सत्यमेव जयते

AESA BASED IPM Package

AESA based IPM – Onion

रा व स्वा प्र सं
NIPHM

National Institute of Plant Health Management
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NCIPM

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LBS Building, IARI Campus, New Delhi

Department of Agriculture and Cooperation
Ministry of Agriculture
Government of India

Important Natural Enemies of Onion Insect Pests

Parasitoids

Ceranisus menes

***Trichogramma* spp.**

***Bracon* spp.**

***Carcelia* spp.**

***Tetrastichus* spp.**

***Chelonus* spp.**

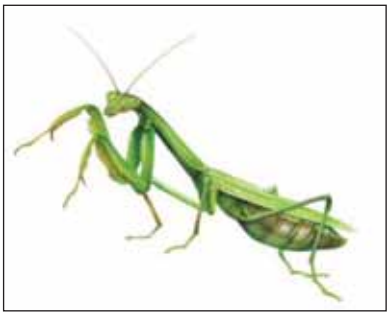
Predators

Lacewing

Ladybird beetle

Spider

Predatory thrips



Praying mantis

Hover fly

The AESA based IPM - Onion 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 onion

Back cover picture Onion 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 ONION

Onion plant description:

Onion (*Allium cepa* L.; Family: Amaryllidaceae) is one of the most important commercial vegetables. It is grown in western, northern as well as in southern India. Maharashtra, Gujarat, Uttar Pradesh, Orissa, Karnataka, Tamilnadu, Madhya Pradesh, Andhra Pradesh and Bihar are Major onion growing states in India.

India stands 2nd position in Onion production after China in the World. In India, Gujarat stands 2nd position in Onion cultivation after Maharashtra state. The productivity of Onion is 12,580 Kg/ha all over the India while in Gujarat state, the productivity is the highest (22,120 Kg/ha) .

Onion is a cool season crop. However it can be grown under a wide range of climatic conditions. It grows well under mild climate without extreme heat or cold or excessive rainfall. In areas where average annual rainfall exceeds 75-100 cm in the monsoon periods, it can be grown only as a summer crop.

The ideal temperature requirement of the onion crop is 12.8-21° C for growth development and 15.5-25° C for bulb development. Very low temperature in the early stages favors bolting, where as sudden rise in temperature favour early maturity in *rabi*, resulting in small–sized bulbs.

Onion can be grown on all type of soils. However, Goradu, and medium black soils are best for its successful production. Good drainage, weeds free plots and presence of organic matter favor production of good crop. It cannot be grown in alkaline or low-lying marshy lands. The optimum pH is 5.8-6.5.

I. PESTS

A. Pests of National Significance

1. Insect and mite pests

1.1 Onion thrips: *Thrips tabaci* Lindeman (Thysanoptera: Thripidae)

1.2 Onion maggot: *Delia antiqua* Meigen (Diptera: Anthomyiidae)

1.3 Bulb mite: *Rhizoglyphus robini* Claparédè (Sarcoptiformes: Acaridae)

1.4 Eriophyid mite: *Aceria tulipae* (Keifer) (Prostigmata: Eriophyidae)

1.5 Red spider mite: *Tetranychus cinnabarinus* (Boisduval) (Trombidiformes: Tetranychidae)

2. Diseases

2.1 Damping off: *Pythium* spp., *Rhizoctonia solani* (Kühn), *Fusarium oxysporum* (Schlecht), *F. oxysporum* f. sp. *cepae* (Schlecht. emend. Snyder & Hansen); *Sclerotium rolfsii* (Sacc.) & *S. cepivorum* (Berk) and *Colletotrichum* sp

2.2 Purple blotch: *Alternaria porri* (Ellis)

2.3 *Stemphylium* leaf blight: *Stemphylium cesicarium/ vesicarium* [(Wallr.) E.G. Simmons]

2.4 *Colletotrichum* blight/Anthracnose/Twister disease: *Colletotrichum gloeosporioides* [(Penz.) Penz. and Sacc]

2.5 Onion yellow dwarf: *Onion yellow dwarf virus*

2.6 Iris yellow spot: *Iris yellow spot virus*

3. Weeds

3.1 Major *kharif*

Broad leaf

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

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

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

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

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

Grassy

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

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

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

Sedge

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

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

3.2 Major *rabi* weeds

Broad leaf

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

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

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

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

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

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

Grassy

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

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

3.2.9 Chinese love grass: *Eragrostis unioloides* (Retz.) Nees. Ex Steud. (Poaceae)

3.2.10 Goose grass: *Eleusine indica* (L.) Gaertner (Poaceae)

Sedge

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

B. Pests of Regional Significance

1. Insect pests

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

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

1.3 Cutworm: *Agrotis ipsilon* (Hufnagel) (Lepidoptera: Noctuidae) (Assam)

2. Diseases

2.1 Downy mildew: *Perenospora destructor* (Berkeley) Caspary (Himachal Pradesh, Delhi)

2.2 Fusarium basal rot/ Basal rot: *Fusarium oxysporum* f. sp. *cepae* Schlecht (Rajasthan, Maharashtra, Karnataka)

2.3 White rot: *Sclerotium cepivorum* Berk.

2.4 Pink root rot: *Phoma (Pyrenochaeta) terrestris* (Hansen) Gorenz, Walker & Larson, *Fusarium solani* (Mart.) Sacc. (Rajasthan, Tamil Nadu)

2.5 Black mold: *Aspergillus niger* van Tiegham

2.6 Green mold: *Aspergillus fumigatus* Fresenius, *A. alliaceus* Thom & Church

2.7 Bacterial brown rot/ Slippery skin: *Pseudomonas aeruginosa* (Schroter) Migula *Pseudomonas allicola* Starr and Burk (Haryana, Delhi, Uttar Pradesh)

2.8. Soft rot: *Erwinia carotovora* pv. *carotovora* Jones

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

A. AESA

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

Decision making in pest management requires a thorough analysis of the agro-ecosystem. Farmer has to learn how to observe the crop, how to analyze the field situation and how to make proper decisions for their crop management. This process is called the AESA. Participants of AESA will have to make a drawing on a large piece

of paper (60 x 80 cm), to include all their observations. The advantage of using a drawing is that it requires the participants/farmers to observe closely and intensively. It is a focal point for the analysis and for the discussions that follow, and the drawing can be kept as a record.

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

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

Principles of AESA based IPM:

Grow a healthy crop

- Select a variety resistant/tolerant to major pests
- Treat the seed/planting material with recommended pesticides especially biopesticides
- Select healthy seeds/seedlings/planting material
- 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 situation at least once a week (soil, water, plants, pests, natural enemies, weather factors etc.)
- Make decisions based on the field situation and P: D ratio
- Take direct action when needed (e.g. collect egg masses, remove infested plants etc.)

Understand and conserve defenders

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

Insect zoo

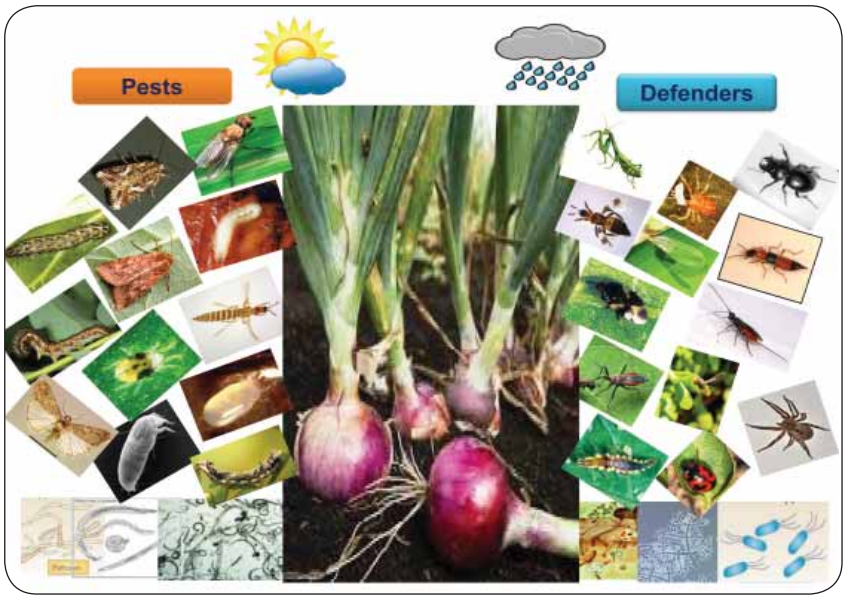
In field various types of insects are present. Some are beneficial and some may be harmful. Generally farmers are not aware about it. Predators (friends of the farmers) which feed on pests are not easy to observe in crop field. Insect zoo concept can be helpful to enhance farmers' skill to identify beneficial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

Pest: Defender ratio (P: D ratio):

Identifying the number of pests and beneficial insects helps the farmers to make appropriate pest management decisions. Sweep net, visual counts etc. can be adopted to arrive at the numbers of pests and defenders. The P: D ratio can vary depending on the feeding potential of natural enemy as well as the type of pest. The natural enemies of onion pests can be divided into 3 categories: 1. parasitoids; 2. predators; and 3. pathogens. The important natural enemies of onion pests are given in ecological engineering table on page number 13-14

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.

Feeding/egg laying potential of different parasitoids/predators

Predators/ Parasitoids	Feeding potential/ Egg laying capacity
 Ladybird beetle	Predatory rate of adult coccinellid on aphids is 50 aphids per day
 Hover fly	1st instar larva can consume 15-19 aphids/day. 2nd instar larva can consume 45-52 aphids/day. 3rd instar larva can consume 80-90 aphids/day. In total life cycle they can consume approx. 400 aphids.
 Green lacewing	Each larva can consume 100 aphids, 329 pupae of whitefly and 288 nymphs of jassids during entire larval period
 Spider	5 big larvae/adults per day

Predators/ Parasitoids	Feeding potential/ Egg laying capacity
 Predatory mite	Predatory rate of adult is 20-35 phytophagous mites/female/day http://www.eduwebs.org/bugs/predatory_mites.htm
 *Bracon hebetor*	Egg laying capacity is 100-200 eggs/ female. 1-8 eggs/larva
 *Trichogramma* sp	Egg laying capacity is 20-200 eggs/ female.

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, crop stage, deficiency symptoms etc.
    - Pests: Observe and count pests at different places on the plant.

- Defenders (natural enemies): Observe and count parasitoids and predators.
- Diseases: Observe leaves and identify any visible disease symptoms and severity.
- Weeds: Observe weeds in the field and their intensity.
- Water: Observe the water situation of the field.
- Weather: Observe the weather condition.

- While walking in the field, manually collect insects in plastic bags. Use a sweep net to collect additional insects. Collect plant parts with disease symptoms.
- Find a shady place to sit as a group in a small circle for drawing and discussion.
- If needed, kill the insects with some chloroform (if available) on a piece of cotton.
- Each group will first identify the pests, defenders and diseases collected.
- Each group will then analyze the field situation in detail and present their observations and analysis in a drawing (the AESA drawing).
- Each drawing will show a plant representing the field situation. The weather condition, water level, disease symptoms, etc. will be shown in the drawing. Pest insects will be drawn on one side. Defenders (beneficial insects) will be drawn on another side. Write the number next to each insect. Indicate the plant part where the pests and defenders were found. Try to show the interaction between pests and defenders.
- Each group will discuss the situation and make a crop management recommendation.
- The small groups then join each other and a member of each group will now present their analysis in front of all participants.
- The facilitator will facilitate the discussion by asking guiding questions and makes sure that all participants (also shy or illiterate persons) are actively involved in this process.
- Formulate a common conclusion. The whole group should support the decision on what field management is required in the AESA plot.
- Make sure that the required activities (based on the decision) will be carried out.
- Keep the drawing for comparison purpose in the following weeks.

Data recording

Farmers should record data in a notebook and drawing on a chart. Keeping records of what has happened help us making an analysis and draw conclusions

Data to be recorded

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

Some questions that can be used during the discussion

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

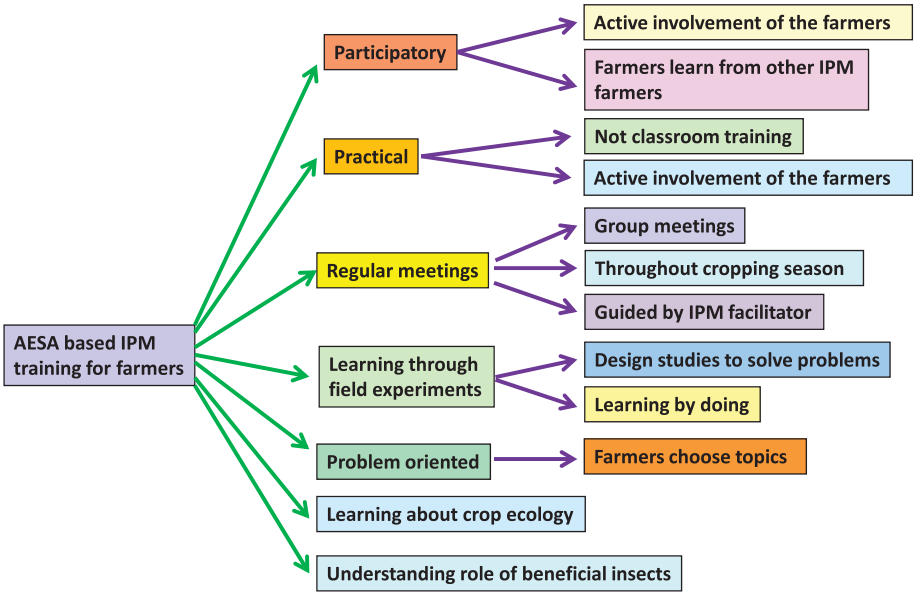
AESA and farmer field school (FFS)

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 field should commence soon after crop establishment after transplanting and at weekly intervals thereafter. In each field, select five spots randomly (four in the corners, at least 5 feet inside of the field borders, and one in the center). Select five random plants at each spot for recording counts of insects as per procedure finalized for individual insects.

For insect pests:

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).

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

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

For weeds:

The goal of weed scouting is to assess the infestation level of known weeds as pests and detect new weeds that may be at very low levels so that action can be taken to control or prevent them from becoming an economic concern. In some cases, early detection of a weed can make eradication possible.

Begin scouting as soon as weeds appear in the field and continue until freeze-up. Record stages of growth of all the weeds and the number of each weed species/square metre.

Frequently, all scouting patterns must be used since weed habitat can be very species specific. Each field usually requires a pattern for a uniform sample and samples in low areas and field margins or ditches to assess immediate or future risk from problem weeds left uncontrolled. Detailed counts of the number of weeds per square metre provide the ideal record of a weed problem. If this is not possible, the following rating system may be useful:

Group I - Wild oats, stinkweed, wild buckwheat, lamb's-quarters, redroot pigweed, hemp-nettle, smartweed, rape, wild mustard, Russian thistle, tartary buckwheat, cow cockle, shepherd's-purse, kochia.

Light	Medium	Heavy
1-10 plants/m^2	10-30 plants/m^2	More than 30 plants/m^2

Group II - Chickweed, green foxtail, corn spurry.

Light	Medium	Heavy
1-20 plants/m^2	20-70 plants/m^2	70 or over plants/m^2

Group III - Canada thistle, sow-thistle, dandelion

Light	Medium	Heavy
1-2 plants/m^2	2-10 plants/m^2	10 or over plants/m^2

These definitions can be used to help standardize ratings. With experience, infestations can be visually estimated. These groupings are based on the competitive characteristics and life cycles of these weeds.

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

Pheromone traps for insects viz., *A. ipsilon, S. litura* and *H. armigera* @ 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/week should be counted and entered. The trapped moths should be removed and destroyed after each recording.

D. Blue pan water/sticky traps

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

E. Light traps

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

III. ECOLOGICAL ENGINEERING FOR PEST MANAGEMENT

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

Natural enemies may require

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

Ecological engineering for pest management – Above ground:

- Raise the flowering plants / compatible cash crops along the field border by arranging shorter plants towards main crop and taller plants towards the border to attract natural enemies as well as to avoid immigrating pest population
- Grow flowering plants on the internal bunds inside the field

- Not to uproot weed plants those are growing naturally like *Tridax procumbens, Ageratum* sp, *Alternanthera* sp etc. which act as nectar source for natural enemies,
- Not to apply broad spectrum chemical pesticides, when the P: D ratio is favourable. The plant compensation ability should also be considered before applying chemical pesticides.

Ecological engineering for pest management – Below ground:

- Crop rotations with leguminous plants which enhance nitrogen content.
- Keep soils covered year-round with living vegetation and/or crop residue.
- Add organic matter in the form of farm yard manure (FYM), vermicompost, crop residue which enhance below ground biodiversity.
- Reduce tillage intensity so that hibernating natural enemies can be saved.
- Apply balanced dose of nutrients using biofertilizers.
- Apply mycorrhiza and plant growth promoting rhizobacteria (PGPR)
- Apply *Trichoderma* spp. and *Pseudomonas fluorescens* as seed/seedling/planting material, nursery treatment and soil application (if commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).

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

Good insectary plants belonging to Lamiaceae, Leguminaceae, Umbelliferae, Brassicaceae, Asteraceae, Graminaceae etc. families


Buckwheat


Spearmint


Sunflower


Castor


French bean


Ryegrass


Alfalfa


Marigold


Chrysanthemum


Mustard


Coriander


Cowpea

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

Flowering plants that attract natural enemies/repel pests

Natural enemies	Attractant/repellent/trap plants
Thrips:	
Parasitoid: *Ceranisus menes* (nymph) **Predators:** Syrphid flies, minute pirate bug/ anthocorid bug (*Blaptosthethus* sp, *Buchananiella whitei, Orius tantilus*), praying mantis, predatory thrips (*Aeolothrips fasciatum*), damsel bug, lace wings, coccinellids (*Cheilomenes sexmaculata*), spiders etc.	• **Attractant plants:** Carrot family, sunflower family, buckwheat, alfalfa, corn, shrubs, marigold, spearmint (ladybug beetle, minute pirate bug & lacewing, syrphid fly, damselfly) • Cosmos (praying mantis) • French bean (predatory thrips) • Sunflower, buckwheat and cowpea (braconid wasp)
Maggot:	
Parasitoid: A braconid wasp (*Aphaereta pallipes*). **Predators:** Rove beetle, ground beetle, spiders etc.	• Interplant strips of ryegrass and cover crops, mulch beds (rove beetle). • Amaranth, white clover, mulching etc (ground beetle).
Gram pod borer:	
Parasitoids: *Trichogramma chilonis* (egg), *Tetrastichus* spp. (egg), *Telenomus* spp. (egg), *Chelonus blackburni* (egg-larval), *Carcelia* spp. (larval-pupal), *Campoletis chlorideae* (larval), *Goniophthalmus halli* (larval), *Bracon* spp. (larval) etc. **Predators:** *Chrysoperla zastrowi sillemi*, coccinellids, King crow, common mynah, wasp, dragonfly, spider, robber fly, reduviid bug, praying mantis, fire ants, big eyed bugs (*Geocoris* sp), pentatomid bug (*Eocanthecona furcellata*), earwigs, ground beetles, rove beetles etc. *Ovomermis albicans,* a nematode	• **Repellant plants:** Basil • **Attractant plants:** Carrot family, sunflower family, buckwheat, alfalfa, corn, shrubs (minute pirate bug & lacewing) • Nectar rich plants with small flowers i.e. anise, caraway, dill, parsley, mustard, sunflower, buckwheat and cowpea (braconid wasp)
Tobacco caterpillar:	
Parasitoids: *Trichogramma chilonis* (egg), *Tetrastichus* spp. (egg), *Telenomus* spp. (egg), *Chelonus blackburni* (egg-larval), *Carcelia* spp. (larval-pupal), *Campoletis chlorideae* (larval), *Eriborus argenteopilosus* (larval), *Microplitis* sp (larval) etc. **Predators:** *Chrysoperla zastrowi sillemi*, coccinellids, King crow, common mynah, wasp, dragonfly, spider, robber fly, reduviid bug, praying mantis, fire ants, big eyed bugs (*Geocoris* sp), pentatomid bug (*Eocanthecona furcellata*), earwigs, ground beetles, rove beetles etc. *Ovomermis albicans*, a nematode	• **Repellant plants:** Basil • **Attractant plants:** Carrot family, sunflower family, buckwheat, alfalfa, corn, and shrubs (minute pirate bug and lacewing) • Nectar rich plants with small flowers i.e. anise, caraway, dill, parsley, mustard, sunflower, buckwheat and cowpea (braconid wasp)

Mites:	
Predators: Anthocorid bugs (*Orius* spp.), mirid bugs, syrphid/hover flies, green lacewings (*Mallada basalis* and *Chrysoperla zastrowi sillemi*), predatory mites (*Amblyseius alstoniae*, *A. womersleyi, A. fallacies* and *Phytoseiulus persimilis*), predatory coccinellids (*Stethorus punctillum*), staphylinid beetle (*Oligota* spp.), predatory cecidomyiid fly (*Anthrocnodax occidentalis*), predatory gall midge (*Feltiella minuta*), spiders etc. *Beauveria bassiana* (entomo pathogen)	• Citrus, avocadoes, bananas, papaya, palms, tea, cassava, maize, strawberries, vegetables, and cotton, as well as ornamental plantings, grasslands attract *Stethorus punctillum*. • *Daucus carota* (Queen Anne's lace) attract lady bugs. • **Crop rotation:** Marigold, *Chrysanthemum* spp., *Sesbania* spp., *Crotalaria* spp., *Gaillardia* spp., castor and *Desmodium* spp., (parasitic nematodes) • **Border crops:** Strips of ryegrass, cover crops and mulch beds (rove beetle). • Carrot family, coriander**,** bishop's weed (spider mite destroyer) • Sunflower family, marigold, buckwheat, spearmint (ladybird beetle) • Carrot family, sunflower family, buckwheat, alfalfa, corn, shrubs (minute pirate bug) • Mustard, radish, sweet clove, dill (aphid midge) • French bean (predatory mites) • Berseem clover and sub-terranean clovers (big-eyed bugs)

A. Resistant/tolerant varieties

Pest	Tolerant/Resistant Variety*
Purple blotch	TNAU hybrid CO2
Thrips	TNAU hybrids CO2, CO3, CO4

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

IV. CROP STAGE-WISE IPM

Management	Activity
Pre-sowing *	
Nutrients	• Before sowing, soil testing should be done to find out the soil fertility status. Nutrient should be provided as per soil test recommendations. • Add well rotten FYM @ 10 t/acre or vermicompost @ 4 t/acre. Incorporate FYM at the time of field preparation at 2 to 3 weeks before transplanting. Vermicompost should be incorporated one week before transplanting.
Weeds	• Deep ploughing during summer. • At the time of field preparation, adopt stale seed bed technique or soil solarization to minimize the weeds menace in field.

	• The boundary & bunds of the field should be free from weeds. • Keep the nursery weeds free by manual weeding.
Soil borne pathogens, nematodes, and resting stages of insects	**Cultural control:** • Deep ploughing of fields during summer to control juveniles and adults of nematodes, and control the overwintering stages. • **Soil solarization:** Cover the beds with polythene sheet of 45 gauge (0.45 mm) thickness for three weeks before sowing for soil solarisation which will help in reducing the soil borne pests.  http://www.nhrdf.com/documents/NHRDF-Research-Achievements.pdf
Damping off	**Cultural control:**. • Avoid excessive watering • Use raised beds: More than 15 cm height is better for water drainage
Sowing / planting*	
Nutrients	• Biofertilizers: Seed/seedling treatment with *Azotobacter* and PSB cultures @ 240 g each/acre seed/ seedling. • Apply NPK fertilizers @ 40: 20: 40 Kg/acre. Apply 1/3 of N, entire P and 60 % K as basal dose at the time of planting. • Based on soil test for micronutrient, the deficient micronutrient should be applied in soil at sowing / transplanting.
Weeds	• In high weed infested fields, apply approved herbicides as mentioned below; • Spray oxyflourfen 23.5% EC @ 170-340 ml in 200-300 l of water/ acre on soil as pre-plant application or quizalofop-ethyl 5% EC @ 300-400 ml 150-180 l of water/acre 20 days after planting of onion seedlings followed by one hand weeding if required.

* Apply *Trichoderma* spp. and *Pseudomonas fluorescens* as seed/seedling/planting material, nursery treatment and soil application (if commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).

Vegetative stage	
Nutrients	• Apply 1/3 of N at 21days and remaining 1/3 at 45 days after transplanting. • Apply remaining 40 % potash as top dressing in standing crop at 21 days after transplanting. • Micronutrient application may be made after soil test.
Weeds	• The crop should be maintained weed free initially for 30-45 days by following timely intercultural and hand weeding if required.
Onion thrips	**Cultural control:** • Use resistant/tolerant varieties. • Practice field sanitation. • Avoid successive planting of garlic or other preferred/alternate host such as cabbage, cotton, tomato, cucumber, melons, pumpkins, strawberries etc. • Plant the new crop in upwind direction of already planted crop which help in escaping infestation from old planting to some extent in the initial stages. • Adjust the transplanting dates • Use of reflective plastic silver colour and aluminium painted black mulches repel the thrips (seed crop) • Use of sprinkler irrigation reduces thrips population considerably compared to drip and surface irrigation • Plant two rows of maize or inner row of wheat and outer row of maize surrounding the onion plots as barrier crop (National Horticultural Mission 2012) **Biological control:** • Conserve parasitoids such as *Ceranisus menes* (nymph) etc. • Conserve predators such as syrphid flies, minute pirate bug/ anthocorid bug (*Blaptosthethus* sp, *Buchananiella whitei, Orius tantilus*), praying mantis, predatory thrips (*Aeolothrips fasciatum*), damselbug, lacewings, coccinellids (*Cheilomenes sexmaculata*), spiders etc. **Chemical control:** • Spray dimethoate 30% EC @ 264 ml in 200-400 l of water/acre or oxydemeton methyl 25% EC @ 480 ml in 200-400 l of water/acre or quinalphos 25% EC @ 480 ml in 200-400 l of water/acre or lambda cyhalothrin 5% EC @ 120 ml in 120-160 l of water/acre. • Use high pressure and volume for good coverage of the crop and direct the nozzle at base of leaves • Add a spreader or sticker (0.05-1.0%) for retention and spread of spray fluid on erect leaves of onion. • In seed crop, thrips should be controlled well before flowers open.
Onion maggot	**Cultural control:** • Avoid close spacing while planting.

	• Follow crop rotation. • Field sanitation. **Biological control:** • Conserve predators such as ground beetle, rove beetles, spiders etc. by providing grassy refuge strips.
Bulb mite	**Cultural control:** • Avoid planting onion after cole crops, as decaying cole crops, especially cauliflower, may harbour very high bulb mite populations in the field. • Avoid planting successive onion or garlic crops. • Flood irrigation reduces mite levels in the soil. **Biological control:** • Conserve predators such as anthocorid bugs (*Orius* spp.), mirid bugs, syrphid/hover flies, green lacewings (*Mallada basalis* and *Chrysoperla zastrowi sillemi*), predatory mites (*Amblyseius alstoniae*, *A. womersleyi, A. fallacies* and *Phytoseiulus persimilis*), predatory coccinellids (*Stethorus punctillum*), staphylinid beetle (*Oligota* spp.), predatory cecidomyiid fly (*Anthrocnodax occidentalis*), predatory gall midge (*Feltiella minuta*), spiders etc.
Eriophyid mite	**Cultural control:** • Flood irrigation reduces mite level in the soil. • Avoid planting successive onion or garlic crops. **Biological control:** • Conserve predators such as anthocorid bugs (*Orius* spp.), mirid bugs, syrphid/hover flies, green lacewings (*Mallada basalis* and *Chrysoperla zastrowi sillemi*), predatory mites (*Amblyseius alstoniae*, *A. womersleyi, A. fallacies* and *Phytoseiulus persimilis*), predatory coccinellids (*Stethorus punctillum*), staphylinid beetle (*Oligota* spp.), predatory cecidomyiid fly (*Anthrocnodax occidentalis*), predatory gall midge (*Feltiella minuta*), spiders etc.
Red spider mite	**Cultural control:** • A thorough water spray washes off the mites from the plant. **Biological control:** • Conserve and augment the natural enemies. Conserve predators such as anthocorid bugs (*Orius* spp.), mirid bugs, syrphid/hover flies, green lacewings (*Mallada basalis* and *Chrysoperla zastrowi sillemi*), predatory mites (*Amblyseius alstoniae*, *A. womersleyi, A. fallacies* and *Phytoseiulus persimilis*), predatory coccinellids (*Stethorus punctillum*), staphylinid beetle (*Oligota* spp.), predatory cecidomyiid fly (*Anthrocnodax occidentalis*), predatory gall midge (*Feltiella minuta*), spiders etc.
Gram pod borer, Tobacco caterpillar**	**Cultural control:** • Field sanitation • Adopt ecological engineering of onion/garlic with growing intercrops such as cowpea, maize, coriander, urdbean etc. and with growing sorghum or maize in 4 rows all around onion/garlic crop as guard crop.

	• Rotate the onion crop with a non-host cereal crop, cucurbit, or cruciferous vegetable. • Adopt ecological engineering of garlic with repellant plants: Ocimum/Basil and marigold as ovipositional trap crop. • Erecting of bird perches @ 20/acre for encouraging predatory birds such as king crow, mynah etc. • Install pheromone traps @ 4-5/acre for monitoring adult moth activity. Replace the lures after every 2-3 weeks • Setting up of light trap @ 1/acre **Biological control:** • Inundatively release *Tricogramma* spp. *T. pretiosum* @ 40,000/acre 4-5 times from flower initiation stage at weekly intervals. • Conserve parasitoids such as *Tetrastichus* spp. (egg), *Telenomus* spp. (egg), *Campoletis chlorideae* (larval) etc. • Conserve predators such as *Chrysoperla zastrowi sillemi*, coccinellids, King crow, common mynah, wasp, dragonfly, spider, robber fly, reduviid bug, praying mantis, fire ants, big eyed bugs (*Geocoris* sp), pentatomid bug (*Eocanthecona furcellata*), earwigs, ground beetles, rove beetles etc. • Apply entomopathogenic nematodes (EPNs) @ 20-120 crore infective juveniles of *Steinernema feltiae*/acre.
Damping off	**Cultural control:** • Soil solarization of nursery beds with transparent polythylene sheet for 30 days before sowing provides good control. • Continuous raising of nursery in the same plot should be avoided. • Avoid excessive soil moisture. • Follow crop rotation. • Maintain proper drainage by leveling the land, and installing drains. • Sow clean and healthy seed on raised beds. • Overcrowding of plants or dense sowing of onion seeds should be avoided. • Well decomposed farmyard manure should be used in nursery.
Purple blotch	**Cultural control:** • Use healthy seeds for planting • Follow crop rotation 2-3 years with non-host crops • Follow proper drainage at regular intervals • Use the recommended doses of N and P fertilizers. • Hot water soaking of onion seed (50 °C for 20 minutes). • Use resistant varieties. **Chemical control:** • Spray difenaconazole 25% EC @ 40 ml in 200 l of water/acre or kitazin 48% EC @ 80 ml in 80 l of water (or as required depending upon crop stage and plant protection equipment used)/acre

***Stemphylium* leaf blight**	**Cultural control:** • Field sanitation: Collect and burn crop residues • Follow long rotations with non-host crops. • Follow proper field drainage and reduce plant density. • Hot water soaking of onion seed (50 °C for 20 minutes). • Plant resistant varietieis such as Welsh onion (*Allium fistulosum*) lines, which are moderately resistant to stemphylium leaf blight. **Chemical control:** • Spray 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 spray zineb 75% WP @ 600-800 g in 300-400 l of water/acre
***Colletotrichum* blight/ anthracnose/twister disease**	**Cultural control:** • Field sanitation: Destruction of infected plant debris. • Use of resistant varieties
Downy mildew**	**Cultural control:** • Select healthy bulbs for seed production. • Follow crop rotation for 3-4 years with non-host crop. • Crop sanitation: Dispose properly the infected crop debris and refuse heaps of onion culled from storage. • Avoid late planting, poor drainage, higher doses of fertilizers and frequent irrigation. • Use resistant varieties. • Onion bulbs meant for seed crop should be exposed to sun for 12 days to destroy the fungus. **Chemical control:** • Spray zineb 75% WP @ 600-800 g in 300-400 l of water/acre
Fusarium* basal rot/basal plate rot*	**Cultural control:** • Follow crop rotation for 4-5 years with non-host crop. • Mixed cropping with tobacco and sorghum is effective in reducing pathogen inoculum and the disease. • Soil solarization by using polythene sheet of 25 guage in summer season for 30 days reduces the pathogen inoculum and in turn reduces the disease. • Follow proper drainage practices. • Deep summer ploughing. • Avoid injury during cultural practices. • Flood the soil in the non-growing season for basal rot control. • Use resistant varieties.
White rot**	**Cultural control:** • Use of disease free areas. • Follow crop rotation with cereal crops. • Hot water treatment of bulbs at 49 °C. • Solarization of soil at high temperature i. e. 35 °C for 18 hours or 45 °C for 6 hours reduces the disease incidence by 50-70%.

Pink root rot**	**Cultural control:** • Follow crop rotation with cereal and green manure crops. • Soil solarization by using polythene sheet of 25 guage in summer season for 30 days reduces the pathogen inoculum and in turn reduces the disease. • Use resistant varieties such as Welsh onion (*Allium fistulosum*) lines, which are resistant to pink root. • Soil solarization reduces pink root incidence. • Late planting reduces disease incidence. • Follow long rotations with non-host crop.
Black mold/green mold**	**Cultural control:** • Leave onions for drying in the field for two days after harvesting. These bulbs should be further dried in shade for 10-15 days before storage. • Store seed and bulb after proper drying. • Maintain proper aeration in the storage • Avoid bruising of onion bulbs during harvest, storage or transport. • Store onion at 1-15 °C.
Bacterial rots (brown rot/soft rot/slippery skin)**	**Cultural control:** • Grow the crop under optimum condition of tilth, fertilizer, drainage, crop rotation and free from weeds. • Follow proper curing and rapid drying of the bulbs after harvesting. • Affected bulbs should be discarded before storage • Dry the crop quickly after harvest • During rainy season, artificial curing is required.
Onion yellow dwarf disease	**Cultural control:** • Manage the vector population. • Plant virus free transplants. • Follow crop rotation of at least three years. • Remove and destroy the diseased plants to check the spread of disease. • Rogueing of diseased plants and isolation from other susceptible crops or volunteer onions • Use blue sticky trap. **Biological control:** • Conserve the predators such as coccinellids, lacewings, spiders, wasps etc. for controlling thrips.
Iris yellow spot disease	**Cultural control:** • Plant healthy seedlings free from thrips and Iris yellow spot virus. • Follow three year or longer rotation between onion crops. • Eliminate alternate host plants, culls, and weeds in and around onion field. • Use sprinkler irrigation for suppression of thrips and disease. • Avoid thin, patchy plant stands and crop stress.

	Biological control: • As in onion yellow dwarf disease.
Reproductive stage	
Nutrients	**Cultural control:** • Apply third dose (second top dressing) of N i.e. 13.33 Kg N/acre at 60 days after transplanting.
Weeds	**Cultural control:** • Left over weeds before shedding of seeds should be removed to avoid further spread.
Insects and diseases	**Cultural control:** • Remove damaged leaves/shoot • Follow crop rotation with cereal and green manuring crops • Other practices same as in vegetative stage • Insect and disease management same as in vegetative stage

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

** Pests of regional significance

V. INSECTICIDE RESISTANCE AND ITS MANAGEMENT

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

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

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

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

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

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

4) **Take an integrated approach to managing pests:** Use as many different control measures as possible viz.,

cultural, mechanical, physical, biological etc. Select insecticides with care and consider the impact on future pest populations and the environment. Avoid broad-spectrum insecticides when a narrow-spectrum or more specific insecticide will work. More preference should be given to green labeled insecticides.

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

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

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

VI. NUTRITIONAL DEFICIENCIES

Nitrogen: Leaves become yellowish green erect and upright curled, wilted and dwarf. At maturity tissue above bulbs become soft.

Correction measure: Foliar spray of Urea 1% or DAP 2% twice at weekly intervals.

Phosphorus: Slow growth, maturity blazed. Leaf colour becomes light green and bulbs have few dried outer peals. Tip burn in older leaves.

Correction measure: Soil application of recommended dose of phosphorous should be applied at the time of sowing or planting. Foliar spray of DAP 2% twice at fortnightly intervals.

Potassium: Since potassium is very mobile within the plant, symptoms only develop on young leaves in the case of extreme deficiency. Tip burn symptoms, leaves become dark green and erect. Bolting promoted. Older leaves become yellow and necrotic.

Correction measure: Foliar application of K_2SO_4 @1% twice at weekly interval.

Sulfur: The leaves show a general overall chlorosis. The yellowing is much more uniform over the entire plant including young leaves.

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

Manganese: Leaves show tip burn, light coloured and curling. Growth restricted. Bulbing delayed with thick necks.

Correction measure: Foliar spray of $MnSO_4$ @ 0.3% twice at fortnightly interval.

Zinc: Growth restricted. 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.

Correction measure: Foliar spray of $ZnSO_4$ @ 0.5% twice at for nightly interval.

Iron: Complete yellowing of young leaves. 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, http://agritech.tnau.ac.in/agriculture/Plant%20Nutrition-Resized/images/Onion.jpg

Physiological and nutritional disorders

Sprouting of bulbs in the field is noticed sometimes towards the start of maturity stage of bulbs particularly when there are winter rains or excessive soil moisture and nitrogen supply. This disorder is, however, not of permanent nature and varies from variety-to-variety. Early-planting also causes sprouting. Splitting is also noticed sometimes in some varieties, which is due to delayed harvesting or irrigation after long spell of drought. For past few years rubberification problem is noticed in Rajkot area and also Nilgiri hills of Tamil Nadu. It is increasing day-by-day. The effects of insecticides, fungicides, micronutrients and growth regulator were studied. It was observed that rubberification was totally controlled by application of micronutrients i.e. zinc sulphate and ammonium molybdate. It was also controlled by neem cake insecticides and growth regulator like gibberellic acid. The aerial bulbil formation is also quite common in onion where lower temperature prevails for more period or there are more temperature variation. It, however, does not affect much on yield or quality of bulbs and varietal variation is noticed. The rubberification and premature sprouting of bulbs are main physiological disorders in onion. The reasons for these disorders are summarized below for hill grown onion.

Rubberification and premature sprouting of bulbs are noticed mostly in fields which are located in low-lying areas of watershed where there is heavy deposition of nutrients along with silt during heavy rains. These problems are severe in onion fields which are more frequently irrigated than the normal requirements of onion bulbs. With the application of higher levels of nitrogen, there is an increased level of pre-mature sprouting of bulbs which results in splitting and rubberification of bulbs. Rubberification incidence also increases when higher level of nitrogen is applied in the form of urea. Due to increased levels of nitrogen, in addition to the increased production of rubberized, there is an increased level of thrips incidence in leaves during the later stage of crop. The thrips lacerate leaves and cause severe damage to the crop. Through lacerated wounds by thrips, there is a severe incidence of blast disease, caused by Boltrytis allii, when crops is 70-90 days old, which further deteriorates the quality of onion bulbs. Short duration type of onion is more susceptible than long duration type. Premature sprouting of bulbs is more in the crop (April-August) when there is high moisture level in soil at maturity of crop due to heavy rains. Delayed harvest during rainy season has increased premature sprouting and splitting of bulbs. Wider spacing of cloves at the time of planting increases uptake of nitrogen and water by the individual plants which increases premature sprouting and rubbenfication of onion bulbs.

http://www.nhrdf.com/htmlfiles/Garlic/gar_plant.htm

VII. DESCRIPTION OF COMMON WEEDS

Major *kharif*

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

It is an erect 6 to 100 cm tall annual herb with especially upwards glabrous to pubescent stem. Leaves are also glabrous or pubescent on the veins of the lower surface; petioles long (up to 10 cm), occasionally longer than the blade; blade ovate to rhombic-oblong, base tapered to blunt, tip rounded. Flowers green, unisexual, male and female intermixed, in slender axillary to terminal paniculate spikes 2-12 cm long and 2-5 mm wide, or in dense axillary clusters in the lower part of the stem. Fruits are capsule almost round shaped 1.25-1.75 mm long with rough surface. Seeds 1-1.25 mm, round, slightly compressed, dark brown to black with a paler thick border.

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

An annual herb with , horizontal or ascending stem, multiple from the base, radiating from a central point; glabrous, green. Leaves are alternate, petiolate, pinnate, 4-5 cm long, 2 cm broad, glabrous. Divisions of the leaves opposite, lobed or devided, linear-elliptic to linear oblong. Inflorescence is a small raceme, up to 4 cm long, opposite to one of the stem leaves, compact. Flowers minute, greenish. Fruits are glabrous, 3-4 mm broad, 2 mm long, slightly compressed, sub-globose, 2-seeded.

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

A variable annual herb upto 1 m tall with an erect, glabrous or sparsely pubescent stem and staggered branching pattern. Leaves are 2.5-9 cm long and 2-5 cm wide, ovate, glabrous, thin, margins toothed, tapering into the petiole, apex subacute. Flowers small, white, borne in drooping, umbellate 3-8 flowered cymes. Fruits berries globose, 5-8 mm in diameter, red, yellow or purplish-black. when ripened, fruits having numerous, disc-shaped, 1.5 mm in diameter, yellow, minutely pitted seeds.

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

An annual glabrous herb with prostrate and succulent stem. Leaves spatulate, flattened, apex round nearly truncate. Flowers 3-10 mm diameter and yellow. Fruits capsules ovoid, 4-9 mm diameter. Seeds black or dark brown, orbiculate or elongate, flattened, 0.6-1.1 mm; surface cells sooth, granular, or stellate, with rounded tubercles.

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

An annual herb, 30-60 cm height with spreading branches. Leaves variable, 2-7.5 cm long and 1.3-4.5 cm wide, ovate or elliptic, acute or rounded at the apex, sometimes with reddish margins, glabrous. Flowers pink, borne in threes axillary, pedunculate spikes, 2.5-12.5 cm long. Fruits globose, approximately 0.3 cm in diameter having yellowish-brown.

Grassy

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

Annual, very variable, grass, 10-44 cm height. Stem erect or creeping culms, rooting from the profusely branched nodes. Leaves are linear, tapering to a fine point, 2-10 cm long and 0.2-0.4 cm wide, flat, glaucous, glabrous or hispid; leaf sheaths striate, the

lower whitish; ligules membranous, very short. Inflorescence comprised of 2-6 digitate spikes, 0.5-4 cm long, olive-grey; spikelets 2-5 flowered, spreading at right angles, pendulous, strongly striate. Grain 0.5-1 mm long, subglobose, reddish, very rugose.

7) Crab grass: *Digiteria sanguinalis* (L.) Scop (Poaceae)

A prostrate or ascending annual grass with spreading, branched stem having rooting at nodes. Leaves are 3-20 cm long, 3-10 mm wide, with hairs on both the surfaces. Stem sheaths hairy and closed. Leaves and sheaths may turn dark red or maroon with age. Seed head composed of 4-6 branches (spikes) at the top of the stems, each approximately 3-15 cm long. Fruit caryopsis shiny, yellowish-brown, 2-3 mm long.

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

Robust, tufted annual grass, erect or at the base decumbent and rooting at the nodes, 20-150 cm tall. Culms cylindrical, glabrous, filled with white spongy pith. Leaf sheaths glabrous and 9-13 cm long. Leaf blades merging into the sheath, linear, with a broad, rounded base and acute top; rough margined, glabrous or at the base with a few long hairs, smooth or the upper surface minutely bristly. Inflorescence is an apical panicle of 5-40 spikes like racemes. Fruit are caryopsis ovoid to obovoid, compressed, 1.5-2 mm long.

Sedge

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

A perennial sedge, hard, fragrant, globose-ovoid tubers, up to 1.2 cm long and 0.3-0.7 cm in diameter; culms solitary or few together, sparsely tufted, erect, 10-75 cm tall, 3-angled at top. Leaves narrowly linear, sometimes longer than stem, 0.4-0.8 cm wide, dark green above, pale beneath. Inflorescence is a simple or compound umbel, rays 2-8, each up to 7.5 cm long, bearing short spikes of 3-10 spreading, red-brown spikelets. Nuts oblong to ovate-oblong, 3-sided, 1.3-1.5 mm long and 0.5-0.7 mm wide, maturing brown.

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

Annual sedge, sometimes behaving as a perennial with 8 to 60 cm height. The culms are tufted, triangular, smooth, green and 0.6-3.0 mm thick. The roots are numerous, short and yellowish-red. Leaves are linear-lanceolate, usually all shorter than the culm, 1-8 mm wide, flat, and rough on the margin and major ribs; leaf sheaths are green to reddish-brown, membraneous and envelope the culm at the base. Inflorescence is simple or compound, usually open, 1-20 cm long and 1-20 cm wide, with groups of spikes which are either attached directly to stem or on 0.5-15.0 cm long peduncles (rays). Spikelets are erect-spreading, crowded, 6-24-flowered, 2-13 mm long, 1.5-2.0 mm wide, golden to yellowish green. Nutlet, 1.0-1.5 mm long, 0.6-0.7 mm wide, obovate, triangular in cross section, dark-brown to almost black; the surface is almost smooth.

Major *rabi*

Broad leaf

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

It is an annual weed found in agricultural fields. It is a polymorphous, non-aromatic, erect herb**,** 0.3-3 m tall with angled stems that are often striped green, red or purple.

Leaves are variable in size and shape, lower leaves are toothed or irregularly lobes, 10-15 cm long, with petioles often as long as leaf blades. Flowers are green, borne in clusters forming a compact or loosely panicled axillary spike. Fruits utricle, seeds round, compressed, black and shining.

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

A low-growing annual, up to 30 cm tall with branched or erect herbaceous, 4-angled, glabrous to pubescent stem. Sometimes rooting observed at the nodes. Leaves are opposite, entire, sessile, ovate variously pubescent, margins somewhat tuberculate. Flowers are bright blue, solitary arising from the area between the stem and leaves (leaf axils) and occur on relatively long stalks (pedicels). Fruits capsule, globose, seeds1.3 mm long, trigonous, brown.

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

It is a sweet-smelling erect herb, up to 10-60 cm height with hairless, spreading or erect stem. Leaves odd-1-pinnate; leaflets 1-2.5 cm, inverted, lance-shaped to wedge-shaped, generally sharply toothed on the broader part. Flowers yellow; appear in slender, compact racemes that are 1-2 inches in length. Plant bear papery, small, round, 2-3 mm long, yellow or grey, reticulately wrinkled and slightly hairy pods. Seeds 2 mm long; 1.5 mm wide; broadly oval, one side plane, the other side rounded; yellowish green; roughened by minute tubercles.

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

Annual herb, up to 60 cm tall. Stem Slender, much branched and succulent. Leaves 2-3 pinnatisect, 2-5 cm long, segments linear oblanceolate, apiculate. Flowers Purplish-red, spurred, in terminal or leaf opposed bracteate racemes. Fruits are rounded nuts, 2-3 mm in diameter, wrinkled when dry.

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

A diffuse annual herb. Stem branched from the root, grooved. Leaves are in pseudo whorls, fleshy, linear-subulate, spreading. Flowers small, white. Fruits capsule rounded, five valved. Seeds are circular, thick lens shaped in cross section; margins winged with one small notch. Seeds are greyish black to black with margins usually light brown.

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

It is one of the worlds' worst weeds mostly found in uncultivated lands but now a - days it can be seen invading cropped fields. It is a short-lived annual herb with an extensive root system and erect shoot upto 2 m height. Upper half of the main stem becomes highly-branched at flowering with strips due to longitudinal grooves or ribs and they become woody with age. Leaves are pale green, deeply lobed and covered with fine soft hairs. Flowers are creamy-white occurring at the tips of the stems. Clusters of male and female florets are grouped as five-lobed flowers on the terminal branches of the flower stem and measure 4–6 mm in diameter. Seeds are achene small (1–2 mm), flattened, triangular and dark brown–black with two thin, white, spoon-shaped appendages.

Grassy

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

Annual cool-season grass grows 6 to 8 inches height when left unmowed. It has light green flattened stems that are bent at the base and often rooted at the lower stem joint. Leaf blades are often crinkled part way down and vary from 1 to 3 inches long with typical *Poa* boat-shaped leaf tips- a key characteristic of annual bluegrass. Inflorescence is branched with three to eight flattened florets in each spikelet.

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

A tufted annual bunchgrass, up to 1.8 meters in height. Stem is erect or horizontal with long, linear leaves. Ligule is an oblong hyaline membrane, about 2-5 mm long, often truncate and/or fringed; auricles absent, sheath smooth. Panicle more or less protruding or entirely protruding from the uppermost swollen leaf sheath, ovate to oblong, 5-8 cm long, green. Spikelets green, broadly lanceolate on short pedicels, shining, 4 -6 mm long, strongly laterally compressed.

19) Chinese lovegrass: *Eragrostis unioloides* (Retz.) Nees. Ex Steud. (Poaceae)

It is an erect annual grass with solitary or tufted stem. It is found in cultivated fields. Leaves are opposite, elliptic or obovate, form an acute or obtuse base, acuminate or rounded at apex. Inflorescence is an oblong panicle, 10 cm long, spikelets two flowered, ovate-oblong, extremely compressed, purplish-red when mature. 4-7 mm long, the florets closely imbricate. Seeds are caryopsis and compressed 0.8 mm long.

20) Goose grass: *Eleusine indica* (L.) Gaertner (Poaceae)

It is an annual grass with Erect, slender, flattened stem, radiating outwards from a central distinctive white center. Leaves are 2-14 inches long, 3-8 mm wide, without hairs or only sparsely hairy, and folded along the midvein. The ligule is 1-2 mm long, fringed, uneven, and membranous. Leaf sheaths are flattened, whitish at the base, and sparsely hairy in the collar region. Flowers or seed heads are composed of 2-13 spikes each 1.5 to 6 inches long, 3-7 mm wide, in clusters at the top of stems. Two rows of flattened spikelets occur along each spike. Seeds are light brown to black and 1-2 mm long.

https://encrypted-tbn1.gstatic.com/images?q=tbn ANd9GcSG4MuoFs9OR2DVI1kYn4zGBww30cuTCuflmyN7cq49wTYFIFJTjg

VIII. DESCRIPTION OF INSECT AND MITE PESTS

1) Onion thrips:

Biology:

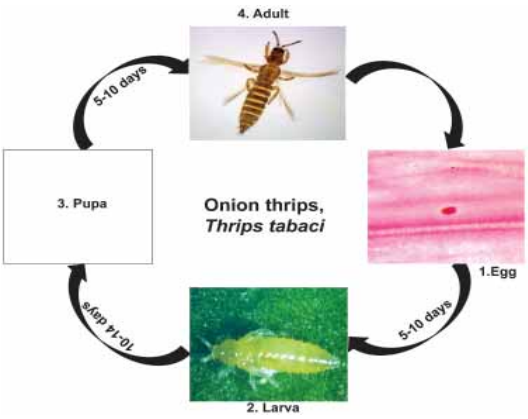
Egg: White to yellow, kidney-bean shaped, microscopic in size. Develop within leaf tissue with one end near the leaf surface. Egg stage is 5-10 days.

Larva: Instars I and II are active, feeding stages. White to pale yellow, elongate and slender body. Resemble adult, but without wings. Antennae are short and eyes are dark in color. Feed on new leaves in the center of the onion neck. Crawl quickly when disturbed. Larval stage is 10-14 days.

Pre-pupa and pupa: Instars III and IV are inactive, non-feeding stages called pre-pupa and pupa. Pale yellow to brown; body more stout than younger instars. Antennae are bent to head; wing buds are visible. Found in the soil, at the base of the onion plant neck, or underneath bulb scales. Lasts 5-10 days.

Adult: About 1.5 mm long; elongate, yellow and brown body with two pairs of fringed (hairy) wings. Mouthparts are beak-like and antennae are 7-segmented. Spend the winter in protected sites under plants and debris in onion, alfalfa and small grain fields, and other plant habitats. In the spring when temperatures warm, adults fly to new onion fields. Parthenogenic (asexually reproducing) females; males are extremely rare. Feed on young leaves in center of onion neck and insert eggs individually into leaves. Fly readily when disturbed. Adult life span is about 1 month; pre-oviposition period (time before egg-laying begins) is 1 week and females will lay eggs for about 3 weeks.

Life cycle:



1,2,4. http://extension.usu.edu/files/publications/factsheet/ENT-117-08PR.pdf

Damage symptoms :

- Both adult and larval thrips feed within the mesophyll layer using a punch-and suck motion.
- The beak and mandible is thrust forward to puncture the leaf epidermis and sap released from injured plant cells is sucked up.
- Removal of chlorophyll causes the feeding area to appear white to silvery in color.
- Areas of leaf injury can occur as patches and streaks.
- When feeding injury is severe, leaves take on a silvery cast and can wither.
- Tiny black "tar" spots of thrips excrement are evident on leaves with heavy feeding injury.

Thrips on onion

Onion crop affected by thrips

http://www.nhrdf.com/documents/NHRDF-Research-Achievements.pdf

Parasitoid of onion thrips:
Nymphal parasitoid:
Ceranisus menes

http://biocontrol.ucr.edu/hoddle/avocadothrips.html

Predators of onion thrips:

1. Syrphid fly

2. Minute pirate bug

3. Praying mantis

4. Predatory thrips

5. Damselbug

6. Lacewing

7. Coccinellid

8. Spider

1. http://freepages.misc.rootsweb.ancestry.com/~larsonmorgan/flies/flies.html
2. http://plantdiagnostics.umd.edu/level3.cfm?causeID=246
3. http://www.kimthompsonartist.com/SingleImages/PrayingMantis.html
4. http://bugguide.net/node/view/205042/bgpage
5. http://en.wikipedia.org/wiki/Nabidae
6. http://www.redorbit.com/education/reference_library/animal_kingdom/ insecta/2576160/neuroptera_lacewing/
7. http://www.cals.ncsu.edu/course/ent425/images/Predators_gallery/pages/06coccinellid8584_jpg.htm
8. http://wakpaper.com/id154616/butterfly-insects-dangerous-spiders-wallpaper-desktop-1600x1200-1600x1200-pixel.html

*For management refer to page number 16

2) Onion maggot:

Biology:

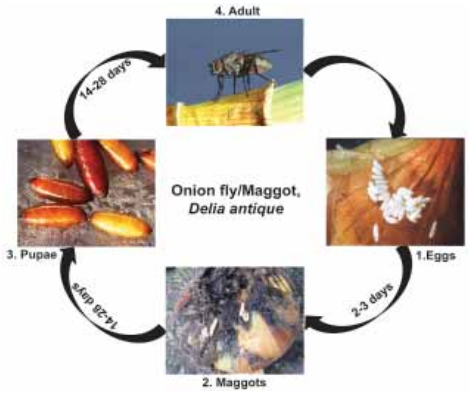
Egg: The onion fly deposits white elongated eggs. About 1/25 inch (l.25mm) in length on the soil near the stem and occasionally on the young leaves and neck of the onion plant. Eggs hatch into maggots 2-3 days after being laid.

Maggot: The legless maggots are tapered, creamy-white in color, and reach a length of about 1/3 inch (8mm). Maggots develop through three larval stages in 2 to 4 weeks depending on the temperature. Most newly hatched larvae crawl below the soil surface and feed upon the roots or burrow into the basal plate of the bulbs. Some maggot larvae may enter into the sides of bulbs rather than through the basal plate, after undercutting has occurred. Any injury site on the bulb facilitates the maggot's entry.

Pupa: When full-sized, the maggot leaves the bulb and enters the soil to pupate at a depth of 1-4 inches (5-10 cm). The pupa is chestnut brown and 1/3 inch (7mm) long. First and second generation pupae remain in the soil for 2-4 weeks before adult emergence. Larvae of the third (fall) generation develop into pupae and pass the winter in that stage. Flies emerging the following spring constitute the spring flight.

Adult: Onion flies are slightly smaller than houseflies. They have longer legs, are more slender, and overlap their wings when at rest.

Life cycle:



1. http://m.animal.memozee.com/m.view.php?q=%EB%8B%B4%EB%B0%B0%EA% B0%80%EB%A3%A8%EC%9D%B4&p=3
2. http://www.forestryimages.org/browse/detail.cfm?imgnum=2511050
3. http://www.fera.defra.gov.uk/plants/publications/documents/factsheets/bemisia.pdf
4. http://www.entomology.umn.edu/cues/inter/inmine/Whitefg.html

Damage symptoms:

- Only the larva causes damage by using its hooked mouth parts to enter the base of the plant.
- Damaged seedlings first wilt, eventually become flaccid, and die.
- Frequently, attacked seedlings die before the maggots are fully grown, forcing them to move to adjacent plants.
- Second generation maggot feeding on developing bulbs usually results in distorted growth accompanied by rotting tissue.
- Feeding by third generation maggots on late season onion bulbs results in an unmarketable product.

Predators of onion maggot:

1. Ground beetle

2. Rove beetle

1. http://organicemily.com/?p=313
2. http://www.ozanimals.com/Insect/Rove-Beetle/Staphylinidae%20family/.html

*For management refer to page number 16-17

3) Red spider mite:

Biology:

The carmine spider mite normally completes a life cycle from egg to adult in about a week. All stages of this mite are present throughput the year. Reproduction is most favorable when the weather is hot and dry.

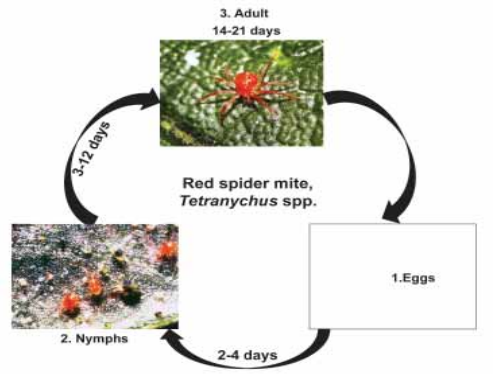
Egg: Eggs are spherical, shiny, straw colored, and hatch in 3 days. They are only about 1/254 inch in diameter. They are laid singly on the underside of the leaf surface or attached to the silken webs spun by the adults.

Larva: Larvae are slightly larger than the egg, pinkish, and have three pairs of legs. This stage lasts a short time, perhaps a day.

Nymph: There are two nymphal stages, the protonymph and deutonymph. The nymphal stage differs from the larval stage by being slightly larger, reddish or greenish, and having 4 pairs of legs. This nymphal stage lasts about 4 days.

Adult: Adult females are about 1/50 inch long, reddish, and more or less elliptical. The males are slightly smaller and wedge shaped. They have a black spot on either side of their relatively colorless bodies. The adult female may live for up to 24 days and lay 200 eggs.

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 :

- Adults and nymphs feed primarily on the undersides of the leaves.
- The upper surface of the leaves becomes stippled with little dots that are the feeding punctures.
- The mites tend to feed in "pockets" often near the midrib and veins.
- Silk webbing produced by these mites is usually visible.
- The leaves eventually become bleached and discolored and may fall off.

1. Attack of red spider mites

2. Mite infested bulb

1, 2. http://nhm.nic.in/Horticulture/IPM-Schedule-for-vegetables.pdf

Predators of red spider mite:

1. Syrphid fly

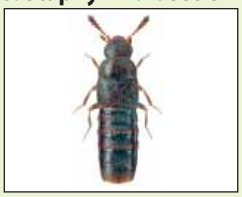
2. Minute pirate bug

3. Lacewing

4. Coccinellid

5. Predatory mite

6. Staphylinid beetle



1. http://freepages.misc.rootsweb.ancestry.com/~larsonmorgan/flies/flies.html
2. http://plantdiagnostics.umd.edu/level3.cfm?causeID=246
3. http://www.redorbit.com/education/reference_library/animal_ kingdom/insecta/2576160/neuroptera_ lacewing/
4. http://www.cals.ncsu.edu/course/ent425/images/Predators_ gallery/pages/06coccinellid8584_jpg.htm
5. http://www.eduwebs.org/bugs/predatory_mites.htm
6. http://www.colpolon.biol.uni.wroc.pl/oligota%20pusillima.htm

*For management refer to page number 17

4) Bulb mite:

Biology:

The developmental stages in the life cycle are egg, larva, protonymph, heteromorphic deutonymph, tritonymph and adult.

Egg: Females lay up to 700 eggs each depending on the host. The eggs mature in 3 to 5 days. The egg is white and translucent, 0.12 mm long, and ellipsoidal.

Larva: Larval period is 3 to 7 days. The protonymph period 3 to 5 days. This stage can be distinguished from the tritonymph by having two genital suckers, whereas the tritonymph has three or four suckers. Deutonymph or Hypopus- This quiescent stage is oval, convex on top, flattened below, brown, and 0.2 to 0.3 mm long. The tritonymph is about 0.5 mm in length and has not yet developed a distinct genital aperture. Hypopi form when the population becomes crowded, or the substrate becomes too polluted by decay. The hypopal stage attaches to insects visiting the bulbs and may be carried to other bulbs.

Adult: The longevity male adult is 62 days and female is 31 days. Mature bulb mites vary from 0.5 to 0.9 mm long and have four pairs of legs. Their bodies are shiny, white, somewhat transparent, and smooth with reddish brown appendages.

The total life cycle from egg to adult could be as short as 12.2 days (at 25°C)

Damage symptoms:

- Bulbs infested with bulb mites may rot and fail to produce new growth, or new growth may be off color, stunted, and distorted.
- Although the bulb mite is not considered a primary pest of bulbs, it is often responsible for serious losses; the slightest injury to a bulb will allow bulb mites to enter and become established.
- Once the mites are inside the bulb, they rapidly turn the bulbs into rotten pulp.
- Infestations of the bulb mite generally indicate that the bulbs have already been injured.
- This damage could have been caused by other pests, such as the bulb scale mite or bulb flies, mechanical injury, or improper storage.
- The root primordia of freesia and gladiolus may be bruised at planting.
- Apparently bulb mites can attack healthy new roots and corms, especially in greenhouses. The mites may penetrate into lily stems which become brittle. Infested lilies are often dwarfed, distorted, and the stem roots are suppressed.
- Bulb mites may enter prematurely opened tulip buds (due to high storage temperatures or ethylene generated by diseased bulbs in storage) and cause bud necrosis.

*For management refer to page number 17

5) Eriophyid mite:

Biology:

The life cycle is composed of the egg, the larva, two nymphal stages (protonymph and deutonymph) and the adult.

Egg: Egg incubation period 2-4 days; The eggs are attached to fine silk webbing and hatch in approximately three days.

Nymph: Protonymphal and deutonymphal period is 2 to 3 days, each.

Adult: Adult mites survive about 8 days. Length 200 to 250 µm and width 36 to 52 µm. The adult female is capable of laying several hundred eggs during her life.

Total life cycle 7 to 9 days. The length of time from egg to adult varies greatly depending on temperature.

Damage symptoms:

- Both adults and immatures feed on the young leaves and between the layers in bulbs of onion
- Their feeding causes stunting, twisting, curling and discoloration of foliage and scarification and drying of bulb tissue
- This damage has been attributed to various viruses thought to be transmitted by the mites

*For management refer to page number 17

IX. DESCRIPTION OF DISEASES

1) Damping off:

Disease symptoms:

- Two types of symptoms are observed-Pre-emergence damping-off: This results in seed and seedling rot before they emerge out of the soil.
- Post-emergence damping-off: The pathogen attacks the collar region of seedlings on the surface of soil. The collar portion rots and ultimately the seedlings collapse and die.

Nursery affected with damping off

http://www.nhrdf.com/documents/NHRDF-Research-Achievements.pdf

Survival and spread:

- Pathogen(s) survives on infected crop debris and soil which are source of primary inoculum.

Favourable conditions:

- The disease is more prevalent during *kharif* season/rainy season and causes about 60-75% damage.
- High soil moisture and moderate temperature along with high humidity leads to the development of the disease.

*For management refer to page number 15 & 18

2) Purple blotch:

Disease symptoms:

- The symptoms occur on leaves and flower stalks as small, sunken, whitish flecks with purple coloured centres.
- The lesions may girdle leaves/stalk and cause their drooping. The infected plants fail to develop bulbs

1. Badly damaged leaves **2. Infection on stem**


1. http://nhm.nic.in/Horticulture/IPM-Schedule-for-vegetables.pdf
2. http://www.nhrdf.com/documents/NHRDF-Research-Achievements.pdf

Survival and spread:

- The disease is soil borne and fungus survives in soil, infected bulbs and may persist in plant debris or on roots of weeds.

Favourable conditions:

- Hot and humid climate with temperature ranging from 21-30°C and high relative humidity (80-90%) favour the development of the disease.

*For management refer to page number 18

3) *Stemphylium* leaf blight:

Disease symptoms:

- Infection occur on radial leaves of transplanted seedlings at 3- 4 leaf stage during late March and early April.
- The symptoms appear as small yellowish to orange flecks or streaks in the middle of the leaves, which soon develop into elongated spindle shaped spots surrounded by pinkish margin.
- The disease on the inflorescence stalk causes severe damage to the seed crop.

***Stemphylium* leaf blight**


1. http://www.semena.org/agro/diseases3/stemphylium-leaf-blight-e.htm
2. http://www.nhrdf.com/documents/NHRDF-Research-Achievements.pdf

Survival and spread:

- The fungus survives in plant debris or soil.

Favourable conditions:

- Warm (18-25°C) humid conditions and long periods of leaf wetness (16 hours or more) favour disease development.

*For management refer to page number 19

4) *Colletotrichum* blight/anthracnose/twister disease:

Disease symptoms:

- The symptoms appear initially on the leaves as water soaked pale yellow spots, which spread lengthwise covering entire leaf blade.
- The affected leaves shrivel and droop down.

1. *Colletotrichum* blight

2. Curling and abnormal elongation of leaves

1. http://www.nhrdf.com/documents/NHRDF-Research- Achievements.pdf
2. http://nhm.nic.in/Horticulture/IPM-Schedule-for-vegetables.pdf

Survival and spread:

- The fungus can survive for many years as sclerotia in the soil or for shorter periods in infected plant debris.

Favourable conditions:

- Disease is most severe in warm [25-30°C], moist soils that are high in organic matter.
- Fungal growth rapidly decreases below 15°C, resulting in little disease development.

*For management refer to page number 19

5) *Fusarium* basal rot/basal rot:

Disease symptoms:

- Initially yellowing of leaves and stunted growth of plant is observed, which later on dry from tip to downwards.
- In early stage of infection, the roots of the plants become pink in colour and rotting take place later. In advanced stage, the bulb starts decaying from lower ends and ultimately whole plant dies.

1. Rotting of onion in the field

2. Fusarial infection on bulbs

1, 2. http://nhm.nic.in/Horticulture/IPM-Schedule-for-vegetables.pdf

Survival and spread:

- Pathogen survives in soil and onion bulb as a primary source of inoculum in the form of Chlamydospore, resting spore) for many years.

Favourable conditions:

- Moist soil and 27°C temperature favours the development of disease.

*For management refer to page number 19

6) White rot (Sclerotial rot):

Disease symptoms:

- The initial symptoms are yellowing and dieback of leaf tips. Later, scales, stem plate and roots get destroyed.
- The bulbs become soft and water soaked.
- Later, white fluffy or cottony growth of mycelium with abundant black sclerotia resembling mustard grain develops on the infected bulbs.

Sclerotial rot on onion bulbs

http://nhm.nic.in/Horticulture/IPM-Schedule-for-vegetables.pdf

Survival and spread:

- Fungus survives in soil as sclerotia for many years and it can over-winter in infected onion debris and in diseased onion sets.

Favourable conditions:

- This disease is most severe in cool and dry soils.

*For management refer to page number 19

7) Pink root rot:

Disease symptoms:

- Reduced bulb size.
- Roots turn pink or maroon when infected.
- In severe cases the roots may die and the plants become weakened or stunted, especially in drier areas of the field.
- Crop suffering from heat or drought stress due to poor soil is more prone to yield losses.

Pink root rot due to *Phoma*

http://nhm.nic.in/Horticulture/IPM-Schedule-for-vegetables.pdf

Survival and spread:

- Fungus can survive in the soil, in diseased roots and the debris of susceptible crops for several years.
- The fungus can be spread through soil movement and in irrigation water.

Favourable conditions:

- This disease can develop at all soil moisture levels that allow onion growth. Optimum temperatures for growth of the pathogen and disease development are 24-28°C.

*For management refer to page number 20

8) Black mould:

Disease symptoms:

- Infection usually is through neck tissues as foliage dies down at maturity.
- Infected bulbs are discolored black around the neck, and affected scales shrivel.
- Masses of powdery black spores develop as streaks along veins on and between outer dry scales.
- Infection may advance from the neck into the central fleshy scales.

Black mould

http://nhm.nic.in/Horticulture/IPM-Schedule-for-vegetables.pdf

Survival and spread:

- Fungus survives in air, soil and infected plant debris.
- Spores of this fungus are very common in the air and soil which are the source of infection.

Favourable conditions:

- Black mold is most common when temperatures are higher than 30°C (86°f) in the field or 24°C in storage.
- Free moisture for six hours or longer on the onion surface is necessary for infection to occur.

*For management refer to page number 20

9) Bacterial soft rot:

Disease symptoms:

- Bacterial soft rot is mainly a problem on mature bulbs. Affected scales first appear water-soaked and pale yellow to light brown.
- As the soft rot progresses, invaded fleshy scales become soft and sticky with the interior of the bulb breaking-down.
- A watery, foul-smelling thick liquid can be squeezed from the neck of diseased bulbs.

https://www.google.co.in/search?q=soft+rot+of+onion&espv=210&es_sm=93&source=lnms&tbm

Survival and spread:

- The pathogen is soil borne and after heavy rains and when leaves are drying the main sources of inoculum are contaminated soil and crop residues.
- The bacterium is also spread by splashing rain, irrigation water and insects.

Favourable conditions:

- This disease is favored by warm, humid conditions with an optimum temperature range of 20-30°C.
- However, during storage or transit soft rot can develop when temperatures are above 3°C.

*For management refer to page number 20

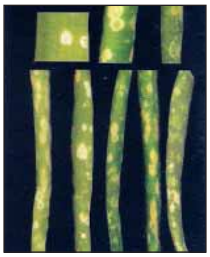
10) Iris yellow spot disease:

Disease symptoms:

- Symptoms of iris yellow spot virus are often seen as a cream, elliptical spots on the leaves. The spots also appear on onion scapes or flower stalks of onions.
- As both infected leaves and scapes age, they can collapse at the site of the spots. The spots may be clear or less obvious. Although the spots may at first be insignificant, the disease has the potential of devastating the whole crop.

Diamond shaped viral lesions

1. **2.**



1. http://nhm.nic.in/Horticulture/IPM-Schedule-for-vegetables.pdf

2. http://www.nhrdf.com/documents/NHRDF-Research-Achievements.pdf

Transmission and favourable conditions:

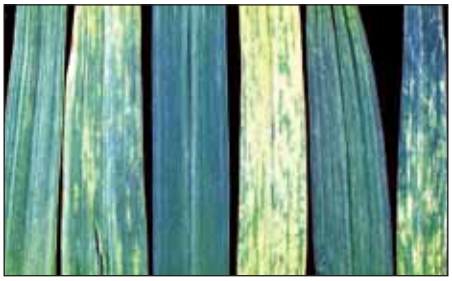
- Onion thrips (*Thrips tabaci*) transmit IYSV in a persistent manner. Disease severity is positively correlated with thrips populations in the field.
- This virus is not seed transmitted. over-wintering onions, volunteers from prior productions, infected transplants and alternate hosts can all serve as sources of both vector and virus.

*For management refer to page number 20 & 21

11) Onion yellow dwarf disease:

Disease symptoms:

- The first symptoms of onion yellow dwarf in young onions are yellow streaks at the bases of the first true leaves.
- All leaves developing after these initial symptoms show symptoms ranging from yellow streaks to complete yellowing of leaves.
- Leaves are sometimes crinkled and flattened and tend to fall over. Bulbs are undersized.



https://www.google.co.in/search?q=onion+yellow+dwarf+disease

Transmission and favourable conditions:

- The virus is carried by infected seed bulbs, onion sets and volunteer onions. Many aphid species can transmit this virus from infected to healthy plants.

*For management refer to page number 20

12) Downy mildew:

Disease symptoms:

- Leaves turn to pale green.
- On leaves, cottony white mycelial growth develops and appears white. Gradually the leaves turn pale yellow to dark brown and dries up.

1.https://www.google.co.in/search?q=downy+mildew+of+onion&sa=

Survival and spread:

- Fungus survive in soil and infected plant debris.

Favourable condition:

- Warm and humid climate favours the development of disease.

*For management refer to page number 19

13) Green mould :

Disease symptoms:

- Infection usually is through neck tissues as foliage dies down at maturity.
- Infected bulbs are discolored green around the neck, and affected scales shrivel.
- Masses of powdery green spores generally are arranged as streaks along veins on and between outer dry scales.
- Infection may advance from the neck into the central fleshy scales.

https://www.google.co.in/search?q=green+mould+onion&sa=X&

Survival and spread:

- Spores of this fungus are very common in the air and soil which act as the source of infection.

Favourable conditions:

- Black mold is most common when temperatures are higher than 30°C in the field or 24°C in storage.
- Free moisture for six hours or longer on the onion surface is conducive for infection to occur.

*For management refer to page number 20

14) Bacterial brown rot:

Disease symptoms:

- Field symptoms often appear as one or two wilted leaves in the center of the leaf cluster. These leaves eventually turn pale yellow and dieback from the tip while older and younger leaves maintain a healthy green appearance.
- During the early stages of this disease, the bulbs may appear healthy except for a softening of the neck tissue. In a longitudinal section, one or more inner scales become watery or cooked.
- The disease progresses from the top of the infected scale to the base
- Eventually, all the internal tissue will rot. Finally, the internal scales dry and the bulb shrivel.
- Squeezing the base of infected plants causes the rotted inner portion of the bulbs to slide out through the neck, hence the name slippery skin.

https://www.google.co.in/search?q=brown+rot+of+onion&espv

Survival and spread:

- This bacterium is soil-borne and can be readily water-splashed to the foliage and necks where it can enter through wounds.

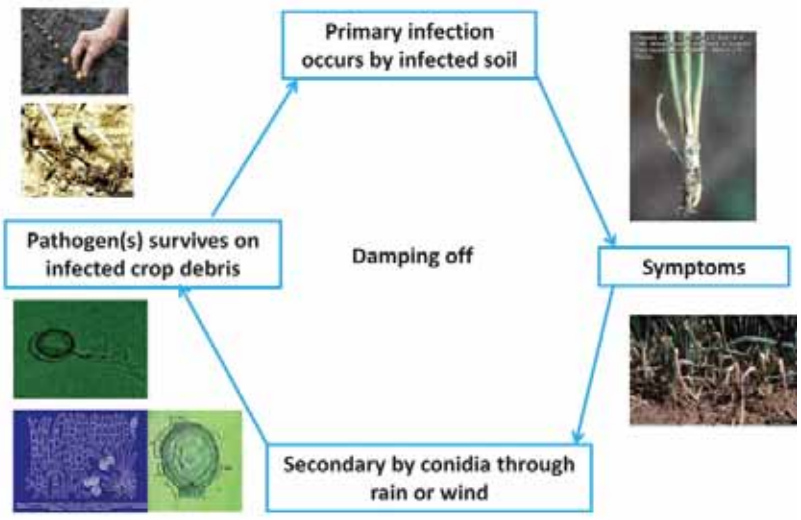
Favourable conditions:

- This bacterium requires moisture for infection and grows in the temperature range of 5-41°C.
- Heavy irrigation and persistent dews are also conducive to this disease.

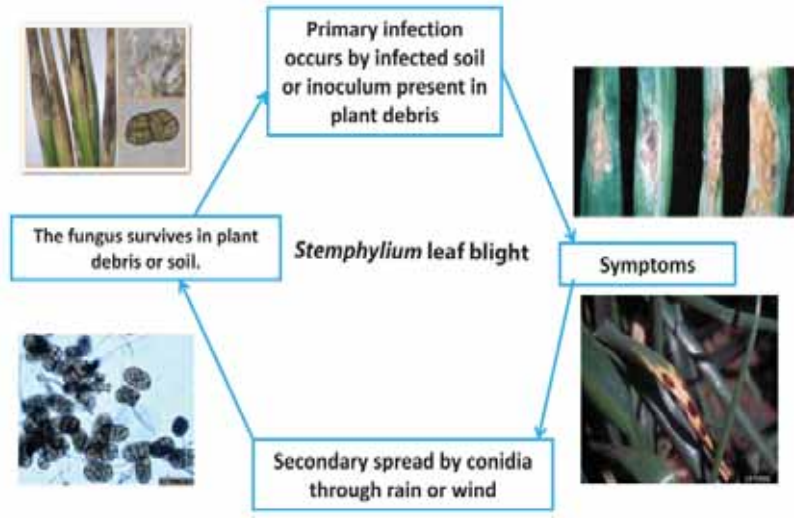
*For management refer to page number 20

Disease cycles:

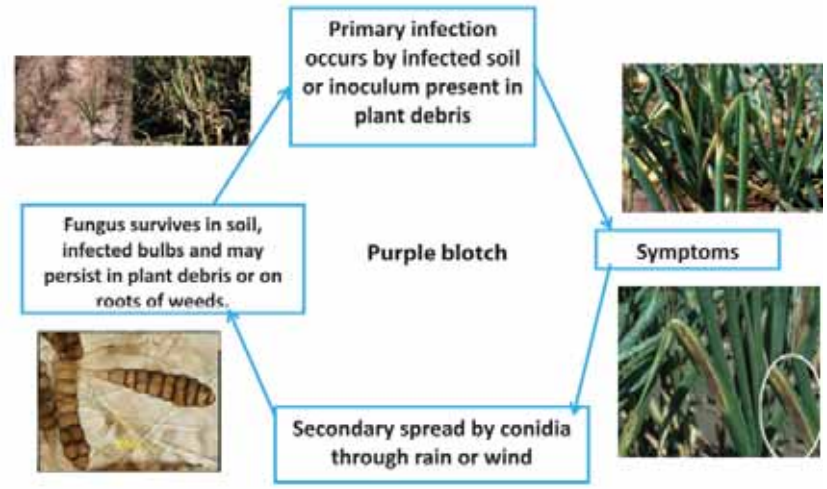
1. Damping off



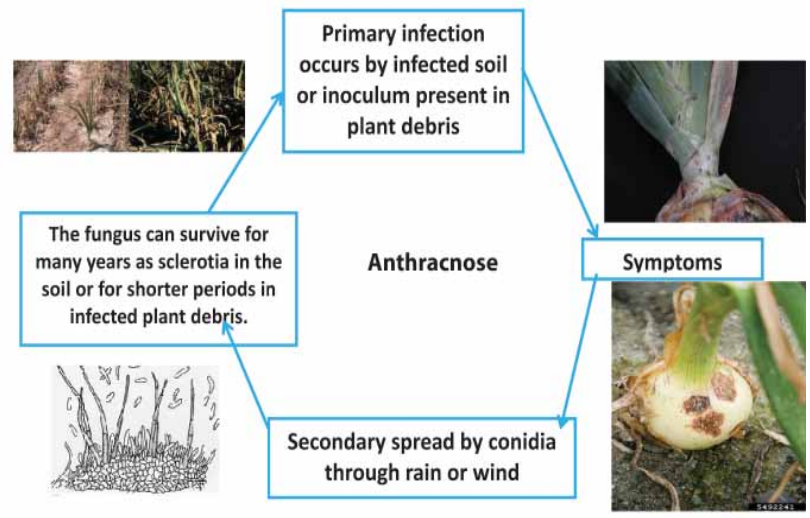
2. *Stemphylium* leaf blight



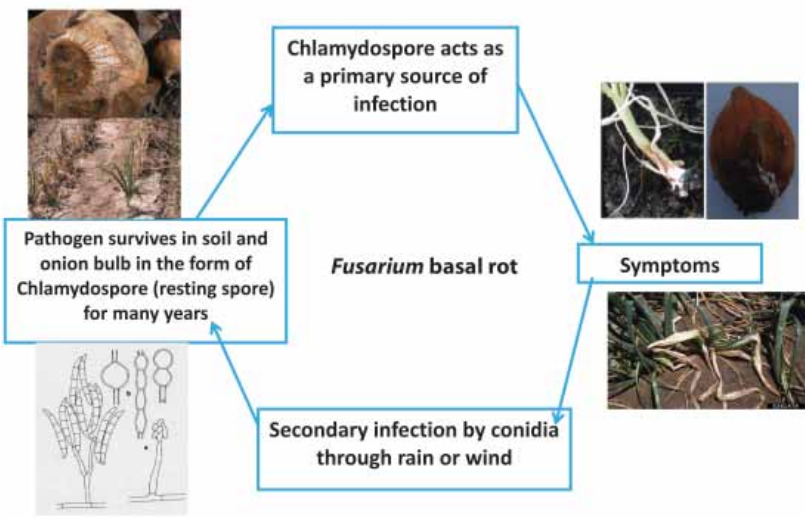
3. Purple blotch



4. Anthracnose



5. *Fusarium* basal rot



X. SAFETY MEASURES

A. At the time of harvest

Onions are ready to harvest when the tops start to turn yellow and die. The most important thing to remember when harvesting (digging up) your bulbs is not to damage their protective outer layers. If the outer layer is damaged, it leaves them exposed to disease and dryness. Use a hand tool or hand to dig the soil around the bulb, and then pull it out by hand. Wet the soil first if it's hard or rocky, and take the time to pull your bulbs gently without damaging them.

B. During post-harvest

Bulbs intended for storage need to be cured (dry out) in a dark, dry place at 30-45 C and 60-75% RH for 1-4 days, until the necks turn brown. When your onion bulbs are completely dry, cut off the necks to about an inch long. Everything else can be stored in a cool, dry place (35 to 45 °F and 70-75% RH is ideal) for up to several months. Avoid keeping bulbs in the sun, as they'll age much faster that way.

XI. DO'S AND DON'TS IN IPM

S. No.	Do's	Don'ts
1.	Deep ploughing is to be done on bright sunny days during the months of May and June. The field should be kept exposed to sun light at least for 2-3 weeks 	Do not plant or irrigate the field after ploughing, at least for 2-3 weeks, to allow desiccation of weed's bulbs and/or rhizomes of perennial weeds.
2.	Adopt crop rotation.	Avoid monocropping.
3.	Grow only recommended varieties.	Do not grow susceptible varieties.
4.	Sow early in the season	Avoid late sowing as this may lead to reduced yields and incidence of white grubs and diseases.
5.	Always treat the seedlings/planting material with approved chemicals/bio products for the control of seed borne diseases/pests 	Do not use seedlings/ planting material without seed treatment with biopesticides/ chemicals.
6.	Grow nursery on raised seed beds.	Do not raise nursery on flat bed
7.	Apply only recommended herbicides at recommended dose, proper time, as appropriate spray solution with standard equipment along with flat fan or flat jet nozzles.	Pre-emergent as well as soil incorporated herbicides should not be applied in dry soils. Do not apply herbicides along with irrigation water or by mixing with soil, sand or urea.
8.	Maintain optimum and healthy crop stand which would be capable of competing with weeds at a critical stage of crop weed competition.	Crops should not be exposed to moisture deficit stress at their critical growth stages.
9.	Use NPK fertilizers as per the soil test recommendation. 	Avoid imbalanced use of fertilizers.
10.	Use micronutrient mixture after planting based test recommendations.	Do not apply any micronutrient mixture after planting without test recommendations.

11.	Conduct AESA weekly in the morning preferably before 9 a.m. Take decision on management practice based on AESA and P: D ratio only.		Do not take any management decision without considering AESA and P: D ratio
12.	Install pheromone traps at appropriate period.		Do not store the pheromone lures at normal room temperature (keep them in refrigerator).
13.	Release parasitoids only after noticing adult moth catches in the pheromone trap or as pheromone trap or as per field observation		Do not apply chemical pesticides within seven days of release of parasitoids.
14.	Apply HaNPV or SINPV at recommended dose when a large number of egg masses and early instar larvae are noticed. Apply NPV only in the evening hours after 5 pm.		Do not apply NPV on late instar larva and during day time.
15.	In case of pests which are active during night 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, and other sucking pests harbouring the low er side of leaves.		Do not spray pesticides only on the upper surface of leaves.
17.	Apply short persistent pesticides to avoid pesticide residue in the soil and produce.		Do not apply pesticides during preceding 7 days before harvest.
18.	Follow the recommended procedure of trap crop technology.		Do not apply long persistent pesticides on trap crop, otherwise it may not attract the pests and natural enemies.

XII. SAFETY PARAMETERS IN PESTICIDE USAGE

S. No.	Pesticide	Classification as per insecticide rules	Colour of toxicity triangle	WHO classification of hazard	First Aid measures	Symptoms poisoning	Treatment of poisoning	Waiting period from last application to harvest (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	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.	--
2	Quinalphos	Highly toxic		Class II Moderately hazardous	--	Excessive salivation, sweating, rhinorrhea and tearing. Muscle twitching, weakness, tremor, incoordination. Hedache, dizziness, nausea, vomiting, abdominal cramps, diarrhea. - Respiratory depression, tightness in chest, wheezing, productive cough, fluid in lungs. - Pin-point pupils, sometimes with blurred or dark vision. - Severe cases: seizures, incontinence, respiratory depression, loss of consciousness.	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.	7
3	Chlorpyrifos	Highly toxic		Class II - Moderately hazardous	Atrophine sulphate	Severe – diarrhoea, pinpoint and non - reactive pupils, respiratory difficulty,	For ingestion lavage stomach with 5 % sodium bicarbonate, if not vomiting. For skin contact, wash with soap	7 days

						pulmonary edema, cyanosis, loss of sphincter control, convulsions, coma and heart block.	and water (eyes – wash with isotonic saline). Wear rubber gloves while washing contact areas. In addition to atropine give 2 – PAM (2 – pyridine aldoximemethiodide). 1 g and 0.25g for infants intravenously at slow rate over a period of 5 minutes and administer again periodically as indicated. More than one injection may be required. Avoid morphine, theophylline, aminophylln, barbiturates Phenothiaznines	--
4	Oxydemeton-methyl	Highly toxic		Class Ib- Moderately hazardous	--	Do-	Do-	--
Neonicotinoid								
5	Imidacloprid	Highly toxic			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	Harmful if swallowed, absorbed through skin or inhaled. Avoid breathing vapor or spray mist. Causes moderate eye irritation.	No specific antidote. Treatment is essentially symptomatic.	3

Synthetic pyrethroids								
6	Lambda-cyhalothrin				Do not induce vomiting unless told to do so by a doctor, do not give anything by mouth to an unconscious person	Toxic if swallowed or inhaled. Irritating to eyes and skin. Vapors may cause drowsiness and dizziness. May be harmful if swallowed and enters airway. May cause temporary itching, tingling, burning or numbness of exposed skin, called paresthesia	There is no specific antidote. Treatment is essentially symptomatic.	4
Fungicides								
7	Mancozeb	Slightly toxic		Unlikely produce acute hazard		Headache, palpitation, nausea, vomiting, flushed face, irritation of nose,throat, eyes and skin etc.	No specific antidote. Treatment is essentially symptomatic	10
8	Difenoco-nazole	Slightly toxic	-do-	-do-		-do-	-do-	15
9	Zineb	Not acutely toxic		Unlikely to be hazard-ous	Remove contaminat-ed clothes. rinse and then wash skin with water and soap. Give plenty of water to drink, then take to a doctor.	Cough. nausea. vomiting, skin redness, diarrhoea.	--	--
Herbicides								
10	Oxyflourfen	Slightly toxic		Unlikely to be hazard-ous	--	--	--	--
11	Quizalofop-ethyl	Slightly toxic	-do-	Not listed	--	--	--	7

XIII. BASIC PRECAUTIONS IN PESTICIDES USAGE

A. Purchase

1. Purchase only just required quantity e.g. 100, 250, 500, 1000 g/ml for single application in specified area.
2. **Do not** purchase leaking containers, loose, unsealed or torn bags; **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** just before the rains and after the rains; **Do not** 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 sprayer
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.

XIV. PESTICIDE APPLICATION TECHNIQUES

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

XV. OPERATIONAL, CALIBRATION AND MAINTENANCE GUIDELINES IN BRIEF

1.	For application rate and dosage see the label and leaflet of the particular pesticide.	
2.	It is advisable to check the output of the sprayer (calibration) before commencement of spraying under guidance of trained person.	
3.	Clean and wash the machines and nozzles and store in dry place after use.	
4.	It is advisable to use protective clothing, face mask and gloves while preparing and applying pesticides. Do not apply pesticides without protective clothing and wash clothes immediately after spray application.	
5.	Do not apply in hot or windy conditions.	
6.	Operator should maintain normal walking speed while undertaking application.	
7.	Do not smoke, chew or eat while undertaking the spraying operation	
8.	Operator should take 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.	

XVI. REFERENCES

- http://www.postharvest.com.au/Produce_Information.htm
- http://postharvest.ucdavis.edu/pfvegetable/Eggplant/
- http://nhb.gov.in/vegetable/brinjal/bri0v08.pdf
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Good insectary plants belonging to Lamiaceae, Leguminaceae, Umbelliferae, Brassicaceae, Asteraceae, Graminaceae etc. families

Buckwheat

Spearmint

Sunflower

Castor

French bean

Ryegrass

Alfalfa

Marigold

Chrysanthemum

Mustard

Coriander

Cowpea

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