सत्यमेव जयते

AESA BASED IPM Package

AESA based IPM – Sugarcane

रा व स्वा प्र सं
NIPHM

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Rajendranagar, Hyderabad, Telangana

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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 Sugarcane Insect Pests

Parasitoids

Cotesia flavipes

***Trichogramma* spp.**

***Encarsia* sp**

***Eretmocerus* sp**

Chrysocharis pentheus

***Aphytis* sp**

Predators

Lacewing

Ladybird beetle

Spider

Dragonfly

Reduviid bug

Praying mantis

The AESA based IPM - Sugarcane, 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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Back cover picture Sugarcane 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)

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AESA BASED IPM PACKAGE FOR SUGARCANE

Sugarcane plant description:

Sugarcane, *Saccharum officinarum* L., is a perennial grass in the family Poaceae grown for its stem (cane) which is primarily used to produce sucrose. Sugarcane has a thick, tillering stem which is clearly divided into nodes and internodes. The leaves of the plant grow from the nodes of the stem, arranged in two rows on either side of the stem. The leaves are tubular and blade-like, thicker in the centres than at the margins and encircle the stem. The inflorescence of sugarcane is a terminal panicle which possesses two spikelets and seeds protected by husks (glumes) covered in silky hair. Two flowers are produced on the inflorescence, one sterile and the other bisexual. Sugarcane can reach a height of up to 6 m (3.3 ft) and once harvested, the stalk will re-grow allowing the plant to live for between 8 and 12 years. Sugarcane may also be referred to as nobel cane and originates from New Guinea.

A mature stalk is typically composed of 11–16% fiber, 12–16% soluble sugars, 2–3% non-sugars, and 63–73% water. A sugarcane crop is sensitive to the climate, soil type, irrigation, fertilizers, insects, disease control, varieties, and the harvest period. The average yield of cane stalk is 60–70 tonnes per hectare per year. However, this figure can vary between 30 and 180 tonnes per hectare depending on knowledge and crop management approach used in sugarcane cultivation. Sugarcane is a cash crop, but it is also used as livestock fodder.

Sugarcane is the world's largest crop by production quantity. In 2012, FAO estimates it was cultivated on about 26.0 million hectares, in more than 90 countries, with a worldwide harvest of 1.83 billion tons. Brazil was the largest producer of sugar cane in the world. The next five major producers, in decreasing amounts of production, were India, China, Thailand, Pakistan and Mexico.

In India about 527 working sugar factories with total installed annual sugar production capacity of about 242 lakh tonnes are located in the country during 2010-11. Broadly there are two distinct agro-climatic regions of sugarcane cultivation in India, viz., tropical (Maharashtra, Andhra Pradesh, Tamil Nadu, Karnataka, Gujarat, Madhya Pradesh, Goa, Pondicherry and Kerala.) and subtropical (U.P, Bihar, Haryana and Punjab). However, five agro-climatic zones have been identified mainly for the purpose of varietal development. They are (i) North Western Zone (ii) North Central Zone (iii) North Eastern Zone (iv) Peninsular Zone (v) Coastal Zone. Maharashtra is the largest producer of sugar contribute about 34% of sugar in the country followed by Uttar Pradesh.

The world demand for sugar is the primary driver of sugarcane agriculture. Cane accounts for 80% of sugar produced. Other than sugar, products derived from sugarcane include falernum, molasses, rum, *cachaça* (a traditional spirit from Brazil), bagasse and ethanol. In some regions, people use sugarcane reeds to make pens, mats, screens, and thatch. The young unexpanded inflorescence of *tebu telor* is eaten raw, steamed or toasted, and prepared in various ways in certain island communities of Indonesia.

I. PESTS

A. Pests of National Significance

1. Insect and mite pests

1.1. Borers

1.1.1 Early shoot borer: *Chilo infuscatellus* Snellen (Lepidoptera: Crambidae)
1.1.2 Pink borer: S*esamia inferens* Walker (Lepidoptera: Noctuidae)
1.1.3 Top shoot borer*: Scirpophaga excerptalis* Walker (Lepidoptera: Crambidae)
1.1.4 Root borer: *Emmalocera depressella (*Swinhoe) (Lepidoptera: Crambidae)
1.1.5 Internode borer*: Chilo sacchariphagus indicus* (Kapur) (Lepidoptera: Crambidae)
1.1.6 Stalk borer: *Chilo auricilius* Dudgeon (Lepidoptera: Crambidae)

1.2. Sucking pests

1.2.1 White woolly aphid*: Ceratovacuna lanigera* Zehntner (Hemiptera: Aphididae)
1.2.2 Black bug: *Cavelerius sweeti* Dist. (Hemiptera: Lygaeidae)
1.2.3 Whitefly: *Aleurolobus barodensis* Maskell (Hemiptera: Aleyrodidae)
1.2.4 Pyrilla: *Pyrilla perpusilla* Walker (Hemiptera: Lophopidae)
1.2.5 Mealybug: *Saccharicoccus sacchari* Cockerell*,* (Hemiptera: Pseudococcoidae)
1.2.6 Mite: *Oligonychus sacchari* McGregor (Trombidiformes: Tetranychidae)

1.3. Subterranean pest

1.3.1 Termites: *Odontotermes* spp. (Isoptera: Termitidae)

2. Diseases

2.1 Red rot: *Colletotrichum falcatum* Went
2.2 Wilt: *Acremonium implicatum,* (Gilman & Abbott) Gams*, Fusarium moniliforme* sub sp. *Glotinans* J. Sheld
2.3 Grassy shoot: *Mycoplasma like organism* (MLO)
2.4 Smut: *Ustilago scitaminea* (Syd.) M. Piepenbr., M. Stoll & Oberw
2.5 Scald: *Xanthomonas albilineans* Dowson
2.6 Red striped disease: *Xanthomonas rubrilineans* Dowson

3. Weeds

3.1 Major *Kharif*

Broad leaf

3.1.1 Pigweed: *Amaranthus viridis*Hook. F. (Amaranthaceae)
3.1.2 Swine cress: *Coronopus didymus*(L.) Sm. (Brassicaceae)
3.1.3 Black nightshade: *Solanum nigrum* L. (Solanaceae)
3.1.4 Common purselane: *Portulaca oleracea* L. (Portualacaceae)
3.1.5 False amaranth: *Digera arvensis* Forssk. (Amaranthaceae)
3.1.6 Lambs quarter: *Chenopodium album* L. (Chenopodiaceae)
3.1.7 Scarlet pimpernel: *Anagallis arvensis L. (*Primulaceae)
3.1.8 Sweet clover: *Melilotus indica*(L.) All. (Fabaceae)
3.1.9 Field bindweed: *Convolvulus arvensis* L. (Convolvulaceae)
3.1.10 Fine leaf fumitory: *Fumaria parviflora* Lam. (Fumariaceae)
3.1.11 Corn spurry: *Spergula arvensis* L. (Caryophyllaceae)
3.1.12 Carrot grass: *Parthenium hysterophorus* L. (Asteraceae)

3.1.13 Horse purslane: *Trianthema portulacastrum* L. (Aizoaceae)
3.1.14 Goat weed*: Ageratum conyzoides* L. (Asteraceae)
3.1.15 Tropical spider wort: *Commelina benghalensis* L. (Commelinaceae)
3.1.16 False daisy: *Eclipta alba* L. (Asteraceae)
3.1.17 Spurge: *Euphorbia hirta* L. (Euphorbiaceae)

Grasses

3.1.18 Crabgrass: *Digiteria sanguinalis* (L.) Scop. (Poaceae)
3.1.19 Barnyard grass*: Echinochloa crusgalli*(L.) Beauv. (Poaceae)
3.1.20 Bermuda grass*: Cynodon dactylon*(L.) Pers. (Poaceae)
3.1.21 Wild sugarcane: *Saccharum spontaneum* L. (Poaceae)
3.1.22 Johnson grass: *Sorghum halapense* (L.) Pers. (Poaceae)
3.1.23 Torpedo grass: *Panicum repens* L. (Poaceae)
3.1.24 Bluegrass: *Poa annua* L. (Poaceae)
3.1.25 Chinese lovegrass: *Eragrostis unioloides* (Retz.) Nees. Ex Steud. Poaceae
3.1.26 Goosegrass: *Eleusine indica* (L.) Gaertner (Poaceae)

Sedges

3.1.27 Purple nutsedge*: Cyperus rotundus* L. (Cyperaceae)
3.1.28 Flat sedge: *Cyperus iria* L. (Cyperaceae)

4. Rodent & Mammals

4.1. Lesser bandicoot: *Bandicota bengalensis* Gray (Rodentia: Muridae)
4.2 Soft furred field rat: *Millardia meltada* Gray (Rodentia: Muridae)
4.3 Jackal: *Canis aureus* L. (Carnivora: Canidae)

5. Nematodes

5.1 Lesion nematode: *Pratylenchus coffeae* Goodey
5.2 Lance nematode: *Hoplolaimus indicus,* Sher
5.3 Reniform nematode: *Rotylenchulus reniformis* Linford and Oliveira
5.4 Root knot nematode: *Meloidogyne* spp.

B. Pest of Regional Significance

1. Insect pests

1.1 Plassy borer: *Chilo tumidicostalis* Hampson (Lepidoptera: Crambidae)
1.2 Scale insect: *Melanaspis glomerata* Green (Hemiptera: Diaspididae)
1.3 White grub: *Holotrichia consanguinea* Blanch. (Coleoptera: Scarabeidae)
1.4 Gurdaspur borer: *Acigona steniellus* Hampson (Lepidoptera:Crambidae)
1.5 Green borer: *Raphimetopus ablutellus* (Lepidoptera: Crambidae)

2. Diseases

2.1 Pokkahboeng: *Fusarium moniliforme* Sheldon
2.2 Rust: *Puccinia melanocephala* H. & P. Syd.
2.3 Mosaic: *Sugarcane mosaic virus*
2.4 Yellow Leaf Disease: Sugarcane yellow leaf virus (SCYLV)

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

A. AESA

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

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

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

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

Principles of AESA based IPM:

Grow a healthy crop

- Select a variety resistant/tolerant to major pests
- Select healthy setts/planting material
- Treat the setts 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. Lesser cornstalk borer damage was much higher in the burnt cane field with conventional tillage than in the green cane field with intermediate tillage. Maintaining the harvest residue near the plants may reduce suitable egg deposition sites near the plants (Bennett, 1962), which reduces sugarcane plant damage. Early infestation of young plants produced more damage, but because of greater compensatory growth response (i.e., plant recovery) during the early growth period, the yield losses were lower than those recorded for late-infested plants. Older plants infested with lesser cornstalk borer did not respond with compensatory growth (did not recover well from lesser cornstalk borer damage), and thus yield losses were more pronounced when older plants suffered lesser cornstalk borer damage (Sandhu et al., 2012).

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

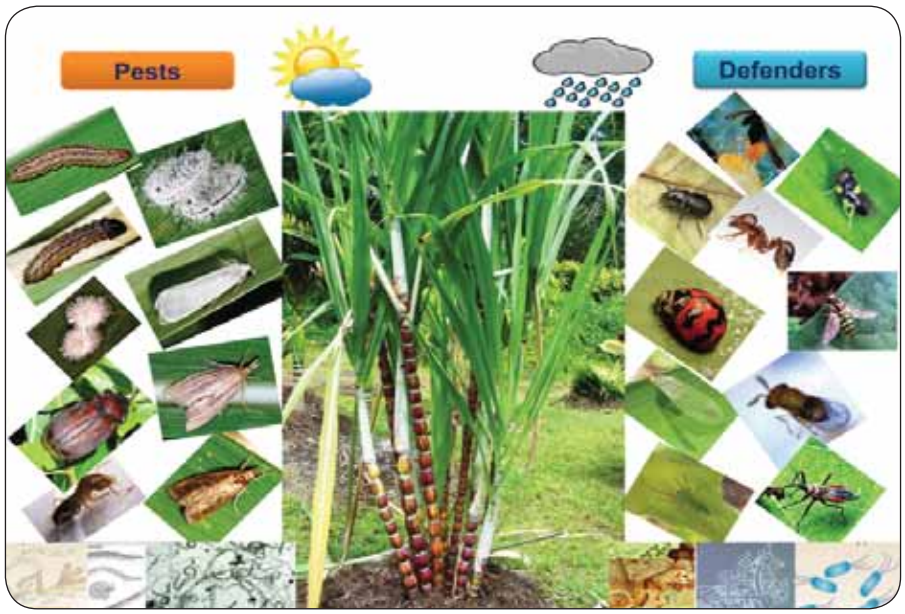
In field various types of insects are present. Some are beneficial and some may be harmful. Generally farmers are not aware about it. Predators (friends of the farmers) which feed on pests are not easy to observe in crop field. Insect zoo concept can be helpful to enhance farmers' skill to identify beneficial 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 sugarcane pests can be divided into 3 categories 1. parasitoids; 2. predators; and 3. pathogens. The important natural enemies of sugarcane insect pests are given in ecological engineering table on page number 15

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

Decision making

Farmers become experts in crop management

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

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

AESA methodology

- Go to the field in groups (about 5 farmers per group). Walk across the field and choose 20 plants/acre randomly. Observe keenly each of these plants and record your observations:
    - Plant: Observe the plant height, crop stage, deficiency symptoms etc.
    - Pests: Observe and count pests at different places on the plant.
    - Defenders (natural enemies): Observe and count parasitoids and predators.
    - Diseases: Observe leaves and stems and identify any visible disease symptoms and severity.

- Rats: Count number of plants affected by rats.
- Weeds: Observe weeds in the field and their intensity.
- Water: Observe the water situation of the field.
- Weather: Observe the weather condition.

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

Data recording

Farmers should record data in a notebook and drawing on a chart.

- Keeping records of what has happened help us making an analysis and draw conclusions

Data to be recorded

- **Plant growth (weekly)** : Height of plant; Number of leaves
- **Crop situation (e.g. for AESA)** : Plant health; Pests, diseases, weeds; Natural enemies; Soil conditions; Irrigation; Weather conditions
- **Input costs :** Setts / planting material; 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.

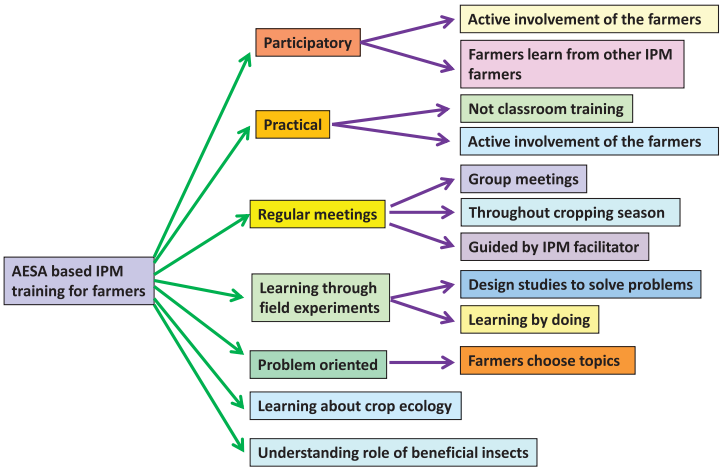
AESA and farmer field school (FFS)

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

For insect pests:

Shoot borer : i) Per cent incidence (based on dead-hearts)

ii) No. of bored plants/acre

Observations to be recorded in post-germination phase at 30 days interval up to 120 days

Top borer : Per cent incidence during the 3rd and 4th broods (July, August and September) in North West, North Central and North East Zones and during 5th & 7th months and at harvest in Peninsular and East Coast Zones

Stalk and internode borers : (i) At harvest both per cent incidence and per cent intensity (25 canes per replication) may be recorded. The infestation index may also be computed as follows:

$$\text{Infestation index} = \frac{\text{Per cent incidence x per cent intensity}}{100}$$

(ii) The yield and quality parameters are also to be recorded in both healthy and bored canes and CCS/plot calculated separately.

Pyrilla : Population of nymph, adult and egg masses be recorded from a unit of 10 canes (20 leaves) and average per leaf sheath be reported.

Whitefly : Population of nymph and puparia should be recorded from a unit of 10 canes (20 leaves), from proximal, middle and distal region. Average population cm^2 be reported.

White grub : Grub as well as adult population be recorded by digging 1 square meter area at 5 sites in the field. Population/acre be calculated and reported.

Observations also to be recorded on termites and mite infestation and broad categorisation be made as less susceptible, susceptible and highly susceptible.

For diseases:

Whenever scouting, be aware that symptoms of plant disease problems may be caused by any biotic factors such as fungal, bacterial, viral pathogens or abiotic factors such as weather, fertilizers, nutrient deficiencies, pesticides and abiotic soil problems. In many cases, the cause of the symptom is not obvious. Close examination, and laboratory culture and analysis are required for proper diagnosis of the causal agent of disease. Generally fungal diseases cause the obvious symptoms with irregular growth, pattern & colour (except viruses), however abiotic problems cause regular, uniform symptoms. Pathogen presence (signs) on the symptoms can also be observed like fungal growth, bacterial ooze etc. Specific and characteristic symptoms of the important plant diseases are given in description of diseases section.

Root sampling: Always check plants that appear unhealthy. If there are no obvious symptoms on plants, examine plants randomly and look for lesions or rots on roots. Observe the signs of the causal organism (fungal growth or ooze). It is often necessary to wash the roots with water to examine them properly. If the roots are well developed, cut them to examine the roots for internal infections (discolouration & signs). Count the total number of 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.

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

For weeds:

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

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

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

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

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

Group II - Chickweed, green foxtail, corn spurry.

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

Group III - Canada thistle, sow-thistle, dandelion

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

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

C. Surveillance through pheromone trap catches for borer

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

D. Yellow pan water/sticky traps

Set up yellow pan water/sticky traps 15 cm above the canopy for monitoring woolly aphids and whitefly @ 4-5 traps/acre. Locally available empty tins can be painted yellow and coated with grease/ Vaseline/caster oil on outer surface may also be used. Count the number of woolly aphids and white flies on the traps daily and take up the intervention when the population exceeds 100 per trap.

E. Rapid roving surveys

Undertake regular roving surveys at 10 days interval for monitoring pests/diseases and assess biocontrol potential. Select randomly five observation plots at 5 to 10 km distance and examine thoroughly 25 clumps (i.e. 5 clumps at five spots) diagonally or zig-zag manner. Record the data from sowing to cane formation.

F. 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).

G. 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 mychorrhiza and plant growth promoting rhizobacteria (PGPR)
- Apply *Trichoderma* spp. and *Pseudomonas fluorescens* as setts, nursery treatment and soil application (if commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).

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

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

Dill

Sunflower

Carrot

Marigold

Chrysanthemum

Mustard

Coriander

Alfalfa

French bean

Cowpea

Buckwheat

Maize

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
Borers:	
Parasitoids: *Trichogramma chilonis, Tetrastichus* spp., *Chelonus* spp., *Telenomus* spp. (egg), *Sturmiopsis infarens, Isotima javensis, Stenobracon nicevelli, Cotesia flavipes* (larval). **Predators:** *Chrysoperla zastrowi sillemi,* coccinellids, King crow, dragon fly, spider, robber fly, reduviid bug, praying mantis *Ovomermis albicans*, a nematode	• Growing intercrops such as cowpea, onion, garlic, coriander, urdbean. • Repellant plants: Basil • Attractant plants: Carrot family, sunflower family, buckwheat, alfalfa, corn, shrubs (minute pirate bug and lacewing) • Nectar rich plants with small flowers i.e. anise, caraway, dill, parsley, mustard, sunflower, buckwheat and cowpea (Braconid wasp)
Whitefly:	
Parasitoids: *Encarsia* sp, *Eretmocerus* spp., *Dicyphus hesperus, Chrysocharis* sp (nymphal and pupal) **Predators :** Spiders, coccinellids and lacewings	• Repellant plants: Peppermint • Attractant plants: French bean (predatory thrips) • Plant tall border crops like maize, sorghum or pearl millet to reduce whitefly infestations. • Yellow sticky traps or cards to monitor the activity of whiteflies
Sugarcane woolly aphid:	
Parasitoids: *Encarsia flavoscutellum, Diaeretiella rapae* (nymphal and adult) **Predators:** *Dipha aphidivora*, *Micromus igorotus*, Syrphid fly **Entomopathogenic fungi :** *Acremonium zeylanicum*, *Cephalosporium* spp., *Entomophthora* and *Verticillium lecanii*	• Attractant plants: Buckwheat, alfalfa, corn, shrubs (minute pirate bug & lacewing) • Sunflower family, marigold, buckwheat.
Mites:	
Predators: Predatory mites, predatory beetles such as small staphilinids (*Oligota* spp.), and lacewings, predatory thrips, anthocorid bugs (*Orius* spp.), mirid bugs, and predatory flies such as hover flies. **Entomo pathogenic fungi:** *Beauveria* sp.	• Attractant plants: Carrot family, (spider mite destroyer) • Carrot family, sunflower family, buckwheat, alfalfa, corn, shrubs (minute pirate bug) • Mustard, sweet clove, dill (aphid midge) • French bean (predatory mites) • Berseem clover and common knotweed (big –eyed bugs)
Black bug:	
Parasitoid: Tachinid fly **Predator:** *Geocorid* spp. (big eyed bugs)	• Carrot family, dill, sweet clover, *Amaranth*, *Trifolium*, knotweed.
Mealybug:	
Parasitic wasps, hover flies, coccinellid (*Cryptolaemus montrouzieri*)	• Attractant plants: Coriander, attract wasps.
White grub:	

Parasitoid: Parasitic wasp (*Tiphia* spp.) Entomopathogenic nematode. Entomopathogenic fungi – *Metarhizium, Beauvaria* **Predators:** Ground beetle, ants, wasps.	• Repellent crop: Garlic

A. Resistant/tolerant varieties

Pest	Tolerant/ resistant Varieties
Shoot borer (*Chilo infuscatellus)*	CO 312, CO 421, CO 661, CO 917 and CO 853
Stem or internode borer	CO 975, CO 7304 and COJ 46
Top shoot borer	CO 419, CO 745, CO 6516, CO 859, CO1158 and CO 7224
Smut	Co 8371, Co 85004, Co 86032, Co 86249, Co 87025, Co 87044, Co 87263, Co 87268, Co 91010, CoM 88121, Co Pant,
Red rot	BO 128, Co 89029, CoH 2201, CoSe 92423, CoSe 95422

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

IV. CROP STAGE-WISE IPM

Management	Activity
Pre –sowing*	
Nutrients	Soil test based nutrient recommendations should be followed also, • Apply organic manures @ 8 to 10 tonnes/acre treated with *Trichoderma*. • Press mud can also be used as organic manure @ 2 tonnes/acre which is particularly useful in saline alkali soils. • Sugarcane trash can be used as a mulch. Spray trash with 32 Kg urea, 40 Kg Single Super Phosphate and 4 Kg decomposing culture/acre for better decomposition. • Sugarcane trash can also be incorporated while making organic manure along with press mud and use of earthworms for preparing vermicompost. • Crops like sun hemp and dhaincha are grown as green manure crop. Green manure crops can be grown as a sole crop and buried in the field at an age of 1.5 to 2 months (before flowering).
Weeds	**Cultural control**: • Deep ploughing in summer and left undisturbed 20-25 days. • Cross ploughing of land followed by clod crushing and 1-2 harrowing. • At the time of field preparation, adopt stale seed bed technique i.e. pre sowing irrigation followed by shallow tillage to minimize the weeds menace in field.
Sowing*	
Nutrients	• Use biofertilizers such as *Acetobactor, Azotobactor, Azospirillium, Bacillus* or *Pseudomonas*. Either of these biofertilizers or in combination should be used at the time of sowing @ 5 Kg / acre for sett treatment or in soil along with FYM. • Basal application of NPK is done on soil test basis.

	• In sugarcane, fertilizer should be applied as per the table mentioned below. • Apply zinc sulphate @10 Kg/acre in soil at the time of planting. • In soils deficient with micro nutrients like iron, zinc, manganese, copper, molybdenum and boron, 10 Kg ferrous sulphate, 8 Kg zinc sulphate, 4 Kg manganese sulphate, 4 Kg copper sulphate,1 Kg, sodium molybdate and 2 Kg borax per hectare should be applied. • Micro nutrient fertilizers should be mixed with well decomposed dung manure or compost and applied as basal dose.
Weeds	**Cultural control:** • Adopt proper crop rotation and intercropping. • Avoid mono cropping. • Follow recommended agronomic practices. • If intercropping has been adopted no chemical herbicide should be use in the field. **Chemical control:** • 2, 4-D dimethyl amine salt 58% SL @2.52 l in 200 l of water/acre • 2, 4-D sodium salt technical (having 2, 4-D acid 80 % w/w) (earlier registered as 80%WP) @1-1.3 Kg in 240-360 l of water/acre • Hexazinone 13.2% + diuron 46.8 % WP @800 g in 200 l of water/acre • 2, 4-D ethyl ester 38 % EC (having 2,4-D acid 34 % w/w) @1.412-2.116 l in 200 l of water/acre • Diuron 80% WP @ 0.8-1.6 Kg in 2.4 l of water/acre **Note:** Herbicide should be selected as per the weed species in previous season in the same field as per recommendation of CIBRC.
Soil & seed borne diseases, insect pests	**Cultural control:** • Select tolerant / resistant varieties • Select the seed cane from aerated steam treated nurseries • Crop like potato, mustard, lentil, pulses and winter vegetables can be grown as inter crop during autumn planted sugarcane i.e. Oct-Nov &, sunflower, soybean, green gram , groundnut etc. during Feb-March planted sugarcane to reduce the pests population and to conserve bioagents of white woolly aphid and other pests • Adopt paired row method of planting
Nematodes	**Cultural control:** • Deep ploughing, solarisation, flooding, crop rotation and apply organic manure. • Under wetland conditions, intercropping with sun hemp or marigold or daincha • Apply pressmud at 6 t/acre or poultry manure @ 0.8 t/acre or neem cake 0.8 t/acre or poultry manure @ 0.4 t/acre before last ploughing. **Biological control:** • Application of biocontrol agents like *Pochonia chlamydosporia, Paecilomyces lilacinus* or *Trichoderma viride or Pseudomonas fluorescens* @ 4 Kg/acre at the time of planting mixed with moist FYM or cured pressmud and distributed uniformly helps in suppressing the plant parasitic nematodes.
Termites & white grubs**	**Cultural control:** • Remove stubble and debris of previous crops • Dig the termatoria and destroy the queen.

	Physical control: • Locate and destroy the termite colony and affected setts. • Set up light trap for trapping of white grubs adults and kill them in kerosene oil water. • At onset of monsoon collect and destroy the adult beetles by shaking the branches of trees on which they settle during night. **Biological control:** • Entomopathogenic nematodes (EPNs) can be sprayed at the rate of 100 million nematodes per acre, in root grub and termite infested sugarcane fields OR • EPN infected cadavers of *Galleria/Corcyra* larvae containing live infective juveniles (IJs) are implanted in soil at plant bases at the rate of four cadavers per plant during May/ June and/or September for sugarcane root grub control. **Chemical control:** **For termite:** • Chlorantraniliprole 18.5% SC @ 200-250 ml in 400 l of water/acre or clothianidin 50%WDG @100 g in 400 l of water/acre or imidacloprid 70% WS @28-42 g in 40-60 l of water/acre or imidacloprid 17.8% SL @ 140 ml in 750 l of water/acre or chlorpyrifos 20% EC @ 2.5 l/acre **For white grubs:** • Fipronil 40% + imidacloprid 40% WG@175-200 g in 400-500 l of water/acre or phorate 10% CG @ 10,000 g/acre
*Apply *Trichoderma* spp. and *Pseudomonas fluorescens* for setts and soil application (for usage of commercial products check label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).	
Tillering stage	
Nutrients	• Top dressing of N should be done as per the fertilizer recommendations mentioned in table below.
Weeds	**Cultural control:** • The initial 30-120 days is the critical period of weed competition. Therefore the weed management practice should be ensured for the first 3-4 months. • Shallow Blind hoeing may be performed after planting before germination. • Being wildly spacing crop, tractor or bullock drawn implement should be used for intercultural operations at 30 and 60 DAS along with hand weeding within rows. • Trash mulch @ 2 tonnes/acre at 45 days after planting is useful to control weeds and avoid cost on hand weeding/hoeing in ratoon crops. **Chemical control:** • Same as sowing stage except diuron 80% WP or metsulfuron methyl 20% WP@ 12 g in 200-240 l of water/acre **Note:** Herbicide should be selected as per the weed species in the field as per recommendation of CIBRC
Early shoot borer, root borer	**Cultural control:** • Deep summer ploughing • Inter culture and hand weeding • Timely irrigation • Light earthing up of crops three months after planting • Grow onion/garlic/coriander as intercrop • In ratoon crop mulching with trash reduce shoot borer attack

	Mechanical control: • Use of pheromone traps @ 4-5/acre for monitoring • Remove and destroy the dead hearts along with larvae • Installation of light trap with exit option for natural enemies @ 1 per acre **Biological control:** • Release 125 gravid females of *Sturmiopsis inferens* a tachinid parasitoid per acre. • Release *Trichogramma chilonis* @ 20,000/acre @ 10 days interval at the time of incidence. **Chemical control:** • Fipronil 5% SC @ 600-800 ml in 200 l of water/acre • Fipronil 0.3 % GR @ 30-40 ml in 10000-13320 l of water/ acre • Chlorpyrifos 20% EC @ 500-600 ml in 200-400 l of water/acre • Chlorantraniliprole 18.5% SC@ 150 ml in 400 l of water/acre • Cypermethrin10% EC @ 260-304 ml in 200-280 l of water/acre • Quinalphos 5% granule @ 2000 g/acre • Chlorantraniliprole 0.4% GR @ 7.5 g/acre • Monocrotophos 36% SL @ 600-900 ml in 200-400 l of water/acre • Quinalphos 25 % EC @ 800 ml in 200-400 l of water/acre
White grubs**	• Same as sowing stage
Top shoot borer	**Mechanical control:** • Collection and destruction of adult moths • Collection and destruction of egg masses • Collection and destruction of dead hearts • Use of pheromone traps @ 4-5/acre for monitoring coinciding with brood emergence • Installation of light trap with exit option for natural enemies @ 1/ acre **Biological control:** • Release of *Trichogramma* spp. @ 20,000/acre 2-3 times at 10 days interval **Chemical control:** • Chlorantraniliprole18.5% SC @150 ml in 400 l of water/acre • Phorate10% CG @ 12,000 g/acre • Carbofuran 3% CG @ 26640 g/acre • Chlorantraniliprole 0.4% GR @ 7.5 Kg/acre
Black bug	**Chemical control:** • Quinalphos 25 % EC @ 800 ml in 200-400 l of water/acre
Scale insect **	**Cultural control:** • Use resistant/tolerant varieties. • Select the healthy and pest free setts for planting. • Keep the fields and bunds free from weeds. • Avoid water stagnation in the field for the longer period. • Avoid repeated ratoons.

	Physical control: • Detrash the crop at 150th and 210th day of planting. **Biological control:** • Release coccinellid predators. **Chemical control:** • Monocrotophos 36% SL @ 600 ml in 200-400 l of water/acre
White woolly aphid	**Cultural control:** • De-trashing of canes if infestation exceeds low intensity and remove water shoots. • Paired row system of planting. • Avoid excessive use of nitrogenous fertilizers. • Use of organic fertilizers. • Rapping of canes all along the rows. • Do not transport Infested tops • Infested canes should not be used as seed for planting. **Biological control:** • Conserve and augment the natural enemies • Create congenial conditions for promoting entomo pathogens such as *Cladosporium oxysporum*, *Metarhizium anisopliae*, *Verticillium lecanii* and *Beauveria bassiana*.
Cane formation stage	
Nutrients	• Incorporate crop residues in soil immediately after harvest.
Weeds	• Remove left over weeds before shedding of seeds to prevent weed infestation.
Pyrilla	**Cultural control:** • Avoid late application of nitrogenous fertilizers. • Collect and put egg masses in cage to facilitate emergence of parasitoids. • Removal and destruction of lower dried leaves. **Biological control:** • Release of 3,200 to 4,000 cocoons or 3.2-4.0 lakh eggs of *Epiricania melanoleuca* per acre when 3-5 Pyrilla individuals per leaf are seen. • Conserve and augment *Epiricanica* population from rich to scanty fields. **Chemical control:** • Chlorpyrifos 20% EC @ 600 ml in 200-400 l of water/acre • Dichlorvos 76% EC @ 150.4 ml in 200-400 l of water/acre • Monocrotophos 36% SL @ 200 ml in 200-400 l of water/acre
Stalk borer, internode borer, pink borer and plassy borer**	**Cultural control:** • Proper water management to avoid lodging • De-trashing of canes and removal of water shoots once in a month from 5th months on wards. • Balanced doses of fertilizers. • Use of pheromone traps @ 4-5/acre **Biological method:** • Release egg parasitoid, *Trichogramma chilonis* @ 20,000/acre six releases at fortnightly intervals starting from 4th month onwards.

	• Setting pheromone traps at spindle level on 5th month of the crop @ 4-5 traps/acre 15 meter grid. The pheromone septa need to be changed twice at 45 days interval. **Chemical control:** • Chlorpyrifos 20% EC @ 500-600 ml in 200-400 l of water/acre • Monocrotophos 36% SL @ 750 ml in 200-400 l of water/acre
Scale insect and mealy bug**	• For scale insects same as tillering stage **For mealy bug** **Cultural control:** • Use resistant/tolerant varieties • De-trashing of canes and removal of water shoots. • Drain excess water from the field and avoid water stress conditions. **Biological control:** • Conserve and augment the natural enemies such as *Chilocorus, Hyperaspis, Chrysoperla, Aphytis, Coccophagus* and *Encarsia* etc. **Chemical control:** • Monocrotophos 36% SL @ 600 ml in 200-400 l of water/acre
Whitefly	**Cultural control:** • Clipping of infested leaves. • Avoid water stress and water logged conditions. • Avoid planting in low land areas • Synchronization of sugarcane planting and harvesting maybe adopted zone wise. **Mechanical control:** • Detrashing the puparia bearing leaves and immediately disposing by burning or burying to prevent emergence of adult whiteflies. • Use yellow sticky trap. **Biological Control:** • Conserve and augment the natural enemies such as *Encarsia* sp, *Eretmocerus* spp., • Mirid bug, dragonfly, spider, robber fly, praying mantis, fire ants, coccinellids, lacewings, big eyed bugs (*Geocoris* sp) etc.
Red rot, smut, grassy shoot, wilt, leaf scald, red stripe, mosaic diseases, rust** and pokkahboeng****	**Cultural control:** • Use resistant or moderately resistant varieties. • Any sett showing reddening at the cut ends or at the nodal region should be discarded. • Healthy setts should be planted. Such setts must be produced from crop raised from heat treatment *of* seed canes in moist hot air at 54° C for 2.5 hour at 99% humidity. • Remove affected clump along with root system and burn. • Bunding of affected field should be done to avoid movement of rain or floodwater to healthy fields. • Ratooning of diseased crop should be avoided. • Diseased crop should be harvested as early as possible. • Crop rotation should be followed in affected fields. • Use yellow sticky traps for the control of aphid vector.

Rodents: **lesser bandicoot,** **soft furred field rat**	**Cultural control:** • Practice clean cultivation/maintain weed free fields which reduces the harboring/ hiding points for rodents. • Practice trapping with locally available traps using bait. In areas, where bandicoote is a problem, wonder traps/multi-catch traps work better and enable to trap more animals into a single trap. • Identify live rodent burrows and smoke the burrows with burrow smoker for 2-3 minutes • Erect owl perches @ 5-6/acre to promote natural control of rodents **Chemical control:** • Bromadiolone 0.25 % CB @ 0.005% • Bromadiolone 0.005 % RB @ 0.005%
Reproductive /maturity	
Nutrients	Incorporate crop residues in soil immediately after harvest.
Weeds	Remove left over weeds to prevent weed infestation in ratoon crop.
Harvesting	• Deep harvesting. • Removal of late shoots and water shoots.
After harvesting	
	• Avoid trash burning to preserve the natural enemies • Stubble shaving should be done at ground level. • Destroy the stubble in borer and white grub infested field.
Ratoon	
	• Avoid ratoons to reduce the pest problems. • Avoid ratoons in late harvested crop.

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

** Pests of regional significance

Fertilizers application: The dose (Kg/acre) and time of nutrient (NPK) application in sugarcane is as below:

No	Time of application	Adsali			Pre seasonal			Seasonal/Ratoon		
		N	P	K	N	P	K	N	P	K
1	At planting	20	40	40	15	34	34	14	28	28
2	6-8 weeks after planting	80	-	-	65	-	-	55	-	-
3	12-16 weeks after planting	20	-	-	15	-	-	14	-	-
4	At earthing up	80	40	40	65	34	34	55	28	28
	Total	200	80	80	160	68	68	138	56	56

V. INSECTICIDE RESISTANCE AND ITS MANAGEMENT

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

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

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

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

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

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

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

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

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

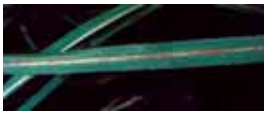
7) Preserve susceptible genes: Preserve susceptible individuals within the target population by providing unsprayed areas within treated fields, adjacent "refuge" fields, or habitat attractions within a treated field that facilitate immigration. These susceptible individuals may outcompete and interbreed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

VI. NUTRITIONAL DEFICIENCIES

Nitrogen: Die back of older leaves. Leaf baldes turn light green to yellow. Short and slender stalks. Tips and margins of older leaves become necrotic.
Management: Soil application of N fertilizer or foliar spray of urea 1-2% twice at weekly interval.

Phosphorus: Red and purple discolouration of tips and margins. Slender leaves. Short sand slender stalks. Poor or no tillering
Management: Foliar spray of DAP 2% twice at fortnight interval.

Potassium: Yellow-orange chlorosis of leaf borders & tips. Stalks slender. Older leaves brown or "fired". Spindles distorted producing "bunched top" or "fan' appearance.
Management: Foliar spray of KCL 1% twice at fortnight interval.



Calcium: Mottling and chlorosis of older leaves. Spindles often become necrotic at the leaf tip and long margins. Rusty appearance and premature death of older leaves
Management: Soil application of 25 Kg/acre of gypsum

Magnesium: Mottled or chlorotic appearance at the tip and margins. Red necrotic lesions resulting in "rusty" appearance. Internal browning of rind
Management: Soil application of $MgSO_4$ 10 Kg/acre or foliar spray of $MgSO_4$ 2% twice at fortnight interval.

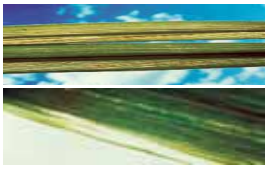
Sulphur: Chlorotic young leaves. Narrower and shorter leaves with faint purplish tinge. Slender stalks
Management: It is advisable to use sulphur containing fertilisers: Ammonium Sulphate - 24% S. Single Super Phosphate - 12% S. Potassium Sulphate - 18% S. Gypsum - 13-18% S . Any one of the above fertilizers at the rate of 4-8 Kg/acre.

Copper: Green splotches with leaves eventually showing bleaching. Stalk and meristems lack turgidity. Reduced inter-nodal length and tillering.

Iron: Varying degrees of chlorosis. Interveinal chlorosis from tip to base of leaves.
Management: Soil application of 10 Kg/acre of $FeSO_4$ or foliar spray of $FESO_4$ 0.5% on 90, 105 and 120 days after planting.

Manganese: Occurrence of interveinal chlorosis from leaf tip towards the middle of leaf. Bleaching of leaves under severe deficiency.

Boron: Distorted leaves. Formation of translucent lesions or water sacks along leaf margins. Brittle and bunched with many tillers. Death of apical meristem.



Molybdenum: Short longitudinal chlorotic streaks on the top one-third of the leaf. Short and slender stalks. Slow vegetative growth
Management: Application of ammonium molybedate (54% Mo) and sodium molybdate (39% Mo) are common sources of Mo to rectify its deficiency in soils and crops.

Zinc: Midrib and leaf margin remain green and yellowing of leaf blade. Red lesions on leaves. Reduced tillering and shorter internodes. Thin stalks with loss of turgidity.
Management: Soil application of 15 Kg Zinc sulphate/acre before the last ploughing.

http://edis.ifas.ufl.edu/sc075
http://www.sugarcanecrops.com/110/

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

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

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

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

4) Common purselane: *Portulaca oleracea* L. (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) False amaranth: *Digera arvensis* Forssk. (Amaranthaceae)

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

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

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

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

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

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

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

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

A herbaceous perennial weed growing from a very deep root system. Shoots develop from adventitious buds on the deep root system at almost any depth down to 1 m. Stem slender upto 1.5 m long, twining anti clockwise, glabrous or finely pubescent. Leaves alternate, variable in shape, ovate to narrow-oblong, 1.2-5.0 cm long, acute at the apex, pubescent with scattered crisped hairs. Flowers white or pink, axillary, solitary, peduncles, 2.5-5 cm long, slender with a pair of small linear bracts at the apex from which the pedicels arise; pedicels 3-25 mm long. Fruits capsules 6-8 mm in diameter, globose. Seeds are subtrigonous, dark reddish-brown and glabrous.

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

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

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

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

12) 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.

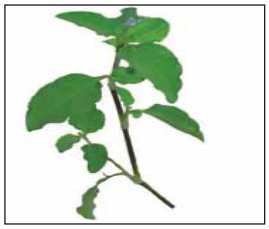
13) Horse purslane: *Trianthema portulacastrum* L. (Aizoaceae)

It is an annual herb with prostrate mat and stems up to a meter long. Stem is green to red in color, hairless except for small lines of hairs near the leaves and fleshy.Leaves have small round or oval blades up to 4 cm long borne on short petioles. Flowers are solitary occur in leaf axils. The flower lacks petals but has purple, petal like sepals.Fruits are curved, cylindrical capsule emerging from the stem. Seeds are kidney-shaped, spiral, ended by a beak, 2 mm in diameter.

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

It is an erect, often branched, annual herb up to 120 cm tall. Stem, nodes and younger parts with rather long, partly crispy hairs. Leaves opposite or the upper alternate, broadly ovate to triangular, 2-10 cm long and 1.5-5 cm wide, apex subacute, margins crenate, more or less hairy on both surfaces. Flower peduncled (5-17 mm long) corymbs (60-70 flowers). Flowers white, pale blue or violet, flat-topped with a disagreeable odour. Fruits achene oblong, 5-angular, black with pale base, glabrous or slightly hairy, 1.5-2 mm long with awn-tipped, serrate pappus-scales.

15) Tropical spider wort: *Commelina benghalensis* L. (Commelinaceae)



A creeping or procumbent annual herb, 60-90 cm long. Dichotomously branched with diffuse branches, often rooting at nodes. Leaves 2.5-7.5 cm long and 1.3-3.8 cm wide, ovate or oblong, apex obtuse, base unequal-sided, rounded, sessile or short petioled, pubescent on both surfaces. Flowers 1-3 together, funnel-shaped, auricled on one side, pubescent, blue, borne in branched cymes. Fruits capsules 0.6 cm long, membranous. Seeds oblong, closely pitted.

16) False Daisy: *Eclipta alba* L. (Asteraceae)

It is a prostrate, ascending or erect, rough-hairy annual herb, up to 90 cm tall. Much-branched, slender, reddish, covered with short, stiff hairs, rooting at the lower nodes. Opposite, simple, rough, dull green, ovate to oblong-lanceolate, 2-10 cm long, 1-3 cm wide, apex acute or blunt, base attenuate, margin entire or slightly serrate, pubescent, mostly sessile, the lower leaves sometimes short-petioled. Flower heads up to 1 cm in diameter, a cluster of sessile white flowers, in upper axils or terminal, solitary or two heads together. Ray flowers white. Achenes light-brown to black, laterally-flattened, wedge-shaped, 2-3 mm long, 0.9 mm wide. Apex with short, usually white hairs that are easily broken off but two hornlike projections often remain, pappus absent. The rest of the achene is glabrous and covered with many small warts.

17) 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

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

A prostrate or ascending annual grass with spreading, branched stem having rooting at nodes. Leaves are 3-20 cm long, 3-10 mm wide, with hairs on both the surfaces. Stem sheaths hairy and closed. Leaves and sheaths may turn dark red or maroon

with age. Seed head composed of 4-6 branches (spikes) at the top of the stems, each approximately 3-15 cm long. Fruit caryopsis shiny, yellowish-brown, 2-3 mm long.

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

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

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

It is a perennial grass found on bunds and channels of cultivated fields. The rhizomes are mainly in the top 10 cm of the soil. They spread horizontally for several meters, with nodes at approximately 10 cm intervals. In dense stands, shoots developing from buds on rhizomes or runners tend to be erect and quite short, up to 25 cm high, but develop into prostrate runners under less dense conditions. Leaves are usually dull grey-green, flat, up to 15 cm long and finely parallel-ribbed on both surfaces, without a conspicuous midrib. Ligule is very short but with a conspicuous fringe of white hairs. The inflorescence is supported on a culm up to 25 cm high and consists of a single whorl of 3-7 narrow racemes, each 3-8 cm long.

21) Wild sugarcane: *Saccharum spontaneum* L. (Poaceae)

It is strong perennial, 1-2 m tall weed. Culm tufted; solid above, fistularbelow, polished, silky below panicles. Leaves erect, glaucous, midrib white, margins, sheath longer than internode. Panicle conical-oblong, with 3-15 cm long fragile racemes, joints and pedicels; branches ascending, usually reddish or purplish, primary rachis silky with long, white hairs. Fruits caryopsis 2 mm long oblong.

22) Johnson grass: *Sorghum halapense* (L.) Pers. (Poaceae)

A perennial weed growing from rhizomes that may reach 6.5 feet in height. Stem round to somewhat flattened, usually without hairs. Sheaths may be green to maroon, especially near the base of the plant. Leaves rolled in the shoot, without auricles, 6 to 20 inches long and 1 to 3 cm wide, with a prominent white midvein. Leaf blades are usually without hairs, however, some hairs may be present at the base of the leaf blade. The ligules are 3 to 4 mm long, membranous, and often toothed at the top. Seed head is a large, open panicle, often with apurplish tint. Fruits elliptical in outline with sharply pointed apex, smooth and glossy. Seeds oval, 3 to 5 mm in length, and dark red to black at maturity.
http://www.unavarra.es/herbario/fotos/Sorg_hale/image001b.jpg

23) Torpedo grass: *Panicum repens* L. (Poaceae)

A rhizomatous, creeping perennial, rooting at the base, 30-90 cm tall weed. Leaf-blades usually rolled when dry, 5-15 cm long and 5-12 mm wide with scattered hairs on the upper surface. Inflorescence an open panicle 6-20 cm long, branches ascending, spikelets 3 mm long, acute and gaping at the tip. Fruit glossy white. Young shoots covered by leaf-sheaths (hence "torpedo grass").

http://www.fao.org/ag/agp/AGPC/doc/gbase/data/Pf000282.HTM
http://en.wikipedia.org/wiki/File:Starr_050902-4373_Panicum_repens.jpg

24) Bluegrass: *Poaannua* L. (Poaceae)

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

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

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

26) 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

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

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

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

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

Source:

Naidu, V.S.G.R. 2012, Hand Book on Weed Identification Directorate of Weed Science Research, Jabalpur, India Pp 354.

1. & 2. https://encrypted- tbn1.gstatic.com/images?q=tbn: ANd9GcSG4MuoFs9OR2DVI1kYn4zGBww30cu TCuflmyN7cq49wTYFIFJTjg

VIII. DESCRIPTION OF INSECT AND MITE PESTS

1) Early shoot borer:

Biology:

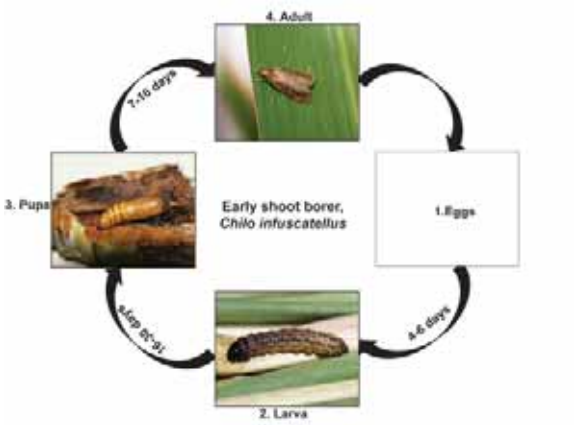
Egg: Flat – scale like eggs are laid in 3-5 rows on the lower surface of leaves in masses of 4-100. The masses are slightly overlapping like tiles. It hatches 4-6days.

Larva: Larva is dirty white with five dark violet longitudinal stripes and dark brown head. Duration 16-30days.

Pupa: Pupation takes within the tunnel. Caterpillar before pupating makes a large exit hole in the stem and blocks the opening with silken discs.

Adult: Pale greyish brown moth with black dots near the coastal margin of the forewings and with white hind wings.

Life cycle:



1,2,3,4. http://www.nbaii.res.in/insectpests/index.php

Damage symptoms:

Dead heart in 1-3 month old crop, which can be easily pulled out, rotten portion of the straw coloured dead – heart emits an offensive odour. A number of bore holes at the base of the shoot just above the ground level.




http://agritech.tnau.ac.in/crop_protection/crop_prot_crop_insectpest%20_sugarcane.html#1a

Parasitoids of early shoot borer:

Egg parasitoid :
1. *Trichogramma* spp.

Larval parasitoid:
2. *Cotesia flavipes*

2. http://en.wikipedia.org/wiki/File:Cotesia9061.8.15.07.c.jpg

Predators of early shoot borer:

1. Spider

2. Reduviid bug

3. Praying mantis

3. http://spirit-animals.com/praying-mantis/

*For management refer to page number 18

2) Internode borer:

Biology:

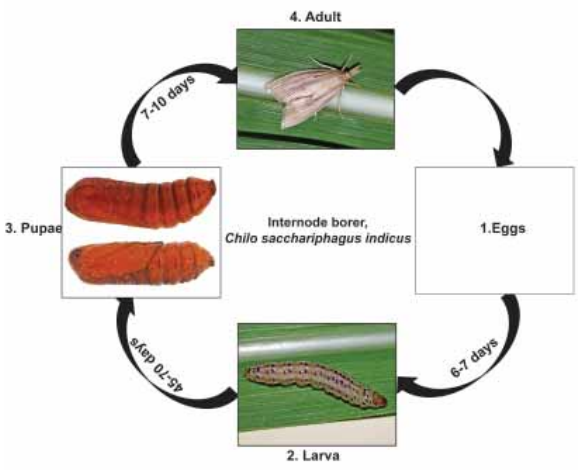
Egg: Scale – like oval, flat, shiny and waxy white eggs are laid by female moths in batches of 9-11, near the midribs, on leaf sheaths or on stem.

Larva: White larva with four violet longitudinal stripes and light brown head.

Pupa: Pupation takes place in semi – dried sheath. Pupal period 7 - 10 days

Adult: Straw coloured with a dark spot on each of the forewings

Life cycle:



Damage symptoms:

- Internodes constricted and shortened with a number of bore holes and frass in the nodal region
- affected tissues reddened

Different stages of damaged symptoms

http://agritech.tnau.ac.in/crop_protection/crop_prot_crop_insectpest%20_sugarcane.html#1a

Parasitoids of internode borer:

Egg parasitoid:

***Trichogramma* spp.**

*For management refer to page numbers 20-21

3) Top shoot borer:

Biology:

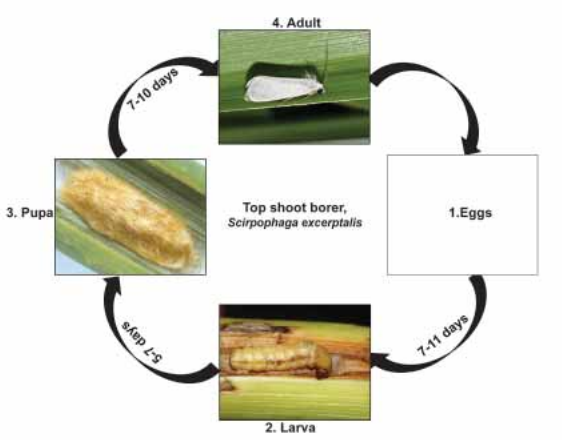
Egg: Eggs are laid on the lower surface of top leaves in clusters particularly near midribs. The clusters are covered with buff coloured hairs. : 10-80 eggs per egg mass

Larva: Smooth, white or cream coloured with a red coloured mid – dorsal line and yellow head.

Pupa: Pupation takes place within the larval tunnel in a chamber with an exit hole Constructed by the caterpillar. Pupal period 6 - 21 days

Adult: White Coloured moth (with a buff Coloured anal tuft in the abdominal tip of female)

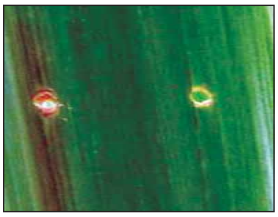
Life cycle:



Damage symptoms:

- Dead heart arises on after sixth month grown up canes, which cannot be easily pulled.
- Parallel row of shot holes in the emerging leaves.
- Bore holes at the top of the shoot and shows bunchy top appearance.

Shot holes on leaves



Dead heart

http://agritech.tnau.ac.in/crop_protection/crop_prot_crop_insectpest%20_sugarcane.html#1a

*For management refer to page number 19

4) Termites:

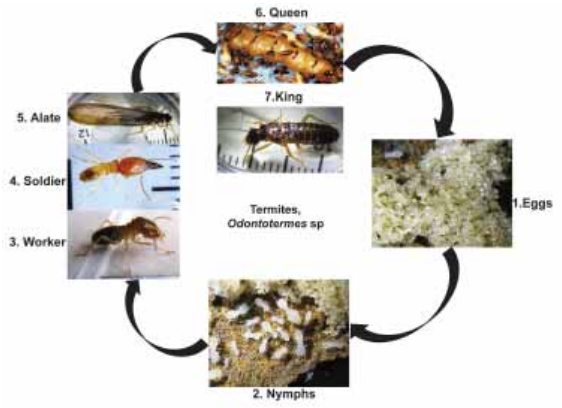
Biology:

Egg: Dull, kidney shaped and hatches in 30-90 days.

Nymph: Moult 8-9 times and are full grown in 6-12 months.

Adult: Creamy coloured tiny insects resembling ants with dark coloured head.

Life cycle:



http://www.termitenewyorkcity.com/more-about-termites/life-cycle/

*For management refer to page numbers 17-18

Damage symptoms:

- Characteristic semi- circular feeding marks on the leaves in the standing crop
- Entire shoot dries up and can be pulled out easily
- Setts hollow inside and may be filled with soil
- Cane collapses if disturbed
- Rind filled with mud

http://agritech.tnau.ac.in/crop_protection/crop_prot_crop_insectpest%20_sugarcane.html#1a

5) White grub:

Biology:

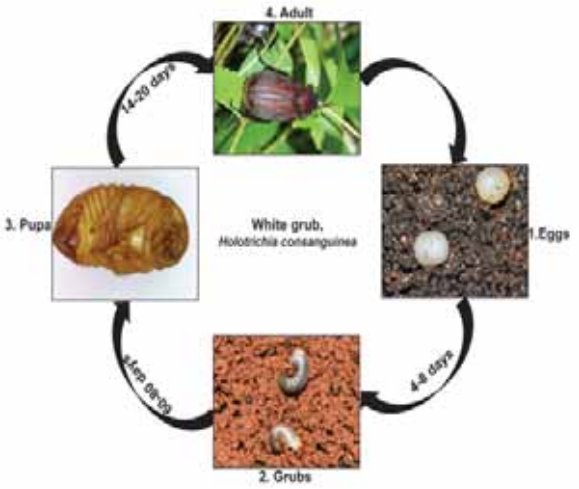
Egg: A female lays on an average of 27 eggs in the soil, which are pear like white enclosed in earthen cells.

Grub: Fleshy 'C' shaped, whitish yellow in colour found close to the base of the clump.

Pupa: Pupae are tan to brown, and occur deeper in the soil in earthen chambers.

Adult: Adult beetles are a rusty-red color just after emerging from the pupal stage, but turn nearly black.

Life cycle:



https://www.google.co.in/search?q=white+grub+life+cycle&espv=210&es_sm=93&source=lnms&tbm=isch&sa

Damage symptoms:

- Yellowing and wilting of leaves.
- Drying of entire crown.
- Affected canes come off easily when pulled.
- Cause extensive damage to roots and base of shoot.

Biological control of root grubs and termites through EPNs:

EPNs seek out and kill all stages of harmful soil-dwelling insects. They can be used to control a broad range of soil-inhabiting insects and above-ground insects in their soil-inhabiting stage of life. The IJs emerge from cadaver, search for root grubs and termites, infect, kill and again multiply and remain in the moist soil. Root grubs and termites which are major pests in sugarcane can be managed by using EPNs effectively. EPN can be produced even at farmer level using either *Galleria* or *Corcyra* as a host.

Mass multiplication of EPNs	Emergence of EPNs	Infected root grub with EPNs	Termite killed by EPNs
			

*For management refer to page numbers 17-18, 19

6) White woolly aphid:

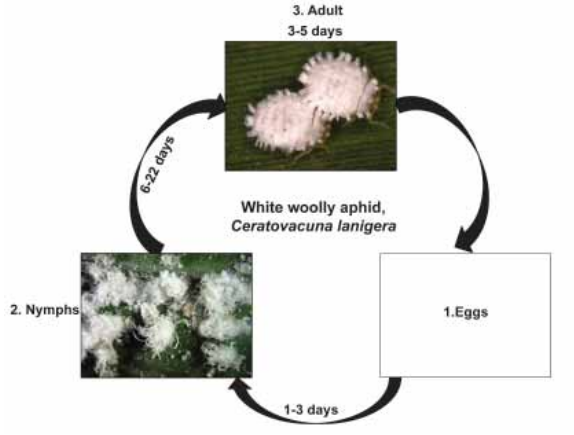
Biology:

Egg: Eggs are spherical yellow in colour and microscopic.

Nymph: Nymph takes 6 to 22 days to complete four instars and become adult.

Adult: Adult emerged after fourth moult and viviparous reproduction. Apterous (Wingless) female reproduce parthenogenetically. Each female produced about 15 – 35 young ones within 24 hr after mating. Each female reproduces maximum of 217 nymphs during the period of 20 days. The life cycle of female complete within one – month period. The longevity of adult is from 32 to 57 days. The life cycle may vary according to the climatic conditions and variety. In most of the affected fields at various locations all the nymphal instars and adults are noticed.

Life cycle:



http://iitk.agropedia.in/content/sugarcane-woolly-aphid-ceratovacuna-lanigera

Damage symptoms:

- Adults and nymphs suck sap from leaves by piercing styles through stomata. Whitish patches – coalesce and turn yellowish then drying starts from the tip along margins.
- Leaves become brittle and dry completely. Heavy secretion of honey dew leads to– development of sooty mould. Deposition of woolly matter on ground / soil distinctly visible.

http://www.homa1.com/noticias/newsletter_19.htm

Parasitoids of white woolly aphid:

Pupal parasitoid:

***Flavoscutellum* sp**

http://www.nhm.ac.uk/research-curation/about-science/staff-directory/life-sciences/a-polaszek/

Predators of white woolly aphid

1. Lacewing

2. Ladybird beetle

3. Syrphid fly

*For management refer to page number 20

7) Whitefly:

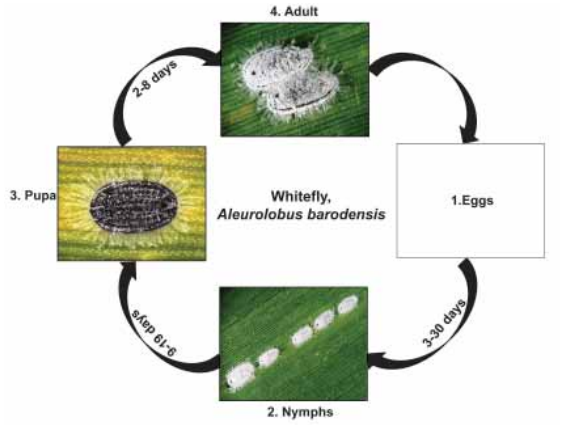
Biology:

Egg: Females lay eggs in a line near the midrib or anywhere on the lower surface of the leaves. Eggs are yellowish with a small curved stalk. Colour changes to black about two hours after the eggs are laid.

Nymph & Pupa: Neonate nymphs are pale yellow in colour, flat and oval in shape, later turn shiny black. Its body is surrounded by fringes of wax. The fourth instar being the pupal stage, is flat, oval, grayish in colour and slightly bigger than the nymph. There is a 'T' shaped white marking on the thorax, which splits at the time of adult emergence.

Adult: Pale yellow body with hyaline wings dusted with waxy bloom, exhibit brisk fluttering movements.

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 symptom:

- Yellowing of leaves
- Leaf turns pinkish or purple and later gradually dry.
- Infested leaves look white with black dots.

Parasitoids of whitefly:

Pupal parasitoids :

1. *Encarsia formosa*

2. *Eretmocerus* sp

3. *Chrysocharis pentheus*

1. http://www.buglogical.com/whitefly-control/encarsia-formosa/, 2. http://www.dongbufarmceres.com/main/mboard.asp?strBoardID=c_ , 3. http://baba-insects.blogspot.in/2012/05/blog-post_21.html

Predators of whitefly: :

1. Mirid bug

2. Big-eyed bug

3. Lacewing

4. Ladybird beetle

1. http://nathistoc.bio.uci.edu/hemipt/Dicyphus.htm
2. http://commons.wikimedia.org/wiki/File:Geocoris_punctipes.

*For management refer to page number 21

8) Mealybug:

Biology:

Egg: Eggs are retained in the female reproductive organs until almost fully mature. Incubation period is short. The females may bring forth hundreds of young ones parthenogenetically. Egg is yellowish, smooth, cylindrical and rounded at both ends.

Nymph: Newly emerged nymphs are quite active with a pinkish transparent body.

Adult: White with mealy coating, sessile.


https://www.google.co.in/search?q=Saccharicoccus+sacchari&espv=210&es_sm=93&tbm=isch&imgil=

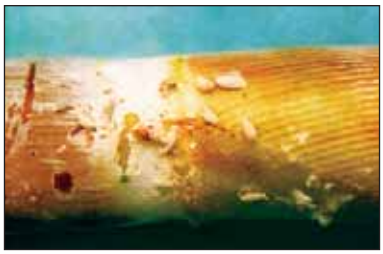
Predator of mealybug:

Hover fly

*For management refer to page number 21

Damage symptoms:

- Pinkish oval insects beneath leaf sheath on the nodes, with whitish mealy coating, main cane stunned also attack roots. Sooty mould develops on the honey dew giving blackish appearance on canes.



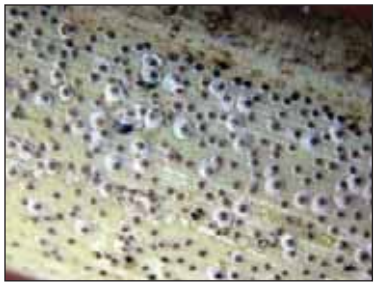
https://www.google.co.in/search?q=Saccharicoccus+sacchari&espv=210&es_sm=93&tbm=isch&imgil=

9) Scale insect:

Biology:

Nymph: Females multiply ovo-viviparously. The nymphs that hatch out from the eggs within the female's body come out through the genital aperture. They are called 'crawlers'. They settle after selecting suitable site for feeding.

Adult: Greyish black or brown circular scales, they cover the nodal region forming a thick encrustation.



http://sugarcane.res.in/index.php/miscellaneous/photo-gallery/25-scale-insect/detail/187-scale-insect?phocaslideshow=1&tmpl=component

Damage symptoms:

- The leaves of infested canes show signs of tip drying and unhealthy pale green colour and with continued infestation these turn yellow.
- Desapping leads to non-opening of leaves also, which also turn yellow and finally dry up.
- Nodal region is more infested than internodal region.
- Infested crop losses its vigour, canes shrivel, growth is stunted and the internodal length is reduced drastically.
- Ultimately cane dries up. Such canes when slit open appear brownish red

Parasitoids of scale insect:

Egg parasitoid:

1. *Encarsia* sp

Nymph and adult parasitoids:

2. *Aphytis* sp

3. *Coccophagus lecanii*

1. 3. http://www.bcpcertis.com/Certis.bcp/English/Home/Our+Solutions/Biological+Controls/Whitefly+control/page.aspx/994
2. http://www.buglogical.com/aphytis-melinus/aphytis-melinus-red-scale-parasite/
3. http://caribfruits.cirad.fr/production_fruitiere_integree/fiches_synthetiques/quelques_auxiliaires_du_verger

Predators of scale insects:

1. *Chilocorus* sp

2. *Hyperaspis* sp

1.http://www.discoverlife.org/mp/20q?search=Chilocorus
2. http://www.discoverlife.org/mp/20q?search=Hyperaspis

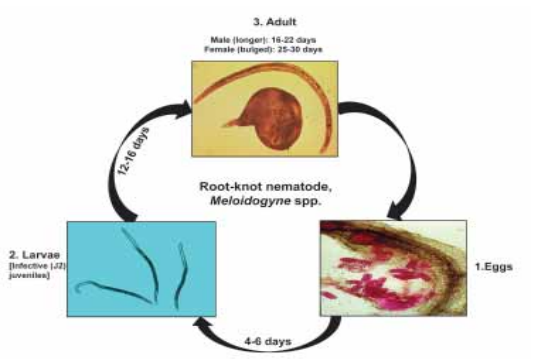
*For management refer to page numbers 19-20, 21

10) Nematode:

There are several nematodes present in the soil of which, four nematodes are mainly damaging the sugarcane crop. They are:

1. **Lesion nematode** –*Pratylenchus coffeae:* Root-lesion nematodes are migratory endoparasites Females of *P. penetrans* lay about 1 or 2 eggs/day for about 35 days, with a maximum of 68 eggs being laid by one female. Eggs are laid singly or in clusters in both soil and roots. Second stage juveniles hatch after eggs have incubated for 9 (30 C) to 25 (15 C) days. Males are required for reproduction by *P. penetrans* but not by *P. neglectus*.
2. **Lance nematode** –*Hoplolaimus indicus* Lance nematodes, *Hoplolaimus* spp., are ecto-parasites, sometimes semi-endo-parasites. Nematodes which are large are highly resistant to effects of temperature extremes and dry soil conditions. Larvae look similar to adults except that they aresmaller.This group of nematodes is easily detected with soil sampling.
3. **Root knot nematode** –*Meloidogyne* spp. Root knot nematodes are microscopic roundworms, obligate endo-parasites that complete most of their life cycle within their host roots. The nematodes survive in soil as eggs and also second stage larvae.
4. **Reniform nematode –***Rotylenchulus reniformis*. The term 'reniform' refers to the kidney-shaped body of the mature female. They are semi-endoparasitic (partially inside roots) species in which the females penetrate the root cortex, establish a permanent-feeding site in the stele region of the root and become sedentary or immobile.

Life cycle:



1. http://keys.lucidcentral.org/keys/sweetpotato/key/Sweetpotato%20Diagnotes/Media/Html/TheProblems/Nematodes/RootKnotNematode/Root-knot.htm
2. http://nematology.umd.edu/rootknot.html
3. http://www.cals.ncsu.edu/pgg/dan_webpage/Introduction/Images/pyroform.htm

Entomopathogenic Nematodes

http://www.biocontrol.entomology.cornell.edu/pathogens/nematodes.html

Damage symptoms:

- Usually yellowing of leaves, first in the form of streaks, later complete yellowing-chlorosis, occurring in patches spread out all over the field. Chlorosis in severe cases, accompanied by drying up of margins and leaf tips is more common in ratoon and young crop.
- Stunting of crop, reduction in number and size of internodes.
- Roots are stubby and spares.
- Affected field shows pale green to whitish look.

http://jamaica-gleaner.com/gleaner/20080417/news/news3.html

*For management refer to page number 17

IX. DESCRIPTION OF DISEASES

1) Red rot:

Disease symptoms:

- The spindle leaves (3rd & 14th)) display drying. At a later stage, stalks become discoloured and hollow.
- Acervuli (black fruiting bodies) develop on rind and nodes. After splitting open the diseased stalk, a sour smell emanates.
- The internal tissues are reddened with intermingled transverse white spots.

https://www.google.co.in/search?q=red+rot+of+sugarcane&oq=red+rot+&aqs=chrome.1.69i57j0j69i59j0l3.3515j0j7&

Survival and spread:

- In rainy season, the disease spreads so fast that whole crop dries and not a single milleable cane is obtained

Favourable conditions:

- Primary transmission through soil and diseased setts, while the secondary transmission through air, rain splash and soil.

*For management refer to page number 21

2) Wilt:

Disease symptoms:

- Externally gradual yellowing and drying of foliage, shrinkage/withering of canes.
- Internally light to dark purplish or brown discolouration of ground tissue, pithiness and boat shaped cavities in the middle of the internodes

https://www.google.co.in/search?q=wilt+of+sugarcane&oq=wilt+of+sugarcane&aqs=chrome..69i57j0.4767j0j7

Survival and spread:

- The wilt pathogens are transmitted through soil, seed pieces, wind, rain and irrigation water.

Favourable conditions:

- The disease symptoms appear during the monsoon and post monsoon periods, affected plants are present either singly or in small groups

*For management refer to page number 21

3) Grassy shoot:

Disease symptoms:

- The disease is characterized by proliferation of vegetative buds from the base of the cane giving rise to crowded bunch of tillers bearing narrow leaves.
- The tillers bear pale yellow to completely chlorotic leaves.
- Cane formation rarely takes place in affected clumps and if formed the canes are thin with short internodes.

https://www.google.co.in/search?q=grassy+shoot+of+sugarcane&espv=210&es_sm=93&source=lnms

Survival and spread

- The grassy shoot disease is primarily transmitted through the diseased seed material (setts) and perpetuated through ratooning.
- The MLO is readily transmitted by sap inoculation and in the field it is transmitted through infected setts and perpetuated through crop ratooning.
- The aphids are the vectors for this disease
- This disease is also transmitted by a) mechanically by cutting knife, b) Insects (aphids, black hopper) and c) Dodder (root parasite).

*For management refer to page number 21

4) Smut:

Disease symptoms:

- Production of whip like structure of 25 – 150 cm. from the growing point of the canes.
- Whip covered by translucent silvery membrane enclosing mass of black powdery spores.
- Initial thin canes with elongated internodes later become reduced in length.
- Profuse sprouting of lateral buds with narrow, erect leaves especially in ratoon crop

https://www.google.co.in/search?q=smut+disease+of+sugarcane&espv=210&es_sm=93

Survival and spread:

- Sugarcane smut is disseminated via teliospores that are produced in the smut whip. These teliospores located either in the soil or on the plant, germinate in the presence of water.
- The primary transmission of the disease is through diseased seed pieces, while the secondary transmission is through windblown spores.
- In addition, spores or sporidia, present in or on the soil surface, are also carried to different fields through rain or irrigation water.

Favourable conditions:

- Hot dry weather is suitable for the completion of disease cycle however; pathogen requires wet conditions for development of teliospores.

*For management refer to page number 21

5) Leaf scald disease:

Disease symptoms:

- The disease can be latent, it can develop unseen for some time and when symptoms first appear, the plant is already seriously infected.
- The first sign of the disease is the development of "pencil lines" of white with yellow borders following the veins on the leaf that lead to necrosis (death) of tissue.
- The term "scald" for the disease comes from areas of the leaf that loose their color and become a pale green (chlorotic) as they fail to produce chloroplasts.

https://www.google.co.in/search?q=leaf+scald+disease+of+sugarcane&espv=210&es_sm=93&source=lnms&tbm=isch&sa=

Survival and spread:

- Pathogen survives in cane stubble and on agricultural implements and this is an important mechanism of spreading the disease.
- It can also survive on grasses, including elephant grass and may be transmitted from them to sugarcane.

Favourable conditions:

- Periods of stress such as drought, waterlogging, and low temperature are reported to increase disease severity.

*For management refer to page number 21

6) Red striped disease:

Disease symptoms:

- Red stripe is characterized by the appearance on the leaves of chlorotic lesions carrying dark red stripes 0.5-1.0 mm in breadth and several mm in length, either distributed all over the blade, or concentrated in the middle
- Several of them may coalesce to cover large areas of the leaf blade, and to cause wilting and drying of the leaves.
- Whitish flakes occur on the lower surface of the leaf, corresponding to the red lesions on the upper surface.
- These flakes are the dry bacterial ooze. When young shoots are affected, shoot or top rot may result. The growing points of the shoot are yellow and later reddish with dark brown stripes on the shoots.
- If the affected plants are cut by splitting the shoot downwards, dark red discolouration of the tissues may be seen.
- In the affected canes cavities may form in the pith region, and the vascular bundles are distinct because of the dark red discolouration.

https://www.google.co.in/search?q=red+stripe+disease+of+sugarcane&espv=210&es_sm=93&source=lnms&tbm=i

Survival and spread:

- The disease spreads in the field by wind and rain, and by cutting, as the basal stem from which the setts are taken is mostly free from the bacterial infection.

Favourable conditions:

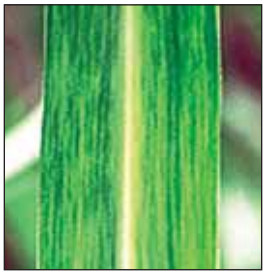
- Moist humid conditions favour the development of disease.

*For management refer to page number 21

7) Mosaic disease:

Disease symptoms:

- Young leaves of the crown held against the light source display chlorotic and normal green area imparting mosaic pattern.
- The chlorotic area may show reddening or necrosis.
- Leaf sheath may also display such symptoms.



https://www.google.co.in/search?q=mosaic+disease+of+sugarcane&espv=210&es_sm=93&source=lnms&tbm=isch&sa=

Transmission:

- Primarily transmitted through the diseased seed material and perpetuated through ratooning.This disease is also transmitted mechanically by cutting knife

*For management refer to page number 21

8) Pokkahboeng:

Disease symptoms:

The general symptoms of Pokkahboeng are mainly of three types;

- **Chlorotic Phase:** The earliest symptom of Pokkahboeng is a chlorotic condition towards the base of the young leaves and occasionally on the other parts of the leaf blades.
- Frequently, a pronounced wrinkling, twisting and shortening of the leaves accompanied the malformation or distortion of the young leaves. The base of the affected leaves is seen often narrower than that of the normal leaves..
- **Acute Phase or Top-Rot Phase**: The most advanced and serious stage of Pokkahboeng is a top rot phase. The young spindles are killed and the entire top dies.
- Leaf infection sometimes continued to downward and penetrates in the stalk by way of a growing point. In advanced stage of infection, the entire base of the spindle and even growing point showed a malformation of leaves, pronounced wrinkling, twisting and rotting of spindle leaves. Red specks and stripes also developed.
- **Knife-cut Phase (associate with top rot phase):** The symptoms of knife-cut stage are observed in association with the acute phase of the disease characterized by one or two or even more transverse cuts in the rind of the stalk /stem in such a uniform manner as if, the tissues are removed with a sharp knife, This is an exaggerated stage of a typical ladder lesion of a pokkahboeng disease.

1. Chlorotic phage **2. Top rot phase** **3. Knife cut phase**



https://www.google.co.in/search?q=pokkah+boeng+disease+of+sugarcane&espv=210&es_sm=93&source=l

Survival and spread:

- This is an air-borne disease and primarily transmitted through the air-currents and secondary transmission is through the infected setts, irrigation water, splashed rains and soil.

Favourable conditions:

- 20-30°C temperature and the average relative humidity higher than 70 to 80% with a cloudy weather, drizzling rains favors the growth of pathogen.

*For management refer to page number 21

9) Rust:

Disease symptoms:

- The earliest symptoms of common rust on the leaves are small, elongated yellowish spots which are visible on both the surfaces.
- These spots increase in size, mainly in length, and turn red-brown to brown in color. A narrow, pale yellow-green halo develops around the lesions.
- When the common rust is severe, numerous lesions occur on individual leaves giving them an overall brown or rusty appearance. These lesions coalesce to from large, irregular necrotic areas is usually result in premature death of the leaf. In such cases, the number of live leaves per plant can be seriously reduced.


https://www.google.co.in/search?q=rust+of+sugarcane&espv=210&es_sm=93&source=lnms&tbm=i

Survival and spread:

- The rust pathogen is transmitted by wind and water splash of the urediospores.

Favourable conditions:

- High humidity and warm temperature favours the development of diseases.

*For management refer to page number 21

10) Sugarcane yellow leaf disease:

Disease symptoms:

- Symptoms of SCYLD are a yellowing of the leaf midrib on the underside of the leaf. The yellowing first appears on leaves 3 to 6 counting down from the top expanding spindle leaf.
- Initial symptoms of yellow leaf, with a yellowing of the lower surface of the leaf midrib of leaves 3 to 6 counting from the top expanding spindle leaf.
- Yellowing is most prevalent and noticeable in mature cane from October until the end of harvest in March.
- The yellowing expands out from the leaf midrib into the leaf blade as the season progresses until a general yellowing of the leaves can be observed from a distance.

https://www.google.co.in/search?q=sugarcane+yellow+leaf+disease&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=

Transmission:

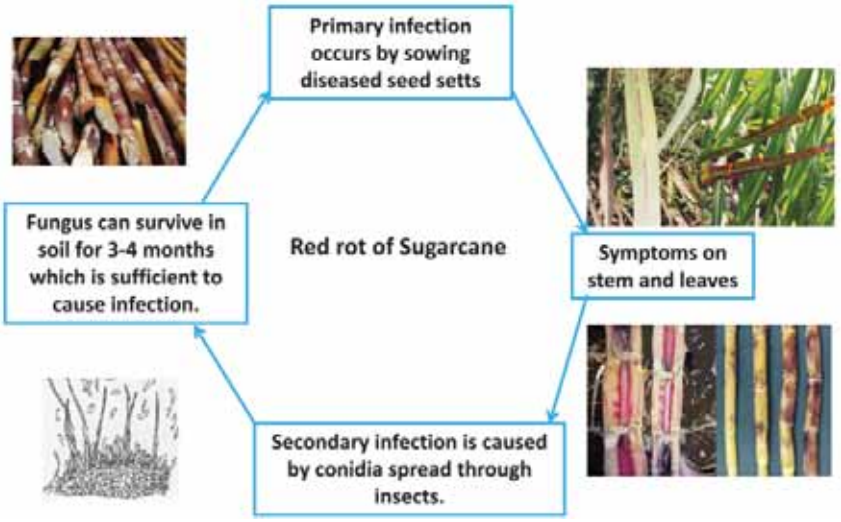
- The virus is transmitted by aphids, *Melanaphis sacchari* and *Rhopalosiphum maidis,* in a semi-persistent manner. The virus is also spread by planting infected seed cane.

Favourable conditions:

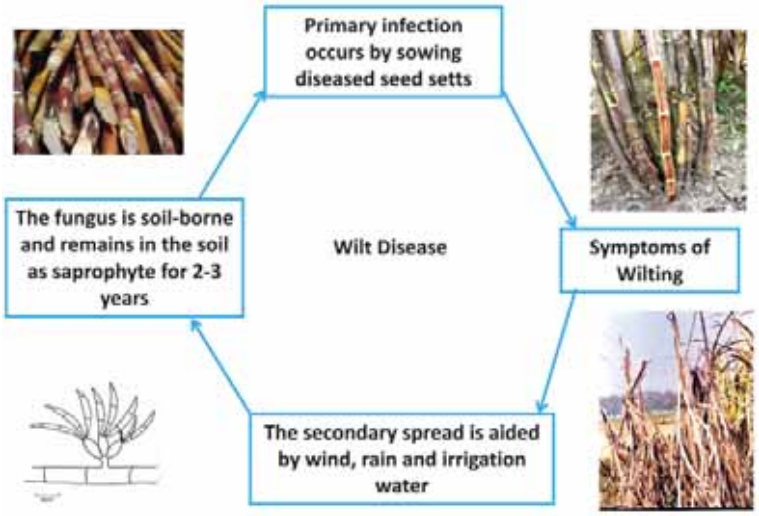
- Dry weather conditions during October to until the end of harvest in March.

Disease cycle:

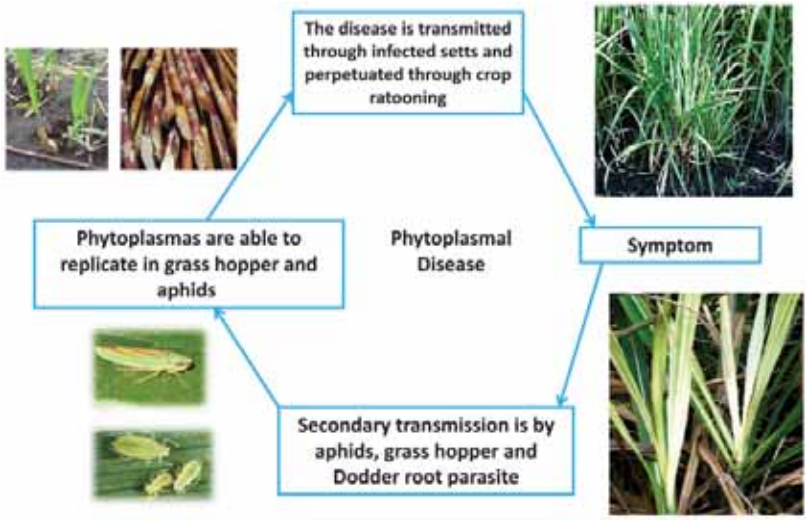
1. Red rot of sugarcane:



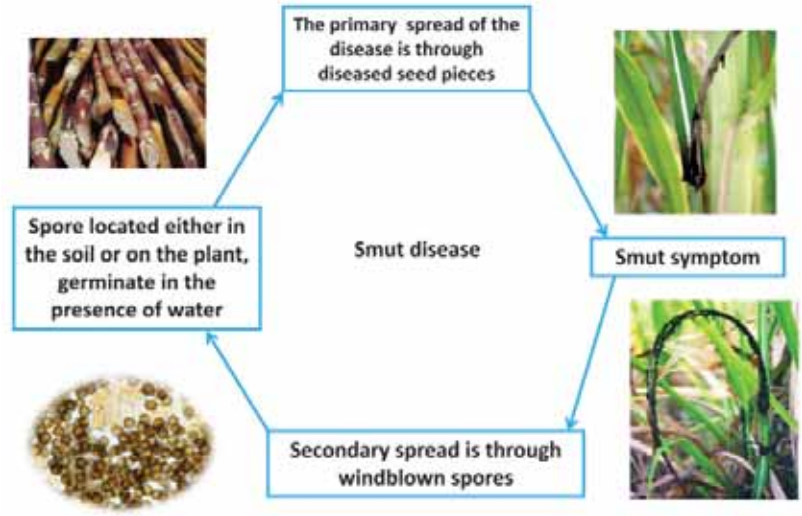
2. Wilt:



3. Grassy shoot (Phytoplasmal disease):



4. Smut disease:



X. DESCRIPTION OF RODENT PEST

1) Lesser bandicoot:

Distribution and Identification:

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

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

Damage symptoms:

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

XI. SAFETY MEASURES

A. At the time of harvest:

Harvesting of sugarcane at a proper time i.e., peak maturity, by adopting right technique is necessary to realize maximum weight of the millable canes (thus sugar) produced with least possible field losses under the given growing environment. On the other hand harvesting either under-aged or over-aged cane with improper method of harvesting leads to loss in cane yield, sugar recovery, poor juice quality and problems in milling due to extraneous matter.

Therefore, proper harvesting should ensure:

- To harvest the cane at peak maturity (i.e., avoiding cutting of either over-matured or under-matured cane)
- Cutting cane to ground level so that the bottom sugar rich internodes are harvested which add to yield and sugar
- De-topping at appropriate height so that the top immature internodes are eliminated
- Proper cleaning of the cane i.e., removing the extraneous matter such as leaves, trash, roots etc.
- Quick disposal of the harvested cane to factory

B. During post-harvest:

- By products such as bagasse as fuel compressed fibre board paper
- Molasses in distilleries for manufacture of ethyl alcohol and used as additives of livestock
- Press mud is used as manure. Green tops of cane-Angola as green fodder for cattle
- Uses of sugarcane include the production of sugar, Falernum, molasses, rum, soda, cachaça (the national spirit of Brazil) and ethanol for fuel
- Bagasse used in the mill and electricity, typically sold to the consumer electricity grid
- Used as raw material for paper and cardboard
- Fiber from Bengal cane is used to making mats, screens or baskets etc. in West Bengal. This fiber is also used in Upanayanam, a rite-of-passage ritual in India and therefore is also significant religiously

XII. DO'S AND DON'TS IN IPM

S. No.	Do's	Don'ts
1.	Deep ploughing is to be done on bright sunny days during the months of May and June. The field should be kept exposed to sun light at least for 2-3 weeks. 	Do not plant or irrigate the field after ploughing, at least for 2-3 weeks, to allow desiccation of weed's bulbs and/or rhizomes of perennial weeds.
2.	Adopt crop rotation.	Avoid monocroping.
3.	Grow only recommended varieties.	Do not grow varieties not suitable for the season or the region.
4.	Sow/plant early in the season	Avoid late sowing/planting as this may lead to reduced yields and incidence of white grubs and diseases.
5.	Always treat the setts with approved bioproducts/ chemicals for the control of sett borne diseases/pests. 	Do not use setts without setts treatment with biopesticides/chemicals.
6.	Apply only recommended herbicides at recommended do seat proper time, with recommended dilution by standard equipment along with flat fan or flat jet nozzle (s).	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 excessive use of fertilizers.
9.	Use micronutrient mixture after sowing based on soil test-.	Do not apply any micronutrient mixture after sowing without soil test or deficiency symptoms on the crops.
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.	Spray pesticides thoroughly to treat the undersurface of the leaves, particularly for mites, whiteflies, etc. 	Do not spray pesticides only on the upper surface of leaves.
14.	Apply short persistent pesticides to avoid pesticide residue in the soil and produce.	Do not apply pesticides during preceding 7 days before harvest.

XIII. 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)
Insecticides								
1.	Chlorpyrifos	Highly toxic		Class II - Moderately hazardous	Atrophine sulphate	Severe – diarrhoea, pinpoint and non - reactive pupils, respiratory difficulty, pulmonary edema, cyanosis, loss of sphincter control, convulsions, coma and heart block.	For ingestion lavage stomach with 5 % sodium bicarbonate, if not vomiting. For skin contact, wash with soap and water (eyes – wash with isotonic saline). Wear rubber gloves while washing contact areas. In addition to atropine give 2 – PAM (2 – pyridine aldoximemethiodide). 1 g and 0.25g for infants intravenously at slow rate over a period of 5 minutes and administer again periodically as indicated. More than one injection may be required. Avoid morphine, theophylline, aminophylln, barbiturates Phenothiaznines	-
2.	Monocro-tophos	Extremely toxic		Class I b Highly hazardous		-do-	-do-	-

3	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	--
4.	Phorate	Extremely toxic	-do-	Class Ia- Extremely hazardous	Remove the person from the contaminated environment In case of (a) Skin contact Remove all contaminated clothings and immediately wash with lot of water and soap. (b) Eye contamination Wash the eyes with plenty of cool and clean water; (c) Inhalation – Carry the person to the open fresh air, loosen the clothings around neck and chest, and (d) Indigestion – If the victim is fully conscious,	Nausea, vomiting, restlessness, tremor, apprehension, convulsions, coma, respiratory failure and death Mild – anorexia, headache, dizziness, weakness, anxiety, tremors of tongue and eyelids, miosis, impairment of visual acuity. Moderate- nausea, salivation, lacrimation, abdominal cramp, vomiting, sweating, slow pulse, muscular tremors, miosis. Severe – diarrhea, pinpoint and non-reactive pupils, respiratory difficulty, pulmonary edema, cyanosis, loss of sphincter control, convulsions, coma and heart block.	- Gastric lavage with 2-4 L. tap water. Catharsis with 30 gm (10 oz) sodium sulphate in the cup of water - Barbiturates in appropriate dosages repeated as necessary for restlessness or convulsions. - Watch breathing closely, aspirate oxygen and/or artificial respiration, if needed. - Avoid oils, oil laxatives and epinephrine (Adrenalin) – do not give stimulants. - Give calcium gluconate (19% in 10 ml Ampules) intravenously every four hours. For extreme symptoms of O.P 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.	

					induce vomiting by tickling back of the throat. Do not administer milk, alcohol and fatty substances. In case the person is unconscious make sure the breathing passage is kept clear without any obstruction. Victim's head should be little lowered and face should be turned to one side in the lying down position.		Speed is imperative - Atropine injection – 1 to 4 mg. Repeat 2 mg, when toxic symptoms begin to recur (15-16 minute intervals), Excessive salivation good sign, more atropine needed. - Keep airways open, Aspirate, use oxygen, insert endotracheal tube. Do tracheotomy and give artificial respiration as needed. - For ingestion lavage stomach with 5% sodium bicarbonate if not vomiting. For skin contact, wash with soap and water (eye wash with isotonic saline). Wear rubber gloves while washing contact areas.	

					In case of breathing difficulty, give mouth to mouth or mouth to nose breathing. Medical aid: Take the patient to the docto r/Primary Health Centre immediately along with the original container, leaflet and label		In addition to atropine give 2-PAM (2- pyridine aldoximemethiodide) 1g and 0.25 g for infants intravenously at a slow rate over a period of 5 minutes and administer again periodically as indicated. More than one injection may be required. Avoid morphine, theophylline, aminophyllin, barbituaratesofrphe-nothiazines. Do not give atropine to a cyanotic patients. Give artificial respiration first then administer atropine.	-
5.	Quinalphos	Highly toxic		Class II Moderately hazardous	-do-	-do-	-do-	-
6.	Chloranthra-niliprole				When used as directed this product does not present a hazard to humans or domestic animals			-
7.	Cypermethrin	Highly toxic		Class II Moderately hazardous		Headache, palpitation, nausea, vomiting, flushed face, irritation of nose,throat, eyes and skin, allergic manifestation etc.	No specific antidote. Treatment is essentially symptomatic.	14

8.	Imidacloprid	Highly toxic			Have person sip a glass of water if able to swallow. Do not induce vomiting unless told to do so by a doctor, do not give anything by mouth to an unconscious person	Harmful if swallowed, absorbed through skin or inhaled. Avoid breathing vapor or spray mist. Causes moderate eye irritation.	No specific antidote. Treatment is essentially symptomatic.	3
9.	Fipronil	Highly toxic	Yellow	Class II Moderately hazardous		Headache, palpitation, nausea, vomiting, flushed face, irritation of nose, throat, eyes and skin etc.	No specific antidote, Treatment is essentially symptomatic.	270
10.	Dichlorvos	Extremely toxic		Class I b highly hazardous		Moderate nausea, salivation, lacrimation, abdominal cramp, vomiting, sweating, slow pulse, muscular tremors, miosis	Speed is imperative. Atropine injection- 1-4 mg. repeat 2 mg when symptoms begin to recur (15-16 min interval) excessive salivation- good sign, more atropine needed	-

XIV. BASIC PRECAUTIONS IN PESTICIDE USAGE

A. Purchase

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

B. Storage

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

C. Handling

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

D. Precautions for preparing spray solution

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

E. Equipment

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

F. Precautions for applying pesticides

1. Apply only at recommended dose and dilution
2. **Do not** apply on hot sunny day or strong windy condition; **Do not** 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.

XV. PESTICIDE APPLICATION TECHNIQUES

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

XVI. OPERATIONAL, CALIBRATION AND MAINTENANCE GUIDELINES IN BRIEF

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

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

Dill

Sunflower

Carrot

Marigold

Chrysanthemum

Mustard

Coriander

Alfalfa

French bean

Cowpea

Buckwheat

Maize

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