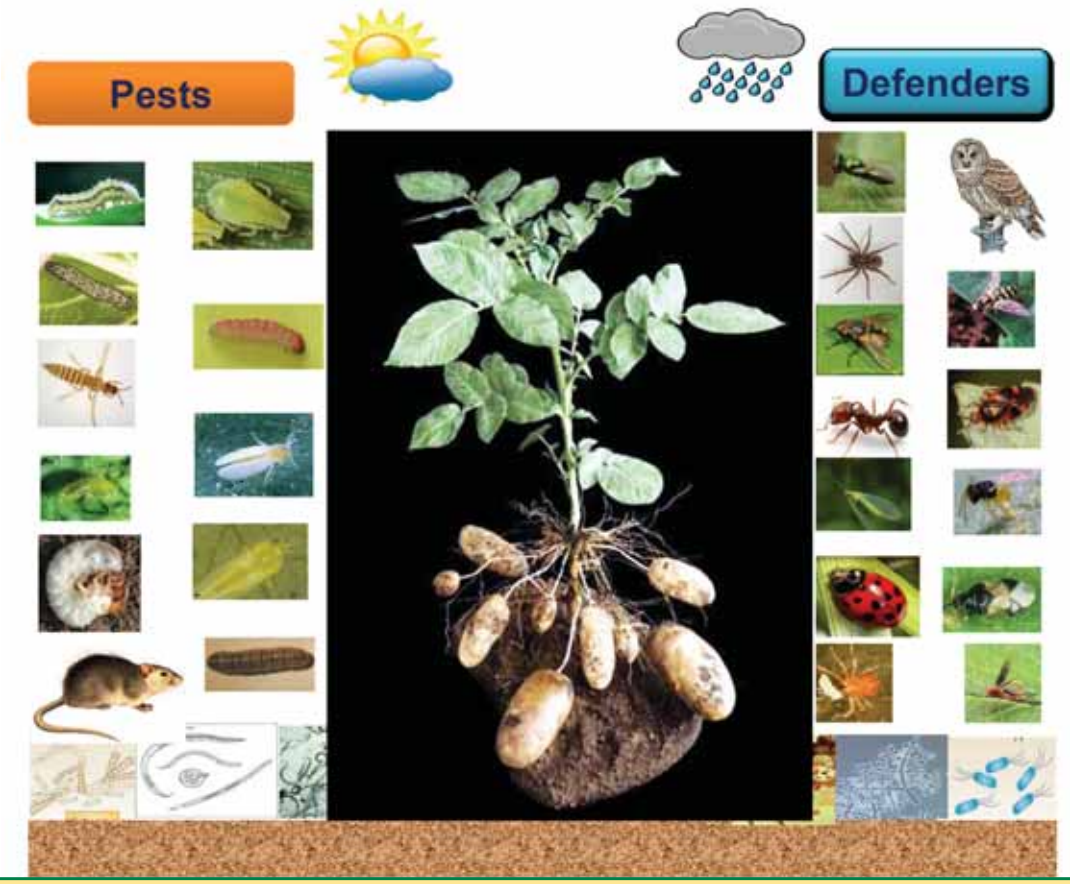
AESA BASED IPM PACKAGE

AESA based IPM – Potato



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National Institute of
Plant Health Management
Rajendranagar, Hyderabad, Telangana

Department of Agriculture and Cooperation
Ministry of Agriculture
Government of India

Important Natural Enemies of Potato Insect Pests

Parasitoids

***Trichogramma* spp.**

***Bracon* spp.**

Chrysocharis pentheus

***Ichneumon* spp.**

***Apanteles* sp**

***Encarsia* sp**

Predators

Lacewing

Ladybird beetle

Reduviid bug

Spider

Red ant

Pentatomid bug
(Eocanthecona furcellata)

The AESA based IPM - Potato, 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 Potato

Back cover picture Potato 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 POTATO

Potato plant description:

Potato (*Solanum tuberosum* L.; Family: Solanaceae) is one of the four major food crops of the world. The potato originated from South America, most likely from the central Andes in Peru. The potato was domesticated and has been grown by indigenous farming communities for over 4,000 years. Introduced into Europe in the sixteenth century, the crop subsequently was distributed throughout the world, including Asia. Worldwide, the potato comes fourth in terms of production after wheat, maize, and rice. In many countries potato serves as their major staple food because of its excellent nutritional content. It can supplement the food needs of the country in a substantial way as it produces more dry-matter food, has well balanced protein and produces more calories from unit area of land and time than other major food crops.

There is a great potential of exporting potatoes from India both for seed and table purposes to our neighbouring countries of South-East Asia and to Middle East countries. Potatoes can even be exported to some of the European countries during March-May when fresh potatoes are not available in these countries. The present area under potato in India is about 1.5 million hectares. India ranks fifth in production after China, Russian Federation, Poland and Ukraine.

Potato is basically a crop of temperate region but there is a large variation in the gene pool with respect to crop's response to thermo periods. Generally potato crop is raised in India when maximum temperatures are below 35°C and minimum temperatures are below 20^0C with ideal tuberization temp. between 16-22^0C.

The potato plant is a herbaceous perennial in that it lacks a woody stem and lives more than two years. It grows 90 to 100 centimetres (3 to 4 feet) tall and is covered with dark green leaves. The above-ground part of the plant dies each winter and re-grows in spring.

I. PESTS

A. Pests of National Significance

1. Insect pests

1.1 Aphids: *Myzus persicae* Sulzerand, *Aphis gossypii* Glover (Hemiptera: Aphididae)
1.2 Potato tuber moth: *Phthorimaea operculella* Zeller (Lepidoptera: Gelechiidae)
1.3 Jassids/ leaf hoppers: *Amrasca devastans* Dist. and *Empoasca fabae* Harris (Hemiptera: Cicadellidae)
1.4 Whitefly: *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae)

2. Nematode

2.1 Root-knot nematode: *Meloidogyne* sp.

3. Diseases

3.1 Late blight: *Phytophthora infestans* (Mont.) de Bary
3.2 Black scurf: *Rhizoctonia solani* J.G. Kühn
3.3 Leaf spot complex: *Alternaria* sp, *Phoma* sp.
3.4 *Septoria* leaf spot: *Septoria lycopersici* var. *malagutii* Ciccarone & Boerema
3.5 Early blight: *Alterneria solani* Sorauer
3.6 Common scab: *Streptomyces scabies* Lambert and Loria
3.7 Bacterial wilt: *Ralstonia solanacearum* Smith
3.6 Viral diseses (Potato virus X, S, Y and *Potato leaf roll virus*)

4. Weeds

Kharif

Broadleaf

4.1 Pigweed: *Amaranthus viridis* Hook. F. (Amaranthaceae)
4.2 Swine cress: *Coronopus didymus* (L.) Sm. (Brassicaceae)
4.3 Black nightshade: *Solanum nigrum* L. (Solanaceae)
4.4 Common purselane: *Portulaca oleracea* L. (Portulacaceae)
4.5 False amaranth: *Digera arvensis* Forsk. (Amaranthaceae)

Grasses

4.6 Rabbit/ crow foot grass: *Dactyloctenium aegyptium* (L.) Beauv. (Poaceae)
4.7 Crabgrass: *Digiteria sanguinalis* (L.) Willd. (Poaceae)
4.8 Barnyard grass: *Echinochloa crusgalli* (L.) Beauv. (Poaceae)

Sedges

4.9 Purple nutsedge: *Cyperus rotundus* L. (Cyperaceae)
4.10 Flat sedge: *Cyperus iria* L. (Cyperaceae)

Rabi

Broadleaf

4.11 Lamb's quarter: *Chenopodium album* L. (Chenopodiaceae)
4.12 Scarlet pimpernel: *Anagallis arvensis* L. (Primulaceae)
4.13 Sweet clover: *Melilotus indica* (L.) All. (Fabaceae)
4.14 Fine leaf fumitory: *Fumaria parviflora* Lam. (Fumariaceae)
4.15 Corn spurry: *Spergula arvensis* L. (Caryophyllaceae)
4.16 Goat weed: *Ageratum conyzoides* L. (Asteraceae)
4.17 Rough medic: *Medicago denticulata* Willd (Fabaceae)

4.18 Broad leaf wood sorrel: *Oxalis latifolia* Kunth. (Oxalidaceae)
4.19 Horse purslane: *Trianthema portulacastrum* L. (Aizoaceae)
4.20 Onion weed: *Asphodelus tenuifolius* Cav. (Liliaceae)
4.21 Field bindweed: *Convolvulus arvensis* L. (Convolvulaceae)

Grasses
4.22 Blue grass: *Poa annua* L. (Poaceae)
4.23 Canary grass: *Phalaris minor* Retz. (Poaceae)

5. Rodent and non-rodent vertebrate pests

5.1 Lesser bandicoot: *Bandicota bengalensis*
5.2 Indian creased porcupine: *Hystrix indica*
5.3 Wild boar: *Sus scrofa*

B. Pests of Regional Significance

1. Insect and mite pests

1.1 Cut worm: *Agrotis segetum* Denis & Schiffer müller (Lepidoptera: Noctuidae) (Tripura, Gujarat, Himachal Pradesh)
1.2 White grub: *Lachnosterna longipennis* Blanchard and *L. coracea* (Coleoptera: Scarabaeidae)(Himachal Pradesh, Uttar Pradesh)
1.3 Leafminer: *Liriomyza huidobrensi* Blanchard (Diptera: Agromyzidae)
1.4 Spider mites: *Polyphagotarsonemus latus* Banks (Acarina: Tarsonemidae) (Maharashtra, Karnataka, Orissa)
1.5 Thrips: *Thrips* sp (Hemiptera: Aphididae) (Orissa)
1.6 Tobacco caterpillar: *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae) (Uttar Pradesh, Karnataka)
1.7 Leaf eating caterpillar/gram pod borer: *Helicoverpa armigera* Hübner (Lepidoptera: Noctuidae) (Punjab, Haryana, Himanchal Pradesh)
1.8 Semi looper: *Trichoplusia ni* Hübner (Lepidoptera: Noctuidae) (Haryana, Himanchal Pradesh)

2. Diseases

2.1 Potato spotted wilt virus (Karnataka)
2.2 Charcoal rot: *Macrophomina phaseolina* (Tassi) Goid. (Himachal Pradesh, Delhi, Bihar, Madhya Pradesh, Assam, Central provinces, Punjab, Uttar Pradesh)
2.3 Potato spindle tuber viroid (PSTVd) (Himachal Pradesh, Bihar)
2.5 Pink rot: *Phytophthora erythroseptica* Pethybr. (Himachal Pradesh)
2.6 Soft rot: *Erwinia carotovora* Winslow (Delhi)
2.7 Black heart (disorder): Acute oxygen deficiency

3. Nematodes

3.1 Golden nematode: *Globodera rostochinensis* (Wollenweber) (Tamil Nadu)
3.2 Potato cyst nematode: *Globodera pallida* (Stone) (Tamil Nadu, Kerala)

4. Rodent

4.1 Indian porcupine: *Hystrix indica* Kerr

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

A. AESA:

The IPM has been evolving over the decades to address the deleterious impacts of synthetic chemical pesticides on environment ultimately affecting the interests of the farmers. The economic threshold level (ETL) was the basis for several decades but in modern IPM (FAO 2002) emphasis is given to AESA where farmers take decisions based on larger range of field observations. The health of a plant is determined by its environment which includes physical factors (i.e. sun, rain, wind and soil nutrients) and biological factors (i.e. 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 to observe closely and intensively. It is a focal point for the analysis and for the discussions that follow, and the drawing can be kept as a record.

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

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

Principles of AESA based IPM:

Grow a healthy crop

- Select a variety resistant/tolerant to major pests
- Select healthy seed/seedling/planting material tubers
- Treat the seed/seedling/planting material tuber with recommended pesticides especially biopesticides
- Follow proper spacing
- Soil health improvement (mulching and green manuring whereeve applicable)
- Nutrient management through fertilizers 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 of fertilizers 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 Pest: Defender ratio (P: D ratio)
- Take direct action when needed (e.g. collect egg masses, remove infested plants etc.)

Plant compensation ability:

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

Understand and conserve defenders:

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

Insect zoo:

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

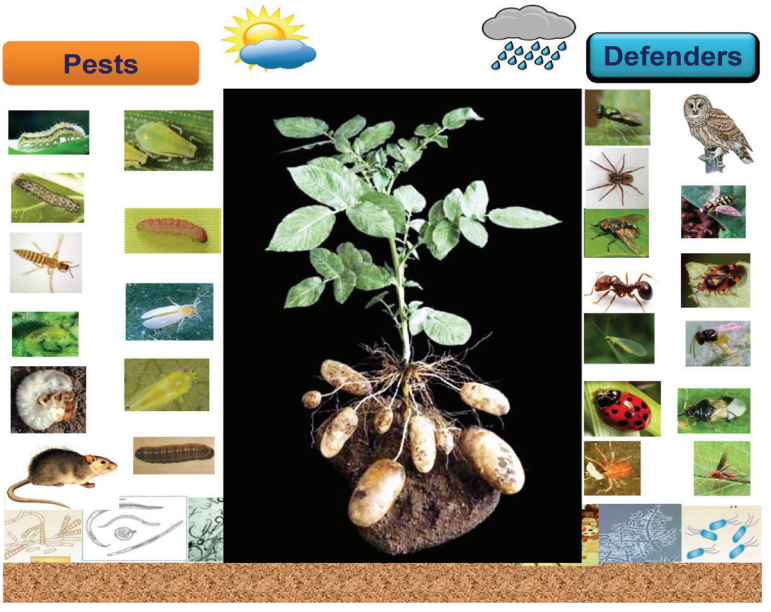
Pest: Defender ratio (P: D ratio):

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

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.

Model Agro-Ecosystem Analysis Chart

Date:
Village:
Farmer:



Decision taken based on the analysis of field situations

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

Decision making:

Farmers become experts in crop management:

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

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

AESA methodology:

- Go to the field in groups (about 5 farmers per group). Walk across the field and choose 20 plants/acre randomly. Observe keenly each of these plants and record your observations:
    - Plant: Observe the plant length, number of leaves, crop stage, deficiency symptoms, no of pods etc.

- Insect pests: Observe and count insect pests at different places on the plant.
- Defenders (natural enemies): Observe and count parasitoids and predators.
- Diseases: Observe leaves and stems and identify any visible disease symptoms and severity.
- Rat: Count the number of plants affected by rats.
- Weeds: Observe weeds in the field and their intensity.
- Water: Observe the water situation of the field.
- Weather: Observe the weather conditions.

- While walking in the field, manually collect insects in plastic bags. Use a sweep net to collect additional insects. Collect plant parts with disease symptoms.
- Find a shady place to sit as a group in a small circle for drawing and discussion.
- If needed, kill the insects with some chloroform (if available) on a piece of cotton.
- Each group will first identify the pests, defenders and diseases collected.
- Each group will then analyze the field situation in detail and present their observations and analysis in a drawing (the AESA drawing).
- Each drawing will show a plant representing the field situation. The weather conditions, 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):** Lenght of plant; Number of leaves
- **Crop situation (e.g. for AESA):** Plant health; pests, diseases, weeds; natural enemies; soil conditions; irrigation; weather conditions
- **Input costs:** Seeds; fertilizer; pesticides; labour
- **Harvest:** Yield (Kg/acre); Price of produce (Rs/Kg)

Some questions that can be used during the discussion:

- Summarize the present situation of the field.
- Is there a big change in crop situation compared to last visit? What kind of change?
- Is there any serious pest or disease outbreak?

- What is the situation of the beneficial insects?
- Is there a balance in the field between pests and defenders?
- Were you able to identify all pests and diseases?
- Do you think the crop is healthy?
- What management practices are needed at this moment?
- When will it be done? Who will do it? Make sure that responsibilities for all activities are being discussed.
- Are you expecting any problems to emerge during the coming week such as congenial weather conditions for pest buildup?
- What are the problems? How can we avoid it? How can we be prepared?
- Summarize the actions to be taken.

Advantages of AESA over ETL:

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

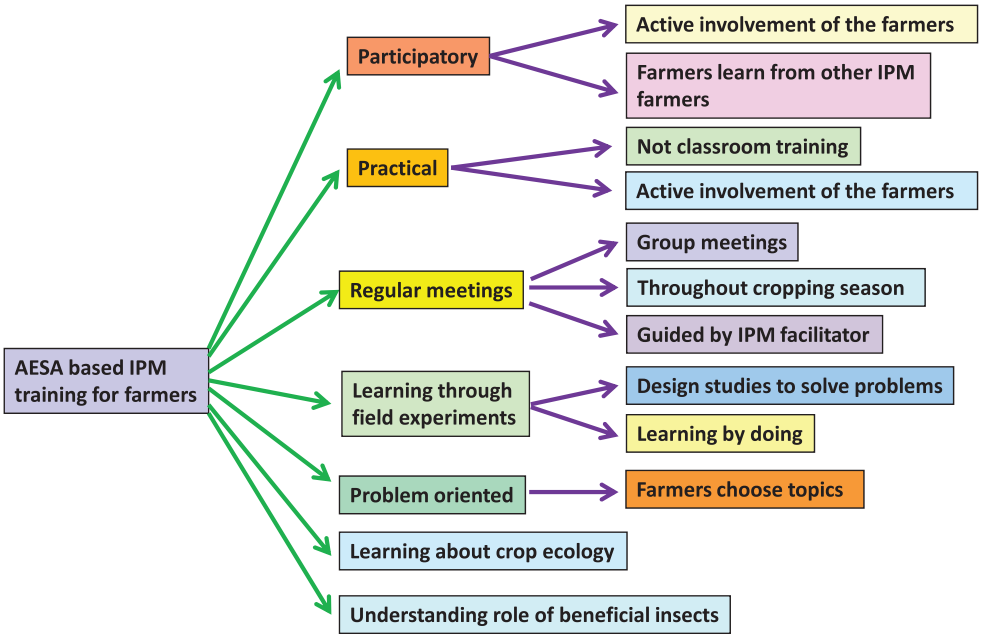
AESA and farmer field school (FFS):

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

Farmers can learn from AESA:

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

FFS to teach AESA based IPM skills:



B. Field scouting:

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

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

For insect pests:

Aphid, jassid, whitefly and mite: Count and record the number of both nymphs and adults on five randomly selected leaves per plant.

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

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

Potato tuber moth, *Spodoptera, Helicoverpa* and cutworm: Total number of fruits, damaged fruits due to potato tuber moth, *Helicoverpa, Spodoptera* and cutworm 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). Always check plants that appear unhealthy. It is often necessary to wash the roots with water to examine them properly. If the roots are well developed, cut into them to examine the roots for internal infections (discolouration & signs). Count the total number of roots damaged/infested/infected due to rotshould be counted and incidence should be recorded.

Leaf sampling: Examine all leaves and or leaflets on each plant for lesions and determine the amount area of leaf infection. Leaf diseases cause most damage during the seedling and flowering stages of plant growth. Observe for the symptoms and signs on the infected plant parts. Count the number of leaves (leaf area diameter)/ plant infected due to disease and incidence should be recorded.

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

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

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

D. Yellow /blue pan water/ sticky traps:

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

E. Light traps:

Set up light 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).

F. Nematode extraction:

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

III. ECOLOGICAL ENGINEERING FOR PEST MANAGEMENT

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

Natural enemies may require:

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

Ecological Engineering for Pest Management – Above Ground:

- Raise the flowering plants / compatible cash crops along the field border by arranging shorter plants towards main crop and taller plants towards the border to attract natural enemies as well as to avoid immigrating pest population
- Grow flowering plants on the internal bunds inside the field
- Not to uproot weed plants those are growing naturally 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 FYM, Vermicompost, crop residue which enhance below ground biodiversity.
- Reduce tillage intensity so that hibernating natural enemies can be saved.
- Apply balanced dose of fertilizers and nutrients.
- Apply mycorrhiza and plant growth promoting rhizobacteria (PGPR)
- Apply *Trichoderma viride/ harzianum* and *Pseudomonas fluorescen* to seed/ seedling/ planting material, nursery, 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 zastrowi sillemi*, earwigs, etc.

Ecological Engineering Plants
Attractant plants

Cowpea

Carrot

Dill


Sunflower


Buckwheat


French bean


Alfalfa


Mustard


Parsley

Repellent plants


Ocimum spp.


Peppermint

Border plants


Sorghum


Maize


Bajra

Intercrops


Maize


Coriander


Onion

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

Biodiversity of natural enemies observed in Ecological Engineering field at NIPHM

Biodiversity of natural enemies: Parasitoids

Biodiversity of natural enemies: Predators

Biodiversity of natural enemies: Spiders

A. Resistant/tolerant varieties*:

Name of variety	Disease/pest
Kufrianand	Moderate resistant to late blight. Immune to wart disease. Tolerant to hopper burn.
Kufriarun Kufrihimalina	Moderate resistant to late blight.
KufriBadshah	Resistant to PVX, early and late blight
Kufrianand	Immune to wart disease; Tolerant to Gemini virus.
Kufrichamatkar	Immune to wart disease; Resistant to early blight and charcoal rot.
Kufrichipsona- 1	Resistant to late blight.
Kufrichipsona- 2 Kufrifrysona	Resistant to late blight; Immune to wart disease.
Kufrichipsona- 3	Resistant to late blight.
Kufrichipsona- 4	Field resistant to late blight.
Kufrifrysona	Field resistant to late blight; Immune to wart disease.
Kufrigaurav	Moderate resistant to late blight; High tolerance to nutrient stress.
Kufrigarima	Moderate resistant to late blight.
Kufrigirdhari	Highly resistant to late blight.
Kufrigiriraj Kufrihimsona Kufrijawahar	Moderate resistant to late blight; Immune to wart disease.
Kufrijeevan	Moderately resistant to early and late blight
Kufrijyoti Kufrikanchan Kufrikashigaro	Moderately resistant to early and late blight; Immune to wart disease.
Kufrikhyati	Field resistant to early and late blight.
Kufrikuber	Resistance to PLRV.
Kufrikumar	Immune to wart disease; Moderate resistant to late blight and charcoal rot.
Kufrikundan	Moderate resistant to late blight and resistance charcoal rot.

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

IV. CROP STAGE-WISE IPM

Management	Activity
Pre sowing*	
	Common cultural practices: • Summer deep ploughing • Soil solarization during summer. • Field sanitation, rogueing. • Avoid water logged conditions in the field. • Follow crop rotation. • Apply manures and fertilizers as per soil test recommendations • Start to grow ecological engineering plants. • Sow/plant 4 rows of maize, sorghum, bajra (pearl millet) around the potato crop field as a guard/barrier crop.
Nutrient	• Apply FYM @ 8 t/acre or vermicom post @ 4-6 t/acre • Apply 2 Kg each of *Azospirillum* and *Phosphobacterium* with 10 Kg FYM /acre as soil application before planting.
Weed	• Stale seed bed technique before sowing. • Destroy all the germinated weeds by shallow ploughing before sowing.
Soil borne pathogens, nematodes and resting stages of insect pests	**Cultural control:** • Give light irrigation and cover the beds with polythene sheet of 45 gauge (0.45 mm) thickness for three weeks before sowing. • Raise African marigold in the nursery 15 days prior to sowing against cyst nematode. • Use raised seed beds of more than 35cm height (for better water drainage). **Biological control:** • Apply neem cake@ 80 Kg/acre.
Sowing*	
	Common cultural practices: • Use resistant/tolerant varieties. • Use healthy, certified and weed seed free tubers.
Nutrients	• Apply 48 Kg nitogen (N), 16 Kg phosphorus (P_2O_5) and 48 Kg potassium (K_2O)/acre. • Apply N and K in two splits; half as basal and half as top dressing at 30 days after sowing.
Plant growth regulator (PGR)	• Dipp cut pieces of tuber (seed) for 10 minutes in chlormequat chloride 50% SL @ 100 ppm solution.
Weeds	• Adopt recommended agronomic practices like field preparation, time of sowing, row and plant spacing, gap filling etc. to obtain the healthy plant stand to reduce the weed menace. • If weed flora of the field is known based on previous season experience the pre-emergence recommended herbicide oxyflourfen 23.5% EC @170-340 ml in 200-300 l water/ acre be applied within 3-4 days after sowing. • When 5-10 % tubers are germinated, application of paraquat dichloride 24 % SL @ 200 gram a.i./acre can be used to control broadleaf, sedges and grassy weeds.

Management	Activity
Resting stage of the diseases, black heart/ scurf	**Cultural control:** • Tubers stored in oxygen deficient structures should not be used. **Chemical control:** • Treat tuber with M.E.M.C. 6% FS @ 0.415 g/ Kg tubers in 100 ml water for 3-5 minute or soaking potato seed tubers in streptocycline 40 to 100 ppm solution for half an hour prior to planting or with carbendazim 25%+ mancozeb 50% WS @ (1.5 + 3.0) to (1.75 + 3.5) for 10 Kg seed (tuber) or with carboxin 37.5% + thiram 37.5% DS@ (1.5 + 3.0) to (1.75 + 3.5) for 10 Kg seed (tuber).
*Apply *Trichoderma viride/harzianum* and *Pseudomonas fluorescens* for treatment of seed tubers 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/ seed/tuber stage	
	Common cultural practices: • Collect and destroy crop debris • Judicious use of fertilizers • Provide irrigation at critical stages of the crop • Avoid water logging • Avoid any stress to the crop as much as possible • Enhance biocontrol activity by avoiding chemical spray, when 1-2 natural enemies are observed. **Common mechanical practices:** • Collect and destroy disease infected and insect infested plant parts • Collect and destroy eggs and early stage larvae • Handpick the older larvae during early stages of crop • Use yellow and blue sticky traps @ 4-5 trap/acre • Use light trap @ 1/acre and operate between 6 pm and 10 pm • Install pheromone traps @ 4-5/acre for monitoring adult moths activity (replace the lures with fresh lures after every 2-3 weeks) • Erect bird perches @ 20/acre for encouraging predatory birds such as King crow, common mynah etc. • Set up bonfire during evening hours at 7-8 pm **Common biological practices:** • Conserve natural enemies through ecological engineering • Augmentative release of natural enemies
Bacterial wilt	**Cultural control:** • Use pathogen free tubers. • Disinfect the cutting knife using 1% sodium hypochlorite solution. • Apply lime (dolomite) in the soil as acidic or alkaline soil is not conducive to the bacterial wilt pathogen. **Biological control:** • Apply neem cake @ 80 Kg/acre **Chemical control:** • Two to three sprays of (streptomycin sulphate 9% + tetracylin hydrocloride 1%) SP @ 40 to 50 ppm solution at an interval of 20 days. First spray 30 days after planting.

Management	Activity
Root-knot nematode	**Cultural control:** • Plant crop during the 2nd week of October in autumn and in early January to limit root-knot nematode infestation on tubers. • Grow one row of repellent plants like *Tagetes patula* and *T. erecta* (African marigold) in between 2 or 3 rows of potatoes. **Biological control:** • Apply NSKE 4% and neem cake @ 80 Kg/acre.
White grub / root grub	• Follow common cultural, mechanical and biological practices **Biological control:** • Entomopathogenic nematodes (EPNs) can be sprayed at the rate of 1 billion nematodes per acre, in white grub / root grub infested fields OR • EPN infected cadavers of *Galleria/Corcyra* larvae containing live infective juveniles (IJs) are implanted in soil at plant bases at the rate of four cadavers per plant during May/June and/or September for white grub / root grub control.
Tuber initiation	
Leaf spot complex	• Follow common cultural, mechanical and biological practices
Early blight	• Follow common cultural, mechanical and biological practices **Chemical control:** • Spray aureofungin 46.15% w/v. SP @ 0.005% in 300 l of water/acre or captan 50% WG @ 600 g in 200 l of water/acre (second spray after 5 days interval) or captan 50% WP @ 1 Kg in 300- 400 l of water/acre or captan 75% WP @ 666 g in 400 l of water/acre. (second spray after 8 days interval) or chlorothalonil 75% WP @ 350-500 g 240-320 l of water/acre (second spray after 14 days interval) or copper oxychloride 50% WP @ 1 Kg in 300-400 l of water/acre or mancozeb 35% SC @ 0.5% or 500 g/100 l water 500 l water or as required depending upon crop stage and equipment used or mancozeb 75% WP@ 600-800 g in 300 l of water/acre or hexaconazole 2% SC @ 1.2 l in 200 l of water/acre (second spray after 21 days interval) or kitazin 48% EC @ 0.20% or 200 ml in 200 l of water or propineb 70% WP @ 300 g in 100 l of water or 0.30% as required depending upon crop stage and plant protection equipment used (second spray after 15 days interval) or zineb 75% WP @ 600- 800 g in 300-400 l of water/acre or captan 70% + hexaconazole 5% WP @ 200- 400 g in 200 l of water/acre (second spray after 21 days interval).
Late blight	• Follow common cultural, mechanical and biological practices **Cultural control:** • Use short-duration varieties. • The model specifies that 7 days moving sum of RH > 85% for at least 90 hr coupled with a 7 day moving sum of temperature between 7.2 and 26.6°C for at least 115 hr would predict appearance of late blight within 10 days of satisfying the conditions.

Management	Activity
	Chemical control: • Spray captan 50% WG @ 600 g in 200 l water (second spray after 5 days interval) or captan 50% WP @ 1 Kg in 300- 400 l water/acre or captan 75% WP @ 666 g in 400 l water/acre (second spray after 8 days interval) or chlorothalonil 75% WP @ 350-500 g in 240-320 l of water/acre (second spray after 14 days interval) or copper oxychloride 50% WP @ 1 Kg in 300-400 l of water/acre or copper sulphate 2.62 % SC @ 400 ml in 200 l of water/acre (second spray after 3 days interval) or cyazafamid 34.5% SC @ 80 ml in 200 l water/acre (second spray after 27 days interval) or dimethomorph 50% WP@ 400 g in 300 l water/acre (second spray after 16 days interval) or mancozeb 75% WG @ 400 in 200 l water/acre (second spray after 3-5 days interval) or mancozeb 75% WP@ 600-800 g in 300 l water/acre or hexaconazole 2% SC @ 1.2 l in 200 l water/acre (second spray after 21 days interval) or mandipropamid 23.4% SC @ 0.2 ml/ l in 200-300 l of water/acre (second spray after 40 days interval) or propineb 70% WP @ 300 g in 100 l of water or 0.30% as required depending upon crop stage and plant protection equipment used (second spray after 15 days interval) or zineb 75% WP@ 600- 800 g in 300-400 l of water/acre or captan 70% + hexaconazole 5% WP @ 200- 400 g in 200 l of water/acre (second spray after 21 days interval) or cymoxanil 8% + mancozeb 64% WP @ 600- 800 g in 200-300 l of water/acre (second spray after 10 days interval) or famoxadone 16.6% + cymoxanil 22.1% SC @ 200 ml in 200-300 l of water/acre (second spray after 27 days interval) or fenamidone 10% + mancozeb 50% WDG @ 500- 600 g in 200 l of water/acre (second spray after 30 days interval) or metalaxyl M 4% + mancozeb 64% WP @ 025% 1 Kg/ acre in 200-400 l water (second spray after 24 days interval) or metalaxyl 8% + mancozeb 64% WP @ 025% 1 Kg/ acre in 400 l water (second spray not less than7 weeks) or metiram 55% + pyraclostrobin 5% WG @ 600-700 g in 200 l water/ acre (second spray after 15 days interval) or azoxystrobin 23% SC@200 ml in 200 l of water/acre or treat tuber with carbendazim 25% + mancozeb 50% WS @ (1.5 + 3.0) to (1.75 + 3.5) for 10 Kg seed (tuber).
Leaf curl diseases	• Follow common cultural, mechanical and biological practices **Cultural control:** • Use peppermint repellant plant for whitefly (vector). • Show attractant plant like French bean to attract predatory thrips.
Spider mites**	• Follow common cultural, mechanical and biological practices **Cultural control:** • Grow flowering plants for natural enemies attraction: carrot family, bishop's weed (spider mite destroyer), sunflower family, French bean (predatory mites) etc.
Leaf miner**	• Follow common cultural, mechanical and biological practices
Tobacco caterpillar**	• Follow common cultural, mechanical and biological practices **Cultural control:** • Grow castor as ovipositional trap crop. **Biological control:** • Release egg parasitoid, *Trichogramma pretiosum*@ 20,000/acre/week four times. • Spray NSKE 5% against eggs and first instar larva. • Apply entomopathogenic nematodes (EPNs) @ 2,50,000 infective juveniles of *Steinernema feltiae*/sq mt area.

Management	Activity
Leaf eating caterpillar**	• Follow common cultural, mechanical and biological practices **Biological control:** • Release egg parasitoid *Trichogramma pretiosum* @ 20,000/ acre/week four times. • Spray NSKE 5% against eggs and first instar larva . • Apply entomopathogenic nematodes (EPNs) @ 2,50,000 infective juveniles of *Steinernema feltiae*/sqmt area.
Aphid, thrips and leaf hopper (aphid's transmit potato virus Y (PVY) and potato leaf roll virus (PLRV), whitefly**	• Follow common cultural, mechanical and biological practices **Cultural control:** • Use healthy seed, hot and cold weather cultivation, green manuring, irrigation, fertilizer application. • Plant early bulking and/or maturing cultivars to help seed production programme in areas having short aphid-free periods so that the seed crop may escape the population pressure of aphid vectors. **Biological control:** • Spray NSKE 5%. **Chemical control:** • Apply carbofuran 3% CG @ 6.64 Kg/ acre or oxydemeton–methyl 25% EC @ 0.4 l in 200-400 l of water/acre or thiamethoxam 25% WG @ 40 g in 200 l of water/acre or phorate 10% CG @ 4 Kg/ acre or soil drenching of thiamethoxam 25% WG @ 80 g in 200 l water/ acre for aphid control. • Spray carbofuran 3% CG @1.328 Kg/ acre for controlling leaf hopper • Spray dimethoate 30% EC @ 264 ml in 200- 400 l water/acre for controlling thrips.
Cutworms**	• Follow common cultural, mechanical and biological practices **Cultural control:** • Attracting cutworm larvae using rice bran – heaps of rice bran should be placed in several places in the late afternoon. They can be removed from the rice bran on the next day and destroyed. • Flood field prior to planting - where/whenever possible farmers can consider temporarily flooding fields, particularly on severely infested fields.
Potato wart	• Follow common cultural, mechanical and biological practices **Cultural control:** • Adopt intercropping potato with maize or rotational crops such as bean and radish (reduce population of viable resting spores in soil)
Potato scab	• Follow common cultural, mechanical and biological practices **Cultural control:** • Use healthy tubers and treat the seed tubers with boric acid (3% for 30 minutes) before or after cold storage. • Maintain optimum soil moisture from tuber initiation. • Practice crop rotation with wheat, peas, oats, barley, lupin, soybean, sorghum, bajra and green manures crops. **Chemical control:** • Spray thiram 75% WS @ 25 g/ l water (second spray after 7-10 days interval)

Management	Activity
Vegetative and tuber development stage	
Nutrients	• Apply 2nd half of N & K at 30 days after planting after hoeing / weeding.
Plant growth regulators	• Apply mepiquat chloride 5% AS @ 1.25-1.5 l (mix 200 -300 ml of products in 10 l of water) at 45 days after sowing to restrict the excessive vegetative growth of potato and increasits yield • Apply gibberellic acid 0.001% L @ 180 ml in 450-500 l of water twice at 45 days after sowing and 65 days after sowing or Apply triacontanol 0.05% EC @ 0.50 l in 500-600 l of water twice at 30 and 45 days after sowing to enhance the yield
Weeds	• Hand tool weeding/hoeing along with earthing twice at 30 and 60 days after planting. • Pre-emergence application of oxyflourfen 23.5% EC @170-340 ml in 200-300 l of water/acre • Post-emergence overall/ inter-row application (at 5-10% emergence) of paraquat dichloride 24% SL @ 800 ml in 200 l of water/acre or 2,4-D dimethyl amine salt 58% SL @1.376 l in 160 l of water/acre. • Use mulch on ridges to suppress weed growth such as paddy straw, maize or sorghum stalks or farm refuses. • In hilly regions, used local available materials such as pine needles or leaf litter as mulch for controlling weeds and reduce run off loss and conserving moisture.
Potato tuber moth	• Follow common cultural, mechanical and biological practices **Cultural control:** • Grow intercrops such as cowpea, onion, maize, coriander, urdbean in 1:2 ratio • Rotate the potato crop with a non host cereal, cucurbit, or cruciferous vegetable crop • Grow repellant plants such as ocimum/basil • Use healthy seed, hot and cold weather cultivation, green manuring, irrigation, fertilizer application, storage and adoption of seed plot technique • Plant seed tubers at a depth of 10 cm • The fields should be ridged after 6 to 7 weeks of planting so that the tubers are buried at least 25cm below the soil surface • Timely and adequate irrigations minimize soil cracking and thereby reduce the risk of tuber exposure to potato tuber moth attack or their egg laying • Always keep the tubers underneath the soil surface **Biological control:** • Inundative release of *T. pretiosum* @ 0.4 lakh/acre 4-5 times from flower initiation stage at weekly intervals

Management	Activity
Bacterial diseases, black surf / canker	• Follow common cultural, mechanical and biological practices **Cultural control:** • Soak seed tubers in a solution of trisodium phosphate (90 g/l of water) one day before sowing. The tubers should be thoroughly rinsed and dried in shade.
Potato virus Y, S, X	• Same as in aphid/thrips control.
Bacterial soft rot	• Follow common cultural, mechanical and biological practices **Cultural control:** • Physical damage must be avoided as it encourages post harvest rots.
Harvesting	
Weeds	• Prior to harvesting/ after harvesting left over weeds should be removed before shedding of their seeds to reduce the spread of weeds.
Potato tuber moth	**Cultural control:** • After harvesting, potatoes should be kept in heaps in cool places for another 10-15 days for drying and further curing of skin. Heaps 3-4 meter long, wide at the base and about 1 meter wide at the top are the best. In hills the harvested potatoes are spread in well-ventilated rooms for drying. • Fresh market potatoes should be stored between 5 to 6 °C. Potatoes that are used for making chips should be stored between 7 and 10 °C. • Collection of left over tubers in the field after harvesting • Storage of healthy tubers in moth proof structures
Bacterial soft rot	**Cultural control:** • Physical damage must be avoided as it encourages post-harvest rots. • Before storage curing is effective and non-chemical control method can be done by exposing tubers for 5 days at 15 – 20 °C and 90 - 95% RH.
Black heart	**Cultural control:** • Maintain cold storage at 4 °C or slightly higher. • Maintain proper aeration in the storage.

Note: Pesticides dosages and spray fluid volume are based on high volume sprayer.

** Pests of regional significance

V. RODENT AND NON-RODENT VERTEBRATE PEST MANAGEMENT

Management of rodents:

- Plough the fields to demolish the rodent habitat and maintain weed free fields to reduce alternate source of food and habitat.
- Practice burrow smoking using natural smoking materials in ANGRAU/ NIPHM burrow fumigator for 2-3 min. for each burrow.
- Application of 0.005% bromadiolone in ready to use form (wax blocks) or loose bait in packets near rodent burrows.
- Apply 2% zinc phosphide poison baits when the rodent infestation is very high. Practice pre-baiting incase of zinc phosphide poison baiting.
- Don't apply zinc phosphide poisons more than one time in a crop season as rodents develop bait shyness to this poison.

Management of porcupine and wild boars:

- Fencing around crop fields with local available materials (bamboo etc.) RCC constructions, solar fencing, wood fencing, thread/wire fencing, trenching, bio-fencing etc.
- Dig 2 ft wide and 1½ feet deep trench around the cropped area at a distance 1ft from the crops keeps away the wild boars from the field.
- Plant four rows of safflower, castor plantation, thorny bushes while act as biological fenses.
- Local practices like plantation of jatropha along borders of crop fields, application of bio pesticides/ repellents, at a distance of 10 ft, spraying of egg solution, arrangement of niwar soaked in kerosene (three rows), arrangement of coconut ropes soaked in mixture of sulphur+pig oil (castor oil based repellent) found effective in repelling the animal.

  (These animals are protected under wild life protection act, 1972).

VI. INSECTICIDE RESISTANCE AND ITS MANAGEMENT

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

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

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

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

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

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

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

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

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

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

VII. NUTRITIONAL DEFICIENCIES

Nitrogen: The yellowing in nitrogen deficiency is uniform over the entire leaf including the veins. Recovery of deficient plants to applied nitrogen is immediate (days) and spectacular.Younger leaves turn darker green, older leaves remain yellow. Upward cupping of deficient when severs.

Correction measure: Foliar application of 2% urea thrice at fortnightly interval or soil application of Nitrogen based on soil test recommendation.

Phosphorus: The symptoms first develop on older leaves showing some necrotic spots and plants are dwarfed or stunted. Phosphorus deficient plants develop very slowly. Plants develop a distinct purpling of the stem, petiole and the under sides of the leaves. Plant remains stunted, darker than normal color. Lower leaf surface gray-green. Leaflets roll upward, severely if deficiency is severe.

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

Potassium: Since potassium is very mobile within the plant, symptoms only develop on young and full sized leaves in the case of extreme deficiency. Leaflets become rugose (crinkled). Some of the leaves show marginal necrosis (tip burn), and at a more advanced deficiency status show interveinal necrosis. As the deficiency progresses, most of the interveinal area becomes necrotic, the veins remain green and the leaves tend to curl and crinkle. Leaves take on a scorched appearance with black pigmentation and necrtic (dead tissue) edges.

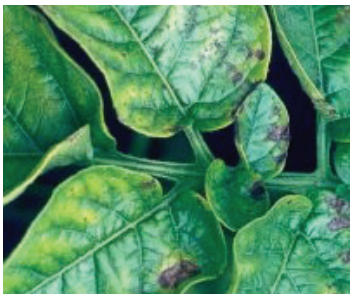
In contrast to nitrogen deficiency, chlorosis is irreversible in potassium deficiency, even if potassium is given to the plants.

Correction measure: Foliar application of K_2SO_4 @1%.

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

Correction measure: Apply gypsum@ 100 Kg /acre in soil and use sulphur containing fertilizers e.g. SSP. Foliar spray of K_2SO_4 or $CaSO_4$ @1% twice at fortnightly interval.

Magnesium: The Mg-deficient leaves show advanced inter veinal chlorosis. Interveinal necrosis causes scorched look. In its advanced form, magnesium deficiency may superficially resemble potassium deficiency. The symptoms generally start with mottled chlorotic areas developing in the interveinal tissue. Symptoms appear first on young mature leaves.



Correction measure: Foliar application of 0.2% $MgSO_4$.

Manganese: The leaves show a light interveinal chlorosis developed under a limited supply of Mn. The early stages of the chlorosis induced by manganese deficiency are somewhat similar to iron deficiency. As the stress increases, the leaves develop dark necrotic areas along the veins. Leave cup upward. Browing spotting ocurs on leaflets, especially along larger veins and mid-ribs.

Correction measure:: Spray 0.2 % manganese sulphate 2-3 times at weekly intervals.

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

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

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

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

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

Correction measure: Foliar spray of borax @ 0.2%.

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

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

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

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

Iron: The iron-deficient leaves show strong chlorosis at the base of the leaves with some green netting. The most common symptom for iron deficiency starts out as an interveinal chlorosis of the youngest leaves, evolves into an overall chlorosis, and ends as a totally bleached leaf. Because iron has a low mobility, iron deficiency symptoms appear first on the youngest leaves. Iron deficiency is strongly associated with calcareous soils, anaerobic conditions, and it is often induced by an excess of heavy metals.Growing point and young leaves become yellow or in extreme cases, white. Usually not accompanied by necrosis. Veins and leaflet ends remain green.

Correction measure: Soil application of 10 Kg/ acre $FeSO_4$ orspray 0.5% ferrous sulphate solution 2-3 times at weekly intervals.

Source: Epstein and Bloom (2004). *Plant Nutrition,* Sinauer Associates, Sunderland, MA. edis.ifas.ufl.edu/; http://agritech.tnau.ac.in/agriculture/agri_min_fldcrops_vegetables.html; http://14.139.61.86/ebook-cpri/k_deff2.jpg; http://www.haifa-group.com/files/Deficiencies/Field_crops/Potatoes/P-def-2.jpg; http://agritech.tnau.ac.in/agriculture/Plant%20Nutrition-Resized/images/Potato-S.jpg; http://www.yara.us/images/399-73091Carousel%20Image%201.jpg; http://www.fielder-nutrition.co.uk/images/potatoes%20nitrogen.jpg

VIII. COMMON WEEDS

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

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

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

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

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

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

7. Barnyard grass:
Echinochloa crusgalli **(L.)**
(Poaceae)

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

9. Flat sedge:
Cyperus iria **L. Beauv.**
(Cyperaceae)

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

11. Scarlet pimpernel
Anagallis arvensis **L.**
(Primulaceae)

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

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

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

15. Goat weed:
Ageratum conyzoides **L.**
(Asteraceae)

16. Broad leaf wood sorrel:
Oxalis latifolia **Kunth.**
(Oxalidaceae)

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

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

19. Horse purslane:
Trianthema portulacastrum **L.**
(Aizoaceae)

20. Onion weed:
Asphodelus tenuifolius **Cav.**
(Liliaceae)

21. Field bindweed:
Convolvulus arvensis **L.**
(Convolvulaceae)

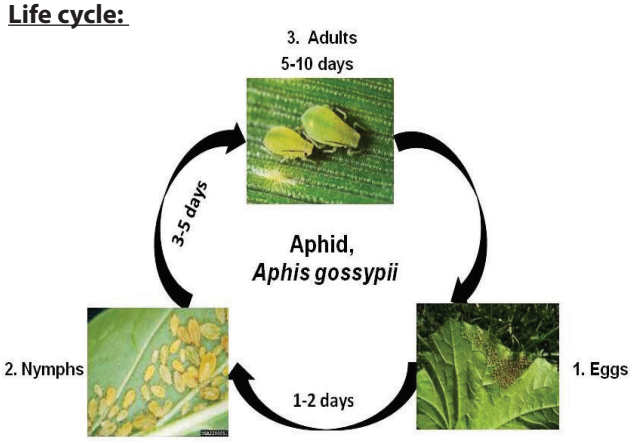
IX. DESCRIPTION OF INSECT, MITE AND NEMATODE PESTS

1) Aphid:

Biology:

- Aphids reproduce in two ways: by laying eggs and giving birth to young ones. Which birth process is used depends on environmental conditions and the availability of food.
- When food is plentiful, aphids give birth to live young. Populations develop quickly as this pest has many young ones, a short lifespan and pre-adult insects can also give birth.
- Eggs hatch after three or four days. Young aphids, called nymphs, need five to eight days to become adults.

Life cycle:



Damage symptoms:

- **Direct damage:** Aphids damage plants by puncturing them and sucking their juices. They damage the young and soft parts of plants, such as new leaves and shoots. Signs of damage are leaves not opening properly and being smaller in size. Severe infestation can cause shoots to wilt and dry out.
- **Indirect damage**: Aphids have wings and can move from plant to plant spreading viral diseases, picked up from infected plants. Aphids secrete a sugary liquid that stimulates black sooty mold growth. It can cover the surface of leaves which affects the way they absorb sunlight.

Favorable conditions:

- A relative humidity of 66 + 2.8% and 11 – 14^{0}C temperature are ideal for development of this aphid.
- Its population sharply decreases with increase in RH over 73 percent.

Natural enemies of aphid:

Parasitoids: *Lysiphlebus* sp, *Diaeretiella* sp., *Aphelinus* sp., *Aphidius colemani* etc.

Predators: Ladybird beetle, lacewing, spider, hover fly etc.

*For management refer to page number 19

2) Leaf miner:

Biology:

It was introduced into India through *Chrysanthemum* cuttings.

Egg: Eggs are laid inside leaves, they are very small and clear in color. Larvae hatch after about 2 - 3 days.

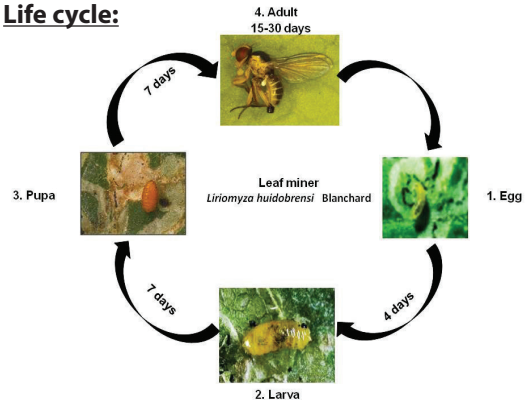
Larva: Larvae remain inside leaves. They are very small and have no legs so cannot move from one leaf to another. The larval stage lasts around 6-12 days. Full grown larvae measure 3 mm.

Pupa: These are formed in the ground or inside leaves. On potato plants, pupae usually fall to the ground. The pupal stage lasts around 14-16 days. Pupation takes place inside a thin loose mesh of silken cocoon.

Adult: These are extremely small at 2-4 mm in length, black in color with two yellow spots on their backs, measuring 1.5 mm in length. They are most active in the morning from 7:00 to 9:00 and in the afternoon from 16:00 to 18:00. Adult flies produce an average of 166 eggs per female. They are attracted to the color yellow. The female fly punctures upper surface of leaf to lay eggs singly. The egg hatches in 4 days.

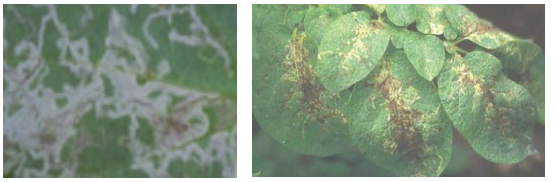
Total life cycle takes 3 weeks. Generally it does not cause economic damage.

Life cycle:



Damage symptoms:

- The leafminer flies damage plants during its larval and adult stages mainly on the lower third of plants.
- Larvae begin eating the insides of leaves immediately after hatching, and bore mines inside them.
- In instances of severe infestation, all that is left of leaves is their upper and lower skins.
- Affected leaves become dry and drop off the plant.
- Adult flies puncture holes in leaves in order to lay eggs and feed on plant juices.



Mining on leaves

Natural enemies of leaf miner:

Parasitoids: *Chrysocharis pentheus* ,

Gronotoma micromorpha, Diglyphus isaea etc.

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

*For management refer to page number 18

3) Whitefly:

Biology:

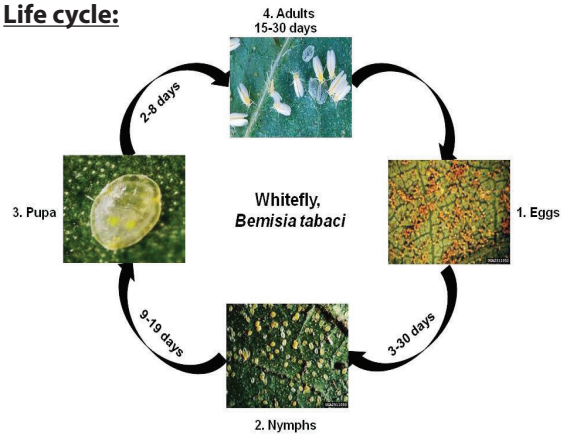
Egg: The female whiteflies lay eggs singly on the underside of the leaves. Eggs are smooth, sub elliptical, stalked, broader at basal end. Its colour is light yellow, when freshly laid, turn dark brown later on. The eggs hatch in 5-17 days.

Stalked nymph: It is louse like, sluggish creature having pale-yellow body. The nymphal stage lasts 14 to 81 days.

Pupa: Convex in shape and possesses deep yellow patches on the abdomen.

Adult: In 2-8 days, the pupae change into white flies. Adult fly is small winged insect having light yellow body of 1.0-1.5 mm length dusted with a white waxy powder. Wings are pure white and have prominent long legs. The life cycle is completed in 14-122 days. Eleven generations of this pest are completed in a year.

Life cycle:



Damage symptoms:

- Chlorotic spots
- Yellowing
- Downward curling and drying of leaves.
- Vector of potato leaf curl disease

Favorable conditions:

The temperature of 28-36 ^{0}C and 62-92% relative humidity and scanty rainfall during August to January are quite favorable for this pest.

Natural enemies of whitefly:

Parasitoid: *Encarsia formosa, Eretmocerus* spp. etc.

Predators : Ladybird beetle, lacewing, spider, hover fly, reduviid bug, robber fly etc.

*For management refer to page number 19

4) Spider mites:

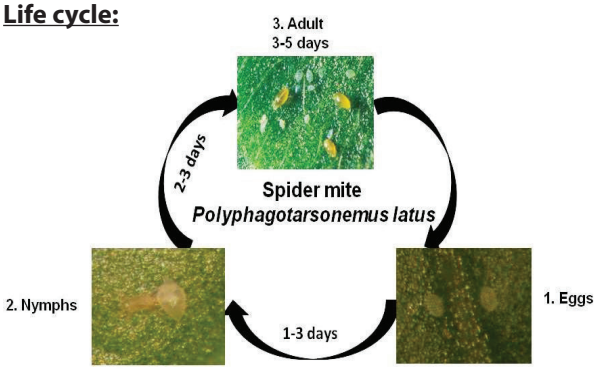
Biology:

Egg: Eggs are hyaline, globular laid in mass

Nymph: Yellowish in colour

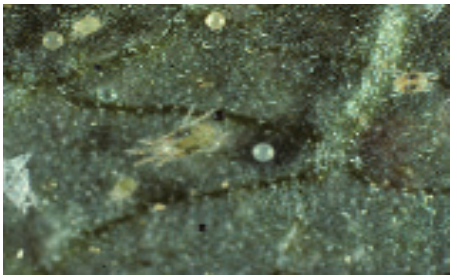
Adult: Red coloured small size

Life cycle:



Damage symptoms:

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



Damage symptoms

Natural enemies of spider mite:

Predators: Predatory mites, predatory thrips, *Oligota* spp., *Orius* spp., anthocorid bugs, hover flies, mirid bug etc.

*For management refer to page number 18

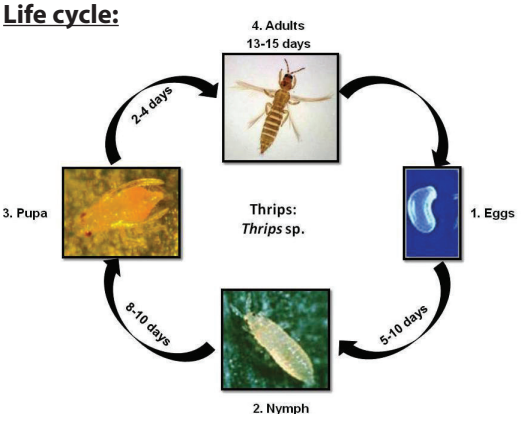
5) Thrips:

Biology:

Thrips are very small, have elongated abdomens and are yellowish or blackish in color. Although the adults have wings, these insect pests do not usually fly. They are often found on potato plants throughout all growth stages, from sprout development to tuber maturation.

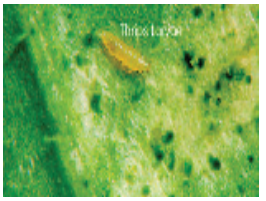
Thrips reproduce by laying eggs. Nymphs emerge from the eggs. It takes between 7 and 12 days to develop from eggs into adult thrips.

Life cycle:



Damage symptoms:

- As with aphids, thrips also cause direct and indirect damage:
- **Direct damage:** Thrips damage the undersides of leaves by sucking their juices. They damage young and soft parts of plants such as new leaves and shoots. As a result, leaves curl downwards and change to a blackish-silver color. Severe infestation causes young leaves to wilt and dry out.
- **Indirect damage:** Thrips can carry and spread viral diseases.



Damage symptoms

Natural enemies of thrips:

Parasitoids: *Ceranisus menes*

Predators: Predatory thrips, minute piratebug, lacewing etc.

*For management refer to page number 19

6) Jassid / leaf hopper:

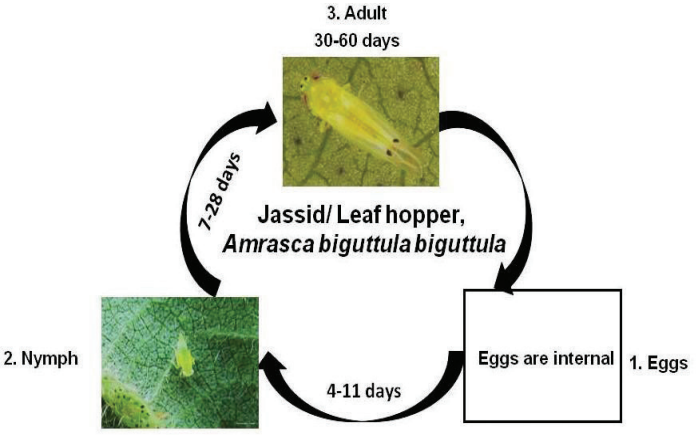
Biology:

Egg: Elongated yellow-white eggs are deposited in leaf vein. It becomes greyish yellow before hatching. The female jassids lay about 15 eggs on the underside of leaves embedding them into leaf veins. The eggs hatch in 4-11 days.

Nymph: Nymphs are pale – green, wedge shaped and their wing pads extend up to the fifth abdominal segment.The nymphal stage is complete in 7-21 days.

Adult: It is a wedge shaped and pale green insect of about 3.5 to 5mm length having a black spot on each transparent forewing. It turns reddish brown during winter. Winged adults live for 35-50 days. This pest completes seven generations in a year.

Life cycle:



Damage symptoms:

Both nymphs and adults of Jassids suck plant sap as a result of their severe attack, the leaves curl; turn pale, bronze and dry up.

Favorable conditions:

Temperature 27 to 36^0 C and relative humidity below 75% favors the multiplication of Jassid.

Leves showing leaf hopper damage

Natural enemies of leaf hopper:

Parasitoids: *Anagrus flaveolus, Stethynium triclavatum* etc.

Predators: Lacewing, red ant, mirid bug, big-eyed bug, ladybird beetle etc.

*For management refer to page number 19

7) Potato tuber moth:

Biology:

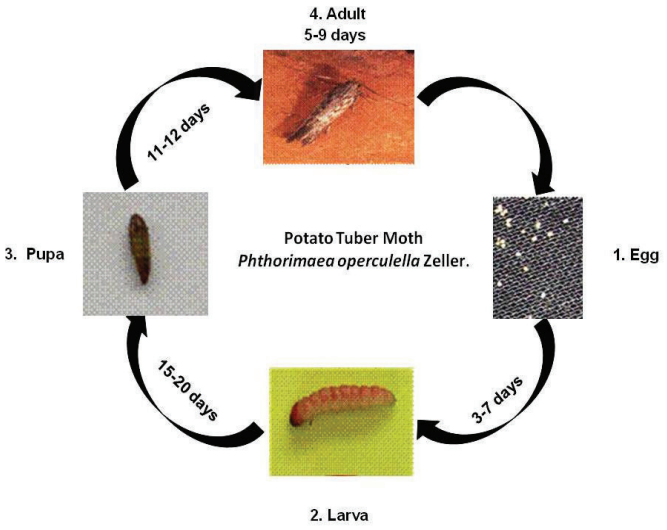
Eggs: The eggs are oval and measure less than 1mm in diameter. The female moth lays eggs on the underside of leaves or on exposed tubers near the eye. Each female can lay 150-200 eggs. Incubation period is 3-7 days.

Larva: Newly emerged larvae are gray, yellowish white with brown head. Larval period is 15-20 days.

Pupa: Full grown caterpillars come out of the tubers/ foliage and pupate in silken cocoons either in dried leaves, soils, over the stored tubers or in cracks and crevices in the store. Pupal period lasts for 11-12 days.

Adult: It is a small grayish brown moth. Total life cycle is completed in 20-30 days at optimum conditions of 22-28 ºC temperature and 60-70% relative humidity. There are 8-9 overlapping generations in a year.

Life cycle:



http://14.139.61.86/ebook_potato_pest/storage_pest_ptm_files/image008.gif

Damage symptoms:

- Potato tuber moths affect both tubers and foliage.
- Larvae eat their way inside tubers either in the field or the storage area.
- Severe infestation generally occurs in storage causing irregular galleries and 'tunnels' deep inside the tube.
- Larvae feces can be seen near bore holes.
- On foliage, larvae attack the stems and leaves of potato plants.
- They enter leaves, eat the inside and leave only a dried up outer skin.
- Severe infestation occurs in same areas, but yield loss is generally limited.

http://14.139.61.86/ebook_potato_pest/storage_pest_ptm.

Potato infested by potato tuber moth

Natural enemies of potato tuber moth:

Parasitoids: *Chelonus blackburni*, *Copidosoma koehleri*, *Trichogramma* spp., *Apanteles* sp., *Pristomerus vulnerator* etc.

Predators: Lacewing, red ant, ladybird beetle, spider, robber fly, dragonfly etc.

*For management refer to page numbers 20, 21

8) Potato cutworm:

Biology:

Cutworms damage potato plants, and affect almost all types of plants including weeds. Cutworms reproduce by laying eggs. Their life cycle includes eggs, larvae, pupae and moths. It takes up to 36 days for them to develop from eggs to adult insects. The various stages display the following characteristics:

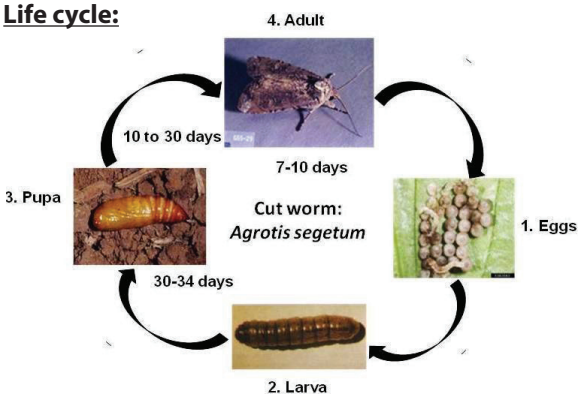
Egg: Eggs are creamy white, dome-shaped laid on the surface of the soil, but are very difficult to see. Each female moths come out at dusk and lay eggs (200-350) in clusters of about 30 each, either on the under surface of the leaves of host plants or in the soil.

Larva: Newly emerged young larva is yellow or blackish- green in colour, 1.5 mm long with a shiny, black head and a black shield on the prothorax. The full-grown larva is about 42-45 mm long and is dark or dark brown with a plump and greasy body and lives in the soil. They have striped markings running down the sides of their bodies. The larval stage varies from 30-34 days,

Pupa: Pupae are brown to dark brown, about 1.5 to 2.0 cm in length and are usually found in or on piles of leaf mould. Pupation takes place underground in an earthen chamber is completed in 10 to 30 days

Adult: It measures about 25 mm from the head to the tip of the abdomen and looks dark with some grayish patches on the back and dark streaks on the forewings. Adults live for 7-10 days. The moths usually emerge at night. The life cycle is completed in 48 to 77 days. This pest generally completes three generations in a year.

Life cycle:



Damage symptoms:

- These pests damage plants and tubers during dark.
- They attack young plants by severing their stems, pulling all parts of the plant into the ground and devouring them.
- Plants with severed stems have difficulty growing again.
- This pest can cause serious damage; particularly when crops are at 25 – 35 days after planting. Signs of damage on tubers are boreholes larger than those made by potato tuber moths.

Tubers and leaf showing damage symptoms

Favorable conditions:

- Persistent dry weather with lesser or no rainfall, reduced humidity & 16 - 23 ^{O}C temperature favor the development of cutworm

Natural enemies of cutworm:

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

Predators: Lacewing, ladybird beetle, spider, red ant, dragonfly, robber fly, reduviid bug, praying mantis, King crow etc.

*For management refer to page number 19

9) Tobacco caterpillar:

Biology:

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

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

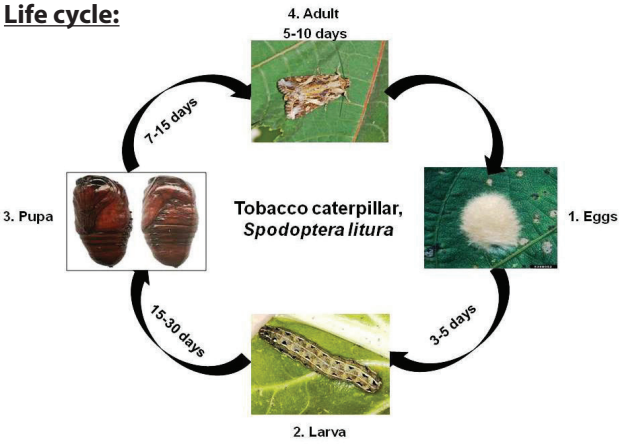
Egg: Female lays about 300 eggs in clusters. The eggs are covered over by brown hairs and they hatch in about 3-5 days.

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

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

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

Life cycle:



Damage symptoms:

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

Bored fruits with irregular holes

Favorable conditions:

- Maximum *S. litura* built up at temperature ranges from 26 to 35.1°C, relative humidity ranges from 89 and 62%, zero rainfall, total sunshine hours (64.6 hrs/week).
- *S. litura* population showes a positive correlation with relative humidity, sunshine hours, whereas negatively correlated with wind velocity.

Natural enemeis of tobacco caterpillar:

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

Predators: Lacewing, ladybird beetle, spider, red ant, dragon fly, robber fly, reduviid bug, praying mantis, King crow etc.

*For management refer to page number 18

10) Leaf eating caterpillar / gram pod borer:

Biology:

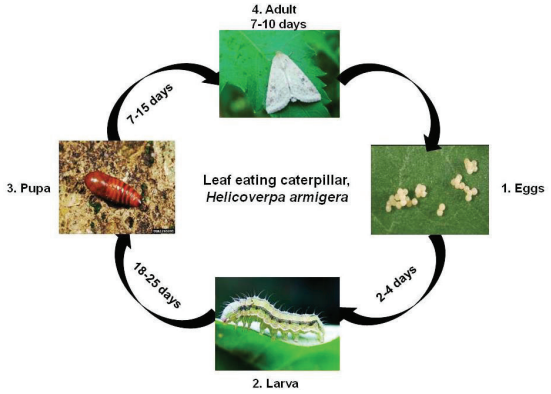
Egg: The spherical, yellowish eggs are laid singly on tender parts and buds of plants. The egg period lasts for 2-4 days.

Larva: Caterpillars vary in colour, initially brown and later turn greenish with darker broken lines along the side of the body. The larval period lasts for 18-25 days. Body covered with radiating hairs. When full grown, they measure 3.7 to 5 cm in length. The full grown caterpillar pupates in the soil in an earthen cell and emerges in 16-21 days.

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

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

Life cycle:



Damage symptoms:

- Young larva feeds on the leaves.
- Feed on leaves, shoots and buds.

Natural enemeis of leaf eating caterpillars / gram pod borer:

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

Predators: Lacewing, ladybird beetle, spider, red ant, dragonfly, robber fly, reduviid bug, praying mantis, King crow etc.

*For management refer to page number 19

11) White grub / root grub:

Biology:

White grubs are the larval form of beetles. The length of the life cycle varies from 1–4 years, depending on the species.

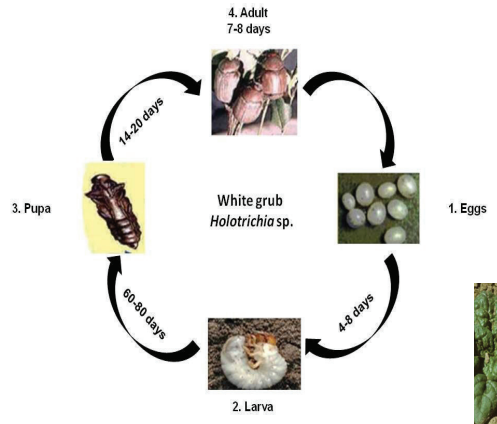
Egg: This insect develops by laying eggs. Females lay 50–100 eggs individually or in groups in small cells composed of soil particles glued together with a sticky substance secreted by the beetle. Eggs hatch in 1 to several weeks, and grubs feed on roots of plants until cold weather when they move down 10– 12 inches below the soil surface to spend the winter.

Larva: They are large reaching 2-3 cm in length, are shaped like the letter C, and have three pairs of legs on their thorax. Their heads are hard and ruddy-brown in color, and they have strong mandibles. White grubs develop for up to seven months.

Pupa: After 7 months the larva have a rest period of 40 days after which they pupate and remain in that form for two months.

Adult: Pupa overwinter deep in the soil for five to 10 months and become active again as the ground warms up in the spring then they pupate and transform into adults.

Life cycle:



Damage symptoms:

- The grubs initially feed on rootlets/roots and then on tubers.
- The first stage grubs feed on live roots while the second and third instar grubs make large, shallow and circular holes in the tuber
- Tubers damaged by white grubs have irregular holes. More than two holes are often found in one tuber. These holes are not so deep, as white grubs do not enter and live.

Root grub damaged seedlings and tubers

*For management refer to page number 17

12) Root-knot nematode & cyst nematode:

Cyst nematode:

- One life cycle of the golden cyst nematode is completed with each crop.
- Between crops, eggs survive within cysts in the soil. When a potato plant is growing, substances exuded by the roots stimulate the eggs to hatch.
- Each egg contains a second-stage juvenile which hatches, moves from the cyst into the soil and penetrates a host root just behind the root-tip.
- The juvenile establishes a permanent feeding site in the root and develops to become an adult. Adult stage, males leave the root and move through the soil to find females.
- Females remain in the root, expanding and eventually rupturing it, remaining attached by the head and neck only.
- After fertilization, the female produces 300 to 500 eggs which it retains within her body. The female dies with the root, but her skin hardens and turns brown while forming a protective cyst for the eggs.

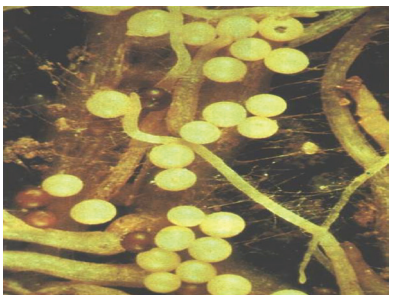
Damage symptoms:

A. Root-knot nematode:

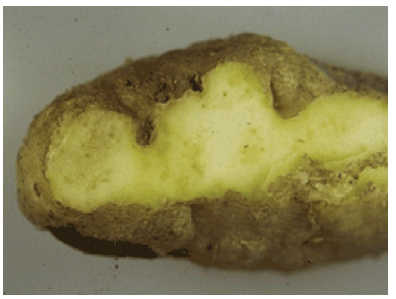
- *Swelling of roots* – Nematodes damage and live in the roots of potato plants, causing them to swell. Swollen roots cannot function normally and affect growth of the plant above them. In hot conditions, plants damaged by nematodes will show wilting.
- *Irregular tuber shape* – Tubers change shape and lumps appear on their surfaces.Heavily infested plants are stunted and exhibit early maturity. Reduction in size and number of tubers reduces the yield and warty 'pimple-like' outgrowths formed on tubers result in qualitative reduction.

B. Cyst nematode:

- Small patches of poorly growing plants appear in the field. Such plants show temporary wilting, stunting and premature yellowing symptoms. The size and number of tuber is reduced. Small mustard seed size yellow or white female nematodes are seen sticking to the roots.



Cyst nematode



Root-knot nematode

Survival and spread:

Primary: Cysts and egg masses in infected plant debris and soil or collateral and other hosts like Solonaceous, Malvaceous and Leguminaceous plants act as sources of inoculum

Secondary: Autonomous second stage juveniles that may also be water dispersed

*For management refer to page numbers 15, 17

Natural Enemies of Potato Insect and Mite pests

Parasitoids

Egg parasitoids

1. *Anagrus flaveolus*

2. *Stethynium triclavatum*

3. *Trichogramma* spp.

4. *Tetrastichus* spp.

5. *Telenomus* spp.

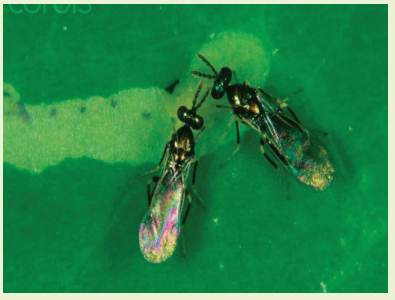
Egg-larval parasitoids

6. *Chelonus blackburni*

7. *Copidosoma koehleri*

Larval parasitoids

8. *Chrysocharis pentheus*



9. *Diglyphus isaea*

10. *Apanteles* spp.

11. *Pristomerus vulnerator*

12. Bracon spp.

13. Ichneumon spp.

14. *Campoletis* spp.

Larval pupal parasitoids

15. *Cercelia* spp.

16. *Gronotoma micromorpha*

Nymphal and adult parasitoids

17. *Lysiphlebus* sp

18. *Diaeretiella* sp

19. *Aphelinus* sp

20. *Aphidius colemani*

21. *Encarsia formosa*

22. *Eretmocerus* spp.

1. http://www.plantwise.org/default.aspx?site=234&page=4279&dsID=5090; 2. http://www.nbaii.res.in/IndianMymaridae/Mymaridae/html/Mymaridae/Stethynium_Enock.htm; 4. http://www.pbase.com/image/135529248; 5. http://baba-insects.blogspot.in/2012/02/telenomus.html; 8. http://1.bp.blogspot.com/kgNmlowdsO8/T9sZZsgOdRI/AAAAAAAAFNM/ldPwsclxwMM/s1600/Chrysocharis_pentheus02_01.jpg; 9. http://www.ento.csiro.au/science/Liriomyza_ver3/key/Eucoilidae_Key/Media/Html/gronotoma_400.jpg; 10. http://nathistoc.bio.uci.edu/hymenopt/Apanteles.jpg; 11. http://delta-intkey.com/britin/images/bent1201.jpg; 12. http://www.nbaii.res.in/Featured%20insects/Bracon%20brevicornis.htm; 13. http://www.organicgardeninfo.com/ichneumon-wasp.html; 14. http://www.nbaii.res.in/Featured%20insects/Campoletis.htm; 15. http://72.44.83.99/forum/viewthread.php?thread_id=40633&pid=178398; 16. http://www.corbisimages.com/eimage/Corbis-42-29388041.jpg?size=67&uid=2e721bad-ef13-4d8c-bbb2-333ece17713a; 17. http://www.nuetzlinge.de/uploads/pics/lysiphlebus_Aphis_gossypii.jpg; 18. http://www.nbaii.res.in/Featured%20insects/diaeretiella4.jpg; 19. http://australianmuseum.net.au/Uploads/Images/23077/Pro%20019_big.jpg; 20. http://www.goodbugs.org.au/Good%20bugs%20available/Resources/aphidius254a.jpeg; 21. http://www.buglogical.com/whitefly-control/encarsia-formosa/; 22. http://www.dongbufarmceres.com/main/mboard.asp?strBoardID=c_product01_en

Predators

1. Lacewing

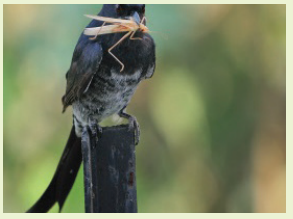
2. Ladybird beetle

3. Reduviid bug

4. Spider

5. Robber fly

6. Red ant



7. Black drongo

8. Common mynah

9. Big-eyed bug

10. Earwig

11. Ground beetle

12. Pentatomid bug


13. Preying mantis

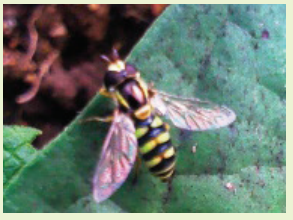

14. *Dicyphus hesperus*


15. Predatory mite


16. Predatory thrips


17. *Oligota* spp.


18. *Orius* spp.


19. Hover fly


20. Mirid bug

5.http://www.warpedphotosblog.com/robber-fly-and-prey;6.http://www.couriermail.com.au/news/queensland/queensland-launched-a-war-against-the-fire-ant-invasion-but-12-years-later-they8217re-still-on-the-march/story-fnihsrf2-1226686256021; 7.http://nagpurbirds.org/blackdrongo/picture/1639;8.http://nickdobbs65.wordpress.com/tag/herbie-the-love-bug/;9. http://bugguide.net/node/view/598529;10.http://www.flickr.com/photos/johnhallmen/2901162091/;11.http://www.mattcolephotography.co.uk/Galleries/insects/Bugs%20&%20Beetles/slides/Ground%20Beetle%20-%20Pterostichus%20madidus.html;12.http://www.ndsu.nodak.edu/ndsu/rider/Pentatomoidea/Genus_Asopinae/Eocanthecona.htm;13.http://spirit-animals.com/praying-mantis/; 14. http://nathistoc.bio.uci.edu/hemipt/Dicyphus.htm; 15. http://www.dragonfli.co.uk/natural-pest-control/natural-enemies;16.http://biocontrol.ucr.edu/hoddle/persea_mite.html; 17. http://www.fugleognatur.dk/forum/show_message.asp?MessageID=560188&ForumID=33;18.http://en.wikipedia.org/wiki/File:Orius_insidiosus_from_USDA_2_(cropped).jpg; 19. http://freepages.misc.rootsweb.ancestry.com/~larsonmorgan/flies/flies.html;20.http://www.britishbugs.org.uk/heteroptera/Miridae/blepharidopterus_angulatus.html

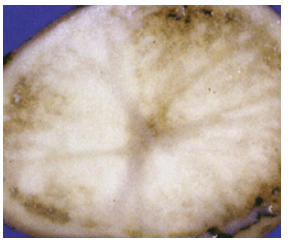
X. DESCRIPTION OF DISEASES

1) Bacterial wilt:

Disease symptoms:

- In addition to the potato, the pathogen also damages plants such as chili, tomato, tobacco and egg plant, as well as several species of weeds.
- The symptoms of bacterial wilt infection can be seen on all parts of infected plants.
- Infected plant begins to wilt, starting from the tips of the leaves or where the stems branch out, and then spreading to all parts of the plant.
- Leaves become yellow at their bases, then the whole plant wilts and dies. When stems are cut a brown colored ring will be visible.
- When a tuber is cut in half, black or brown rings will, however, be visible. If left for a while or squeezed, these rings will exude a thick white fluid.
- A further symptom is fluid coming out of tuber eyes. This can be signified by soil sticking to tuber eyes when crops are harvested. Serious infection causes tubers to rot.


Plant showing wilting symptoms


Tuber showing wilting symptoms

Survival and spread:

- Bacterial wilt pathogen can survive in soil (without a host for several seasons), water, seed tubers, potato plant remnants.
- The disease can spread from field to field or from plant to plant within field via infected seed, air, water, soil, farming tools, livestock and people.

Favourable conditions:

- High temperature, soil moisture, low pH.
- The disease spread rapidly in the warmer temperatures in storage areas. Infected seed can also be a source of the disease in the field.

*For management refer to page numbers 16, 17

2) *Septoria* leaf spot:

Disease symptoms:

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

Leaves showing disease symptoms

Survival and spread:

- **Primary**: Mycelium or conidia found in pycnidia in infected plant debris or on solanaceous weeds
- **Secondary**: Conidia spread through rain splash or wind and also by slimy conidia sticking on to hands and clothing of potato pickers.

Favourable conditions:

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

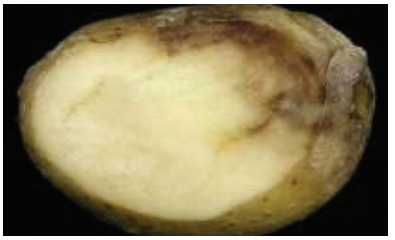
*For management refer to page number 17

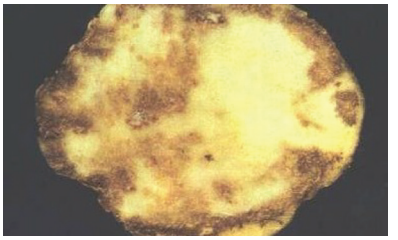
3) Late blight:

Disease symptoms:

- This disease damages leaves, stems and tubers. Affected leaves appear blistered as if scalded by hot water and eventually rot and dry out.
- When drying out, leaves turn brown or black in color. When infections are still active, spots appear on the underside of leaves blanketed in what looks like flour.
- Affected stems begin to blacken from their tips, and eventually dry out.
- Severe infections cause all foliage to rot, dry out and fall to the ground, stems to dry out and plants to die.
- Affected tubers display dry brown-colored spots on their skins and flesh. This disease acts very quickly. If it is not controlled, infected plants will die within two or three days.

Leaves showing disease symptoms





Tubers showing disease symptoms

Survival and spread:

- The pathogen survives in plant debris in the soil.
- It spreads through soil and infected seed tubers.

Favourable condition:

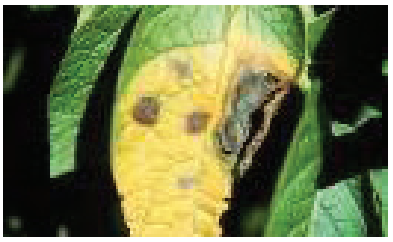
- High humidity
- Low temperature and leaf wetness

*For management refer to page numbers 17, 18

4) Early blight:

Disease symptoms:

- This is a common disease of potato occurring on the foliage at any stage of the growth and causes characteristic leaf spots and blight.
- Normally the disease symptoms become apparent during tuber bulking stage and develop leading to the harvest.
- The early blight is first observed on the plants as small, black lesions mostly on the older foliage.
- Spots enlarge, and by the time they are one-fourth inch in diameter or larger, concentric rings in a bull's eye pattern can be seen in the center of the diseased area.
- Tissue surrounding the spots may turn yellow. If high temperature and humidity occur at this time, much of the foliage is killed.
- Lesions on the stems are similar to those on leaves, sometimes girdling the plant if they occur near the soil line.



Leaves showing disease symptoms

Tuber showing disease symptoms

Survival and spread:

- **Primary:** The pathogen overwinters in infected plant debris in or on the soil where it can survive at least one and perhaps several years. It can also be seed borne.
- **Secondary:** The spores are transported by water, wind, insects, other animals including man, and machinery.

Favourable conditions:

- Warm, rainy and wet weather

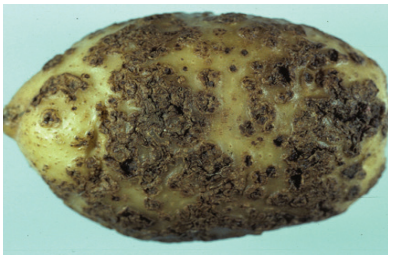
*For management refer to page number 17

5) Common scab:

Disease symptoms:

- Pathogen infects young developing tubers through the lenticels and occasionally through wounds.
- Symptoms of common potato scab are quite variable and are manifested on the surface of the potato tuber. The disease forms several types of cork-like lesions including surface .
- Damaged tubers have rough, cracked skin, with scab-like spots. Severe infections leave potato skins covered with rough black welts.
- Initial infections result in superficial reddish-brown spots on the surface of tubers. As the tubers grow, lesions expand, becoming corky and necrotic.





Tubers showing disease symptoms

http://apps.rhs.org.uk/Advice/ACEImages//SCN0000150_460601.jpg,http://www.potato.org.uk/sites/default/files/styles/media_gallery_large/public/x%20Common%20scab.jpg?itok=Oj3v4__E, http://www.abgenternasyonel.com/images/icerik/potato_scab.jpg

Survival and spread:

- Pathogen can survive in soil, uncomposted manure or seed
- It spreads through contaminated soil, seed and water.

Favourable conditions:

- Disease is common in fields with low soil pH favoured by high soil moisture. Disease problems may be aggravated by excessive irrigation.

*For management refer to page number 19

6) Black scurf/ canker:

Disease symptoms:

- *Rhizoctonia* canker occurs when stolons contact soil borne fungal bodies.
- Pathogen infects plant tissue and causes stolon blinding thus reducing tuber production and yield.
- It also infects tubers causing black scurf but this is purely cosmetic , reduce tuber appearance and does not reduce yield.

Tubers showing disease symptoms

http://www.science.oregonstate.edu/bpp/Plant_Clinic/images/potato,%20rhizoctoniaAPS.jpg

Survival and spread:

- Pathogen is soil and seed borne, remain in soil and plant debris including infected tubers

Favourable conditions:

- High temperature and moisture is the favourable for disease development

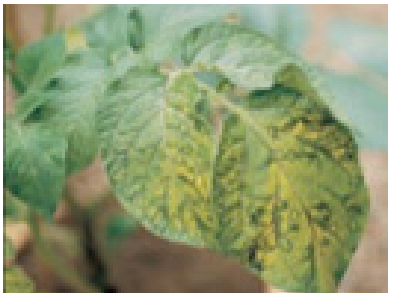
*For management refer to page number 21

7) Viral disease (potato virus X, S, & Y):

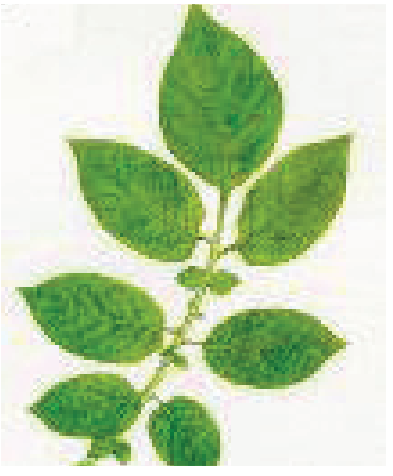
Disease symptoms:

- Potato virus Y (PVY) is a *Potyvirus*, causes stipple streak. The necrotic strain generally causes mild foliage symptoms, but necrosis in the leaves of susceptible potato varieties.
- Potato virus S (PVS) is a *Carlavirus*, if plant infected early in the season, show a slight deepening of the veins, rough leaves, more open growth, mild mottling, bronzing, or tiny necrotic spots on the leaves. PVS is transmitted by aphids non-persistently.
- Potato virus X (PVX) is the type member of the *Potyvirus* family of plant viruses. Plants often do not exhibit symptoms, but the virus can cause symptoms of chlorosis, mosaic, decreased leaf size, and necrotic lesions in tubers.
- PVX can interact with PVY and PVS to cause more severe symptoms and yield loss than either virus alone. The source of this virus is infected tubers.

Tuber showing disease symptoms due to Potato virus Y



Leaves showing disease symptoms due to Potato virus Y



Leaves showing disease symptoms due to Potato virus X

Survival and spread:

- PVY is mechanical and aphid transmitted
- PVS is transmitted by aphids, including *Myzus persicae*, the green peach aphid. It is also mechanically transmissible, and transmissible through tubers.
- PVX is transmitted mechanically, not by an insect vector. Tobacco, pepper, and tomato can also serve as hosts of PVX.

*For management refer to page number s 18, 19

8) Potato Spindle Tuber Viroid (PSTVd):

Disease symptoms:

- It causes mild foliar symptoms including smaller leaves that curl downward, giving the plant a more upright growth habit. Plants can also be stunted, and leaves can be grey and distorted.
- The stems are often more branched, with the branches having sharp angles on the stem.
- Tubers become narrow and spindle or oblong in shape, or more rounded than expected for a particular variety, and have prominent eyebrows.
- Tubers can also become cracked or develop knobs and swellings.


Leaves and tubers showing disease symptoms

1. http://vegetablemdonline.ppath.cornell.edu/Images/Potatoes/PotatoViruses/PotatoVirusfs8.jpg
2. https://www.apsnet.org/edcenter/intropp/lessons/viruses/Article%20Images/PotatoSpindleTuber01b.jpg

Survival and spread:

- The PSTVd often transmitted mechanically, as well as through pollen and true seed.
- PSTVd can also infect tomato and nightshade.

*For management refer to page number

10) Black leg and soft rot:

Disease symptoms:

- Black leg is a rot of the lower stem region. This is encouraged by cool, damp conditions.
- Soft rot occurs when the bacteria gains access to the tuber through wounds & other entry points.
- Symptom can range from cultivator damage to fungal lesions.
- The bacteria dissolve the cell walls and liquefy the tuber invards. No distinct smell is present in true soft rot.

Seedlings and tubers showing disease symptoms

http://www.biology-blog.com/images/blogs/11-2007/potato-blackleg-3810.jpg

Survival and spread:

- The introduction of bacteria is always through a wound in the plant tissue. It can reside in plant residue for short periods. The pathogen may spread through the soil water and infected seed.

Favourable conditions:

- Disease is encouraged by cool, humid conditions.

*For management refer to page number 21

11) Pink rot:

Disease symptoms:

- Foliar symptoms of underground infections include wilting and chlorosis.
- Tubers become infected through diseased stolons and show darkened diseased area on the skin.
- The rotted tissues remain firm and become slightly spongy.
- If the tuber is cut the tissue oxidizes to a pinkish tinge, an easy diagnostic characteristic.



Tubers showing disease symptoms
http://www.ogrin.org/Zitter_Overview_slide_10.gif

Survival and spread:

- Soil and seed borne.

Favourable conditions:

- High soil moisture and cool condition increase disease incidence.

*For management refer to page number 21

12) Black heart- disorder:

Disease symptoms:

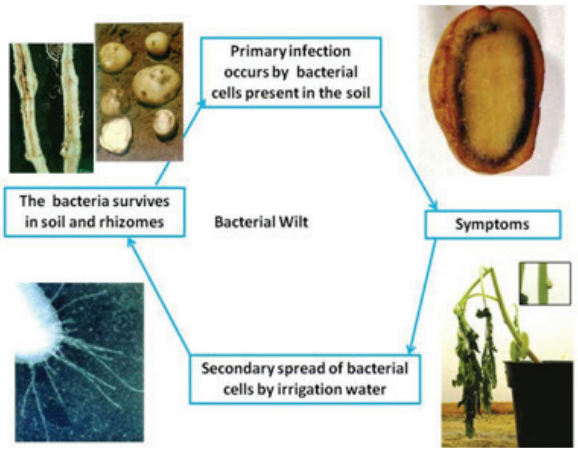
- Black heart occurs primarily in storage when the tubers do not receive enough oxygen.
- Blackening of the tuber center follows acute oxygen deficiency associated with either low temperature in confined storage or high field soil temperatures
- The tissue dies from the inside out and turns jet black. Smell is absent.
- Affected tubers rot later.


Tubers showing disease symptoms
http://www.potatodiseases.org/images/blackheart_thumb.jpg
http://www.potato.org.uk/sites/default/files/BPC%20blackheart%20for%20Bob%20Pringle.jpg

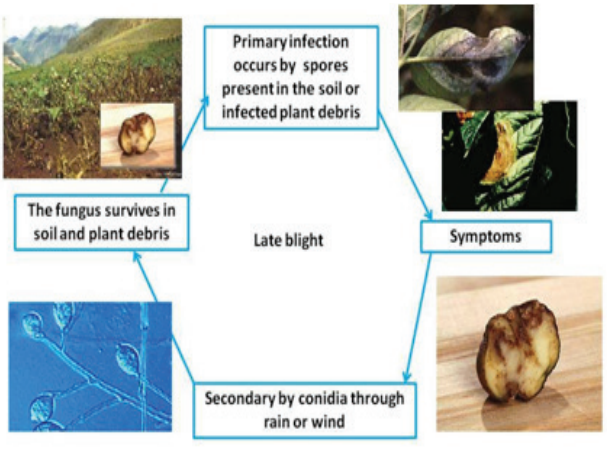
*For management refer to page number 21

Disease cycles:

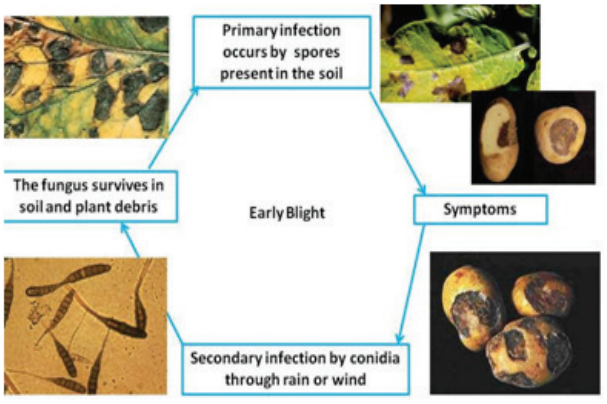
1. Bacterial wilt:



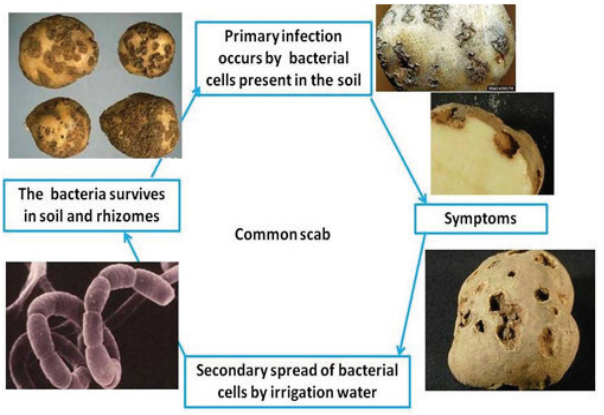
2. Late blight:



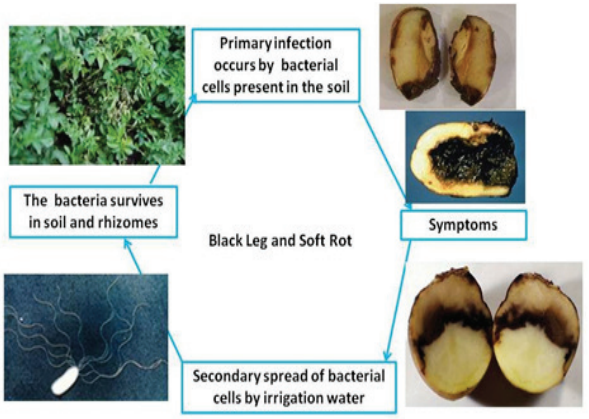
3. Early blight:



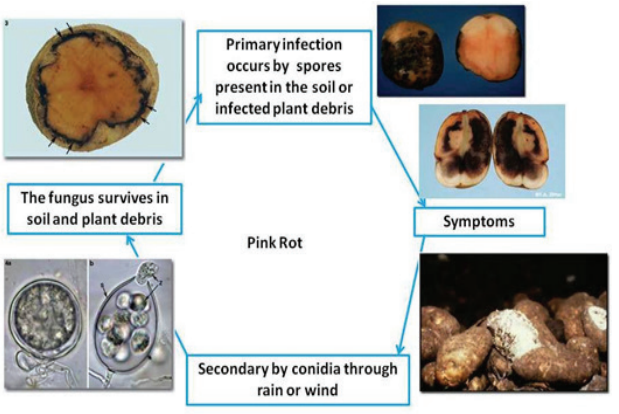
4. Common scab:



5. Black leg and soft rot:



6. Pink rot:



XI. DESCRIPTION OF RODENT AND NON-RODENT VERTEBRATE PESTS

1) Lesser bandicoot:

Distribution and identification:

Distributed throughout India and infests almost all crops. It is a robust rodent (200 to 300 g body weight) with a rounded head and a broad muzzle. Dorsum covered with grey-brownish rough hairs. Tail is naked, shorter than head and body. Breeds throughout the season and litter size 4-8 in normal conditions.

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

Damage symptoms:

- During sowing, the sown seed material (tubers) will be dug out and damaged by the bandicoots
- Mostly damage occurs at tuber formation/ harvesting stage. Bandicoots dig out the tubers by extensive burrowing; the damaged plants wither and dry up.
- Often they hoard and damage the tubers.

*For management refer to page number 22

Tuber damaged by lesser bandicoot

2) Indian creased porcupine:

Distributed throughout the India. Problematic in especially in Himachal Pradesh, Jammu and Kashmir, UP, Bihar and North Eastern region. Characterized by the presence of quills/ spines (modified fur). Tail is covered with short quills. Body weight more than 5-8 Kg.

Damage symptoms : Cause severe damage to young and mature potato crops. They make very extensive burrow and mostly live in the rock cavities near hilly/hillock areas.

*For management refer to page number 22

3) Wild boar:

These animals are widely distributed in the country. Wild boars prefer grasslands, scanty bush jungles, forests and agriculture ecosystems.

Damage symptoms: Wild boars dug the soil for the tubers during sowing and harvesting and cause extensive damage to the crop during these two stages.

*For management refer to page number 22

XII. SAFETY MEASURES

A. At the time of harvest:

Most potatoes are ready for harvest 80 - 115 days after planting. If the potatoes are stored after harvest, the plant should be allowed to mature (die) before harvesting the potatoes. If a plant has not begun the maturation stage on its own, induction of maturation by killing the tops of the plant can be done. Harvesting of the tubers should be done approximately two to three weeks after the plant death. Shallow digging may damage the tubers and limit their storage life. Discard the seed piece--if it is still on the plant at the end of the season--and any green tubers. Harvesting can be done mechanically by cutting the plants at the soil surface with pruning shears or a knife. The top of the potato plant can be discarded. Leave the potatoes buried for two to three weeks after removing the tops so that the tubers can mature. Cover any exposed tubers with soil. The mature tuber has a tough skin that rubbing will not easily remove. A mature tuber will store much longer than an immature tuber.

B. During post-harvest storage:

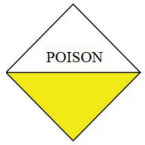
After harvesting, potatoes are kept in heaps in cool places for another l0-15 days for drying and further curing of skin. Maintaining heaps 3-4 metre long, wide at the base and about 1 metre wide at the top are the best. In hills the harvested potatoes are spread in well-ventilated rooms for drying. Before grading, all the cut, damaged and rotted tubers are removed. The tubers are then graded and packed in gunny bags according to sizes preferably in 4 sizes, e.g. small (less than 25g), medium (25-50g), large (50-75g) and extra large (above 75g). After grading potatoes meant for use as seed during the next year are treated with 3% boric acid solution for 30 minutes for protecting against soil-borne pathogens, e.g. black scurf, common scab, etc. before storing in bags.

Keep potatoes in a dark, well-ventilated cool place (60 - 65° F) for t 10 to 14 days after harvest to allow cuts and bruises to heal. They should be moved to a final storage location with a high relative humidity, good aeration, and colder temperature (38 - 40° F). The tubers may sprout at warmer temperatures. So apply chlorpropham 50% HN as antisprouting agent for stocked potatoes under cold storage condition @ 36-40 ml/MT. Be sure to remove any damaged or rotten potatoes prior to placing the crop in long term storage as these will produce a nasty smell and greatly shorten the storage life of the rest of the crop. If you wash the tubers, allow them to dry thoroughly before storing. Under proper conditions, potatoes can be stored for three to six months or more.

XIII. DO'S AND DON'TS IN IPM

S.No.	Do's	Don'ts
1.	Deep ploughing is to be doneon 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 growing monocropping
3.	Grow only recommended varieties	Do not grow varieties not suitable for the season or the region
4.	Sow tubers early in the season	Avoid late plantingas this may lead to reduced yields and incidence of white grubs and diseases
5.	Always treat the seed tubers with approved biopesticides/ chemicals for the control of seed borne diseases/pests	Do not use seed tubers without seed treatment with biopesticides/chemicals
6.	Sow in rows at optimum depthsunder proper moisture conditions for better establishment	Do not sow seed tubersbeyond 5-7 cm depth
7.	Apply only recommended herbicides at recommended dose, proper time, as appropriate spray solution with standard equipment along with flat fan or flat jet nozzles	Pre-emergent as well as soil incorporated herbicides should not be applied in dry soils. Do not apply herbicides along with irrigation water or by mixing with soil, sand or urea
8.	Maintain optimum and healthy crop stand which would be capable of competing with weeds at a critical stage of crop weed competition	Crops should not be exposed to moisture deficit stress at their critical growth stages
9.	Use NPK fertilizers as per thesoil test recommendation	Avoid imbalanced use of fertilizers
10.	Use micronutrient mixture after sowing based test recommendations	Do not apply any micronutrient mixture after sowing without test recommendations
11.	Conduct weekly AESA in the morning preferably before 9 a.m. Take decision on management practice based on AESA and P: D ratio only	Do not take any management decision without considering AESA and P: D ratio
12.	Install pheromone traps at appropriate period	Do not store the pheromone lures at normal room temperature (keep them in refrigerator)
13.	Release parasitoids only afternoticing 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 earlyinstar larvae are noticed. Apply NPV only in the evening hours	Do not apply NPV on late instar larva and during day time
15.	In case of pests which are active during night such as *Spodoptera* spray recommended biopesticides/ chemicals at the time of their appearance in the evening	Do not spray pesticides at midday since, most of the insects are not active during this period
16.	Spray pesticides thoroughly to treat the undersurface of the leaves, particularly for mites,whiteflies, *Spodoptera* etc.	Do not spray pesticides only on the upper surface of leaves
17.	Apply short persistent pesticides to avoid pesticide residue in the soil and produce	Do not apply pesticides during preceding 7 days before harvest
18.	Follow the recommended procedure of trap crop technology	Do not apply long persistent pesticides on trap crop, otherwise it may not attract the pests and natural enemies

XIV. SAFETY PARAMETERS IN PESTICIDE USAGE

S. No.	Pesticide; Classification as per insecticide rules 1971; Colour of toxicity triangle	WHO classification of hazard	Symptoms of poisoning	First aid measures; Treatment of poisoning	Harvesting interval (days)
1.	Carbofuran Extremely toxic 	Class I b Highly azardous	Constriction of pupils, salivation, profuse sweating, muscle incordination, nausea, vomiting,diarrhea, epigastric pain, tightness in chest	**First aid measures:** Rush the victim to the nearest physician. **Treatment of poisoning:** Atropine injection-1-4 mg. repeat 2 mg when symptoms begin to recur (15-16 min interval) excessive salivation- good sign, more atropine needed	--
2.	Phorate Extremely toxic 	Class I b Highly hazardous	-do-	-do-	--
3.	Dimethoate Highly toxic 	Class II Moderately hazardous	Mild-anorexia, headache, dizziness, weakness, anxiety, tremors of tongue and eyelids, miosis, impairment of visual acuity	**First aid measures:** Rush the victim to the nearest physician. **Treatment of poisoning:** For extreme symptoms of OP poisoning, injection of atropine (2-4 mg for adults, 0.5-1.0 mg for children) is recommended. Repeated at 5-10 minute intervals until signs of atropinization occur.	--
4.	Oxydemeton–methyl Moderately toxic 	Class III Slightly hazardous	Headache, palpitation, nausea, vomiting, flushed face, irritation of nose,throat, eyes and skin etc.	**First aid measures:** Rush the victim to the nearest physician. **Treatment of poisoning:** No specific antidote. Treatment is essentially symptomatic	6

5.	Endosulfan Highly toxic 	--	Harmful if swallowed, absorbed through skin or inhaled. Avoid breathing vapor or spray mist. Causes moderate eye irritation.	**First aid measures:** Have person sip a glass of water if able to swallow. Do not induce vomiting unless told to do so by a doctor, do not give anything by mouth to an unconscious Perso **Treatment of poisoning:** No specific antidote. Treatment is essentially symptomatic.	3
6.	Thiamethoxam Moderately toxic 	Class III Slightly hazardous	Headache, palpitation, nausea, vomiting, flushed face, irritation of nose, throat, eyes and skin etc.	**First aid measures:** Rush the victim to the nearest physician. **Treatment of poisoning:** No specific antidote. Treatment is essentially symptomatic	6
7	M.E.M.C. Extremely toxic 	Class I b Highly hazardous	Constriction of pupils, salivation, profuse sweating, muscle incordination, nausea, vomiting, diarrhea, epigastric pain, tightness in chest	**First aid measures:** Rush the victim to the nearest physician. **Treatment of poisoning:** Atropine injection-1-4 mg. repeat 2 mg when symptoms begin to recur (15-16 min interval) excessive salivation- good sign, more atropine needed	--
8	Captan Moderately toxic 	Class III Slightly hazardous	Headache, palpitation, nausea, vomiting, flushed face, irritation of nose,throat, eyes and skin etc.	**First aid measures:** Rush the victim to the nearest physician. **Treatment of poisoning:** No specific antidote. Treatment is essentially symptomatic	6
9	Thiram Moderately toxic 	Class III Slightly hazardous	-do-	-do-	6

10	Propineb Moderately toxic 	Class III Slightly hazardous	-do-	-do-	6
11	Copper sulphate Moderately toxic 	Class III Slightly hazardous	-do-	-do-	6
12	Aureofungin Moderately toxic 	Class III Slightly hazardous	-do-	-do-	6
13	Copper oxychloride Moderately toxic 	Class III Slightly hazardous	-do-	-do-	6
14	Cyazafamid Slightly toxic 	Unlikely to produce acute hazard	-do-	**First aid measures:** Rush the victim to the nearest physician. **Treatment of poisoning:** Treat symptomatically as there is no known specific antidote	10

15	Dimethomorph Slightly toxic 	Unlikely to produce acute hazard	-do-	-do-	10
16	Mandipropamid Slightly toxic 	Unlikely to produce acute hazard	-do-	-do-	10
17	Hexaconazole Slightly toxic 	Unlikely to produce acute hazard	-do-	-do-	10
18	Chlorothalonil Slightly toxic 	Unlikely to produce acute hazard	-do-	-do-	10
19	Zineb Slightly toxic 	Unlikely to produce acute hazard	-do-	-do-	10

20	Mancozeb **Slightly toxic** 	Unlikely to produce acute hazard	-do-	-do-	10
21	Metalaxyl + Mancozeb Moderately toxic 	Class III Slightly hazardous	-do-	**First aid measures:** Rush the victim to the nearest physician. **Treatment of poisoning:** No specific antidote. Treatment is essentially symptomatic	6
22	Streptomycin Sulphate + Tetracylin Hydrocloride **Slightly toxic** 	Unlikely to produce acute hazard	-do-	**First aid measures:** Rush the victim to the nearest physician. **Treatment of poisoning:** Treat symptomatically as there is no known specific antidote	10
23	Captan 70% + Hexaconazole 5% WP Moderately toxic 	Class III Slightly hazardous	-do-	**First aid measures:** Rush the victim to the nearest physician. **Treatment of poisoning:** No specific antidote. Treatment is essentially symptomatic	6

XV. BASIC PRECAUTIONS IN PESTICIDE USAGE

A. Purchase

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

B. Storage

1. Avoid storage of pesticides in house premises.
2. Keep only in original container with intact seal.
3. **Do not** transfer pesticides to other containers; **Do not** store expose to sunlight or rain water; **Do not** weedicides along with other pesticides
4. Never keep them together with food or feed/fodder.
5. Keep away from reach of children and livestock.

C. Handling

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

D. Precautions for preparing spray solution

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

E. Equipments

1. Select right kind of equipment.
2. **Do not** use leaky and defective equipments
3. Select right kind of nozzles
4. Don't blow/clean clogged nozzle with mouth. Use old tooth brush tied with the sprayer and clean with water.
5. **Do not** use same sprayer for weedicide and insecticide.

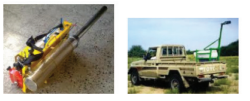
F. Precautions for applying pesticides

1. Apply only at recommended dose and dilution
2. **Do not** apply on hot sunny day or strong windy condition; **Do not** apply just before the rains and after the rains; **Do not** apply against the windy direction
3. Emulsifiable concentrate formulations should not be used for spraying with battery operated ULV sprayer
4. Wash the sprayer and buckets etc with soap water after spraying
5. Containers buckets etc used for mixing pesticides should not be used for domestic purpose
6. Avoid entry of animals and workers in the field immediately after spraying
7. Avoid tank mixing of different pesticides

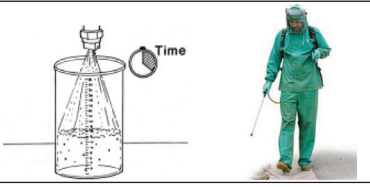
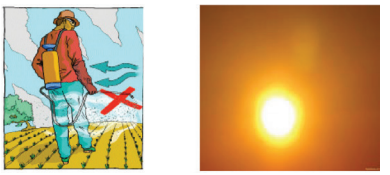
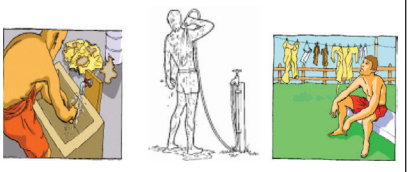
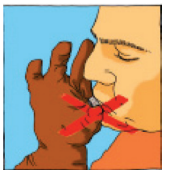
G. Disposal

1. Left over spray solution should not be drained in ponds or water lines etc. throw it in barren isolated area if possible
2. The used/empty containers should be crushed with a stone/stick and buried deep into soil away from water source.
3. Never reuse empty pesticides container for any other purpose.

XVI. 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)	

XVI. OPERATIONAL, CALIBRATION AND MAINTENANCE GUIDELINES IN BRIEF

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

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Ecological Engineering Plants for Potato

Alfalfa

Cowpea

Carrot

Sunflower

Buckwheat

French bean

Mustard

Parsley

Dill

Spearmint

Caraway

Maize

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