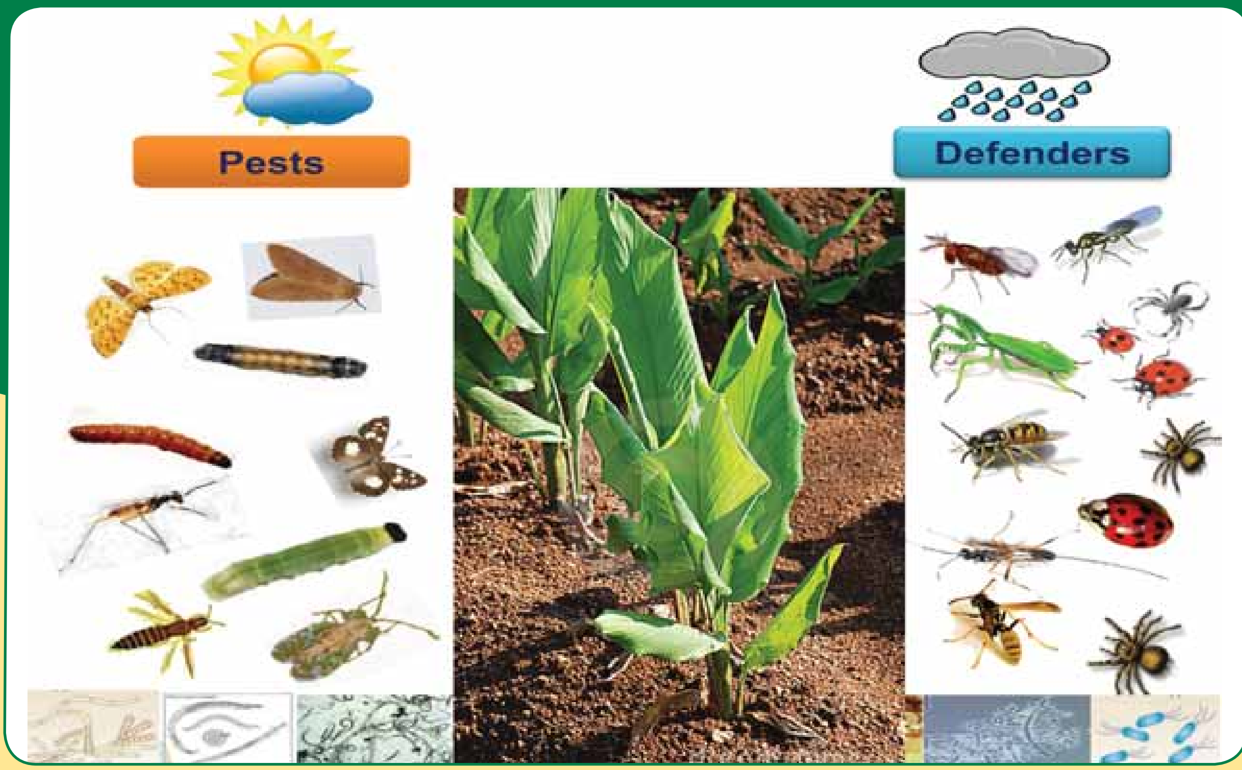
AESA BASED IPM Package

AESA based IPM – Turmeric



राष्ट्रीय वनस्पति स्वास्थ्य प्रबंधन संस्थान
N I P H M

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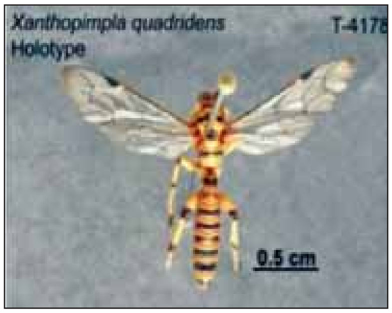
Department of Agriculture and Cooperation
Ministry of Agriculture
Government of India

Important Natural Enemies of Turmeric Insect Pests

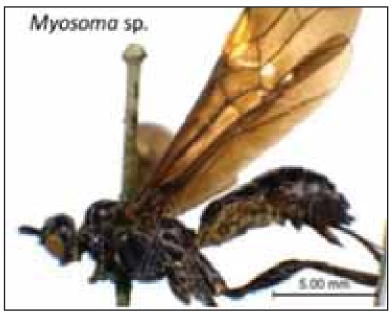
Parasitoids



Xanthopimpla quadridens

***Trichogramma* spp.**

***Bracon* spp.**



***Mysoma* sp**

Ceranisus menes

***Apanteles* sp**

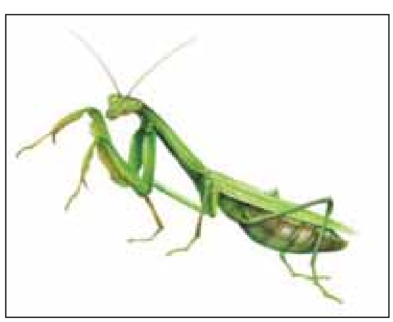
Predators

Lacewing

Ladybird beetle

Spider

Predatory thrips



Praying mantis

Hover fly

The AESA based IPM - Turmeric, 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 turmeric

Back cover picture Turmeric 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.

AK Srivastava

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)

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AESA BASED IPM PACKAGE FOR TURMERIC

Turmeric plant description:

Turmeric (*Curcuma longa* L.; Family: Zingiberaceae) is the boiled, dried, cleaned and polished rhizome. The plant is a herbaceous perennial, 60-90 cm high, with a short stem and tufted leaf. There are 7 to 12 leaves, the leaf sheaths form the pseudo stem. The lamina is green above and pale green below and has a length of 30-40 cm and width 8-12 cm. Inflorescence is a central spike of 10-15 cm length. 1-4 flowers are born in axil of the bract opening one at a time. About 30 flowers are produced in a spike. Seeds are produced in capsules and there will be one to numerous sunken capsules in an inflorescence.

Origin and distribution: It is a native of India. Apart from India, it is cultivated in Pakistan, Malaysia, Myanmar, Vietnam, Thailand, Philippines, Japan, Korea, China, Sri Lanka, Nepal, East & West Africa, South Pacific Islands, Malagasy, Caribbean Islands and Central America. In India, it is cultivated in the States of Andhra Pradesh, Maharashtra, Orissa, Tamil Nadu, Karnataka and Kerala. Turmeric is a tropical crop cultivated from sea level to 1200 meters above MSL. It grows in light black, black clayey loams and red soils in irrigated and rainfed conditions. The crop cannot stand water logging or alkalinity.

Uses: Turmeric is used to flavour and to colour foodstuffs. It is a principal ingredient in curry powder. Turmeric oleoresin is used in brine pickles and to some extent in mayonnaise and relish formulations, non-alcoholic beverages, gelatins, butter and cheese etc. The colour curcumin extracted from turmeric is used as a colourant. Turmeric is also used as a dye in textile industry. It is used in the preparation of medicinal oils, ointments and poultice. It is stomachic, carminative, tonic, blood purifier and an antiseptic. It is used in cosmetics. The aqueous extract has biopesticidal properties.

I. PESTS

A. Pests of National Significance

1. Insect pests

1.1 Shoot borer: *Conogethes punctiferalis* (Guenée) (Lepidoptera: Crambidae)

1.2 Rhizome scale: *Aspidiella hartii* (Cockerell) (Hemiptera: Diaspididae)

2. Diseases

2.1 Rhizome rot: *Pythium graminicolum or P. aphanidermatum* (Edson)

2.2 Leaf spot: *Colletotrichum capsici* Syd.

2.3 Leaf blotch: *Taphrina maculans* E. J. Butler

3. Weeds

3.1 Major *kharif*

Broad leaf

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

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

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

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

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

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

Grassy

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

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

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

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

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

Sedges

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

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

3.2 Major *rabi*

Broad leaf

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

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

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

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

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

Grassy

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

B. Pests of Regional Significance

1. Insect pests

- **1.1 Bihar hairy caterpillar: *Spilosoma obliqua* Walker (Lepidoptera: Arctiidae)**
- **1.2 Rhizome fly: *Mimegralla coeruleifrons* Macquart (Diptera : Micropezidae)**
- **1.3 Leaf roller/Skipper: *Udaspes folus* Cramer (Lepidoptera: Hesperidae)**
- **1.4 White grub: *Holotrichia* spp. (Coleoptera: Scarabaeidae)**
- **1.5 Lacewing bug: *Stephanitis typicus* Distant (Hemiptera: Tingidae)**
- **1.6 Thrips: *Stenchaetothrips indicus* (L.) (Thysanoptera: Thripidae)**
- **1.7 Leaf beetle: *Lema praeusta.* Fab., *L. signatipennis* (Coleoptera: Chrysomelidae)**

2. Diseases

- **2.1 Bacterial wilt: *Ralstonia solanacearum* (C. Martin and E. R.. French)**
- **2.2 Dry rot: *Rhizoctonia bataticola* (Taubenh. and E.J. Butler)**

3. Nematodes

- **3.1 Root-knot nematode : *Meloidogyne* sp**
- **3.2 Burrowing nematode: *Radopholus similis***
- **3.3. Lesion nematode: *Pratylenchus* spp.**

4. Animal and rodent pests

In some areas, rodents damage the turmeric crop by making holes in the turmeric fields. Sometimes, monkeys, buffaloes, wild boar and other grazing animals also destroy the turmeric cultivation by grazing or trampling over it.

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

Observe the field regularly (climatic factors, soil and biotic factors)

Farmers should

- Monitor the field situation at least once a week (soil, water, plants, pests, natural enemies, weather factors etc.)
- Make decisions based on the field situation and P: D ratio
- Take direct action when needed (e.g. collect egg masses, remove infested plants etc.)

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

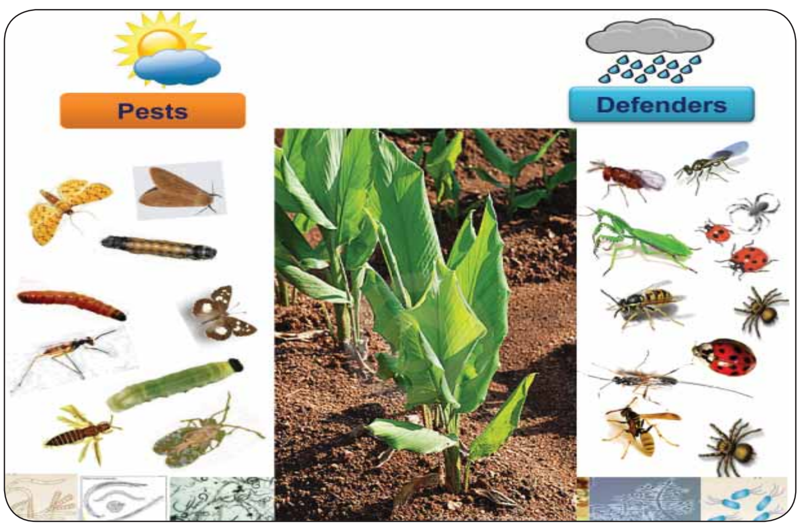
In field various types of insects are present. Some are beneficial and some may be harmful. Generally farmers are not aware about it. Predators (friends of the farmers) which feed on pests are not easy to observe in crop field. Insect zoo concept can be helpful to enhance farmers' skill to identify beneficial 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 turmeric pests can be divided into 3 categories: 1. parasitoids; 2. predators; and 3. pathogens. The important natural enemies of turmeric pests are given in ecological engineering table on page number 14

Model agro-ecosystem analysis chart

Date:
Village:
Farmer:

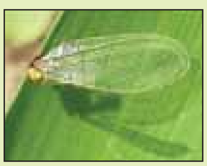


Decision taken based on the analysis of field situation

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

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

Feeding/egg laying potential of different parasitoids/predators

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

Predators/ Parasitoids	Feeding potential/ Egg laying capacity
 Reduviid bug	1st & 2nd nymphal instars can consume 1 small larva/day 3rd & 4th nymphal instars can consume 2 to 3 medium larvae/day 5th nymphal instar & adult can consume 3 to 4 big larvae/day In total life cycle they can consume approx. 250 to 300 larvae
 Predatory mite	Predatory rate of adult is 20-35 phytophagous mites/female/day http://www.eduwebs.org/bugs/predatory_mites.htm
 *Bracon hebetor*	Egg laying capacity is 100-200 eggs/female. 1-8 eggs/larva
 *Trichogramma* sp	Egg laying capacity is 20-200 eggs/female.

Decision making

Farmers become experts in crop management

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

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

AESA methodology

- Go to the field in groups (about 5 farmers per group). Walk across the field and choose 50 beds/acre randomly across the diagonal of the field. Observe keenly each of these plants and record your observations:
    - Plant: Observe the plant height, number of shoots, crop stage, deficiency symptoms etc.
    - Pests: Observe and count pests at different places on the plant.
    - Defenders (natural enemies): Observe and count parasitoids and predators.
    - Diseases: Observe leaves and pseudostems and identify any visible disease symptoms and severity.
    - Rats: Count number of plants affected by rats.
    - Weeds: Observe weeds in the field and their intensity.
    - Water: Observe the water situation of the field.
    - Weather: Observe the weather condition.
- While walking in the field, manually collect insects in plastic bags. Use a sweep net to collect additional insects. Collect plant parts with disease symptoms.
- Find a shady place to sit as a group in a small circle for drawing and discussion.
- If needed, kill the insects with some chloroform (if available) on a piece of cotton.
- Each group will first identify the pests, defenders and diseases collected.
- Each group will then analyze the field situation in detail and present their observations and analysis in a drawing (the AESA drawing).
- Each drawing will show a plant/hill representing the field situation. The weather condition, water level, disease symptoms, etc. will be shown in the drawing. Pest insects will be drawn on one side. Defenders (beneficial insects) will be drawn on another side. Write the number next to each insect. Indicate the plant part where the pests and defenders were found. Try to show the interaction between pests and defenders.
- Each group will discuss the situation and make a crop management recommendation.
- The small groups then join each other and a member of each group will now present their analysis in front of all participants.
- The facilitator will facilitate the discussion by asking guiding questions and makes sure that all participants (also shy or illiterate persons) are actively involved in this process.
- Formulate a common conclusion. The whole group should support the decision on what field management is required in the AESA plot.
- Make sure that the required activities (based on the decision) will be carried out.
- Keep the drawing for comparison purpose in the following weeks.

Data recording

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

Data to be recorded

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

Some questions that can be used during the discussion

- Summarize the present situation of the field?
- What crop management aspect is most important at this moment?
- Is there a big change in crop situation compared to last visit? What kind of change?

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

Advantages of AESA over ETL

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

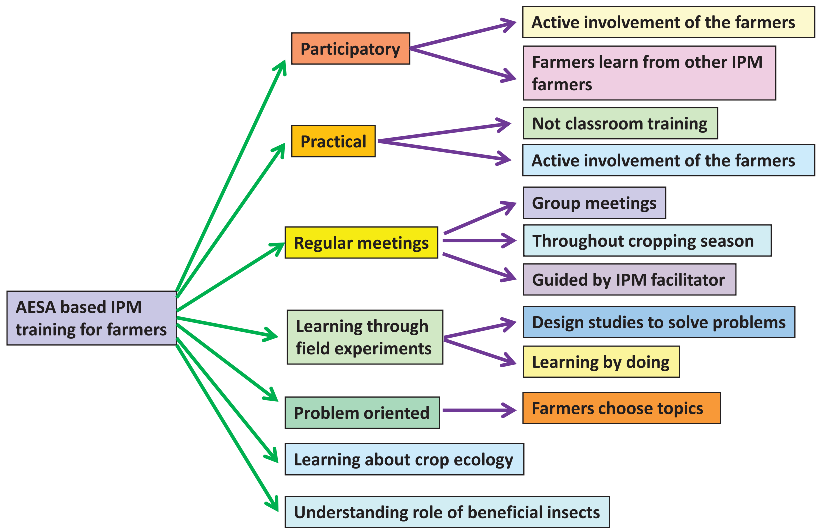
AESA and farmer field school (FFS)

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

Farmers can learn from AESA

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

FFS to teach AESA based IPM skills



B. Field scouting

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

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

For insect pests:

Shoot borer and leaf roller: Count and record the number of both insects.

Rhizome fly: Count and record the number of adults of rhizome fly present (tapping method also can be used to count fly).

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. Observe the signs of the causal organism (fungal growth or ooze). It is often necessary to wash the roots with water to examine them properly. If the roots are well developed, cut them to examine the roots for internal infections (discolouration & signs). Count the total number of pseudostem damaged/infested/infected due to rot should be counted and incidence should be recorded.

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

Pseudostem/rhizome sampling: Carefully examine the pseudostem/rhizome of plants for symptoms and signs of fungal or bacterial diseases. The pseudostem/rhizome should be split or taken apart and examined for discoloration caused by fungi and bacteria. Count the number of pseudostems/rhizomes infected due to disease and per cent disease incidence should be recorded.

For weed:

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

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

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

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

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

Group II - Chickweed, green foxtail, corn spurry.

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

Group III - Canada thistle, sow-thistle, dandelion

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

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

C. Surveillance through pheromone trap catches for shoot borer, bihar hairy caterpillar and leaf roller:

Pheromone traps for insect's viz., shoot borer, bihar hairy caterpillar and leaf roller @ 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 once a month. During each week of surveillance, the number of moths/trap/week should be counted and entered. The trapped moths should be removed and destroyed after each recording.

D. Blue pan water/sticky traps

Set up blue pan water/sticky traps 15-30 cm above the canopy for monitoring thrips etc. @ 4-5 traps/acre. Locally available empty tins can be painted blue and coated with grease/ Vaseline/castor oil on outer surface may also be used as blue sticky trap.

E. Light traps

Set up light traps @ 1 trap/acre 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 cm3 (200-300 g) representative soil sample. Mix soil sample and pass through a coarse sieve to remove rocks, roots, etc. Take a 600 cc subsample of soil, pack lightly into a beaker uniformly. Place soil in one of the buckets or pans half filled with water. Mix soil and water by stirring with paddle; allow to stand until water almost stops swirling. Pour all but heavy sediment through 20-mesh sieve into second bucket; discard residue in first bucket; discard material caught on sieve. Stir material in second bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 200-mesh sieve into first bucket; discard residue in second bucket. Backwash material caught on 200-mesh sieve (which includes large nematodes) into 250-ml beaker. Stir material in first bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 325-mesh sieve into second bucket; discard residue in first bucket. Backwash material caught on 325-mesh sieve (which includes small to mid-sized nematodes and silty material) into 250-ml beaker. More than 90% of the live nematodes are recovered in the first 5-8 mm of water drawn from the rubber tubing and the sample is placed in a shallow dish for examination.

III. ECOLOGICAL ENGINEERING FOR PEST MANAGEMENT

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

Natural enemies may require

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

Ecological Engineering for Pest Management – Above Ground:

- Raise the flowering plants / compatible cash crops along the field border by arranging shorter plants towards main crop and taller plants towards the border to attract natural enemies as well as to avoid immigrating pest population
- Grow flowering plants on the internal bunds inside the field
- Not to uproot weed plants those are growing naturally like *Tridax procumbens, Ageratum* sp, *Alternanthera* sp etc. which act as nectar source for natural enemies,
- Not to apply broad spectrum chemical pesticides, when the P: D ratio is favourable. The plant compensation ability should also be considered before applying chemical pesticides.

Ecological Engineering for Pest Management – Below Ground :

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

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

Good insectary plant belonging to Compositae, Umbelliferae, Brassicaceae, Graminaceae etc. families

Sunflower

Cowpea

Mustard

Alfalfa

Buckwheat

Maize

Coriander

Carrot

Chrysanthemum

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

Biodiversity of natural enemies observed in Ecological Engineering field at NIPHM

Biodiversity of natural enemies: Parasitoids

Biodiversity of natural enemies: Predators

Biodiversity of natural enemies: Spiders

Flowering plants that attract natural enemies/repel pests

Natural enemies	Attractant/Repellent/Trap plants
Shoot borer:	
<u>Parasitoids:</u> *Bracon* sp (larval), *myosoma* sp (larval), *Apanteles* sp (larval) , *Xanthopimpla* sp (larval and pupal) etc., **<u>Predators</u>:** *Chrysoperla zastrowi sillemi*, coccinellids, king crow, wasp, dragonfly, spiders, robber fly, reduviid bug, praying mantids, fire ants **Entomopathogenic nematode (EPN)** of the genus *Rhabditis/ Oscheius* and *Hexamermis* sp.	• **Attractant plants for natural enemies:** Carrot family, sunflower family, buckwheat, alfalfa, corn, shrubs (minute pirate bug, lacewing and ladybird beetle). • **Nectar rich plants** with small flowers i.e. anise, caraway, dill, parsley, mustard, sunflower, buckwheat and cowpea (braconid wasp) • **Maintaining hedgerows** around the turmeric plantation also helps to maintain a population of ladybird beetle, spiders, etc. • **Mulching** with green leaves @ 4–4.5 t/acre at the time of planting. It is repeated @ 2 t/acre at 40 and 90 days after planting. • Use of *Lantana camara* and *Vitex negundo* as mulch at the time of planting may reduce the infection of shoot borer. • **EPN,** *Rhabditis/Oscheius* as biopesticides for management of the shoot borer and other insect pests of turmeric.
Leaf roller:	
<u>Parasitoids:</u> *Apanteles* sp, *Sympiesis* sp, *Brachymeria oxodentata* **<u>Parasite</u>:** *Ceromyia* sp.	• **Attractant plants for natural enemies:** Carrot family, sunflower family, buckwheat, cowpea, alfalfa, corn, shrubs (*Apanteles* sp, *Sympiesis* sp, *Brachymeria oxodentata* & *Ceromyia* sp). • **Nectar rich plants** with small flowers i.e. anise, caraway, dill, parsley, mustard, sunflower, buckwheat and cowpea (*Apanteles* sp, *Sympiesis* sp, *Brachymeria oxodentata*)
Rhizome / soft rot:	
	• Incorporation of neem cake and pine needle in the soil. • Different types of cropping systems cropping like maize, chili, brinjal, papaya, cucumber, pumpkin, yam, tree tomato, tapioca and different types of leguminous crops. • Application of oil cakes made from *Azadirachta indica, Calophyllum inophyllum, Pongamia glabra, Hibiscus sabdariffa* and *Brassica campestris* • Intercrop turmeric with maize and pineapple.
Root-knot nematode:	
	• Intercropping with marigold @ 5:1 • **Repellant plants for nematodes:** Marigold, *Gliricidia*, Asparagus, Dahelia etc. • **Crop rotation:** Marigold, *Chrysanthemum, Sesbania, Crotalaria* spp., *Gaillardia*, cluster bean and *Desmodium* spp., • Border crops: Strips of ryegrass, cover crops and mulch beds (rove beetle) • Soil incorporation of *Gliricidia* compost, neem seed cake.

A. Resistant/tolerant varieties

Pest	Tolerant/resistant variety*
Shoot borer	Dindigam, Ca-68, Mannuthy local.
Taphrina leaf blotch, *Colletotrichum* leaf spot	Roma, Swarna, Sudarshana, Suguna, Sugandham, Ranga, Rashmi, Rajendra Sonia, Krishna, Prabha, Pratibha, Alleppey Supreme, Kedaram,

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

IV. CROP STAGE-WISE IPM PRACTICES

Management	Activities
Pre-sowing*	
Nutrients	• Turmeric crop requires clean cultivation and fine tilth. • Turmeric needs very heavy manuring during the four months period after planting. Crop requires 120 Kg N, 50 Kg P_2O_5 and 80 Kg K_2O per acre in organic and inorganic forms. • The NPK requirement has to be applied in two or three splits. The first dose of N has to be applied before planting through inorganic sources. • Use 10 t/ acre Farmyard manure or 4 t / acre vermicompost at the time of field preparation. • Apply castor or neem cake @ 200 Kg/ acre. • Incorporate manure / compost in soil at 2 -3 weeks before planting. • Use coir compost @ 1 t/acre combined with FYM, biofertilizer (*Azospirillum*). • Use leguminous green manure crops like pigeon pea, black gram, cowpea, cluster bean and French bean and incorporate in soil before planting.
Weeds	• Deep summer ploughing and solarisation during summer reduces weed infestation, soil borne diseases, nematodes, etc. • Use raised beds (30 cm with 1 meter width). • At the time of field preparation, adopt stale seed bed technique to minimize weeds menace in field.
Pests, nematode, soil borne pathogens and other diseases	**Cultural control:** • Deep summer ploughing during summer. • **Soil solarization:** Cover the beds with polythene sheet of 45 gauge (0.45 mm) thickness for three weeks before sowing for soil solarization which will help in reducing the soil borne pests. **Biological control:** • At the time of planting, apply 25 g powdered neem cake and mix well with the soil in each pit taken at a spacing of 20-25 cm within and between rows or application of neem cake @ 2 t/ acre is also desirable.
Rhizome rot/ soft rot	**Cultural control:** • Use of resistant varieties to rhizome wilt/ rot. • Crop rotation with maize, cotton, soybean. • Planting of disease-free seed rhizomes. • Use raised beds of 30 cm height. • Flooding treatment for 30 days, soil solarisation during hottest months for 60 days • Treat the rhizomes with hot water at 51° C for 10 minutes. • Rhizomes treatment can be done by keeping them under clear polythene sheet under direct sunlight for raising the temperature 48° C and this temperature is retained for 30 minutes. • Use bio-fumigation using cabbage and mustard plant refuses. • Use raised beds of 15-30 cm height, 1 m width and of convenient length may be prepared giving at least 50 cm spacing between beds.

	Biological control: • Planting of perennial / seasonal flowering plants like basil, marigold, fennel, sunflower etc. along the border to attract and enhance the population of biocontrol agents for managing pests/disease. • Application of pine needle and neem cake powder treatments @ 100 Kg/ acre (in two splits) • Application of oil cakes made from *Azadirachta indica, Calophyllum inophyllum, Pongamia glabra, Hibiscus sabdariffa* and *Brassica campestris* @ 0.8 tonnes/ acre.
Bacterial wilt**	**Cultural control:** • Soil solarisation for 60 days during summer • Planting of disease-free seed rhizomes. • Use crop rotation with non-host crops like ragi, paddy, maize, sorghum etc. • Avoid crop rotation with tomato, potato, chillies, brinjal and peanut, as these plants are hosts for the wilt pathogen *Ralstonia solanacearum.* • Rhizome treatment with hot water 47°C for 3 minutes. • Use bio-fumigation using cabbage and mustard plant refuses. • Avoid over irrigation, and flood irrigation in disease affected areas. • It is sensitive to high pH (alkaline soils).
Planting/ seedling stage*	
Nutrients	• The NPK requirement has to be applied in two or three splits. The first dose of N has to be applied before planting through inorganic sources. • Apply P_2O_5 @ 24 Kg/acre as basal dose at the time of planting/ sowing. • Apply K_2O @ 16 Kg/acre as basal dose at the time of planting/ sowing. • In zinc deficient areas, apply zinc sulphate @ 8 Kg/acre.
Weeds	• **Green mulching:** The first mulching is done at the time of planting with green leaves @ 4.8- 6 tonnes/acre. Mulching is to be repeated @ 3 tonnes/acre at 45 and 90 days after planting, immediately after weeding, application of fertilizers and earthingup.
Rhizome rot/soft rot	**Cultural control:** • Maintain proper drainage by using 30 cm raised bed and avoiding the water stagnation • Adopt phytosanitary measures like infected plants should be uprooted and destroyed. • Adopt crop rotation with non-host crops like ragi, paddy, maize, sorghum etc. • Mulching with green leaves (*Lantana camara* and *Vitex negundo*) @ 4-4.8 t/acre at the time of planting. (It is repeated @ 5 t/acre 40 and 90 days after planting). **Biological control:** • Foliar application of neem oil @ 0.5% twice at fortnightly interval. • Cow dung slurry or liquid manure may be poured on the bed after each mulching to enhance microbial activity and nutrient availability

	• Use Fermented Plant Extract (FPE) prepared by using (garlic + onion leaves + *Canabis* sp + wild poisonous plant) + (cow urine) + (EM solution) + (extract after washing polished rice) + (alcohol) + (water) (1:1:1:1:1:15), sufficient for 1.0 ha for seed treatment against soft rot. • FPE to be applied after every fortnight by using watering can for next 2 month i.e. up to July end.
Rhizome-scale	**Cultural control:** • Collect and destroy severely infested rhizomes. • Collect and destroy damaged leaves • Select healthy rhizomes free from scale infestation for using sowing purpose
* Apply *Trichoderma* spp. and *Pseudomonas fluorescens* as rhizome/planting material, nursery treatment and soil application (if commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).	
Vegetative & rhizome development stage:	
Nutrients	• Top dressing of N in three splits is done at regular periods just after each weeding at monthly intervals. • Apply castor or neem cake @ 200 Kg/ acre (if not applied at sowing) along with 24 Kg of Nitrogen through urea near the rhizomes at 40 days after planting. • Apply 24 Kg nitrogen and 16 Kg potash/ acre at 80 days after planting. • The final dose of 20 Kg nitrogen and 14 Kg potash/ acre should be applied at 120 days after planting followed by eating up of the crop. • Fertilizer application should be completed within 120 days from the time of planting. • Chemical fertilizers should be applied along with FYM and organic cakes. • As and when micro-nutrient deficiencies like zinc, manganese etc., are observed, it should be corrected by foliar spray. • Spray ferrous sulphate @ 5.0 g along with lime salt @ 1.0 g per litre of water to control 'Fe' deficiency. • To control 'Zn' deficiency, zinc sulphate @ 5.0 g + 0.5 ml sticking agent per litter of water.
Weeds	• Hand hoeing and weeding are necessary at 60, 90, 120 and 150 days after planting in light soils. Immediately the plants have to be earthed up. • In black soils where ridge and furrow method of planting and wider spacing are adopted country plough can be worked for earthing up and removal of weeds and followed by weeding in the lines.
Shoot borer	**Cultural control:** • Plant the ecological engineering plants to attractant, augment and conserve natural enemies. • Destroy the infested shoots and destroy them to kill harbouring caterpillars • Place light traps @ 1 /acre and operate between 6 and 10 pm to attract and trap the adult moths. Collect and kill the trapped moths . • Mulching with green *Lantana camara* and *Vitex negundo* leaves @ 2 t/ acre at 40 and 90 days after planting.

	Biological control: • Release of *Trichogramma chilonis* @ 40,000/acre. • Conserve and augment entomopathogenic nematodes (EPN) such as *Rhabditis/Oscheius turmerici* . • Conserve natural enemies such as *Angitia (Dioctes) tronchanterata; Xanthopimpla australis, Theromia inareolata, Bracon hebetor, B. brevicornis, B. nosatoi, B. lasus, Phanerotoma hendecasisella*, *Myosoma* sp, *Apanteles* sp, *Brachymeria euloeae*, mermethid nematode, earwigs, robber flies and spiders, ladybird beetle, spiders, chrysopids, Trichogrammatids etc. • Spray neem oil (0.5%) at fortnightly intervals.
Rhizome fly**	**Cultural control:** • Destroy stray plants in off season • Select and plant healthy rhizomes. • Remove and destroy rotting rhizomes along with the maggots from the field after the harvest of the crop. • Ecological engineering in turmeric with paddy reduces pest attacks. **Biological control:** • Conserve and/or inundate the natural enemies such as ladybird beetle, spiders, chrysopids, Trichogrammatids etc.
Leaf roller/ bihar hairy caterpillar**	**Cultural control:** • Collect and destroy the egg masses and larvae • Remove alternate weed hosts near the field **Biological control:** • Conserve the natural enemies such as ladybird beetle, spiders, chrysopids, *Bracon* sp, fire ants, dragonfly, praying mantis, ground beetle and Trichogrammatids etc. • Release *Trichogramma chilonis* @ 20,000/acre.
Leaf spot	**Cultural control:** • Pluck and remove the infested leaf and uproot the infested plants and destroy them. • Use proper green mulching to reduce soil splashes. **Biological control** • Use of plant extracts such as garlic extracts is effective against foliar pathogens. • Spray of an extract of asafoetida, turmeric and water pathogens including nematodes.
Leaf blotch	**Cultural control:** • Use proper green mulching to reduce soil splashes. **Biological control** • Use of plant extracts such as garlic extracts is effective against foliar pathogens.
Soft rot/ rhizome rot	**Cultural control:** • Maintain proper drainage by using 30 cm raised bed and avoiding the water stagnation • Adopt phytosanitary measures like infected plants should be uprooted and destroyed. • Adopt crop rotation with non-host crops like ragi, paddy, maize, sorghum etc.

	• Mulching with green leaves (*Lantana camara* and *Vitex negundo*) @ 4-4.8 t/acre is at the time of planting. (It is repeated @ 2 t/ acre 40 and 90 days after planting). **Biological control:** • Use Fermented Plant Extract (FPE) prepared by using (garlic + onion leaves + *Canabis* sp + wild poisonous plant) + (cow urine) + (EM solution) + (extract after washing polished rice) + (alcohol) + (water) (1:1:1:1:1:15), sufficient for 1.0 ha for seed treatment against soft rot. • FPE to be applied after every fortnight by using watering can for next 2 month i.e. up to July end.
***Taphrina* leaf blotch**	**Cultural control:** • Field sanitation should be practiced. • Follow crop rotation with cereal and legume crops to reduce the inoculum build up.
***Colletotrichum* leaf spot**	**Cultural control:** • Field sanitation should be practiced. • Follow crop rotation with cereal and legume crops to reduce the inoculum build up.
White grub**	**Cultural control:** • Uproot the infested plants, collect and destroy the infected plant along with larvae. • Use well decomposed FYM
Lacewing bug**	**Cultural control:** • Destroy all volunteer plants and old neglected plantations. • Use healthy and pest free rhizomes for planting. Apply hot water treatment prior to planting.
Nematodes**	**Cultural control:** • Uproot and destroy the infested plants. • Treat infested rhizomes with hot water (50 ^{o}C) for 10 minutes, using nematode free seed rhizomes and solarizing turmeric beds for 40 days. • Intercropping of marigold • Deep ploughing or solarized beds of infested fields during summer. • Follow crop rotation with cereal crops, marigold, *Chrysanthemum, Sesbania, Crotalaria* spp., gaillardia, castor bean and *Desmodium* spp., (parasitic nematodes) • Border crops: Strips of rye grass, cover crops and mulch beds (rove beetle) **Biological control:** • An extract of asafoetida, turmeric and water is effective against several plant pathogens including nematodes. • Application of neem (*Azaradirachta indica*) seed cake 100 Kg/acre before planting • *Pochonia chlamydosporia*, a nematode biocontrol agent can be incorporated in turmeric beds (20 g/bed at 10^6 cfu/g) at the time of sowing.

Rodents	**Cultural control:** • Traps are used to catch and kill rodents. • If possible cultivate turmeric in sloping and steep areas, as the crop will be protected from grazing animals and rodent pests.
Reproductive /maturity:	
Nutrients	• Incorporate crop residues in soil immediately after harvest.
Weeds	• Remove left over weeds to prevent weed seed spread in field.
Dry rot**	**Cultural control:** • Field sanitation should be practiced. • Follow crop rotation with cereal and legume crops reduce the inoculum build up.
Leaf spot/ leaf blight/ rhizome rot	• Same as in vegetative stage.
Harvesting & storage:	
	Cultural control: • Store the harvested rhizomes free from pest/disease in pits dug under shade, the floor of which is lined with sand or saw dust. • Cover the pits with coconut fronds. • Destroy the soft rot/ bacteria rot infected rhizomes.

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

** Pests of regional significance

V. INSECTICIDE RESISTANCE AND ITS MANAGEMENT

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

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

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

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

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

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

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

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

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

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

VI. NUTRITIONAL DEFICIENCIES

Nitrogen: Pale or yellow green leaves (chlorosis) symptoms appear first in the older leaves. Reddish tints gradually appear at the leaf margins spread toward the midrib or central vein. Leaves are small in size. Overall growth is markedly reduced. Deficiency results in reduction of rhizome yield.

Correction measure: Foliar spray of urea 1% or DAP 2% twice at weekly interval.

Potassium: Since potassium is very mobile within the plant, symptoms only develop on young leaves in the case of extreme deficiency. Reduced growth, shortened internodes, marginal burn or scorch (brown leaf edges), necrotic (dead) spots in the leaf, reduction of lateral breaks and tendency to wilt readily.

Correction measure: Application of K @ 36 Kg/acre in four splits (basal, 60, 90 and 120 DAP) or foliar spray of K_2SO_4 @ 1% at fortnightly interval.

Iron: The deficiency of iron shows up first in the young leaves of plants, which develop interveinal chlorosis and it progresses rapidly over the entire leaf. In severe cases, the leaves turn completely white.

Correction measure: Soil application of $FeSO_4$ @ 12 Kg/acre followed by foliar spray of $FeSO_4$ @ 0.5%during 3rd, 4th and 5th months.

VII. DESCRIPTION OF COMMON WEEDS

Major *kharif*

Broad leaf

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

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

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

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

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

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

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

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

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

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

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

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

Grassy

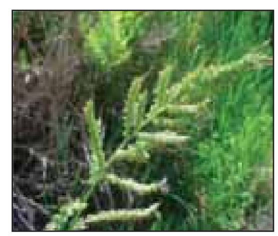
7) Rabbit / crow foot grass: *Dactyloctenium aegyptium* (L.) Willd (Poaceae)

Annual, very variable, grass, 10-44 cm height. Stem is erect or creeping culms, rooting from the profusely branched nodes. Leaves are linear, tapering to a fine point, 2-10 cm long and 0.2-0.4 cm wide, flat, glaucous, glabrous or hispid; leaf sheaths striate, the lower whitish; ligules membranous, very short. Inflorescence comprised of 2-6 digitate spikes, 0.5-4 cm long, olive-grey; spikelets 2-5 flowered, spreading at right angles, pendulous, strongly striate. Grain 0.5-1 mm long, subglobose, reddish, very rugose.

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

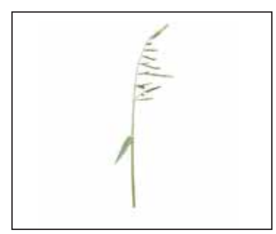
A prostrate or ascending annual grass with spreading, branched stem having rooting at nodes. Leaves are 3-20 cm long, 3-10 mm wide, with hairs on both the surfaces. Stem sheaths hairy and closed. Leaves and sheaths may turn dark red or maroon with age. Seed head composed of 4-6 branches (spikes) at the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

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



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

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



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

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

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

Sedges:

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

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

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

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

Major *rabi* weeds

Broad leaf

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

It is an annual weed found in agricultural fields. It is a polymorphous, non-aromatic, erect herb**,** 0.3-3 m tall with angled stems that are often striped green, red or purple. Leaves are variable in size and shape, lower leaves are toothed or irregularly lobes, 10-15 cm long, with petioles often as long as leaf blades. Flowers are green, borne in clusters forming a compact or loosely panicled axillary spike. Fruits utricle, seeds round, compressed, black and shining.

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

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

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

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

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

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

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

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

Grassy

6) Bluegrass: *Poa annua* L. (Poaceae)

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

VIII. DESCRIPTION OF INSECT AND NEMATODE PESTS

1) Shoot borer:

The pest population is higher in the field during September-October. The pest is most active from July to October.

Biology:

Egg: Eggs are pink, oval, flat laid singly or in group on leaves and other soft and the tender part of the plant. The eggs hatch in about a week.

Larva: The larvae pass through 4–5 instars and are full-fledged in 2–3 weeks. Fully grown larvae are light brown with sparse hairs.

Pupa: Pupation takes place inside the seed or sometimes in the grass that collects after feeding. Pupation takes place in lose silken coccon in larval tunnel. The pupal stage lasts about one week.

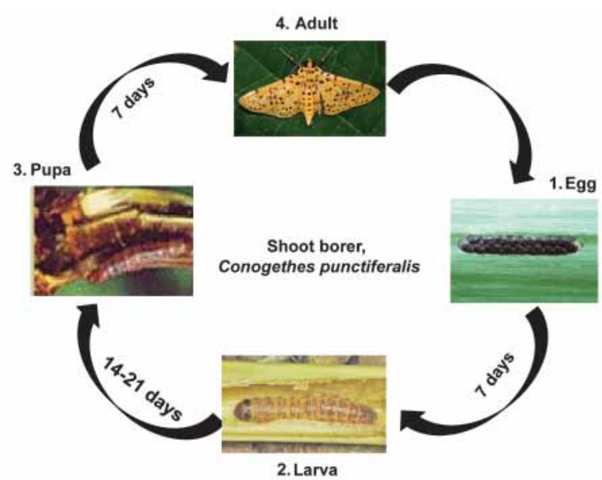
Adult: It is a medium sized moth with a wingspan of about 20 mm; the wings are orange-yellow with minute black spots.

The life cycle is completed in 4– 5 weeks and three generations are completed in a year.

Favourable conditions:

- Temperature range 30 - 33 °C and relative humidity range 60 - 90%.

Life cycle:



Damage symptoms:

- The larvae bore into pseudostems and feed on internal tissues resulting in yellowing and drying of leaves of infested pseudostems.
- The presence of a bore-hole on the pseudostem through which frass is extruded and the withered and yellow central shoot is a characteristic symptom of pest infestation.

Damage symptoms on leaf & rhizome

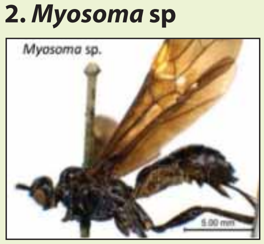
http://agritech.tnau.ac.in/crop_protection/crop_prot_crop_insect_spi_tur&gin.html

Parasitoids of shoot borer:

Larval parasitoids

1. *Bracon brevicornis*

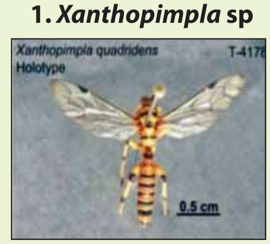
2. *Myosoma* sp



3. *Apanteles* sp

Larval and pupal parasitoid

1. *Xanthopimpla* sp



1.http://www.slideshare.net/AjithKumar46/turmeric-ajith

Predators of shoot borer:

1. Lacewing

2. Ladybird beetle

3. Spider

4. Fire ant

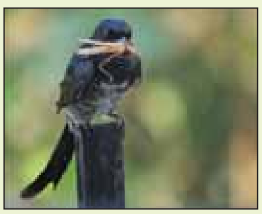
5. Dragonfly

6. Robber fly

7. Reduviid bug

8. Praying mantis

9. Black drongo (King crow)



1. http://www.macro-world.cz/image.php?id_foto=514&gal=29
2. http://lllladybug.blogspot.in/
3. http://en.wikipedia.org/wiki/Wolf_spider
4. 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
5. http://en.wikipedia.org/wiki/Dragonfly
6. http://www.warpedphotosblog.com/robber-fly-and-prey
7. http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-of-predators,-parasites-and-pathogens/assassin-bugs
8. http://spirit-animals.com/praying-mantis/
9. http://nagpurbirds.org/blackdrongo/picture/1639

*For management refer to page numbers 17-18

2) Rhizome scale:

Occurrence: The rhizome scale infests rhizomes in the field (at later stages) and in storage.

Female: scales are circular (about 1mm diameter) and light brown to gray and appear as encrustations on the rhizomes.

Male: Male is orange coloured with transparent wings, distinct head, thorax and abdomen

Damage symptoms:

- Adult (female) scales feed on sap and when the rhizomes are severely infested, they become shriveled and desiccated affecting its germination.
- In initial stage of infestation, the white coloured scales are seen scattered on rhizomes and later they congregate near the growing buds.
- When the infestation is severe the rhizome and buds shrivel and ultimately the entire rhizome dries.

http://agritech.tnau.ac.in/crop_protection/crop_prot_crop_insect_spi_tur&gin.html

*For management refer to page number 17

3) Thrips:

Biology:

Egg: Thrips reproduce by laying eggs.

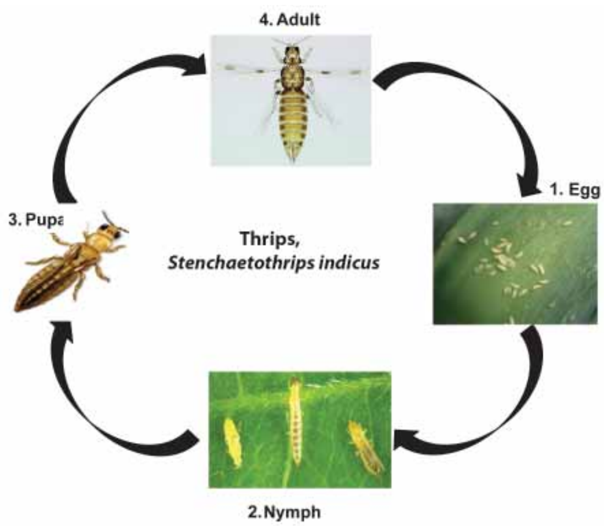
Nymph: Nymphs emerge from the eggs. It takes between 7 and 12 days to develop from eggs into adult thrips.

Adult: 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 plants throughout all growth stages, from sprout development to tuber maturation.

Favourable conditions:

- Warm and humid weather

Life cycle:



Damage symptoms:

- Thrips damage the undersides of leaves by sucking their plant sap.
- They damage young and soft parts of plants such as new leaves and shoots.
- Leaves become rolled up, and turn pale and gradually dry-up
- Severe infestation causes young leaves to wilt and dry out.

Parasitoid of thrips:

Nymphal parasitoid:

Ceranisus menes

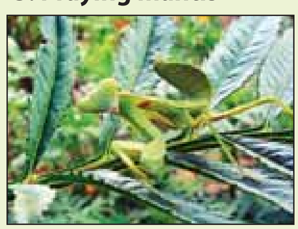
http://biocontrol.ucr.edu/hoddle/avocadothrips.html

Predators of thrips:

1. Syrphid fly

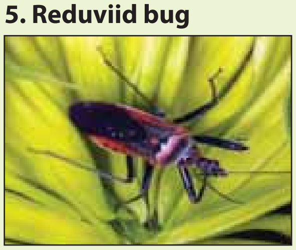
2. Minute pirate bug

3. Praying mantis



4. Predatory thrips

5. Reduviid bug



6. Lacewing

7. Coccinellid

8. Spider

2. http://plantdiagnostics.umd.edu/level3.cfm?causeID=246, 3. http://bugguide.net/node/view/205042/bgpage

4) Bihar hairy caterpillar:

Biology:

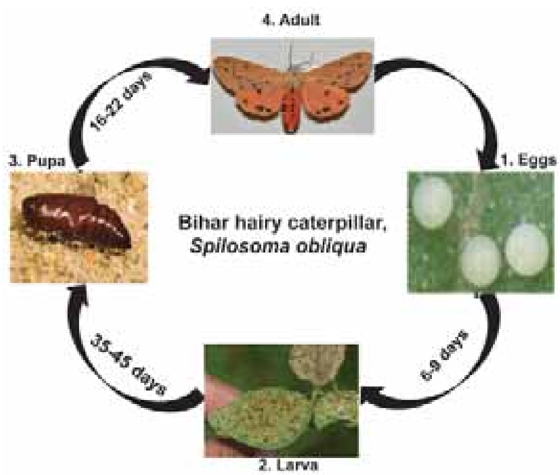
Egg: Eggs are light green spherical in clusters on the underside of leaves. The eggs hatch after about 6-9 days.

Larva: The larvae are covered with long yellowish to black hairs and are up to 5 cm long. Larval stages lasted within 34-45 days.

Pupa: The pupa forms a thin silken cocoon by interwoven shed hairs of the larvae. Pupal stages lasted within 16-22 days. Pupation takes place in the soil under dry foliage and debris where the pupae over wintering.

Adult: Bihar hairy caterpillar moth is brown with a 40-50 mm wing span and a red abdomen. Female lays 533-1287 eggs. A total life cycle is of 59-76 days.

Life cycle :



1. http://www.indianspices.com/html/qltyStandrdGuid. html
2. http://agropedia.iitk.ac.in/sites/default/files/BHC.jpg
3. http://kssrdi.org/admin/photos/530Spilosoma%20obliqua%20pupa.jpg
4. http://www.ccs-hk.org/DM/butterfly/Arctid/Spilosoma-obliqua1.jpg

Damage symptoms:

- Young larvae feed gregariously on the under surface of the leaves and cause loss by way of defoliation.
- Sometimes, after defoliated the crop larvae feed on the capsules.
- In severe cases only stems are left behind.
- They also severely damage other oilseeds such as sunflower.

*For management refer to page number 18

Parasitoids of bihar hairy caterpillar:

Egg parasitoid:

1. *Trichogramma* spp.

Larval parasitoid:

1. *Bracon* spp.

Predators of bihar hairy caterpillar:

1. Lacewing

2. Ladybug beetle

3. Spider

4. Fire ant

5. Dragonfly

6. Praying mantis

7. Ground beetle

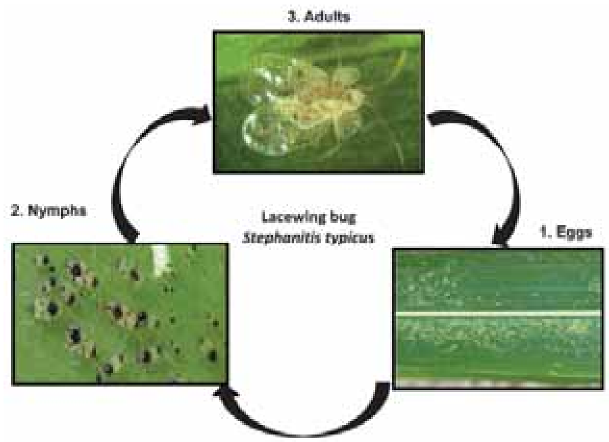
4. http://www.couriermail.com.au/news/queensland/queensland-launched-a-war-against-the-fire-ant-invasion-but-12-years-later-they8217re-still-on-the-march/story-fnihsrf2-1226686256021
5. http://en.wikipedia.org/wiki/Dragonfly
6. http://spirit-animals.com/praying-mantis/
7. http://www.mattcolephotography.co.uk/Galleries/insects/Bugs%20&%20Beetles/slides/Ground%20Beetle%20-%20Pterostichus%20madidus.html

5) Lacewing bug:

Small, whitish lacewing bug found in colonies on the foliage, causing a sickly and spotted appearance of the plant.

The pest infestation is more common during the post monsoon period especially in drier regions of the country

Life cycle:



Damage symptom:

- The foliage of infested plants turns pale or yellow and dries up.

*For management refer to page number 19

6) Leaf roller/skipper:

Biology:

Egg: Pinkish oval flat eggs are laid singly or in groups or 2 or 3 on leaves. The egg, period last for 3-4 days.

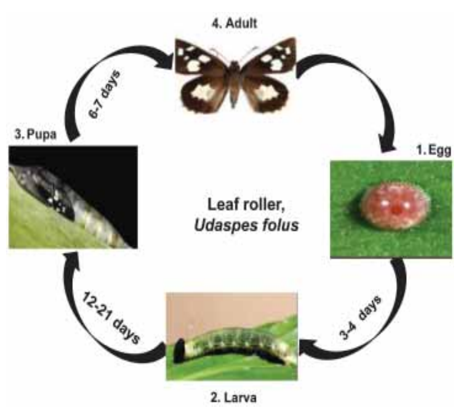
Larva: There are five larval instars, fully grown larvae are dark green with black head and constricted neck. The pest is abundant in the field during August - October. The larval period last for 12-21 days.

Pupa: Pupation takes place on the same plant within a cell. The pupa is long and cylindrical, watery green in colour. It has a long conical projection in front of the head. The most striking characteristic of the pupa is its proboscis. The pupal period last for 6-7 days.

Adult: Adults are medium sized with brownish black wings with eight white spots on forewings and one large patch on hind wing.

Favourable conditions: Temperature 26- 35° C, relative humidity 41 - 100%

Life cycle:



http://agritech.tnau.ac.in/crop_protection/crop_prot_crop_insect_spi_tur&gin.html#3a

Damage symptom:

- The larvae cut and fold the leaves, remain within and feed on them, pupate inside the leaf.

Parasitoids of leaf roller:

Larval parasitoids:

1. *Ceromya* sp

2. *Apanteles* sp

3. *Sympiesis* sp

Pupal parasitoid:

1. *Brachymeria coxodentata*

1. http://chrisraper.org.uk/blog/?tag=ceromya
2. http://tarwi.lamolina.edu.pe/~acg/apanteles_sp.htm
3. http://www.ento.csiro.au/science/eulophid_key/EULOPHIDAE/eulophids/html/SYMPIESIS.html

1. http://digiins.tari.gov.tw/tarie/collection013E.php?id=Tungpu&page=8

*For management refer to page number 18

7) White grubs:

Biology:

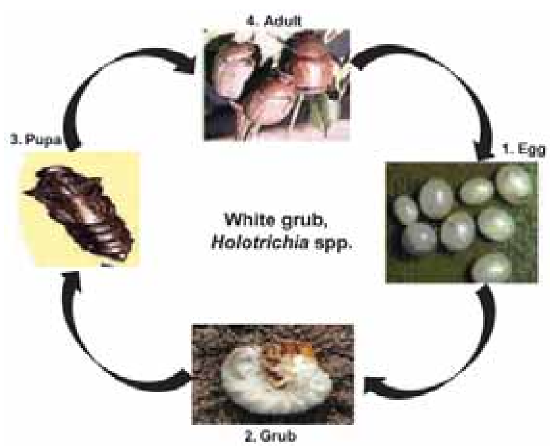
Egg: The females lay eggs singly on the main stem. The eggs are white, almost round in shape

Larva: The larvae are C shaped, slow movers having globular head and elongated, dorsoventrally flattened body. The young grubs are translucent, white and 5 mm long

Pupa: Population takes place in the larval tunnel.

Adult: Adults of *Holotrichia* spp. are about 18-20 mm long and 7-9 mm wide.

Life cycle:



Damage symptoms:

- Grubs are polyphagous and both adults and larvae are damaging stages.
- The grubs live in soil and remain active, feed on the functional roots of the plant, leaving behind only tap root.
- They also burrow into the pseudostem, close to the soil surface and kill the plant.
- Grub infested plants turn pale, leaves and branches drop down, the plant withers and can be easily uprooted.
- It ultimately dies off resulting in patchy crop growth.
- Root grubs occasionally feed on tender rhizomes, roots and base of pseudostems causing yellowing and wilting of shoots.

Favourable conditions:

- Warm and humid weather

*For management refer to page number 19

8) Root knot, burrowing and lesion nematodes:

Damage symptoms:

- Root-knot nematode feed on tender rhizomes, roots and base of pseudostem causing stunting, chlorosis, poor tillering and necrosis of leaves are the common aerial symptoms.
- Characteristic root galls and lesions that lead to rotting are generally seen in roots.
- The infested rhizomes have brown, water soaked areas in the outer tissues.
- Nematode infestation aggravates rhizome rot disease.

Damaged rhizomes

Root-knot

Burrowing

Lesion

Survival and spread:

- Nematodes survive in soil and infected rhizomes as primary inoculum.
- Therefore, tissues from infected crops remaining in the field serve as a reservoir of the fungus.
- It spreads from infected plants or through soil.

Favourable condition:

- Warm, moist soil are favourable conditions

*For management refer to page numbers 15 & 19

IX. DESCRIPTION OF DISEASES

1) Rhizome rot:

The disease is soil-borne and rhizomes borne and occurs with the onset of monsoon. This disease mostly occurs during the months of June to September.

Disease symptoms:

- The infection starts at the collar region of the pseudostem and progresses upwards as well as downwards.
- The collar region of the affected pseudostem becomes water soaked and the rotting spreads to the rhizome resulting in soft rot.
- At a later stage root infection is also noticed.
- Foliar symptoms appear as light yellowing of the tips of lower leaves which gradually spreads to the leaf blades.
- In early stages of the disease, the middle portion of the leaves remain green while the margins become yellow.
- Later, the yellowing spreads to all leaves of the plant from the lower region upwards and is followed by drooping, withering and drying of pseudostems.

http://agropedia.iitk.ac.in/content/rhizome-rot-turmeric

Survival and spread:

- The disease is soil-borne. The fungus multiplies with buildup of soil moisture with the onset of south west monsoon.
- The fungus can survive in two ways: (a) in diseased rhizomes kept for sowing and (b) through resting structures like chlamydospores and oospores that reach the soil from infected rhizomes.

Favourable conditions:

- Younger sprouts are the most susceptible to the pathogen. Nematode infestation aggravates rhizome rot disease.
- Temperature above 30° C and high soil moisture are the important predisposing factors favouring the disease.
- Water logging in the field due to poor drainage increases the intensity of the disease.

*For management refer to page numbers 15, 16-17, 18-19 & 20

2) Leaf spot:

Disease is soil-borne noticed on the leaves from July to October.

Disease symptoms:

- Symptom appears as brown spots of various sizes on the upper surface of the young leaves.
- The spots are irregular in shape and white or grey in the centre.
- Later, spots may coalesce and form an irregular patch covering almost the whole leaf.
- The centre of spots contains fruit head shaped fruiting structures.

http://www.ikisan.com/crop%20specific/eng/Images/tur_dm_taphrinspot.jpg

Survival and spread:

- Disease is soil borne and survives in plant debris.
- The disease spreads through rain splashes during intermittent showers. The incidence of the disease is severe in turmeric grown under exposed conditions

Favourable conditions:

- High soil moisture, temperature 25^{O} C and leaf wetness.

*For management refer to page numbers 18 & 20

3) Leaf blotch:

Disease symptoms:

- Disease symptom appears as small, oval, rectangular or irregular brown spots on either side of the leaves which soon become dirty yellow or dark brown.
- The leaves also turn yellow.
- In severe cases the plants present a scorched appearance and the rhizome yield is reduced.

Survival and spread:

- Soil and seed borne and survive in soil on infected plant debris.

Favourable conditions:

- High soil moisture, temperature 25^{O} C and leaf wetness.

*For management refer to page number 18

4) Dry rot:

Disease symptoms:

- The disease causes root rot and rhizome rot resulting in typical dry rot of rhizomes from October onwards.
- The affected rhizomes appear soft and shrunken to start with, later dry up and become hard.
- Foliar yellowing and drying up of foliage which are the normal symptoms of maturity of the crop during October - November would be indistinguishable from the symptoms of the disease affected clumps.
- When infected rhizomes are cut open, the infected zones typically appear as dull brown and dark.

Infected plant and rhizome

Survival and spread:

- The pathogen is facultative parasites and lives as a saprophyte on the organic matter in the soil for several years.
- It spreads from vulnerable plants

Favourable conditions:

- The disease is favoured by 35° C soil temperature, 15-20 per cent soil moisture and alluvial or sandy soils.

*For management refer to page number 20

5) Bacterial wilt:

Disease symptoms:

- Rapid wilting and death of the entire plant without any yellowing or spotting of leaves are the characteristic symptom.

- All branches wilt at about the same time.
- When the stem of a wilted plant is cut across, the pith has a darkened, water-soaked appearance.
- Greyish slimy ooze comes out on pressing the stem.
- In later stages of the disease, decay of the pith may cause extensive hollowing of the stem.

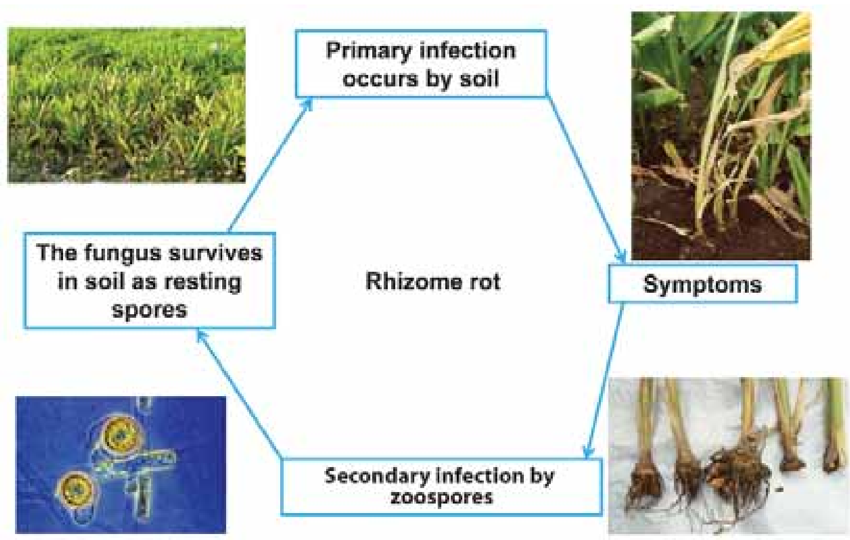
Favourable conditions:

- The bacterium is especially destructive in moist soils at temperatures above 24° C.
- High soil temperature and moisture are favourable for disease.

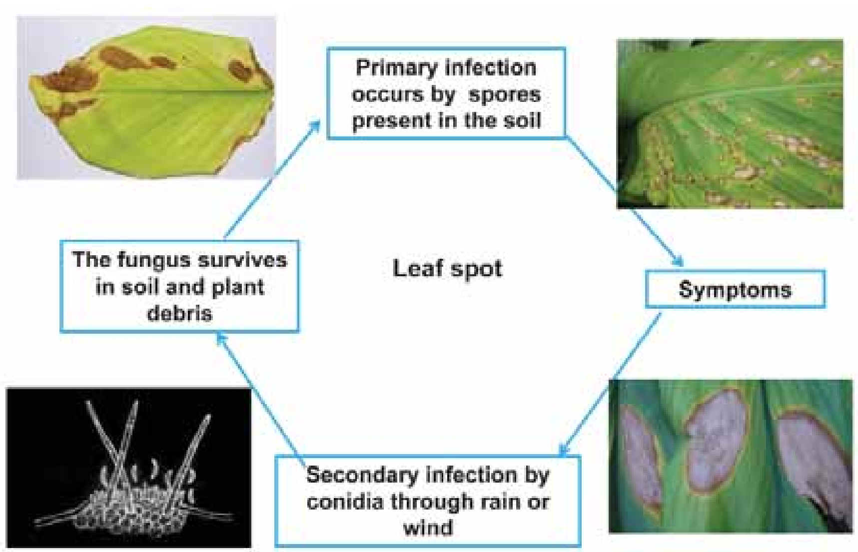
*For management refer to page number 16

Disease cycles:

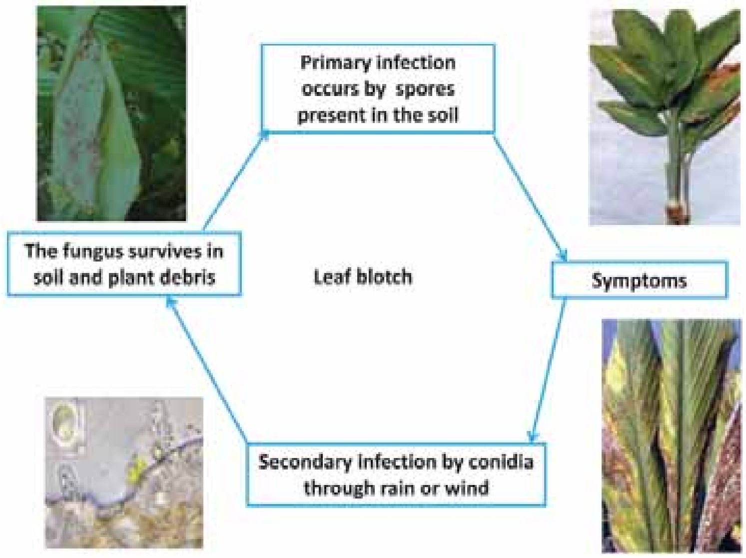
1. Rhizome rot



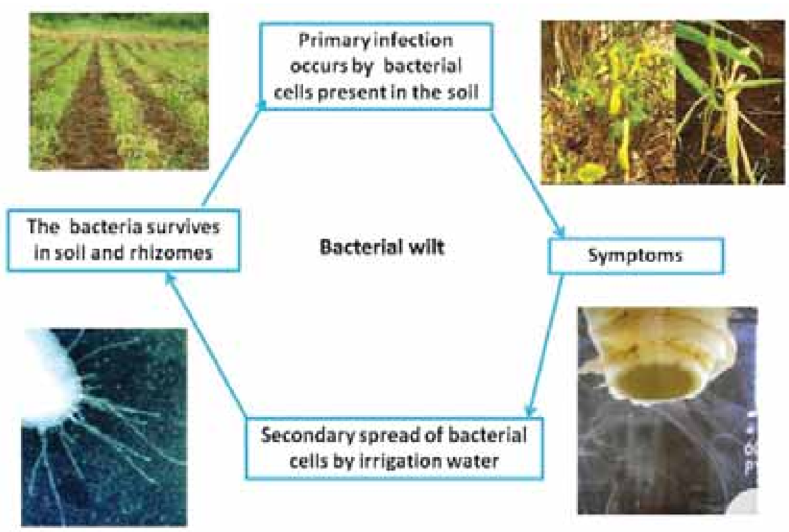
2. Leaf spot



3. Leaf blotch



4. Bacterial wilt



X. SAFETY MEASURES

A. At the time of harvest

Harvest the crop only when it is fully matured. Maturity is indicated by the drying up of the plant including the base of the stem. While harvesting, care should be taken not to cause any damage to the rhizomes. The leafy stems are then cut off, roots removed to the adhering earth shaken off. The rhizomes are washed well with water to remove the mud and dirt adhering to them. The fingers are separated from the bulbs.

B. During post-harvest storage

Turmeric should be stored ensuring protection from dampness. Drainage should be provided to stack the packed bags to prevent moisture ingress from the floor. Care should be taken to stack the bags 50 to 60 cm away from the walls. No insecticide should be used directly on dried turmeric. Stored turmeric should be subjected to periodic fumigation for which only authorised persons should be engaged. Insects, rodents and other animals should be effectively prevented from getting access to the premises where turmeric is stored. Stored turmeric should be periodically exposed to the Sun. If care is taken in all stages of cultivation, harvesting, post harvest handling, processing, packing, storage and transportation by following sound methods and practices we will be able to prevent contamination and deterioration of quality in any farm produce including turmeric and ensure consumer satisfaction.

XI. DO'S AND DON'TS IN IPM

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

9.	Use NPK fertilizers as per the soil test recommendation.	Avoid imbalanced use of fertilizers.
10.	Use micronutrient mixture after sowing based test recommendations.	Do not apply any micronutrient mixture after sowing without test recommendations.
11.	Conduct AESA weekly in the morning preferably before 9 a.m. Take decision on management practice based on AESA and P: D ratio only. 	Do not take any management decision without considering AESA and P: D ratio
12.	Install pheromone traps at appropriate period. 	Do not store the pheromone lures at normal room temperature (keep them in refrigerator).
13.	Release parasitoids only after noticing adult moth catches in the pheromone trap or as pheromone trap or as per field observation 	Do not apply chemical pesticides within seven days of release of parasitoids.
14.	In case of pests which are active during night spray recommended biopesticides/ chemicals at the time of their appearance in the evening.	Do not spray pesticides at midday since, most of the insects are not active during this period.
15.	Spray pesticides thoroughly to treat the under surface of the leaves. 	Do not spray pesticides only on the upper surface of leaves.
16.	Apply short persistent pesticides to avoid pesticide residue in the soil and produce.	Do not apply pesticides during preceding 7 days before harvest.
17.	Follow the recommended procedure of trap or border crops technology. 	Do not apply long persistent pesticides on trap crop, otherwise it may not attract the pests and natural enemies.

XII. BASIC PRECAUTIONS IN PESTICIDES USAGE

A. Purchase

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

B. Storage

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

C. Handling

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

D. Precautions for preparing spray solution

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

E. Equipment

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

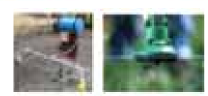
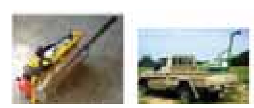
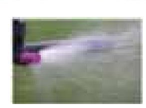
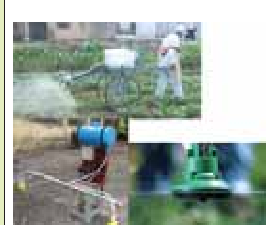
F. Precautions for applying pesticides

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

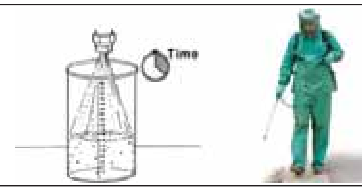
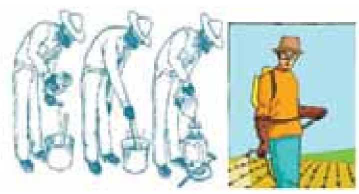
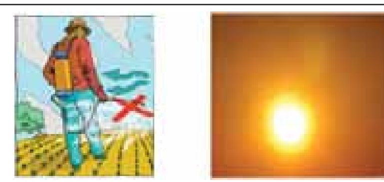
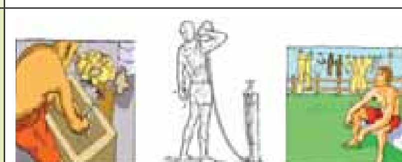
G. Disposal

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

XIII. PESTICIDE APPLICATION TECHNIQUES

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

XIV. OPERATIONAL, CALIBRATION AND MAINTENANCE GUIDELINES IN BRIEF

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

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Good insectary plant belonging to Compositae, Umbelliferae, Brassicaceae, Graminaceae etc. families

Sunflower

Cowpea

Mustard

Alfalfa

Buckwheat

Maize

Coriander

Carrot

Chrysanthemum

राष्ट्रीय वनस्पति स्वास्थ्य प्रबंधन संस्थान

रा व स्वा प्र सं

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NCIPM

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Ministry of Agriculture
Government of India