soil moisture and to be checked

*For management refer to page number 15

8) Leaf curl:

Disease symptoms:

- Leaf curl disease is characterized by severe stunting of the plants with downward rolling and crinkling of the leaves. The newly emerging leaves exhibit slight yellow colouration and later they also show curling symptoms.
- Older leaves become leathery and brittle. The nodes and internodes are significantly reduced in size.
- The infected plants look pale and produce more lateral branches giving a bushy appearance. The infected plants remain stunted.

Symptom on plant

Photo by: SK Sain

Favourable conditions:

- High population of vector whitefly transmitting the leaf curl virus

*For management refer to page numbers 16, 17, 19

9) Mosaic:

Disease symptoms:

- The disease is characterized by light and dark green mottling on the leaves often accompanied by wilting of young leaves in sunny days when plants first become infected.
- The leaflets of affected leaves are usually distorted, puckered and smaller than normal. Sometimes the leaflets become indented resulting in "fern leaf" symptoms.
- The affected plant appears stunted, pale green and spindly.


Disease symptoms

http://www.apsnet.org/edcenter/intropp/lessons/viruses/Pages/TobaccoMosaic.aspx

Survival and spread:

- The virus is spread by contact with clothes, hand of working labour, touching of infected plants with healthy ones, plant debris and implements.

*For management refer to page number 19

10) Tomato spotted wilt disease:

Disease symptoms:

- Symptoms vary among hosts and in a single host species
- Stunting is a common symptom of TSWV infection
- Chlorotic or necrotic rings form on the leaves of many infected hosts
- Thickening of veins and bronzing of young leaves
- Growing tips may die-back and terminal branches may be streaked
- Affected plants may have a one sided growth habit or may be entirely stunted and have drooping leaves, suggesting a wilt
- Pale red or yellow areas with concentric circular marking in the normal red skin of ripe tomato are formed
- Discoloration of seed


Symptoms on leaf and fruit

Photo by: SK Sain

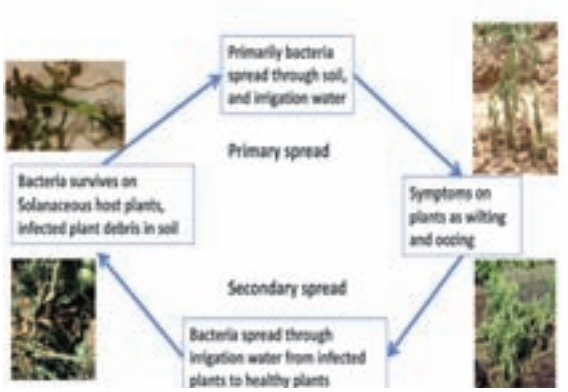
Survival and spread:

Primary: Virus particles in infected plants of many hosts like *Acanthospermum hispidum, Aster* sp., *Boerhaavia diffusa, Chrysanthemum* sp., *Cleome gynandra*, cowpea, *Dahlia variabilis*, egg plant, French bean, *Gerbera* sp., groundnut, *Lagasca mollis*, lettuce, marigold, pea, chilli, pineapple, potato, *Trianthema portulacastrum*, water melon and *Zinnia elegans*

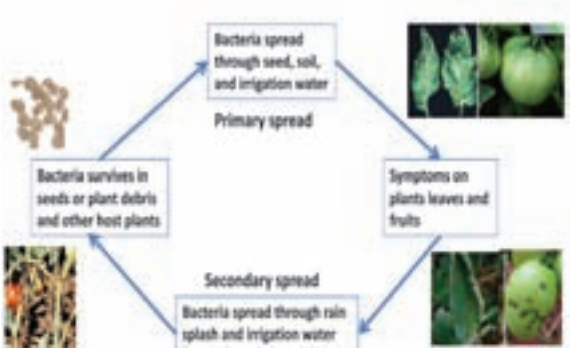
Secondary: Virus particles transmitted by thrips, *Frankliniella schultzii, Scirtothrips dorsalis*

Diseases cycles

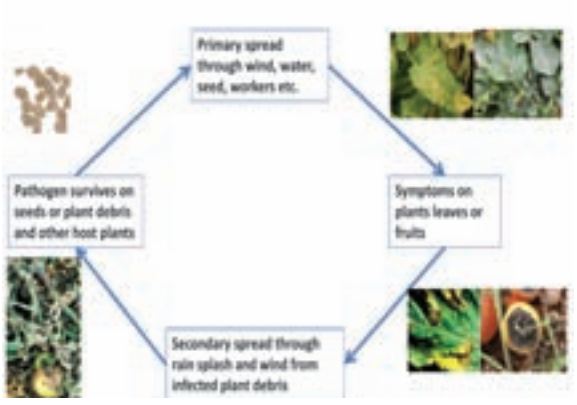
1. Bacterial wilt:



2. Bacterial stem and fruit canker:



3. Leaf spot and powdery mildew:



4. Late blight and wilt:

XII. DESCRIPTION OF RODENT PESTS

1) Lesser bandicoot:

Distribution and identification:

Distributed throughout India and infests almost all crops. It is a robust rodent (200 to 300 g body weight) with a rounded head and a broad muzzle. Dorsum covered with grey-brownish rough hairs. Tail is naked, shorter than head and body. Breeds throughout the season and litter size 6-8 in normal conditions.

Burrows are characterized by the presence of scooped soil at the entrance and mostly burrow openings are closed with soil.

Damage symptoms:

- Mostly damage occurs at fruiting stage. Bandicoots cut the raw and ripened fruits and hoard them in their burrows.

2. House rat:

Distributed throughout India. Medium sized (80-120g) slender rodent. Commonly found in houses and on plantation crops. Very good climberwith

longer tail than head and body. Occasionally causes damage to tomato in certain pockets. Inhabitation on trees and other places and won't make any burrows in fields

3. Indian gerbil:

Distributed throughout the India. Inhabits rain-fed crop fields/ fallow/ wastelands. Medium sized (100-250 g.) with light brownish dorsum and longer tail than head and body. The eyes are large, rounded ears and bicolour tail with terminal black tuft. The burrows have semi-circular openings with zigzag shape and 2 to 4 openings and emergency exits.

*For management refer to page number 20.

XIII. SAFETY MEASURES

A. At the time of harvest:

Pick tomatoes at 2-3 day intervals during warm weather and at weekly intervals during cool weather. Waiting period for all the pesticides, if any, should be observed without fail. Pick tomatoes from the plants by twisting them rather than pulling them to avoid damage. Fruits are generally removed from the upper portion of the plant. Vines and fruit should be completely dry when mature green fruit are harvested. Otherwise, fruit may develop sunken, blackened areas during ripening. Vine-ripes must be hand harvested every other day. A common recommendation for fresh market tomatoes is to harvest green matures when about 10% of the fruit on the first hand is at the breaker stage of maturity. When immature greens are picked, the eating quality is reduced even though these tomatoes can be gassed to redness with ethylene. But the sugar and acid content, which determine the taste of the tomato, are low, resulting in a flavour-less fruit. Mature green tomatoes develop flavour to the same extent as fruit left on the plant another 24 hours, until colour appears.

B. During post-harvest storage:

Usually, tomatoes are packed after harvest and sent to fresh market. Otherwise, fresh market tomatoes are dropped into a water tank after harvest to clean the fruit. The improper tank procedures can spread the disease and increase storage losses. Disease spread can be minimized by not allowing 1) fruit to submerge deeply or to float more than one layer deep in the tank; 2) pressure from deeper submersion forces pathogen-containing water through the stem scar into the fruit; 3) removing fruit after two minutes; 4) slightly chlorinating the water; and 5) warming tank temperature to a few degrees above fruit temperature (cool water constricts the fruit, pulling in pathogens).

In general, the length of storage depends on the harvest stage. Mature green fruits can be stored up to 30 days at cool temperatures, e.g. 10 °C. Ripe fruits can be kept for about a week. Commercial crops of fresh market tomatoes picked at the mature green stage are ripened artificially and uniformly by dipping the fruits in ethephon 39% SL @ 2500 ppm.

XIV. 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 monocroping.

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 high incidence of pests.
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.	Transfer in rows at optimum depths under proper moisture conditions for better establishment.	Do not transfer plant seedlings beyond 2-3 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 recommen-dation.	Avoid imbalanced use of fertilizers.
10.	Use micronutrient mixture after sowing based on soil test recommendations.	Do not apply any micronutrient mixture after sowing without soil 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.	Apply *Ha*NPV or *Sl*NPV at recommended dose when a large number of egg masses and early instar larvae of *Helicoverpa* or *Spodoptera,* respectively 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 *Helicoverpa, Spodoptera* spray recommended biopesticides/chemicals at the time of their appearance in the evening.	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, whiteflies, *Spodoptera* etc.	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.

XV. SAFETY PARAMETERS IN PESTICIDE USAGE

S. No	Pesticide classification as per insecticide rules 1971 Colour of toxicity triangle	WHO classification of hazard	Symptoms of poisoning	First aid measures and treatment of poisoning	Harvesting interval (days)
Organophosphate insecticides					
1.	Dimethoate Highly toxic 	Class II Moderately hazardous	Mild-anorexia, headache, dizziness, weakness, anxiety, tremors of tongue and eyelids, miosis, impairment of visual acuity	**First aid measures:** Rush to the nearest physician. **Treatment of poisoning:** For extreme symptoms of OP poisoning, injection of atropine (2-4 mg for adults, 0.5-1.0 mg for children) is recommended. Repeated at 5-10 minute intervals until signs of atropinization occur.	-
Carbamate insecticides					
2.	Carbofuran Extremely toxic 	Class I b Highly hazardous	Constriction of pupils, salivation, profuse sweating, muscle incordination, nausea, vomiting,diarrhea, epigastric pain, tightness in chest	**First aid measures:** Rush to the nearest physician. **Treatment of poisoning:** Atropine injection-1-4 mg. repeat 2 mg when symptoms begin to recur (15-16 min interval) excessive salivation- good sign, more atropine needed	-
Neonicotinoids					
3.	Imidacloprid Highly toxic 		Harmful if swallowed, absorbed through skin or inhaled. Avoid breathing vapor or spray mist. Causes moderate eye irritation.	**First aid measures:** Have person sip a glass of water if able to swallow. Do not induce vomiting unless told to do so by a doctor, do not give anything by mouth to an unconscious person. **Treatment of poisoning:** No specific antidote. Treatment is essentially symptomatic.	3
4.	Thiamethoxam			**First aid measures:** Have person sip a glass of water if able to swallow. Do not induce vomiting unless told to do so by a poison control center or doctor. Do not give anything by mouth to an unconscious **Treatment of poisoning:** No specific antidote. Treatment is essentially symptomatic.	5

Insect growth regulators					
5.	Novaluron		Causes substantial but temporary eye injury.	**First aid measures:** Have person sip a glass of water if able to swallow. Do not induce vomiting unless told to do so by a poison control center or doctor. Do not give anything by mouth to an unconscious **Treatment of poisoning:** No specific antidote. Treatment is essentially symptomatic.	1-3
Anthranilic diamides					
6.	Flubendiamide Slightly toxic 	Unlikely produce acute hazard		**First aid measures:** Rush to the nearest physician. **Treatment of poisoning:** Treat symptomatically as there is no known specific antidote	5
Other classes insecticides					
7.	Indoxacarb		Altered blood chemistry Abnormal decrease in number of red blood cells (anaemia) which could produce tiredness, rapid heartbeat, dizziness, pale skin, leg cramps, shortness of breath, Central nervous system effects	**First aid measures:** Have person sip a glass of water if able to swallow. Do not induce vomiting unless told to do so by a doctor. Do not give anything by mouth to an unconscious person **Treatment of poisoning:** No specific antidote. Treatment is essentially symptomatic.	5
Fungicides					
8.	Captan Moderately toxic 	Class III Slightly hazardous	Headache, palpitation, nausea, vomiting, flushed face, irritation of nose, throat, eyes and skin etc.	**First aid measures:** Rush to the nearest physician. **Treatment of poisoning:** No specific antidote. Treatment is essentially symptomatic	-
9.	Mancozeb Slightly toxic 	Unlikely produce acute hazard	Headache, palpitation, nausea, vomiting, flushed face, irritation of nose, throat, eyes and skin etc.	**First aid measures:** Rush to the nearest physician. **Treatment of poisoning:** No specific antidote. Treatment is essentially symptomatic	10
10.	Copper oxychloride, Moderately toxic 	Class III Slightly hazardous	Headache, palpitation, nausea, vomiting, flushed face, irritation of nose,throat, eyes and skin etc.	**First aid measures:** Rush to the nearest physician. **Treatment of poisoning:** No specific antidote. Treatment is essentially symptomatic	-

XVI. 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** expose to sunlight or rain water; **Do not** store weedicides along with other pesticides.
4. Never keep them together with food or feed/fodder.
5. Keep away from reach of children and livestock.

C. Handling

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

D. Precautions for preparing spray solution

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

E. Equipment

1. Select right kind of equipment.
2. **Do not** use leaky and defective equipment
3. Select right kind of nozzles
4. **Do not** 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

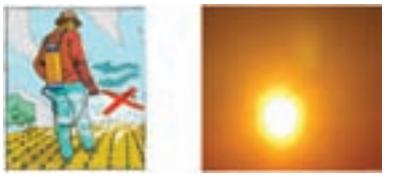
G. Disposal

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.

XVII. PESTICIDE APPLICATION TECHNIQUES

Equipment			
Category A: Stationary, crawling pest/disease			
Vegetative stage i) For crawling and soil 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	 
ii) For small sucking leaf borne pests			
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)	

XVIII. 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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Plants Suitable for Ecological Engineering in Tomato Field

Castor

Sunflower

Carrot

***Ocimum* sp**

Cluster bean

Mustard

Peppermint

Alfalfa

French bean

Cowpea

Buckwheat

Maize

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