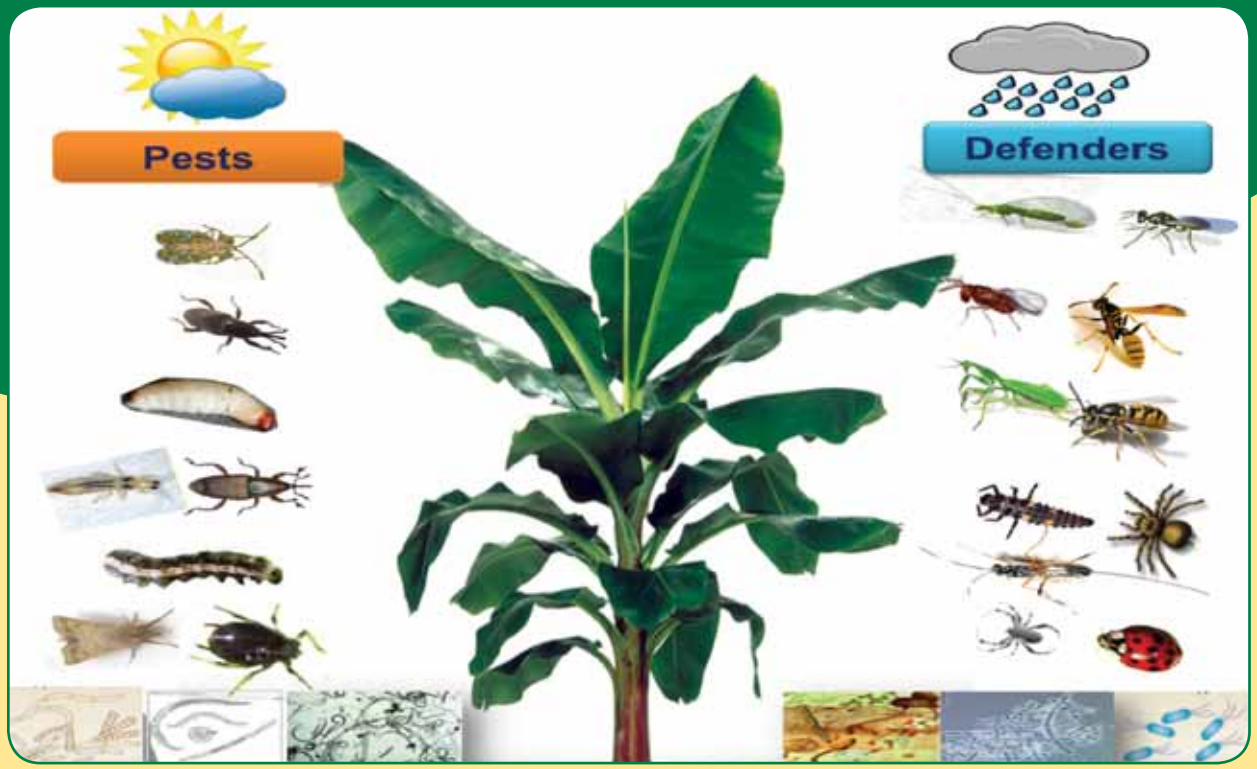
सत्यमेव जयते

AESA BASED IPM Package

AESA based IPM – Banana



रा व स्वा प्र सं
NIPHM

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NCIPM

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LBS Building, IARI Campus, New Delhi

Department of Agriculture and Cooperation
Ministry of Agriculture
Government of India

Important Natural Enemies of Banana Insect Pests

Parasitoids

***Trichogramma* spp.**

***Chelonus* sp**

***Bracon* sp**

***Carcelia* spp.**

Campoletis chlorideae

***Tetrastichus* sp**

Predators

Lacewing

Ladybird beetle

Spider

Dragonfly

Reduviid bug

Hover fly

The AESA based IPM - Banana, 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 banana

Back cover picture Banana field

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FOREWORD

Intensive agricultural practices relying heavily on chemical pesticides are a major cause of wide spread ecological imbalances resulting in serious problems of insecticide resistance, pest resurgence and pesticide residues. There is a growing awareness world over on the need for promoting environmentally sustainable agriculture practices.

Integrated Pest Management (IPM) is a globally accepted strategy for promoting sustainable agriculture. During last century, IPM relied substantially on economic threshold level and chemical pesticides driven approaches. However, since the late 1990s there is conscious shift to more ecologically sustainable Agro-Eco System Analysis (AESA) based IPM strategies. The AESA based IPM focuses on the relationship among various components of an agro-ecosystem with special focus on pest-defender dynamics, innate abilities of plant to compensate for the damages caused by the pests and the influence of abiotic factors on pest buildup. In addition, Ecological Engineering for pest management - a new paradigm to enhance the natural enemies of pests in an agro-ecosystem is being considered as an important strategy. The ecological approach stresses the need for relying on bio intensive strategies prior to use of chemical pesticides.

Sincere efforts have been made by resource personnel to incorporate ecologically based principles and field proven technologies for guidance of the extension officers to educate, motivate and guide the farmers to adopt AESA based IPM strategies, which are environmentally sustainable. I hope that the AESA based IPM packages will be relied upon by various stakeholders relating to Central and State government functionaries involved in extension and Scientists of SAUs and ICAR institutions in their endeavour to promote environmentally sustainable agriculture practices.

Date : 6.3.2014

(Avinash K. Srivastava)

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FOREWORD

IPM as a holistic approach of crop protection based on the integration of multiple strategies viz., cultural, physical, mechanical, biological, botanical and chemical. Over the years IPM underwent several changes, shifting its focus from damage boundary, economic injury to economic threshold. Currently most stake holders rely upon economic threshold levels (ETL) and tend to apply chemical pesticides at the first instance in the event of a pest attack, through Government of India has advocated need based and judicious application of chemicals. This approach is likely to cause adverse effects on agro-ecosystems and increase the cost of agricultural production due to problems of pest resurgence, insecticide resistance and sustainability.

During the late 90s FAO started advocating Agro-Ecosystem Analysis (AESA) based IPM. Experience in different countries have sine show that AESA, which takes into account ecological principles and relies on the balance that is maintained by biotic factors in an ecosystem has also resulted in reduction in cost of production and increase in yields. AESA based IPM also takes into account the need for active participation of farmers and promotes experiential learning and discovery based decision making by farmers. AESA based IPM in conjunction with ecological engineering for pest management promotes bio-intensive strategies as against current chemical intensive approaches, while retaining the option to apply chemical pesticides judiciously as a measure of last resort.

The resource persons of NIPHM and DPPQ&S have made sincere efforts in revising IPM packages for different crops by incorporating agro-ecosystem analysis, ecological engineering, pesticide application techniques and other IPM options with the active cooperation of crop based plant protection scientists working in state Agricultural Universities and ICAR institutions. I hope this IPM package will serve as a ready reference for extension functionaries of Central / State Governments, NGOs and progressive farmers in adopting sustainable plant protection strategies by minimizing the dependence on chemical pesticides.

(Utpal Kumar Singh)

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PREFACE

Need for environmentally sustainable agricultural practices is recognised worldwide in view of the wide spread ecological imbalances caused by highly intensive agricultural systems. In order to address the adverse impacts of chemical pesticides on agro-ecosystems, Integrated Pest Management has evolved further from ETL based approach to Agro-ecosystem Analysis based Integrated Pest Management (IPM).

In AESA based IPM the whole agro-ecosystem, plant health at different stages, built-in-compensation abilities of the plant, pest and defender population dynamics, soil conditions, climatic factors and farmers' past experience are considered. In AESA, informed decisions are taken by farmers after field observation , AESA chart preparation followed by group discussion and decision making. Insect zoo is created to enable the farmer understand predation of pests by Natural Enemies. AESA based PHM also results in reduction of chemical pesticide usage and conserves the agro-ecosystems.

Ecological Engineering for Pest Management, a new paradigm, is gaining acceptance as a strategy for promoting Biointensive Integrated Pest Management. Ecological Engineering for Pest Management relies on cultural practices to effect habitat manipulation and enhance biological control. The strategies focus on pest management both below ground and above ground. There is growing need to integrate AESA based IPM and principles of ecological engineering for pest management.

There is a rising public concern about the potential adverse effects of chemical pesticides on the human health, environment and biodiversity. The intensity of these negative externalities, through cannot be eliminated altogether, can be minimized through development, dissemination and promotion of sustainable biointensive approaches.

Directorate of Plant Protection Quarantine and Storage (DPPQS), has developed IPM package of practices during 2001 and 2002. These packages are currently providing guidance to the Extension Officers in transferring IPM strategies to farmers. These IPM package of practices, have been revised incorporating the principles of AESA based IPM in detail and also the concept of Ecological Engineering for Pest Management. It is hoped that the suggested practices, which aim at enhancing biodiversity, biointensive strategies for pest management and promotion of plant health, will enable the farmers to take informed decisions based on experiential learning and it will also result in use of chemical pesticides only as a last resort & in a safe and judicious manner.

(K. SATYAGOPAL)

CONTENTS

AESA BASED IPM PACKAGE FOR BANANA

Banana plant description:

Banana (*Musa* sp; family: Musaceae) is the second most important fruit crop in India next to mango. Its year round availability, affordability, varietal range, taste, nutritive and medicinal value makes it the favourite fruit among all classes of people. It has also good export potential.

Banana evolved in the humid tropical regions of South East Asia with India as one of its centres of origin. Modern edible varieties have evolved from the two species – *Musa acuminata* and *Musa balbisiana* and their natural hybrids, originally found in the rain forests of S.E. Asia. During the seventh century AD its cultivation spread to Egypt and Africa. At present banana is being cultivated throughout the warm tropical regions of the world between 30^0 N and 30^0 S of the equator.

Banana and plantains are grown in about 120 countries. Total annual world production is estimated at 86 million tonnes of fruits. India leads the world in banana production with an annual output of about 14.2 million tonnes. Other leading producers are Brazil, Eucador, China, Phillipines, Indonesia, Costarica, Mexico, Thailand and Colombia.

In India banana ranks first in production and third in area among fruit crops. It accounts for 13% of the total area and 33% of the production of fruits. Production is highest in Maharashtra (3924.1 thousand tones) followed by Tamil Nadu (3543.8 thousand tonnes). Within India, Maharashtra has the highest productivity of 65.70 metric tones /ha. against national average of 30.5 tonnes/ha. The other major banana producing states are Karnataka, Gujarat, Andhra Pradesh and Assam.

Economic Importance

Banana is a very popular fruit due to its low price and high nutritive value. It is consumed in fresh or cooked form both as ripe and raw fruit.

Banana is a rich source of carbohydrate and is rich in vitamins particularly vitamin B. It is also a good source of potassium, phosphorus, calcium and magnesium. The fruit is easy to digest, free from fat and cholesterol. Banana powder is used as the first baby food. It helps in reducing risk of heart diseases when used regularly and is recommended for patients suffering from high blood pressure, arthritis, ulcer, gastroenteritis and kidney disorders.

Processed products, such as chips, banana puree, jam, jelly, juice, wine and halwa can be made from the fruit. The tender stem, which bears the inflorescence is extracted by removing the leaf sheaths of the harvested pseudostem and used as vegetable. Plantains or cooking bananas are rich in starch and have a chemical composition similar to that of potato.

Banana fibre is used to make items like bags, pots and wall hangers. Rope and good quality paper can be prepared from banana waste. Banana leaves are used as healthy and hygienic eating plates.

http://nhb.gov.in/report_files/banana/BANANA.htm

I. PESTS

A. Pests of National Significance

1. Insect pests

1.1 Banana rhizome weevil: *Cosmopolitus sordidus* Germar (Coleoptera: Curculionidae)

1.2 Banana stem weevil: *Odoiporus longicollis* Olivier (Coleoptera: Curculionidae)

1.3 Banana leaf eating caterpiller: *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae)

1.4 Banana aphid: *Pentalonia nigronervosa* Coquerel (Hemiptera: Aphididae)

1.5 Banana thrips:

1.5.1 Rust thrips: *Cheatanophothrips signipennis* Bagnall (Thysanoptera: Thripidae)

1.5.2 Leaf thrips: *Helionothrips kadaliphilus* Ramak (Thysanoptera: Thripidae)

1.5.3 Flower thrips: *Thrips florum* Schumtz (Thysanoptera: Thripidae)

1. 6 Banana leaf and fruit scarring beetle: *Nodostoma (Basilepta) subcostatum* Jac. (Coleoptera: Chrysomelidae)

1.7 Banana lacewing bug: *Stephanitis typicus* Distant (Hemiptera: Tingidae)

2. Diseases

2.1 Panama wilt: *Fusarium oxysporum* f.sp. *cubense* (E.F.Sm.) W.C.Snyder & H.N. Hansen

2.2 *Mycosphaerella* leaf spot:

2.2.1 Yellow sigatoka: *Mycosphaerella musicola* R. Leach ex J.L. Mulder

2.2.2 Black sigatoka: *Mycosphaerella fijiensis* Morelet

2.3 Anthracnose: *Colletrotrichum musae* Green & Goos, *Gloeosporium musarum* Cke. & Massee

2.4 Tip rot or bacterial soft rot: *Erwinia carotovora* (Jones) Edward

2.5 Banana bunchy top disease (BBTD): *Bunchy top virus or Banana virus* - 1 or *Musa virus*–1

2.6 Banana bract mosaic virus: *Banana bract mosaic virus* (BBMV; potyvirus)

2.7 Banana streak disease (BSV): *Banana streak virus* (Badna virus)

2.8 Infectious chlorosis: *Cucumber mosaic virus* (Cucumovirus)

3. Weeds

Broad leaf

3.1.1 Spiny pigweed: *Amaranthus spinosus* L. (Amaranthaceae)

3.1.2 Slender pigweed: *Amaranthus viridis* Hook. F. (Amaranthaceae)

3.1.3 Carrot weed: *Parthenium hysterophorus* L. (Asteraceae)

3.1.4 Common purslane: *Portulaca olaracea* L. (Portulacaceae)

3.1.5 Tridax daisy: *Tridax procumbens* L. (Asteraceae)

3.1.6 Spurge: *Euphorbia hirta* L., *E. geniculata*, Ortega (Euphorbiaceae)

3.1.7 Knotweed: *Polygonum plebeium* R.Br. (Polygonaceae)

3.1.8 Touch me not weed: *Mimosa pudica* L. (Mimosaceae)

Grasses

3.2.1 Bermuda grass: *Cynodon dactylon* (L.) Pers (Poaceae)

3.2.2 Crab grass: *Digitaria sanguinalis* L. Scop (Poaceae)

3.2.3 Indian goosegrass: *Eleusine indica* L. Gaetrn (Poaceae)

Sedges

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

B. Pests of Regional Significance:

1. Insect pests

1.1 Hard scale: *Aspidiotus destructor* Signoret (Hemiptera: Diaspididae)

1.2 Fruit fly: *Bactrocera dorsalis* Hendel (Diptera: Tephritidae) (Karnataka)

1.3 Bag worm: *Kophene cuprea* Moore. (Lepidoptera: Psychidae)

1.4 Banana scab moth: *Nacoleia octasema* Meyr (Lepidoptera: Pyralidae) (Uttar Pradesh)

2. Diseases

2.2 Cigar end rot: *Verticillium theobromae* (Turconi) E.W. Mason & S. Hughes (Karnataka, Uttar Pradesh, Kerala)

2.3 Finger tip or black tip rots: *Botryodiplodia theobromae* Pat. (Karnataka, Bihar, Punjab, Uttar Pradesh)

3. Nematodes

3.1 Burrowing nematode: *Radopholus similis* Cobb. (Manipur, Kerala, Tamil Nadu, Karnataka, Madhya Pradesh, Jammu and Kashmir, Goa, Assam, Nagaland, West Bengal, Bihar, Uttar Pradesh)

3.2 Root-lesion nematode: *Pratylenchus coffeae* Zimmerman. (Uttar Pradesh, Manipur, Tamil Nadu)

3.3 Spiral nematode: *Helicotylenchus multicinctus* Cobb (Tripura, Tamil Nadu, Maharashtra)

3.4 Root knot nematode: *Meloidogyne incognita* (Kofoid & White) Chitwood (Madhya Pradesh, Tamil Nadu, Andhra Pradesh)

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

A. AESA

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

Decision making in pest management requires a thorough analysis of the agro-ecosystem. Farmer has to learn how to observe the crop, how to analyze the field situation and how to make proper decisions for their crop management. This process is called the AESA. Participants of AESA will have to make a drawing on a large piece of paper (60 x 80 cm), to include all their observations. The advantage of using a drawing is that it requires the participants to observe closely and intensively. It is a focal point for the analysis and for the discussions that follow, and the drawing can be kept as a record.

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

- Plant health at different stages
- Built-in compensation abilities of plants
- Pest and defender population dynamics

- Soil conditions
- Climatic factors
- Farmers past experience

Principles of AESA based IPM

Grow a healthy crop

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

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

Farmers should

- Monitor the field 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

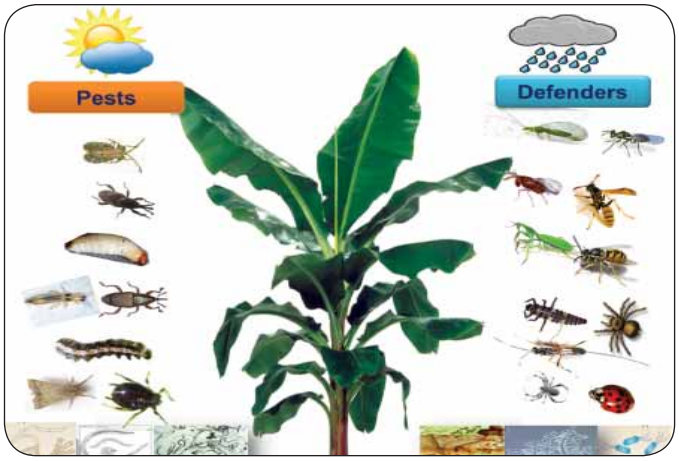
In field various types of insects are present. Some are beneficial and some may be harmful. Generally farmers are not aware about it. Predators (friends of the farmers) which feed on pests are not easy to observe in crop field. Insect zoo concept can be helpful to enhance farmers' skill to identify beneficial 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 banana pests can be divided into 3 categories 1. parasitoids; 2. predators; and 3. pathogens. The important natural enemies of banana pests are given in ecological engineering table on page number 13

Model agro-ecosystem analysis chart

Date:
Village:
Farmer:



Decision taken based on the analysis of field situations

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

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

Feeding/egg laying potential of different parasitoids/predators

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

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

Decision making

Farmers become experts in crop management

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

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

AESA methodology

- Go to the field in groups (about 5 farmers per group). Walk across the field and choose 50 beds/ acre randomly across the diagonal of the field. Observe keenly each of these plants in each bed and record your observations:
    - Plant: Observe the plant height, crop stage, deficiency symptoms etc.
    - Pests: Observe and count pests at different places on the plant.
    - Defenders (natural enemies): Observe and count parasitoids and predators.
    - Diseases: Observe leaves and pseudostems and identify any visible disease symptoms and severity.
    - Weeds: Observe weeds in the field and their intensity.
    - Water: Observe the water situation of the field.

- Weather: Observe the weather condition.

- While walking in the field, manually collect insects in plastic bags. Use a sweep net to collect additional insects. Collect plant parts with disease symptoms.
- Find a shady place to sit as a group in a small circle for drawing and discussion.
- If needed, kill the insects with some chloroform (if available) on a piece of cotton.
- Each group will first identify the pests, defenders and diseases collected.
- Each group will then analyze the field situation in detail and present their observations and analysis in a drawing (the AESA drawing).
- Each drawing will show a plant/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 :** Suckers ; 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 will have to consider many other aspects of the crop (crop ecology, growth stage, natural enemies, weather condition, etc.) and their own economic and social situation before they can make the right crop management decisions. In ETL based IPM, natural enemies, plant compensation ability and abiotic factors are not considered. In AESA based IPM emphasis is given to natural enemies, plant compensation ability, abiotic factors and P: D ratio.

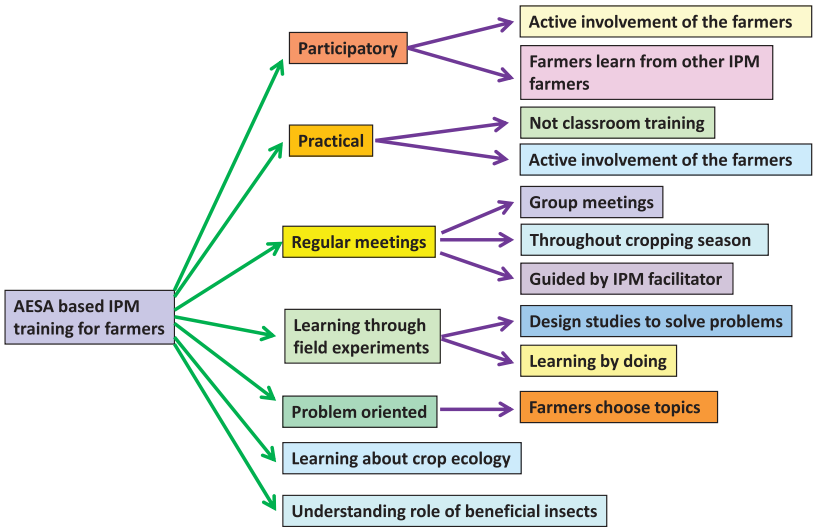
AESA and farmer field school (FFS)

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

Farmers can learn from AESA

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

FFS to teach AESA based IPM skills



B. Field Scouting

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

Surveillance on pest occurrence at the main field should commence soon after crop establishment and at weekly intervals thereafter. In each of the fields, select five spots randomly as shown (four in the corners, at least 5 feet

inside of the field borders, and one in the center). Select twenty random plants at diagonally for recording counts of insects as per procedure finalized for individual insects.

For insect pests:

Scale: Count and record the number of both insects.

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

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

Pseudostem, hands and fruit sampling: Carefully examine the pseudostems, hands and fruits of plants for symptoms and signs of fungal or bacterial diseases. The pseudostems, hands and fruits should be split or taken apart and examined for discoloration caused by fungi and bacteria. Count the number of pseudostem, hand and fruit infected due to disease and percent disease incidence should be recorded.

For weed:

The goal of weed scouting that to assess the infestation level of known weeds as pest and detect new weeds that may be at very low levels so 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 rhizome weevil and leaf eating cater pillar:

Pheromone traps for insect's viz., rhizome weevil and leaf eating caterpillar @ 4-5/acre have to be installed. Install the traps for each species separated by a distance of >75 feet in the vicinity of the selected fixed field. Fix the traps to the supporting pole at a height of mid canopy. Change of lures should be made once a month. During each week of surveillance, the number of moths/trap should be counted and entered. The trapped moths should be removed and destroyed after each recording.

D. Yellow/blue pan water and sticky traps

Set up yellow water pan/sticky traps for monitoring aphid, black fly and blue pan water/sticky traps for thrips @ 4-5 traps/acre at the height of mid canopy. Locally available empty tins can be painted yellow/blue and coated with grease/Vaseline/castor oil on outer surface may also be used. Count the number of aphids, black flies and thrips on the traps daily and take up the intervention when the population exceeds 100 per trap.

E. Light traps

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

F. Nematode extraction

Collect 100 to 300 cm^3 (200-300 g) representative soil sample. Mix soil sample and pass through a coarse sieve to remove rocks, roots, etc. Take a 600 cc subsample of soil, pack lightly into a beaker uniformly. Place soil in one of the buckets or pans half filled with water. Mix soil and water by stirring with paddle; allow to stand until water almost stops swirling. Pour all but heavy sediment through 20-mesh sieve into second bucket; discard residue in first bucket; discard material caught on sieve. Stir material in second bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 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. Shelter such as overwintering sites, moderate microclimate, etc.
3. Alternate host when primary host are not present.

Ecological Engineering for Pest Management – Above Ground :

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

Ecological engineering for pest management – below ground:

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

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

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


Carrot


Sunflower


French bean


Cowpea


Buckwheat


Alfalfa


Maize


Mustard


Marigold

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

Biodiversity of natural enemies observed in Ecological Engineering field at NIPHM

Biodiversity of natural enemies: Parasitoids

Biodiversity of natural enemies: Predators

Biodiversity of natural enemies: Spiders

Flowering plants that attract natural enemies/repel pests

Natural enemies	Attractant/repellent/trap plants
Banana aphid	
• **Predators:** Coccinellids such as *Scymnus*, *Chilomenes sexmaculatus*, lacewings such as *Chrysoperla zastrowi sillemi,* predatory mantids, ladybird beetles and parasitic wasps	• **Attractant plants:** Carrot family, sunflower family, marigold, buckwheat, spear mint (syrphid mite, lace wing, minute pirate bug, damselbug and ladybird beetle) • Cosmos, brambles (praying mantis) • **Nectar rich plants** with small flowers i.e anise, caraway, dill, parsley, mustard. (aphid parasite and Braconid wasp) sunflower, buckwheat and cowpea (Braconid wasp)
Hard scale insects	
• **Predators:** Parasitic wasps, lacewings, ladybird beetles, ants and predatary mites.	• **Nectar rich plants** with small flowers i.e. anise, caraway, dill, parsley, mustard, sunflower, buckwheat and cowpea attract parasitic wasps, predatory mites, Braconid wasp • Corn flower *(Centaurea cyanus),* coriander, sunflower, cosmos attract lacewings. • French bean attract predatory mites
Leaf eating caterpillar	
• **Egg parasitoids:** *Telenomus spodopterae*, *T. remus* • **Larval parasitoids***: Ichneumon* sp, *Carcelia* spp *Campoletis chlorideae* • **Pupal parasitoid:** *Ichneumon* sp • **Predators:** *Chrysoperla zastrowi sillemi,* Coccinellids, King crow, Braconid wasp, dragon fly, spider, robber fly, reduviid, praying mantis, red ants • **Nematode parasite:** *Ovomermis albicans*	• **Attractant plants**: Carrot family, sunflower family, buckwheat, alfalfa, corn, shrubs (minute pirate bug & lace wing) • **Nectar rich plants** with small flowers i.e. anise, caraway, dill, parsley, mustard, sunflower, buckwheat and cowpea attract parasitic wasps, predatory mites, Braconid wasp • Corn flower *(Centaurea cyanus),* coriander, sunflower, cosmos attract lacewings. • French bean attracts predatory mites
Thrips	
• **Parasitoid:** *Ceranisus menes,* • **Predators:** Lacewings, ladybird beetles. syrphid fly, minute pirate bug, predatory thrips, spiders, damselbug.	• **Attractant plants**: Carrot family, sunflower family, buckwheat, alfalfa, corn, corn flower *(Centaurea cyanus),* coriander, cosmos attract lacewings, minute pirate bug & lacewings

A. Resistant/ tolerant varieties:

Pest	Tolerant/ resistant variety
Banana aphid	Musa AAB
Moko disease / Bacterial wilt	poovan and monthan.
Fusarium wilt	Poovan, Robusta, Moongil
Nematode , corm weevil	Poovan, Kadali, Kunnan, Poomkalli.
Sigatoka leaf spot	Ney Poovan, Pachanadan, Karpuravalli, Fhia 1 (Gold finger), Sannachenkadali
Panama wilt disease	Dwarf Cavendish, Robusta, Fhia 1 (Gold finger), Anai komban, Nivedya Kadali.
Bunchy top disease	Poovan, Pachanadan

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

IV. CROP STAGE-WISE IPM

Management	Activity
Pre planting*	
Nutrients	• Banana requires high amount of nutrients, which needs to be supplied in the form of manures and fertilizers. • Nutrients should be supplied on the basis of soil test report and recommendations. • Generally banana crop requires 7-8 Kg N, 0.7- 1.5 Kg P and 17-20 Kg K per metric ton yield. • In acidic soils, use dolomite (Mg_2CO_3) or limestone ($CaCO_3$) as soil amendments.
Weeds	• Deep ploughing and cross harrowing before planting
Nematodes, banana corm weevil and diseases**	**Cultural control:** • Deep ploughing during summer. • Use of disease free planting material. • Storage of large corms in the sun for two weeks prior to planting. • Select healthy suckers. • Avoid growing Robusta, Karpooruvally, Malbhog, Champa and Adukkar. • Grow less susceptible varieties like Poovan, Kadali, Kunnan, Poomkalli. • Intercropping of banana with *Crotalaria juncea,* marigold reduces burrowing nematodes **Chemical control:** • Before planting, the suckers should be dipped in carbofuran 3% CG @ 33g/ sucker then shade dry for 72 hrs then go for planting for rhizome weevil. • For nematode treat the suckers with carbofuran 3% CG @ 50g/suckers.
Planting*	
Nutrients	• At the time of planting, apply 10 kg FYM, 200 – 250 g N; 60-70 g P; 300 g K/ plant. • Further application of 100 g potash and also 40 g of phosphorus are essential and applied at planting. Application of full dose of P and K at planting and N in three equal doses in shallow rings about 8-10 cm deep are recommended.
Weeds	**Cultural Control:** • Use weed free suckers for planting. • Adopt intercropping of recommended crops (e.g. cowpea etc.) with recommended agronomic practices. **Chemical Control:** • Pre-emergence application of diuron 80% WP@ 0.8 Kg in 250 l of water/acre if infestation by the weed species as recommended by CIBRC.
Nematodes, banana rhizome weevil and diseases**	**Cultural control:** • Use of cover crop calopogonium. • Crop rotation with non-host crops. **Chemical control:** • Before planting, the suckers should be dipped in carbofuran 3% CG @ 33g/ sucker then shade dry for 72 hrs then go for planting for rhizome weevil. For nematode treat the seed with carbofuran 3% CG @ 50g/suckers.

* Apply *Trichoderma viride/harzianum* and *Pseudomonas fluorescens* as rhizome, nursery treatment and soil application (if commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).	
Vegetative stage	
Nutrients	• The application of 25 % N in organic form, 75 % N in inorganic form along with growing green manure crops is found to be beneficial. • Application of 25% N as farmyard manure and 1 Kg. neem cake is beneficial. • Apply 100 g of N/plant as top dressing in three equal split doses 60, 90 and 120 days after planting. • In acidic soils, triple superphosphate or diammonium phosphate is recommended. • Application of 100 g K in two splits during vegetative phase should be done. • Application of 200-300 g K_2O is recommended depending upon the cultivar. • Muriate of potash is generally used as a source of K. But in soils with pH above 7.5, potassium sulphate is advantageous. • **Micronutrients:** Combined foliar application of $ZnSO_4$ (0.5%), $FeSO_4$ (0.2%), $CuSO_4$ (0.2%) and H_3BO_3 (0.1%) applied at 3, 5 and 7 months after planting helps to increase yield and quality of banana. • **Fertigation:** In order to avoid loss of nutrients from conventional fertilizers i.e. loss of N through leaching, volatilization, evaporation and loss of P and K by fixation in the soil, application of water soluble or liquid fertilizers through drip irrigation (fertigation) should be adopted.
Weeds	• Regular weeding should be done in the banana basin. • Regular mowing of weeds between banana rows should be done. • Ploughing between banana rows. • Same cultural practices as in vegetative stage
Leaf eating caterpillar	**Cultural control:** • Collect and destroy egg masses and caterpillars • Use burning torch to kill the congregating larvae • Summer ploughing to expose to the pupae. • Grow repellant plants: Ocimum/basil • Attractant plants: Carrot family, sunflower family, buckwheat, alfalfa, corn, shrubs (minute pirate bug & lacewing) • Nectar rich plants with small flowers i.e anise, caraway, dill, parsley, mustard, sunflower, buckwheat and cowpea (Braconid wasp) **Mechanical control:** • Hand pick and destroy the egg masses and caterpillars • Collect and destroy the damaged plant parts. • Use pheromone @ 4-5 traps/acre. • Use light trap to attract and kill the adults. **Biological control:** • Field release of egg parasitoids such as *Telenomus spodopterae*, *T. remus* • Encourage the activity of larval parasitoids *Ichneumon promissorius, Carcelia* spp., *Campoletis chlorideae*

	• Pupal parasitoids such as *Ichneumon* sp etc. • Predators such as *Chrysoperla zastrowi sillemi,* Coccinellids, King crow, Braconid wasp, dragonfly, spider, robber fly, reduviid bug, praying mantis, red ants • Conserve nematode such as *Ovomermis albicans*
Banana rhizome weevil	**Cultural control:** • Removal of pseudostems below ground level • Trimming the rhizome • Prune the side suckers every months. **Mechanical control:** • Pheromone lure ('cosmolure') can be used for monitoring as well as trapping of banana rhizome weevil. Installing traps at low trap density 2/acre. • Initially placed in a line of 10 meters from a border and 20 meters apart. **Chemical control:** • Soil incorporation at the time of planting carbofuran 3% CG @ 33g/sucker.
Banana lacewing bug/ tingid bug	**Cultural control:** • Collect and destroy the damaged leaves, flowers and fruits along with life stages **Chemical control:** • Spray carbofuran 3% CG @ 166g/sucker or dimethoate 30% EC @ 594-792 ml in 600-800 l of water/acre or oxydemeton – methyl 25% EC @ 600-800 ml in 600-800 l of water/acre or quinalphos 25% EC @ 1200-1600 ml in 200-400 l of water/acre, direct the spray towards the crown and pseudostem base
Banana thrips	**Cultural control:** • Collect and destroy the damaged leaves, flowers and fruits along with life stages • Use blue pan water sticky trap @ 4-5/acre • Destroy all volunteer plants and old neglected plantations. Use healthy and pest free suckers for planting • Hot water treatment of suckers prior to planting. • Bunch covers (which cover the full length of the bunch) protection applied very early. • Regular checking of fruit under the bunch covers is essential to ensure that damage. • Conserve predators such as coccinellid and lacewings
Leaf and fruit scarring beetle	**Cultural control:** • Practice clean cultivation by removing the grass weeds from the banana plantations.
Banana aphids	**Cultural control:** • Use yellow pan water sticky trap @ 4-5/acre • Ensure clean cultivation • Encourage activity of predator coccinellids such as *Scymnus*, *Chilomenes sexmaculatus*, and lacewing, *Chrysoperla zastrowi sillemi* **Chemical control:** • Apply carbofuran 3% CG@166g/sucker or dimethoate 30% EC @594-792 ml in 600-800 l of water/acre or oxydemeton – methyl 25% EC @1200-1600 ml in 600-800 l of water/acre, direct the spray towards the crown and pseudostem base upto ground level.

Hard scale insect**	**Cultural control:** • Collect and destroy the affected plant parts. **Biological control:** • Field release of coccinelid predators like *Chilocorus nigritus, Symnus coccivora*
Banana scab moth	**Cultural control:** • Careful selection of following suckers of equal size will ensure a concentrated bunching cycle that streamlines control. **Biological control:** • A range of spiders and other general predators exert a measure of natural control.
Sigatoka disease	**Cultural control:** • Removal and destruction of the affected leaves. • Prevent water accumulation around the plant and go for periodical weeding. • Select tolerant varieties such as Ney Poovan, Pachanadan, Karpuravalli, Fhia 1 (Gold finger), Sannachenkadali **Chemical control:** • Mancozeb 75% WP @600-800 g in 400 l of water/acre. • Propiconazole 25% EC @ 0.1% (100 ml/100 l water.) in 200-400 l of water/acre. • Copper oxychloride 50% WP @ 1Kg in 300-400 l of water/acre.
Moko diseases	**Cultural control:** • Providing good drainage. • Disinfestation of tools with formaldehyde diluted with water in 1:3 ratio. • Crop rotation (3 years rotation with sugarcane or rice) & providing good drainage. • Allow fallow period or flooding during off-season.
Bunchy top disease	**Cultural control:** • Select suckers from disease free areas. • Infected plants are destroyed using 4ml of 2, 4, D (50g in 400 ml of water). • Remove weeds which are attractant to aphids. • Select tolerant varieties such as Poovan, Pachanadan **Chemical control:** • Control vector by spraying carbofuran 3% CG @166g/sucker or dimethoate 30% EC @ 594-792 ml in 600-800 l of water/acre or oxydemeton – methyl 25% EC @ 1200-1600 ml in 600-800 l of water/acre.
Panama disease	**Cultural control:** • Avoid growing of susceptible cultivars *viz.,* Rasthali, Monthan, Red banana and Virupakshi. • Grow resistant cultivar Poovan. • Removal and destruction of affected leaves followed by spraying with BM (1%) +linseed oil (2%). • Select tolerant varieties such as Dwarf Cavendish, Robusta, Fhia 1 (Gold finger), Anai komban, Nivedya Kadali.

Tip rot	**Cultural control:** • Remove infected plants and destroy. **Chemical control:** • Drench with mancozeb 75% WP @ 600-800 g in 400 l of water/acre.
Anthracnose	**Cultural control:** • Proper sanitation of handling and prompt cooling to 14° C are essential in minimising the disease in cold storage.
Cigar end rot**	**Cultural control:** • Prompt cooling to 14° C; proper sanitation of handling facilities reduce the incidence in the cold storage. **Chemical control:** • Mancozeb 75% WP @ 600-800g in 400 l of water/acre.
Infectious chlorosis	**Cultural control:** • Destroy infected plants • Use disease free suckers • Dry heat treatment of suckers at 40° C for 1 day • Avoid growing cucurbits as intercrop **Chemical control:** • Control aphid vector by applying carbofuran 3% CG @ 166g/sucker or dimethoate 30% EC @ 594-792 ml in 600-800 l of water/acre or oxydemeton – methyl 25% EC @ 1200-1600 ml in 600-800 l of water/acre.
Banana bract mosaic virus/streak mosaic	**Cultural control:** • Dry heat treatment of suckers at 40° C for 1 day. • Avoid growing cucurbits as intercrop
Reproductive stage (5th-7th month):	
Weeds	• Same cultural practices as in vegetative stage. • Left over weeds before shading of seeds should be removed to reduce the weed seed bank/spread.
Banana stem weevil	**Cultural control:** • Remove dried leaves periodically and keep the field clean • Prune the side suckers every month • Use healthy and pest free suckers to check the pest incidence • Do not dump infested materials into manure pit • Uproot infested trees, chop into pieces and burn • Use longitudinally split pseudostem trap at 26/acre. • 2ml at 45 cm from ground level; another 2m at 150 cm from ground level. • Uproot infested trees, chop into pieces and burn.
Post harvest	
Anthracnose	• Same as in vegetative stage

Management of regional pests:

Fruit fly:

- Grow less susceptible variety
- Create physical barrier between the host fruits and the egg-laying female fruit fly can be provided by bagging or rapping the fruits before maturity. Bags can be made from double layers of newspaper or brown paper.

- The whole fruit bunches may be bagged inside banana leaves at later stage.
- The collection and destruction of fallen, damaged and overripe fruits is strongly recommended to reduce the resident population of fruit flies.
- Fruit fly trap can be erected at every 20 meter distance.
- Early harvesting may also reduce the fruit infestation and damage.

Bag worm

- The sanitary measures like hand picking and destroying the infested leaf parts should be adopted.

Finger tip or black tip rots

- Wrap the banana fruit bunch in plastic bag prior to hot water dip.

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

** Pests of regional significance

V. INSECTICIDE RESISTANCE AND ITS MANAGEMENT

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

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

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

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

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

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

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

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

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

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

VI. NUTRITIONAL DEFICIENCIES/DISORDERS

Nitrogen: Leaves of all ages become pale green. Mid ribs, petioles and leaf sheaths turn reddish pink and rosette in appearance. Plantations with poor root growth exhibit such symptoms. Bunch weight and fruit quality is affected.

Control: Application of urea (300g/plant) followed by irrigation is recommended.

Phosphorus: Plants show stunted growth with poor root development. Old leaves show saw tooth marginal chlorosis, curling of leaves, breaking of petioles and bluish green colour of younger leaves.

Control: Application of DAP (50g/plant) followed by irrigation is recommended.

Potassium: The deficiency symptoms include orange yellow colour of old leaves, scorching along the margins, reduction in total leaf area, curving of midribs etc. Choking of leaves delay flower initiation leading to reduction in yield and quality.

Control: Spraying Potassium Sulphate (1%) solution on the leaves is recommended.

Boron: Deficiency symptoms include reduced leaf area, curling of leaves, lamina deformation, appearance of white stripes perpendicular to the veins on the lamina of young leaves, thickening of secondary veins and inhibition of root and flower formation.

Control: Application of Borax salt (25 g/plant) in the soil around the root zone of the plant is recommended

Magnesium: Yellow discolouration is observed in the mid blade and midrib portion, however, the margins of the leaf remain green. Purple mottling of the petioles, marginal necrosis and separation of leaf sheaths from the pseudostem is also seen.

Control: Application of Magnesium Sulphate (25g/plant) followed by irrigation is recommended.

Sulphur: The deficiency symptoms include yellow or white appearance of young leaves, necrotic patches on the leaf margins, thickening of veins, stunted growth and small or choked bunches.

Control: Application of complex fertilizer (20:20:0:15) @ 20 g/plant followed by irrigation is recommended.

Iron: The younger leaves turn yellow or white.

Control: Spraying Iron Sulphate (0.5%) along with Urea (1%) on the leaves is recommended.

Copper: Both young and old leaves show symptoms of chlorosis and curve towards the base, which gives an umbrella like appearance to the plant.

Control: Spraying Copper Sulphate (0.5%) on the leaves is recommended.

Zinc: Symptoms appear mostly in limed soils or soils with high pH. Young leaves become smaller in size and more lanceolate in shape. In the furling leaf high amount of anthocyanin pigmentation appear on its underside. The unfurled leaf has alternating chlorotic and green bands. Fruit is light green, twisted, short and thin.

Control: Spraying Zinc Sulphate (0.5%) on the leaves is recommended.

Manganese: Narrow green edge appears at the leaf margins of second or third youngest leaf, which further spreads along the main veins towards the midrib. However, the interveinal areas remain green giving comb tooth appearance.

Control: Spraying Manganese Sulphate (0.5%) on the leaves is recommended.

Calcium: The deficiency symptoms include deformation or absence of leaf lamina (spike leaf), marginal leaf necrosis and thickening of veins

Control : Application of lime (50g/plant) followed by irrigation is recommended.

VII. DESCRIPTION OF COMMON WEEDS

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 long (up to 10 cm), occasionally longer than the blade; blade ovate to rhombic-oblong, base tapered to blunt, tip rounded. Flowers green, unisexual, male and female intermixed, in slender axillary to terminal paniculate spikes 2-12 cm long and 2-5 mm wide, or in dense axillary clusters in the lower part of the stem. Fruits are capsule almost round shaped 1.25-1.75 mm long with rough surface. Seeds 1-1.25 mm, round, slightly compressed dark brown to black with a paler thick border.

2) Spiny pigweed: *Amaranthus spinosus* L. (Amaranthaceae)

Amaranthus, collectively known as amaranth, is a cosmopolitan genus of annual or short-lived perennial plants. Catkin-like cymes of densely packed flowers grow in summer or autumn. Approximately 60 species are recognized, with inflorescences and foliage ranging from purple and red to green or gold. Members of this genus share many characteristics and uses with members of the closely related genus *Celosia*.

3) 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.

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

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

5) Tridax: *Tridax procumbens* L. (Asteraceae)

The plant bears daisy like yellow-centered white or yellow flowers with three-toothed ray florets. Its fruit is a hard achene covered with stiff hairs and having a feathery, plumelike white pappus at one end. Calyx is represented by scales or reduced to pappus. The plant is invasive in part because it produces so many of these achenes, up to 1500 per plant, and each achene can catch the wind in its pappus and be carried some distance. This weed can be found in fields, meadows, croplands, disturbed areas, lawns, and roadsides in areas with tropical or semi-tropical climates.

6) Spurge: *Euphorbia hirta* L. (Euphorbiaceae)

An erect or procumbent annual herb, 15-50 cm height. Densely clothed with yellow hairs; branches often 4-angled. Opposite, 1.3-3.8 cm long and 0.6-1.6 cm wide, obliquely elliptic, apex acute, base usually unequal-sided, margins serrulate or dentate, hairy, dark green above and pale beneath. Numerous, less than 1.3 mm long, crowded in small, globose, greenish-yellow axillary cymes. Capsules minute, 1.25 mm in diameter, trigonous, appressed hairy. Angular, 0.8 mm long, light reddish-brown.

Grasses

7) Bermuda grass: *Cynodon dactylon* (L.) Pers (Poaceae)

The blades are a grey-green colour and are short, usually 2–15 cm (0.79–5.91 in) long with rough edges. The stems are slightly flattened, often tinged purple in colour. The seed heads are produced in a cluster of two to six spikes together at the top of the stem, each spike 2–5 cm (0.79–1.97 in) long. It has a deep root system; in drought situations with penetrable soil, the root system can grow to over 2 m deep, though most of the root mass is less than 60 cm under the surface. The grass creeps along the ground and roots wherever a node touches the ground, forming a dense mat. *C. dactylon* reproduces through seeds, runners, and rhizomes. Growth begins at temperatures above 15 °C (59 °F) with optimum growth between 24 and 37 °C (75 and 99 °F); in winter, the grass becomes dormant and turns brown.

8) 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

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

A perennial sedge, hard, fragrant, globose-ovoid tubers, up to1.2 cm long and 0.3-0.7 cm in diameter; culms solitary or few together, sparsely tufted, erect, 10-75 cm tall, 3-angled at top. Leaves narrowly linear, sometimes longer than stem, 0.4-0.8 cm wide, dark green above, pale beneath. Inflorescence is a simple or compound umbel, rays 2-8, each up to 7.5 cm long, bearing short spikes of 3-10 spreading, red-brown spikelets. Nuts oblong to ovate-oblong, 3-sided, 1.3-1.5 mm long and 0.5-0.7 mm wide, maturing brown.

VIII. DESCRIPTION OF INSECT PESTS

1) Banana rhizome weevil:

Biology:

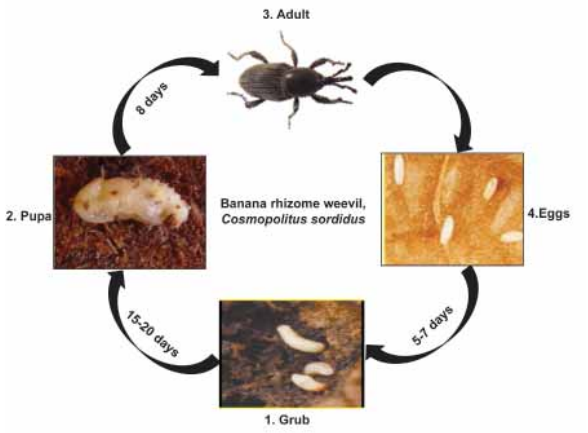
Egg: Eggs are laid singly, white in colour present on the upper part of rhizome.

Grub: Grub is apodous, yellowish white with red head.

Pupa: Pupa is white in colour, occur in inside the corm and tunneling.

Adult: Adult is dark weevil, newly emerged weevil is red brown.

Life cycle:



1,2. http://www.agritech.tnau.ac.in/expert_system/banana/cropprotection.html
3. http://entopcastillo.blogspot.in/2011/12/adulto-de-cosmopolites-sordidus-germar.html
4. http://www.extento.hawaii.edu/kbase/crop/type/cosmopol.htm

Damage symptoms:

- Grubs bore into the rhizome and cause death of the plant. Presence of dark coloured tunnels in the rhizomes and withering of outer leaves.

http://cookislands.bishopmuseum.org/MM/MX5/5AUt117_Cosm-sord_Cornell_Uni_WW_MX.jpg
http://www.extento.hawaii.edu/kbase/crop/type/cosmopol.htm

Favourable conditions:

- Weevils hide under debris or in the soil around banana plants during the day and are active at night

*For management refer to page numbers 14,16

2) Banana stem weevil:

Biology:

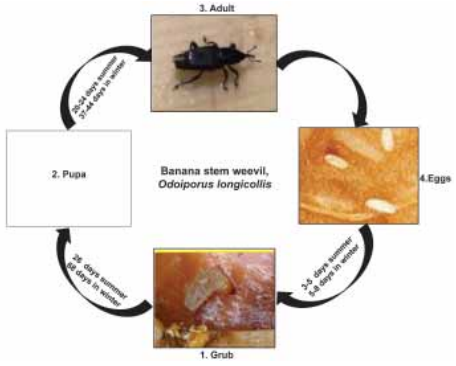
Egg: Eggs are laid at random on cut ends of pseudostem, yellowish-white, cylindrical in shape.

Grub: Grubs are apodous, creamy white with dark brown head.

Pupa: Pupa is pale yellow colour, fibrous cocoon formed inside the tunneling on the periphery.

Adult: Adults are robust, reddish brown and black.

Life cycle:



1,2,3. http://www.yourarticlelibrary.com/wp-content/uploads/2014/01/clip_image008_thumb19.jpg
4. http://www.yourarticlelibrary.com/plants/major-insect-pests-that-attack-banana-tress-in-india-and-their-control/24166/

Damage symptoms:

- Grub bore into pseudostem making tunnels.
- Tunneled part decomposes and pseudostem becomes weak.
- They also cut holes on outer surface later blackened mass comes out from the bore hole.
- Wilting of the plant.

1. Small pin holes in pseudostem, 2. Blackened mass 3. Gummy exudation

Favourable conditions:

- Infestation of the weevil normally starts in 5 month old plants.

*For management refer to page number 18

3) Banana leaf eating caterpillar:

Biology:

It is found throughout the tropical and sub tropical parts of the world, wide spread in India. Besides tobacco, it feeds on cotton, castor, groundnut, tomato, cabbage and various other cruciferous crops.

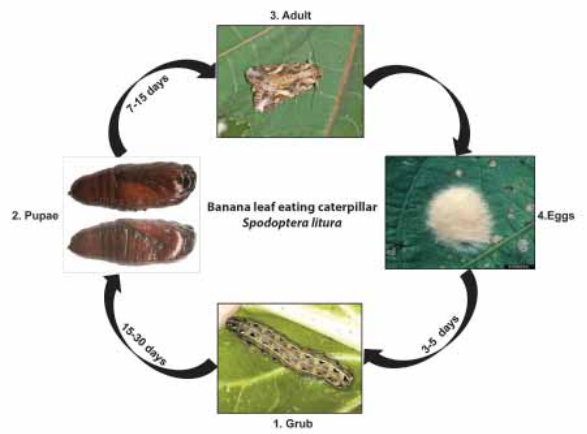
Egg: Female lays about 300 eggs in clusters. The eggs are covered over by brown hairs and they hatch in about 3-5 days.

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

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

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

Life cycle:



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

Damage symptoms:

- Young larvae feed by scrapping the leaves from ventral surface
- Later on feed voraciously at night on the foliage.

Infested leaf

http://www.intechopen.com/books/pesticides-advances-in-chemical-and-botanical-pesticides/biotechnological-approaches-for-the-control-of-insect-pests-in-crop-plants
http://www.agritech.tnau.ac.in/expert_system/banana/cropprotection.html#cutworm

Parasitoids of banana leaf eating caterpillar:

Egg parasitoid:

1. *Telenomus* sp

Larval parasitoid:

2. *Chelonus* sp

1. http://baba-insects.blogspot.in/2012/02/telenomus.html
2. http://www.nbaii.res.in/Featured%20insects/chelonus.htm

Predators of banana leaf eating caterpillar:

1. Lacewing

2. Ladybird beetle

3. Spider

4. Praying mantis

5. Reduviid bug

6. Dragon fly

7. Robber fly

8. King crow

9. Wasp

4. http://spirit-animals.com/praying-mantis/
6. http://en.wikipedia.org/wiki/Dragonfly
7. http://www.warpedphotosblog.com/robber-fly-and-prey
8. http://nickdobbs65.wordpress.com/tag/herbie-the-love-bug/
9. http://somethingscrawlinginmyhair.com/2011/09/17/yellowjacket-with-prey/

*For management refer to page numbers 15-16

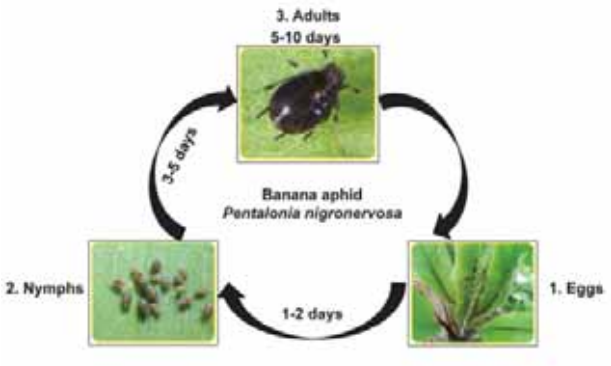
4) Banana aphid:

Biology:

Nymph : Oval or slightly elongated, reddish brown with six segmented antennae

Adult: Small to medium sized aphids, shiny, reddish to dark brown or almost black. They have six segmented antennae and prominent dark veins. Adults start producing young one day after reaching maturity. They can give birth to 4 aphids per day with an average production of 14 offspring per female.

Life cycle:



1. http://www.infonet-biovision.org/res/res/files/1101.280x185.clip.jpeg
2. http://www.ctahr.hawaii.edu/bbtd/images/aphid-1.jpg
3. http://www.agritech.tnau.ac.in/expert_system/banana/cropprotection.html

Damage symptoms:

- Leaves are bunched into a rosette appearance.
- Leaf margins are wavy and upward rolling.
- Do not produce bunches.
- It is vector of bunchy top disease.
- Seen in colonies on leaf axils and pseudostem.

Aphids on under surface of leaves

http://www.slideshare.net/IITA-CO/biology-monitoring-and-management-of-banana-aphid-vector-of-banana-bunchy-top-virus

Predators of banana aphids:

1.*Chrysoperla*

2. Ladybird beetles

3. Predatory mite

4. Parasitic wasp

1. http://micropics.org.uk/Chrysopidae/Chrysoperla/carnea/chrysoperla%20carnea.htm \
3. http://www.shutterpoint.com/Photos-ViewPhoto.cfm?id=94159
4. http://crawford.tardigrade.net/journal/album7023.html

*For management refer to page number 16

5) Rust thrips:

Biology:

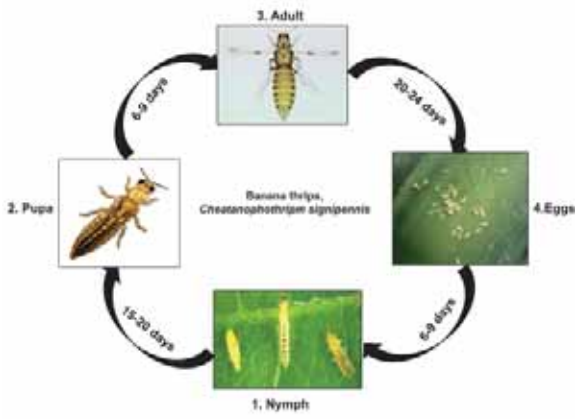
Egg: Eggs are not visible to the naked eye. Eggs are laid just below the fruit or pseudostem surface. In summer, eggs hatch in about eight days

Larva: The wingless creamy white larvae are smaller but have the same shape as the adult. The larval period lasts about 8-10 days.

Pupa: Pupae are white, 1 mm in length, similar to the larvae and can crawl. The pupal stage lasts 7-10 days

Adult: The adult is slender, 1.5 mm long, creamy yellow to golden brown with delicate feathery wings.

Life cycle:



1. http://www.extento.hawaii.edu/kbase/crop/type/BR_thrips.htm
2,3,4.http://www.extento.hawaii.edu/kbase/crop/type/image/bananarustthrips_cycle.jpg

Favourable conditions:

- Warm and humid weather

Parasitoid of rust thrips

Nymphal parasitoid:

Ceranisus menes

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

Damage symptoms:

- The early symptoms appear as water-soaked smoky areas where the colonies congregate to feed and oviposit between touching or adjacent fruit.
- These areas then develop the typical rusty-red to dark brown-black discolouration.
- Further rusty growth of the fruit and yellowing of leaves.

Rusty red dicolouration patches Yellowing of Leaves

http://www.agritech.tnau.ac.in/expert_system/banana/cropprotection.html#4

Predators of rust 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

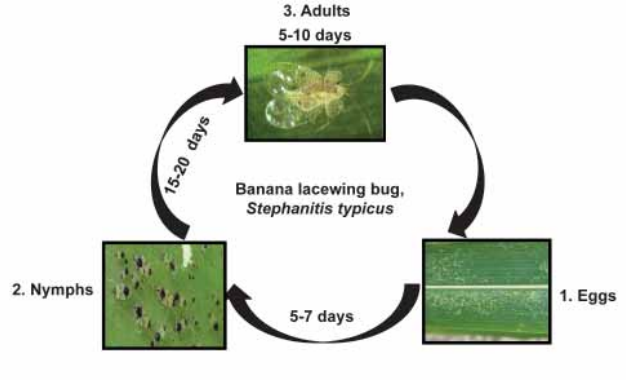
*For management refer to page number 16

6) Lacewing bug:

Biology:

- Small, whitish lacewing bug found in colonies on the foliage

Life cycle:



http://4.bp.blogspot.com/-9AzDOKus4O4/TeePsqSx9zI/AAAAAAAAAal/icQcCQGrPu0
s1600/2+Turmeric+lace+wing+bug+stephanitis-typicus.jpg

Damage symptoms:

- Causing a sickly and spotted appearance of the plant. The foliage of infested plants turns pale or yellow and dries up.
- The pest infestation is more common during the post monsoon period especially in drier regions of the country.

1. Yellowish spots on leaves

2. Adult

3. Leaf Spot

1, 2, 3. http://agritech.tnau.ac.in/crop_protection/crop_prot_crop_insectpest%20_-Banana_pest&disease.html

*For management refer to page number 16

7) Banana scab moth:

Biology:

- The moth is small (25 mm wingspan) tan to light brown with small black spots on the wings.
- The flattened eggs are laid in clusters ranging from a few to 30 eggs. The eggs resemble shiny overlapping fish scales.
- The yellow to orange larvae grow to about 25 mm before pupating.

Adult

http://flickrhivemind.net/Tags/nacoleia/Interesting

Favorable conditions:

- This pest is most active during the hot wet summer months but sudden outbreaks can occur throughout the year in some localities.
- Damage occurs progressively as the hands lift and increases in severity towards the lower hands.

Damage symptoms:

- Larval feeding causes superficial scarring on young fruit. Damaged areas form a black callous, rendering the fruit unmarketable.
- Feeding is generally confined to the curve of the fruit adjacent to the bunch stalk and between the fingers. Damage ceases after the hand lifts. Mature larvae can be found under the bracts enclosing the male flower or 'bell'.

Banana scab moth larva *(Nacoleia octasema)* feeding on immature fruit

http://www.daff.qld.gov.au/plants/fruit-and-vegetables/a-z-list-of-horticultural-insect-pests/banana-scab-moth.

Predators of banana scab moth:

1. Lacewing

2. Ladybird beetle

3. Spider

4. Praying mantis

5. Reduviid bug

6. Dragon fly

7. Robber fly

8. King crow

9. Wasp

4. http://spirit-animals.com/praying-mantis/
6. http://en.wikipedia.org/wiki/Dragonfly
7. http://www.warpedphotosblog.com/robber-fly-and-prey
8. http://nickdobbs65.wordpress.com/tag/herbie-the-love-bug/
9. http://somethingscrawlinginmyhair.com/2011/09/17/yellowjacket-with-prey/

*For management refer to page number 17

8) Hard scale:

Biology:

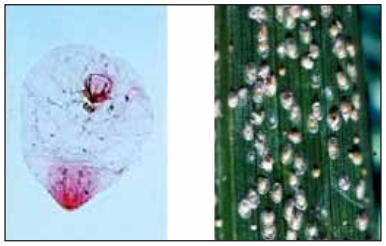
Egg: Eggs are laid beneath the scale. Adult females shrink in size as they lay their eggs. The female rotates as it deposits eggs so that eggs are arranged in concentric circles around the females. Eggs are laid in batches of 3 or 4 at a time. 65 to 110 eggs were laid by female. The eggs are white when first laid and turn yellow after a few days.

Nymph: The larvae, called crawlers, have well-developed legs and antennae and a pair of bristles at the tip of the abdomen. The free living stage lasts from 2 to 48 hours, but usually does not exceed 12 hours. After the larvae have attached themselves to the leaf, they go through a period of rapid growth for 7-11 days before the first molt. The second larval stage lasts for 5-8 days for males and 8-10 days for females.

Pupa: The male pupal period lasts for 4-6 days. Females continue to grow after their second molt for 8-9 days and do not change in body shape. When the female stops growing, she begins to lay eggs and is then considered an adult.

Adult: The adult female is orange-yellow semitransparent, circular in shape and approximately 1/12 inch in diameter. Females produce an average of 90 eggs throughout her lifetime. The adult male does not feed and is short lived. Reproduction primarily occurs through parthenogenesis, or reproduction without fertilization, in which females are able to produce both male and female progenies. Occasionally a female may lay eggs that produce only male scales.

Scale



http://www.extento.hawaii.edu/kbase/crop/type/a_destru.htm

Damage symptoms:

- Grubs bore into the rhizome and cause death of the plant.
- Presence of dark coloured tunnels in the rhizomes.
- Death of unopened pipe, withering of outer leaves.

Infested leaves

http://agritech.tnau.ac.in/crop_protection/crop_prot_crop_insectpest%20_-Banana_pest&disease.html

Predator of hard scale:

Chilocorus nigritus

http://keys.lucidcentral.org/keys/phoenix/ChilocorusSpeciesOfIndia/Chilocorus%20key/html/chinigmax1.jpg

*For management refer to page number 17

IX. DESCRIPTION OF DISEASES

1) Panama wilt:

Disease symptoms:

- Yellowing of the lower most leaves starting from margin to midrib of the leaves
- Yellowing extends upwards and finally heart leaf alone remains green for some time and it is also affected.
- The leaves break near the base and hang down around pseudostem.
- Longitudinal splitting of pseudostem. Discolouration of vascular vessels as red or brown streaks.

Infected plant and Stem

http://tcbanana.blogspot.in/2012/01/fungal-disease-foliar-panama-wilt.html
http://www.icargoa.res.in/dss/banana.html

Survival and spread:

- The pathogen spreads through infected rhizomes

Favourable conditions:

- Continuous cultivation in the infested field or monocroping results in buildup of inoculum

*For management refer to page number 17

2) *Mycosphaerella* leaf spot, yellow sigatoka, black sigatoka:

Disease symptoms:

- Early symptoms appear on the third or fourth leaf from the top, i.e., on young leaves.
- Small spindle shaped spots on foliage with greyish centre and yellowish halo running parallel to veins.
- If the fruit is nearing maturity at the time of heavy infection, the flesh ripens but evenly and individual bananas appear undersized and their flesh develops a buff pinkish colour, and store poorly.

Yellow sigatoka **Black sigatoka**

http://www.agritech.tnau.ac.in/expert_system/banana/cropprotection.html#13
http://visualsunlimited.photoshelter.com/image/I0000rdzD4fDP7EA

Survival and spread:

- The conidia of the fungus are carried by wind ,rain water and old dried infected leaves and they help to spread the disease

*For management refer to page number 17

3) Anthracnose:

Disease symptoms:

- At the initial stage, small, circular, black spots develop on the affected fruits. Then these spots enlarge in size, turn to brown colour
- The skin of the fruit turns black and shrivels and becomes covered with characteristic pink acervuli. Finally the whole finger is affected. Later the disease spreads and affects the whole bunch.
- The disease results in premature ripening and shriveling of the fruits which are covered with pink spore masses.
- Occurrence if black lesions on the pedicel causes withering of the pedicel and dropping of the fingers from the hands
- Sometimes the main stalk of the bunch may become diseased. Infected fruits become black and rotten

http://www.agritech.tnau.ac.in/expert_system/banana/cropprotection.html#6
http://www.plantwise.org/default.aspx?site=234&page=4279&dsID=14923
http://www.plantwise.org/Uploads/CompendiaImages/Normal/col_mus1.jpg

Survival and spread:

- The spread of the disease is by air-borne conidia and numerous insects which frequently visit banana flowers also spread the disease

Favourable conditions:

- The disease is favoured by high atmospheric temperature and humidity, wounds and brusies caused in the fruit and susceptibility of the variety

*For management refer to page number 18

4) Moko disease/bacterial wilt:

Disease symptoms:

- Leaves become yellow and progress upwards. The petiole breaks and leaves hang.
- When it is cut open discolouration in vascular region with pale yellow to dark brown colour.
- The discolouration is in the central portion of the corm.
- Internal rot of fruits with dark brown discoloration.
- When the pseudostem is cut transversely bacterial ooze can be seen.

http://www.freshfruitportal.com/2013/01/28/moko-disease-a-threat-to-colombian-banana-costs/?country=india
http://uasr.agropedia.in/content/banana-moko-disease

Survival and spread:

- The bacterium survives in infected plant material, vegetative propagative organs, wild host plants, and soil.

Favourable conditions

- High temperatures and high soil moisture generally favors disease

*For management refer to page number 17

5) Tip over or bacterial soft rot:

Disease symptoms:

- This disease is more pronounced on young suckers leading to rotting and emitting of foul odour
- Roting of collar region is a commonest symptom followed by epinasty of leaves, which dry out suddenly
- If affected plants are pulled out it comes out from the collar region leaving the corm with their roots in the soil
- In early stage of infection dark brown or yellow water soaked areas are more in the cortex area When affected plants are cut open at collar region yellowish to reddish ooze is seen.

http://www.gardeningknowhow.com/wp-content/uploads/2011/06/bacteria-soft-rot-400x580.jpg
http://www.kissankerala.net:8080/KISSAN-CHDSS/English/Banana/Disease/6.htm

Survival and spread:

- Bacteria survive in crop debris and infect by water splash through damaged tissues.
- Worse in hot wet weather. The bacteria spread in contaminated water.

Favourable conditions

- Higher temperatures and high humidity are ideal growing conditions for the bacteria

*For management refer to page number 18

6) Bunchy top/curly top:

Disease symptoms:

- Prominent dark green streaks on the petioles and midrib along the leaf veins.
- Marginal chlorosis and curling of leaves
- Petioles fail to elongate
- Leaves are reduced in size, chlorotic, stand upright and become brittle and are crowded at the top (Bunchy top) and shoe dark green streaks with 'J hook' shape near the midrib.
- Flowers display mottled and streaked discolouration
- Plants show marked stunting

Infected plant and leaf

http://www.ctahr.hawaii.edu/bbtd/aphid_colonies.asp

http://www.rtb.cgiar.org/category/news-events/blog/

Survival and spread:

- Vector: banana aphid, *Pentalonia nigronervosa*
- The disease can be spread by infected plant debris, plant wounds and injuries.

Favourable conditions:

- Hot and damp weather with plenty of rainfall trigger the disease to occur.

*For management refer to page number 17

7) Banana bract mosaic virus (BBMV):

Disease symptoms:

- The disease is characterized by the presence of spindle shaped pinkish to reddish streaks on pseudostem, midrib and peduncle
- Typical mosaic and spindle shaped mild mosaic streaks on bracts, peduncle and fingers also observed
- Suckers exhibit unusual reddish brown streaks at emergence and separation of leaf sheath from central axis
- Clustering of leaves at crown with a travelers palm appearance, elongated peduncle and half filled hands are its characteristic symptom.

Reddish streaks on pseudostem **Mosaic streak on bracts**

http://svbiosciences.blogspot.in/2012/04/visual-diagnosis-of-banana-viral.html
http://www.agritech.tnau.ac.in/expert_system/banana/cropprotection.html

Survival and spread:

- The disease is caused by a virus belonging to potyvirus group. The virions are flexuous filamentous
- The virus is transmitted through aphid vectors such as *Aphis gosypii, Pentolonia nigronervosa* and *Rhopalosiphum maidis*. In field the disease spread mainly through suckers

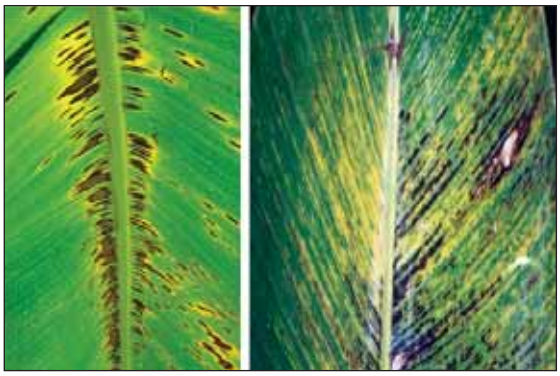
*For management refer to page number 18

8) Banana streak disease (BSV):

Disease symptoms:

- A prominent symptom exhibited by BSV is yellow streaking of the leaves, which becomes progressively necrotic producing a black streaked appearance in older leaves.

Disease symptoms on leaves



http://3.bp.blogspot.com/zmb8YaY69M/T55aLhlwasI/AAAAAAAAAEE/clYZ1Kird80/s1600/Leaf+Streak+Disease+2.jpg
http://www.krishisewa.com/cms/articles/crop-protection/286-dbanana.html

Survival and spread:

- The virus is transmitted mostly through infected planting materials, though mealy bugs (*Planococcus citri*) and more probably *Saccharicoccus sacchari* are also believed to transmit it. Shoot tip culture does not eliminate it from vegetatively propagated materials.

*For management refer to page number 18

9) Infectious chlorosis (CMV):

Disease symptoms:

- The disease manifests itself in all stages of crop growth.
- Due to repeated use of suckers from infected plants the disease spreads and resulting in the gradual decrease in yield and quality.
- The disease is known to occur in all banana-growing states.
- Light yellow streaks run parallel to leaf veins giving the leaf a striped appearance.
- The streaks run usually from mid rib to edge of the blade.

Symptoms on stem

http://www.hawaiiplantdisease.net/glossary/Aphid.htm

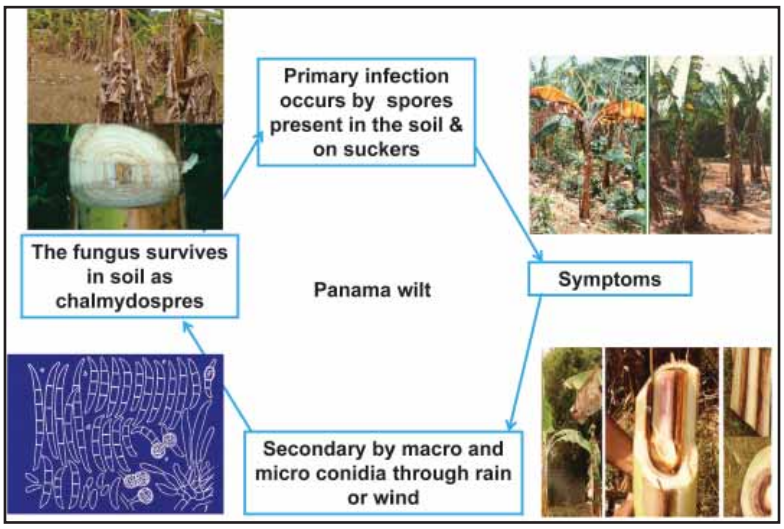
Survival and spread:

- Virus is disseminated by suckers and *Aphis gossypi*.

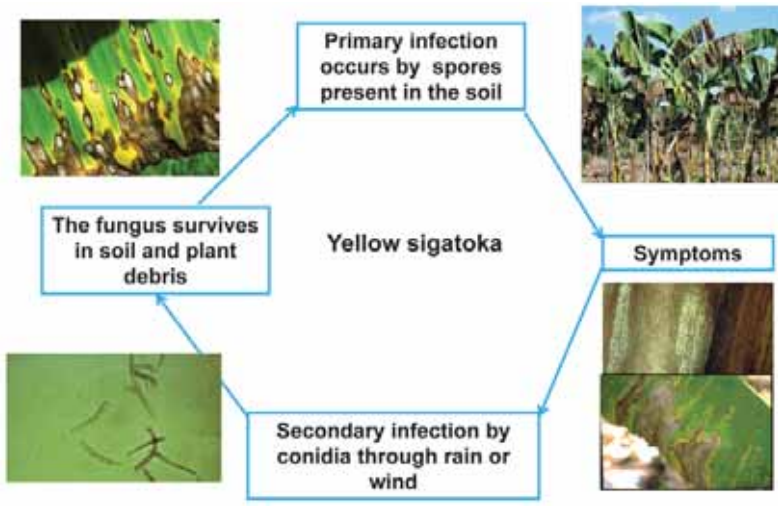
*For management refer to page number 18

Disease cycles:

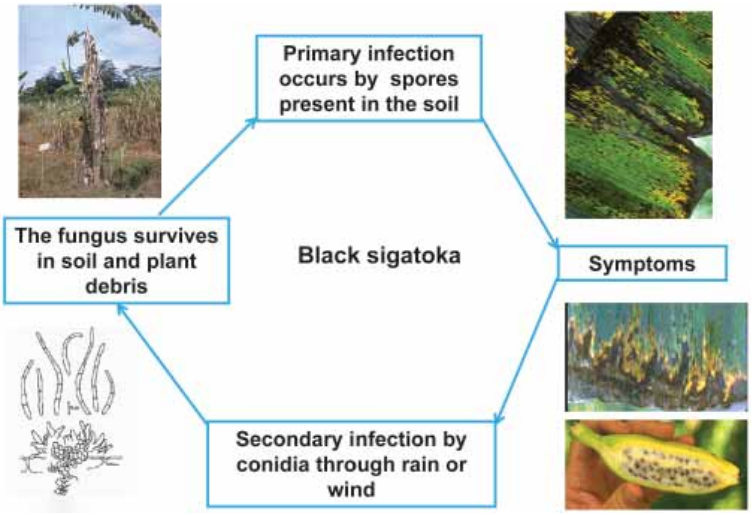
1. Panama wilt:



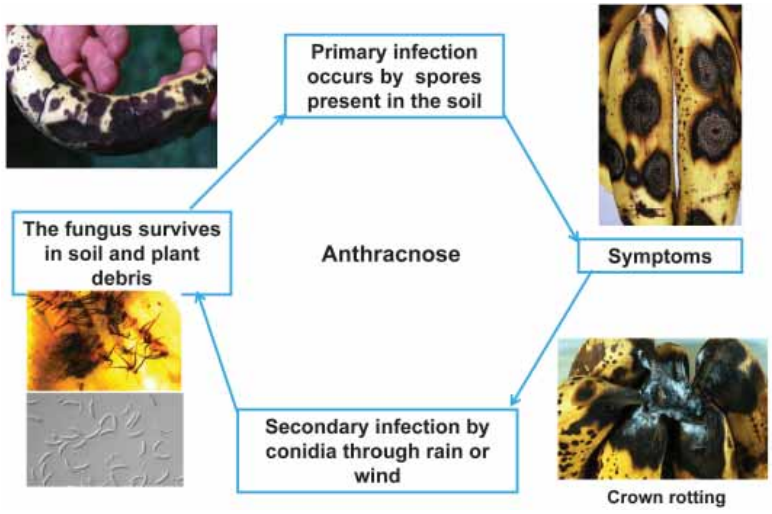
2. *Mycosphaerella* leaf spot, yellow sigatoka:



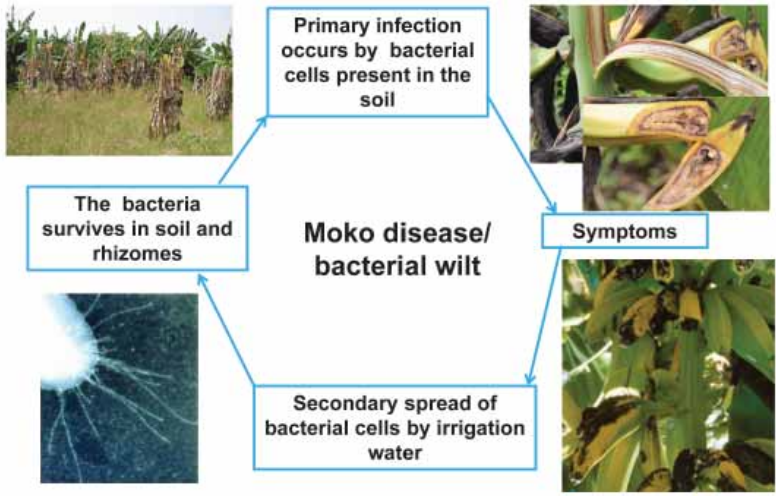
3. Black sigatoka:



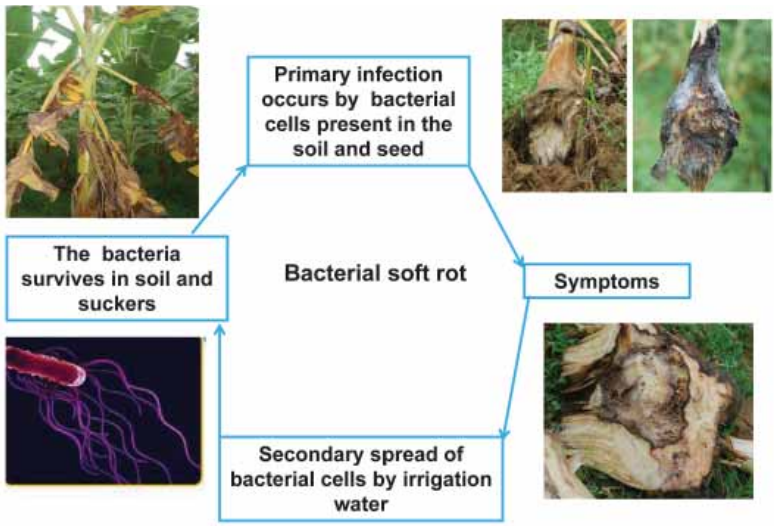
4. Anthracnose:



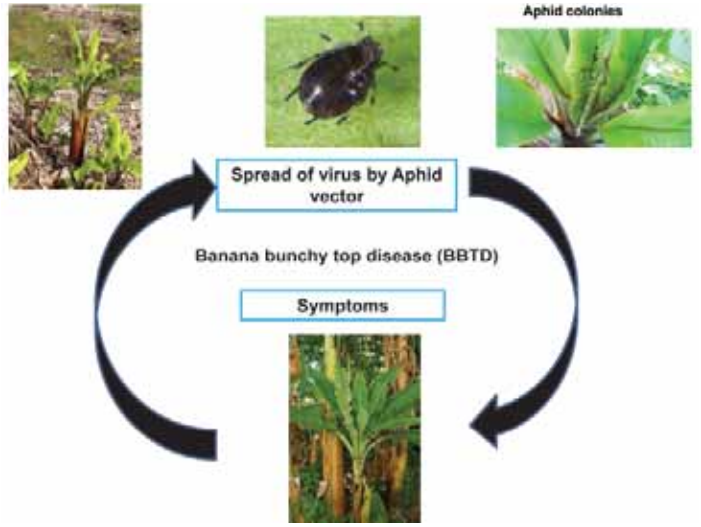
5. Moko disease/bacterial wilt:



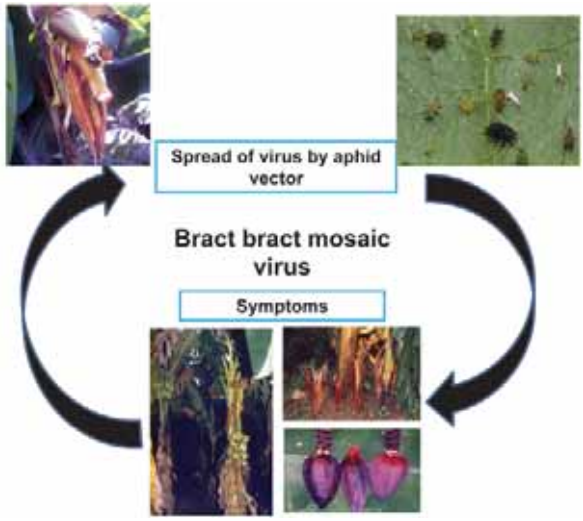
6. Tip over/bacterial soft rot:



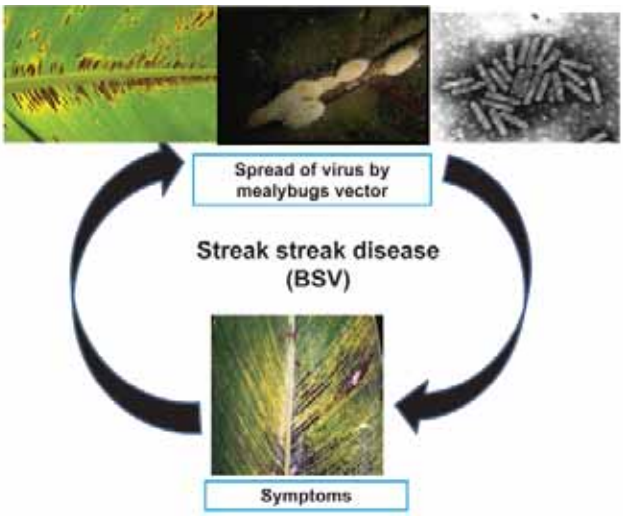
7. Bunchy top/curly top:



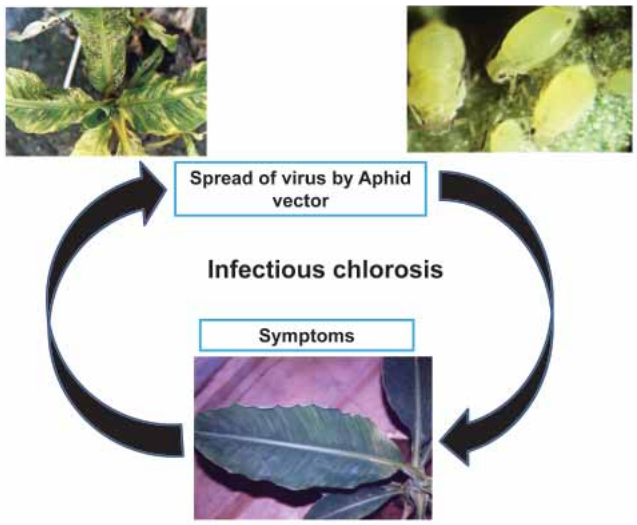
8. Banana bract mosaic virus (BBMV):



9. Banana streak disease (BSV):



10. Infectious chlorosis:



X. SAFETY MEASURES

A. At the time of harvest:

Harvesting bananas includes to cutting of banana bunches, which often weigh more than 50 kg. Particular care needed to avoid injuries to workers and damage to the fruit. Care needs to be taken to avoid bruising the fruit between harvest and market. Always use padding to protect bunches during transport to the packing shed. Specially designed bunch trailers are generally used. Bananas deteriorate rapidly in hot sun thus reducing their shelf life. They should be harvested quickly and kept shaded while in the field. It is best to cool the fruit quickly by getting packed fruit to cold rooms as soon as possible, but ensure that the fruit does not cool below 14°C.

For transportation banana fruits are cut from the bunch, washed, drained, graded and packed as hands into 13 kg cartons. Bananas are graded into extra-large, large and medium sizes. Additionally, banana fruits are graded into no. 1 and no. 2 grades within these sizes according to blemish.

B. During post-harvest storage:

In the cold storage, bananas are stored at 13-14°C with 90-95% relative humidity. Under controlled atmospheric conditions, 2-5% oxygen and 2-5% carbon dioxide can be be used to supplement temperature and humidity management during transport and storage. Maintaining ethylene concentration below 1 ppm can extend postharvest life of mature green bananas. Mature-green bananas can be stored for up to 3 weeks in ethylene-free air or up to 6 weeks in a controlled atmosphere at 14^{O}C.

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.	Grow only recommended varieties.	Do not grow susceptible varieties.
3.	Transplant early in the season.	Avoid late sowing as this may lead to reduced yields and incidence of white grubs and diseases.

4.	Use disease free certified rhizomes. Always treat the rhizomes with approved chemicals/ bio products for the control of seed borne diseases/pests. 	Do not use rhizomes without treatment with biocides/chemicals.
5.	Transplant in rows at optimum depths under proper moisture conditions for better establishment.	Do not sow rhizome beyond 15-20 cm depth depending on the root length.
6.	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.
7.	Maintain optimum and healthy crop stand which would be capable of competing with weeds at a critical stage of crop weed competition 	Crops should not be exposed to moisture deficit stress at their critical growth stages.
8.	Use NPK fertilizers as per the soil test recommendation.	Avoid imbalanced use of fertilizers.
9.	Use micronutrient mixture after sowing based test recommendations.	Do not apply any micronutrient mixture after sowing without test recommendations.
10.	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
11.	Install pheromone traps at appropriate period. 	Do not store the pheromone lures at normal room temperature (keep them in refrigerator).
12.	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.
13.	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.
14.	Spray pesticides thoroughly to treat the undersurface of the leaves, particularly for scales, aphids, etc. 	Do not spray pesticides only on the upper surface of leaves.
15.	Apply short persistent pesticides to avoid pesticide residue in the soil and produce.	Do not apply pesticides during preceding 7 days before harvest.
16	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. SAFETY PARAMETERS IN PESTICIDE USAGE:

S. No.	Pesticide	Classification as per insecticide rules	Colour of toxicity triangle	WHO classification of hazard	First Aid measures	Symptoms poisoning	Treatment of poisoning	Waiting period from last application to harvest (days)
Organophosphate insecticides								
1	Dimethoate	Highly toxic		Class II Moderately hazardous		Mild-anorexia, headache, dizziness, weakness, anxiety, tremors of tongue and eyelids, miosis, impairment of visual acuity	For extreme symptoms of OP poisoning, injection of atropine (2-4 mg for adults, 0.5-1.0 mg for children) is recommended. Repeated at 5-10 minute intervals until signs of atropinization occur.	--
Carbamate insecticides								
2	Carbofuran	Extremely toxic		Class I b highly hazardous		Constriction of pupils, salivation, profuse sweating, muscle incordination, nausea, vomiting, diarrhea, epigastric pain, tightness in chest	Atropine injection- 1-4 mg. repeat 2 mg when symptoms begin to recur (15-16 min interval) excessive salivation- good sign, more atropine needed	--

Fungicides								
3.	Mancozeb	Slightly toxic		Unlikely produce acute hazard		Headache, palpitation, nausea, vomiting, flushed face, irritation of nose, throat, eyes and skin etc.	No specific antidote. Treatment is essentially symptomatic	10
4.	Copper oxychloride	Moderately toxic		Class III slightly hazardous		------do----------	--------do------	--
Herbicide								
5.	Diuron	Moderately toxic		Unlikely produce acute hazard in normal use		Headache, palpitation, nausea, vomiting, flushed face, irritation of nose, throat, eyes and skin etc.	No specific antidote. Treatment is essentially symptomatic	

XIII. BASIC PRECAUTIONS IN PESTICIDES USAGE

A. Purchase

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

B. Storage

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

C. Handling

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

D. Precautions for preparing spray solution

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

E. Equipment

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

F. Precautions for applying pesticides

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

G. Disposal

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

XIV. PESTICIDE APPLICATION TECHNIQUES

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

XV. OPERATIONAL, CALIBRATION AND MAINTENANCE GUIDELINES IN BRIEF

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

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

Carrot

Sunflower

French bean

Cowpea

Buckwheat

Alfalfa

Maize

Mustard

Marigold

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