AESA BASED IPM PACKAGE

AESA based IPM – Castor

Directorate of Plant Protection Quarantine and Storage
N. H. IV, Faridabad, Haryana

National Institute of Plant Health Management
Rajendranagar, Hyderabad, Telangana

Department of Agriculture and Cooperation
Ministry of Agriculture
Government of India

Important Natural Enemies of Castor Insect Pests

Parasitoids

***Trichogramma* spp.**

***Tetrastichus* spp.**

***Chelonus* spp.**

***Bracon* spp.**

***Brachymeria* sp**

***Enicospilus* sp**

Predators

Lacewing

Ladybird beetle

Spider

Reduviid bug

Robber fly

Black drongo

The AESA based IPM-Castor, 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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Citation Satyagopal, K., S.N. Sushil, P. Jeyakumar, G. Shankar, O.P. Sharma, D.R. Boina, S.K. Sain, Ram Asre, K.S. Kapoor, Sanjay Arya, Subhash Kumar, C.S. Patni, Suresh D. Ekabote, K. Rajashekarappa, M. Lakshminarayana, H. Narayanaswamy, B.K. Shivanna. 2014. AESA based IPM package for Castor. pp 38.

Front cover picture Model AESA chart for Castor

Back cover picture Castor field

Published by National Institute of Plant Health Management, Rajendranagar, Hyderabad – 500 030

Copies: 1,000

For internal circulation only. Not for sale.

Contact APPA - IPM, Directorate of Plant Protection, Quarantine & Storage, CGO Complex, NH IV, Faridabad, Haryana - 121 001.

Tel : 0129 2413020, e-mail: ppa@nic.in

Printed at Balaji Scan Pvt. Ltd., A.C. Guards, Hyderabad.

Tel : 040-23303424, balajiscan.com; bsplpress@gmail.com

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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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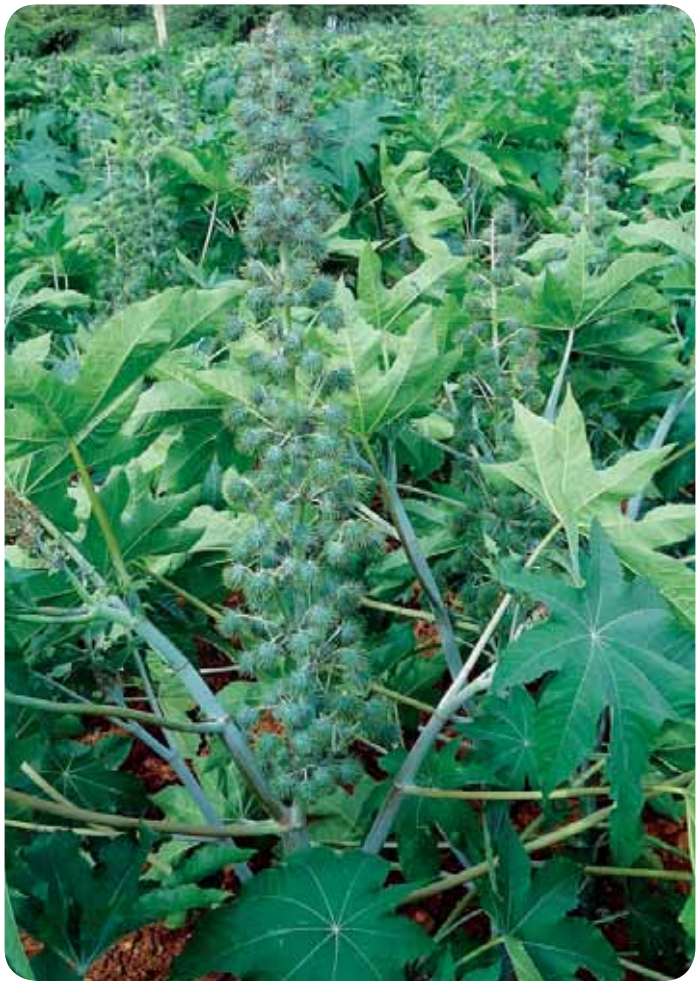
AESA BASED IPM PACKAGE FOR CASTOR

Castor plant description:

The castor (*Ricinus communis* L.; Family: Euphorbiaceae) is the sole member of the genus *Ricinus* and of the subtribe *Ricininae*. The castor plant is native to the Ethiopian region of east Africa. It grows in tropical and warm temperate regions throughout the world. Castor is a perennial, erect, branched, herb, typically less than 2 meters in height. Large leaves are alternate, palmately lobed with 5-11 toothed lobes. Leaves are glossy and often red or bronze tinted when young. Flowers appear in clusters at the end of the main stem in late summer. The fruit consists of an oblong spiny pod which contains three seeds on average. Seeds are oval and light brown, mottled or streaked with light and dark brown and resemble a pinto bean. The plant itself is fast growing, but the seeds require a long frost-free season in order to mature. Castor seed is the source of castor oil, which has a wide variety of uses. The seeds contain between 40% and 60% oil that is rich in triglyceride, mainly ricinolein. The seed contains ricin, a toxin, which is also present in lower concentrations throughout the plant.



I. PESTS

A. Pests of National Significance

1. Insect Pests

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

1.2 Castor semilooper: *Achaea janata* (Linnaeus) (Lepidoptera: Noctuidae)

1.3 Shoot and capsule borer: *Conogethes* (*Dichocrocis*) *punctiferalis* (Guenée) (Lepidoptera: Crambidae)

2. Diseases

2.1 Seedling blight: *Phytophthora colocasiae* Rac.

2.2 *Alternaria* blight: *Alternaria ricini* (Yoshii) Hansford

2.3 *Cercospora* leaf spot: *Cercospora ricinella* Saccardo & Berlese

2.4 Powdery mildew: *Leveillula taurica (*Lev.) Arm.

2.5 Wilt: *Fusarium oxysporum* Schlecht.

3. Weeds

Broad leaf

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

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

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

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

Grasses

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

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

3.7 Burmuda grass: *Cynodon dactylon* (Poaceae)

Sedges

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

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

B. Pests of Regional Significance

1. Insect pests

1.1 Red headed hairy caterpillar: *Amsacta albistriga* (Walker), *A. mooreii.* Butler (Lepidoptera: Arctiidae)

1.2 Bihar hairy caterpillar: *Spilosoma obliqua* (Walker) (Lepidoptera: Arctiidae)

1.3 Whitefly: *Trialeurodes ricini* Misra (Hemiptera: Aleyrodidae)

1.4 Thrips: *Retithrips siriacus*, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae)

1.5 Hairy caterpillars: *Euproctis fraternal* Moore (Lepidoptera: Lymantriidae)

1.6 Castor spiny caterpillar: *Ergolis (Ariadne) merione* (Cramer) (Lepidoptera: Nymphalidae)

1.7 Jassid: *Empoasca flavescens* Fabricius (Hemiptera: Cicadellidae)

1.8 Tussock caterpillar: *Orgyia postica* (Walker) (Lepidoptera: Lymantriidae)

1.9 Castor slug: *Parasa lepida* (Cramer) (Lepidoptera: Limacodidae)

2.0 Serpentine leaf miner: *Liriomyza trifolii* (Burgess) (Diptera: Agromyziidae)

2. Disease

2.1 Collar rot: *Phytophthora* spp.

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 white 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 seeds/seedlings/planting material
- Treat the seeds/seedlings/planting material 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 Pest: Defender ratio (P: D ratio)
- Take direct action when needed (e.g. collect egg masses, remove infested plants etc.)

Plant compensation ability:

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

Understand and conserve defenders

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

Insect zoo:

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

Pest: Defender ratio (P: D ratio):

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

Model Agro-Ecosystem Analysis Chart

Date:
Village:
Farmer:

Decision taken based on the analysis of field situation

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

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

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, number of branches, 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 condition; irrigation; weather conditions
- **Input costs:** Seeds; fertilizer; pesticides; labour
- **Harvest:** Yield (Kg/acre); price of produce (Rs./Kg)

Some questions that can be used during the discussion

- Summarize the present situation of the field
- What crop management aspect is most important at this moment?
- Is there a big change in crop situation compared to last visit? What kind of change?
- Is there any serious pest or disease outbreak?
- What is the situation of the beneficial insects?
- Is there a balance in the field between pests and defenders?

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

Advantages of AESA over ETL:

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

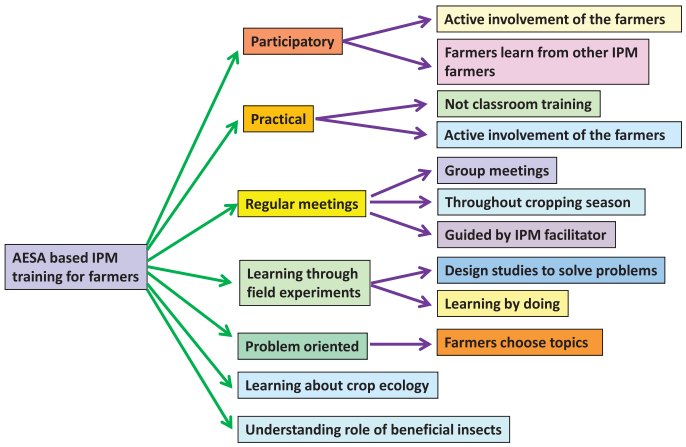
AESA and farmer field school (FFS):

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

Farmers can learn from AESA:

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

FFS to teach AESA based IPM skills:



B. Field scouting:

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

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

For insect pests:

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

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

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

***Spodoptera, Achaea*, and *Conogethes*:** Total number of capsules, damaged capsules due to *Spodoptera, Achaea* and *Conogethes* and number of larvae on individual plants should be counted and recorded.

For diseases:

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

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

Leaf sampling: Examine all leaves 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, flower and capsule sampling: Carefully examine the stem, flower, and capsule of plants for symptoms and signs of fungal or bacterial diseases. The stem, flower, and capsule should be split or taken apart and examined for discoloration caused by fungi and bacteria. Count the number of stems, flowers and capsules infected due to disease and percent disease incidence should be recorded.

C. Surveillance through pheromone trap catches for *Spodoptera, Achaea* and *Conogethes*:

Pheromone traps for insects viz., *Spodoptera*, *Achaea* and *Conogethes* @ 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 recorded year round. The trapped moths should be removed and destroyed after each recording.

D. Yellow/blue pan water/sticky traps:

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

E. Light traps:

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

F. Nematode extraction:

Collect 100 to 300 cm3 (200-300 g) representative soil sample. Mix soil sample and pass through a coarse sieve to remove rocks, roots, etc. Take a 600 cc subsample of soil, pack lightly into a beaker uniformly. Place soil in one of the buckets or pans half filled with water. Mix soil and water by stirring with paddle; allow to stand until water almost stops swirling. Pour all but heavy sediment through 20-mesh sieve into second bucket; discard residue in first bucket; discard material caught on sieve. Stir material in second bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 200-mesh sieve into first bucket; discard residue in second bucket. Backwash material caught on 200-mesh sieve (which includes large nematodes) into 250-ml beaker. Stir material in first bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 325-mesh sieve into second bucket; discard residue in first bucket. Backwash material caught on 325-mesh sieve (which includes small to mid-sized nematodes and silty material) into 250-ml beaker. More than 90% of the live nematodes are recovered in the first 5-8 mm of water drawn from the rubber tubing and the sample is placed in a shallow dish for examination.

III. ECOLOGICAL ENGINEERING FOR PEST MANAGEMENT

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

Natural enemies may require

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

Ecological engineering for pest management – Above ground:

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

Ecological engineering for pest management – Below ground:

- Crop rotations with leguminous plants which enhance nitrogen content.
- Keep soils covered year-round with living vegetation and/or crop residue.

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

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

Ecological Engineering Plants

Attractant plants


Cluster bean


Cowpea


Carrot


Sunflower


Buckwheat


French bean


Alfalfa


Maize


Mustard


***Coreopsis* spp.**


Cosmos


Dandelion


Anise


Caraway


Dill


Parsley

Repellent plants


Ocimum sp


Peppermint

Border plants


Sorghum


Maize


Bajra

Intercrops


Blackgram


Groundnut

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

Biodiversity of natural enemies observed in Ecological Engineering field at NIPHM

Biodiversity of natural enemies: Parasitoids

Biodiversity of natural enemies: Predators

Biodiversity of natural enemies: Spiders

A. Resistant/tolerant varieties:

Pest	Tolerant/ resistant variety*
Leaf hopper (*Empoasca flaviscens*)	GCH-4, DCS-9, GCH-5, Jwala (48-1), DCH-519
Thrips (*Retithrips syriacus*)	GCH-4, DCS-9, GCH-5, Jwala (48-1), DCH-519
Fusarium wilt, *Fusarium oxysporum* f. sp. *ricini*	DCS-9, Jwala (48-1), Harita, GCH-4, GCH-5, DCH-177, and GCH-7
Root rot/Die back (*Macrophomina phaseolina*)	Jwala (48-1)GCH-6, and GCH-7
Grey rot/Grey mould (*Botrytis ricini*)	Jwala (48-1)

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

IV. CROP STAGE-WISE IPM

Management	Activity
Pre sowing*	
	Common cultural practices: • Deep ploughing of fields during summer • After summer ploughing field is left for solarization. • Timely sowing should be done • Field sanitation, rogueing • Destroy the alternate host plants • Apply manures and fertilizers as per soil test recommendations • Sow the ecological engineering plants • Rotate the crop with a non host crop • Sow / plant sorghum/maize/bajra in 4 rows all around castor crop as a guard/barrier crop.
Nutrients	• Deep summer ploughing to break hard pan and to facilitate rain water absorption & deep root penetration. • Nutrients should be applied based on the soil test report and recommendations for the particular agro-climatic zone. • Use well decomposed FYM @ 4-5 t/acre or vermicompost @ 2.0 t/acre or castor cake @ 0.4 t/ acre treated with *Trichoderma* at the time of last ploughing. • Apply vermicompost and FYM at 1 week and 3-4 weeks before sowing, respectively. • Do not leave FYM or compost exposed to sunlight as nutrients may be lost. • Apply 12 Kg sulphur/acre through gypsum at the time of last ploughing for higher castor yield.
Weeds	• Summer ploughing should be done to expose and destroy weed seeds/ rhizomes by soil solarization. • 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. • Black plastic mulch prevents entry of light, which restricts germination of weed seeds and growth.
Soil borne pathogens, nematodes, resting stages of insects	**Cultural control:** • Deep summer ploughing of fields to control resting stages of insect pests. • Avoid excessive watering and provide proper drainage in the field. • Practice green manuring and intercropping with red gram for the control of root rot. **Biological control:** • Apply neem cake @ 100 Kg/acre at the time of transplanting for reducing capsule borer damage

<table>
<tr><td colspan="2">Seed sowing*</td></tr>
<tr><td></td><td><u>Common cultural practices:</u>
Use resistant/tolerant varieties.
Use healthy, certified and weed seed free seeds.</td></tr>
<tr><td>Nutrients</td><td>Before sowing, soil testing should be done to find out the soil fertility status. Nutrient should be provided as per soil test recommendations.
Biofertilizers: Seed/seedling treatment should be done with Azotobactor/Azospirillum and phosphorous solubilizing bacteria (PSB) @ 250 g each /acre seed/seedlings and VAM inoculum @ 1Kg /acre.
Fertilizers should be applied on soil test basis. Generally, it is recommended to apply fertilizers as mentioned below;<table><tr><th>Farming situation</th><th>Recommended NPK Kg/ acre</th></tr><tr><td colspan="2">Rainfed</td></tr><tr><td>Varieties</td><td>18 : 6 : 6</td></tr><tr><td>Hybrids</td><td>25 : 12 : 12</td></tr><tr><td colspan="2">Irrigated</td></tr><tr><td>Varieties</td><td>25 : 12 : 12</td></tr><tr><td>Hybrids</td><td>35 : 18 : 18</td></tr></table>
Apply 1/ 3 of N and full dose of P & K as basal at the time of sowing</td></tr>
<tr><td>Weeds</td><td>Line sowing should be done to facilitate inter-culture operations.
Plant population should be maintained to its optimum right from beginning to minimize the crop weed competition.
Intercropping with short duration pulse crops such as moong bean should be done to suppress weeds between rows.</td></tr>
<tr><td colspan="2">* Apply Trichoderma viride/harzianum and Pseudomonas fluorescens as seed/seedling/planting material, nursery treatment and soil application (if commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).</td></tr>
<tr><td colspan="2">Vegetative stage</td></tr>
<tr><td></td><td><u>Common cultural practices:</u>
Collect and destroy crop debris
Provide irrigation at critical stages of the crop
Avoid water logging
Avoid water stress during flowering stage
Judicious use of fertilizers
Enhance parasitic activity by avoiding chemical spray, when 1-2 larval parasitoids are observed
<u>Common mechanical practices:</u>
Collect and destroy disease infected and insect infested plant parts
Collection and destruction of eggs and early stage larvae
Handpick the older larvae during early stages
The infested shoots and seed capsules may be collected and destroyed
Handpick the gregarious caterpillars and the cocoons which are found on stem and destroy them in kerosene mixed water.
Use yellow sticky traps @ 4-5 trap/acre
Use light trap @ 1/acre and operate between 6 pm and 10 pm
Install pheromone traps @ 4-5/acre for monitoring adult moths activity (replace the lures with fresh lures after every 2-3 weeks)
Erecting of bird perches @ 20/acre for encouraging predatory birds such as King crow, common mynah etc.</td></tr>
</table>

	• Set up bonfire during evening hours at 7-8 pm **Common biological practices:** • Conserve natural enemies through ecological engineering • Augmentative release of natural enemies
Nutrients	• Apply 1/3rd of N as top dressing at first flower initiation state at 35 to 40 days after sowing and remaining 1/3rd at 65 to 70 days after sowing depending on rainfallor along with irrigation.
Weeds	• First hoeing should be done at 3 weeks after germination followed by second hoeing at initiation of first spike. • The crop should be maintained weed free initially for 6-8 weeks by following timely hoeing and weeding. • Mulches like straw hay, plastic, etc. can be used in between the rows to suppress the weed growth.
Castor semilooper	**Cultural control:** • Intercropping with cluster bean, cowpea, black gram, or groundnut (1: 2 ratio proportions) reduces semilooper infestation and builds up natural enemies (*Microplitis*, coccinellids, and spiders) population **Biological control:** • Release egg parasitoid, *Trichogramma minutum* @ 1,00,000/acre • Spray neem seed kernal extract (NSKE) 4% synchronising with egg oviposition and early larval stages. • Spray *Bacillus thuringiensis* var *kurstaki* @ 400 g in 200-300 l of water/acre **Chemical control:** • Spray malathion 50% EC @ 800 ml in 200-400 l of water/acre or dimethoate 30% EC @ 462 ml in 200-400 l of water/acre
Tobacco caterpillar	**Biological control:** • Release egg parasitoid, *Trichogramma pretiosum* @ 20,000/acre/week four times. • Spray NSKE 5% against eggs and first instar larva or azadirachtin 5% W/W neem extract concentrate @ 80 g in 160 l of water/acre • Apply entomopathogenic nematodes (EPNs) @ 2,50,000 infective juveniles of *Steinernema feltiae*/sq mt area.
Red headed hairy caterpillar**	**Cultural control:** • Sowing the trap crop cucumber or cowpea before sowing the main crop all along the field borders attract the migrating caterpillars and facilitate mechanical killing of the larvae by jerking them off into kerosinised water. • Digging trench around the field and killing the trapped larvae **Mechanical control:** • Set light traps (mercury lamp of 250 watts) immediately after first rain and continued for 30-40 days in large areas on community basis and kill trapped moths • Place twigs of *Jatropha*, *Ipomoea* or *Calotropis* on the field borders to attract the migrating caterpillars and kill the feeding larvae mechanically **Biological control:** • Spray *Bacillus thuringiensis* var *kurstaki* @ 400 g in 200-300 l of water/acre **Chemical control:** • Spray dichlorvos 76% EC @ 313.2 ml in 200-400 l of water/acre or dimethoate 30% EC @ 462 ml in 200-400 l of water/acre.

Shoot and capsule borer	**Cultural control:** • Intercropping with cluster bean, cowpea, black gram, or groundnut (1: 2 ratio proportions) reduces shoot and capsule borer infestation and builds up natural enemies (*Microplitis*, coccinellids, spiders etc.) population • The infested shoots and seed capsules may be collected and destroyed.
	Chemical control: • Apply trichlorofon 5% Gr @ 8,000 g/acre or trichlorofon 5% Dust @ 8,000 g/acre
Whitefly**	**Cultural control:** • Peppermint can be used as repellant plant for whitefly. • Plant okra as a trap crop **Biological control:** • Spray NSKE 5% • Spray neem oil @ 5 ml/l on the under surface of the leaf
Jassid**	**Cultural control:** • Intercropping with cluster bean, cowpea, black gram, or groundnut (1: 2 ratio proportions) reduces jassids infestation and builds up natural enemies (coccinellids, spiders etc.) population **Biological control:** • Spray NSKE 5% • Spray azadirachtin 5% @ 0.5 ml/l **Chemical control:** • Spray dimethoate 30% EC @ 330 ml in 200-400 l of water/acre or malathion 50% EC @ 600 ml in 200-400 l of water/acre
Bihar hairy caterpillar**	**Biological control:** • Spray NSKE 5% to kill early stage larvae. • Spray *Bacillus thuringiensis* var *kurstaki* @ 400 g in 200-300 l of water/acre **Chemical control:** • Spray dichlorvos 76% EC @ 313.2 ml in 200-400 l of water/acre or dimethoate 30% EC @ 462 ml in 200-400 l of water/acre
Castor slug**	**Cultural control:** • Handpick the gregarious caterpillars and the cocoons which are found on stem and destroy them in kerosene mixed water. **Biological control:** • Spray NSKE 5% or azadirachtin 5% @ 0.5 ml/l
Thrips**	**Cultural control:** • Intercrop with *Sesbania grandiflora* to provide barrier which regulate the thrips population. • Sprinkle water over the seedlings to check the multiplication of thrips **Biological control:** • Apply neem cake to the beds @ 100 Kg/acre in two split doses at the time of planting and 30 days after transplanting
Seedling blight	**Cultural control:** • Avoid ill drained, damp and low lying place for raising castor
***Alternaria* blight**	• Follow common cultural, mechanical and biological practices
***Cercospora* leaf spot**	• Follow common cultural, mechanical and biological practices
Powdery mildew	**Cultural control:** • Provide irrigation at critical stages of the crop • Follow common cultural, mechanical and biological practices

Collar rot**	**Cultural control:** • Avoid water logging • Practice green manuring and intercropping with redgram • Avoid water stress during flowering stage • Follow common cultural, mechanical and biological practices
Wilt	**Cultural control:** • Avoid ill drained, damp and low lying place for raising castor • Provide good drainage • Follow common cultural, mechanical and biological practices
Reproductive/maturity stage	
Nutrients	• Micronutrient deficiency should be corrected by foliar spray of particular micronutrient. • Incorporate crop residues in soil immediately after harvest.
Weeds	• Remove left over weeds from the field by one manual weeding to avoid further spread of weed seeds.
Shoot and capsule borer	• Remove damaged shoots • Release *T. chilonis* @ 20,000/acre at weekly intervals. • Same as in vegetative stage. • Follow common cultural, mechanical and biological practices
Castor semilooper	• Same as in vegetative stage • Follow common cultural, mechanical and biological practices
Tobacco caterpillar	• Same as in vegetative stage • Follow common cultural, mechanical and biological practices
Jassid**	• Same as in vegetative stage • Follow common cultural, mechanical and biological practices

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

** Pests of regional significance

V. INSECTICIDE RESISTANCDE 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

1. Nitrogen: The deficiency of nitrogen leads to formation of yellowish or light green coloured leaves and plant becomes stunted. The leaves and young fruits tend to drop prematurely. The kernels of cereals and the seed of other crops do not attain their normal size, and become shriveled and light in weight.

http://www.ipni.net/ipniweb/portal.nsf/

Correction measure: Apply 8-10 Kg N/acre as top dressing or foliar spray of urea @ 2-3 percent.

2. Phosphorous: Deficiency of phosphorus leads to restricted root and shoot growth, leaves may shed prematurely, flowering and fruiting may be delayed considerably. In case of potato tubers phosphorus deficiency leads to formation of rusty brown lesions.

3. Potassium: Potassium deficiency causes stunting in growth with shortening of internodes and bushy in appearance, brings about chlorosis, i.e., yellowing of leaves and leaf scorch in case of fruit trees. It is also responsible for the 'dying back tips' of shoots. Its deficiency leads to reduction in photosynthesis, blackening of tubers in case of potato, tips or margin of lower leaves of legumes, maize, cotton, tobacco and small grains are either scorched or burnt.

4. Calcium: Deficiency of calcium leads to 'Die back' at the tips and margins of young leaves. Normal growth of plants is arrested i.e., roots may become short, stubby and bushy, leaves become wrinkled and the young leaves of cereal crops remain folded. The acidity of cell sap increases abnormally and it hampers the physiological function of plant. As a result of which plant suffers and causes the death of plant at last.

5. Magnesium: Deficiency of magnesium leads to yellowing of the older leaves known as chlorosis. Acute deficiency of magnesium also causes premature defoliation. In case of maize the leaves develop interveinal white strips, in cotton they change to purplish red, veins remain dark green, in soybean they turn yellowish and in apple trees, brown patches (blotches) appear on the leaves.

6. Sulphur: The deficiency of sulphur leads to slow growth with slender stalks, nodulation in legumes may be poor and nitrogen fixation is reduced. The young leaves turn yellow and the root and stems become abnormally long and develop woodiness. In case of fruit trees, the fruits become light green, thick skinned and less juicy. Sulphur deficient plant produces less protein and oil.

VII. COMMON WEEDS

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

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

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

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

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

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

7. Burmuda grass: *Cynodon dactylon* (Poaceae)

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

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

VIII. DESCRIPTION OF INSECT PESTS

1) Red headed hairy caterpillar:

Biology:

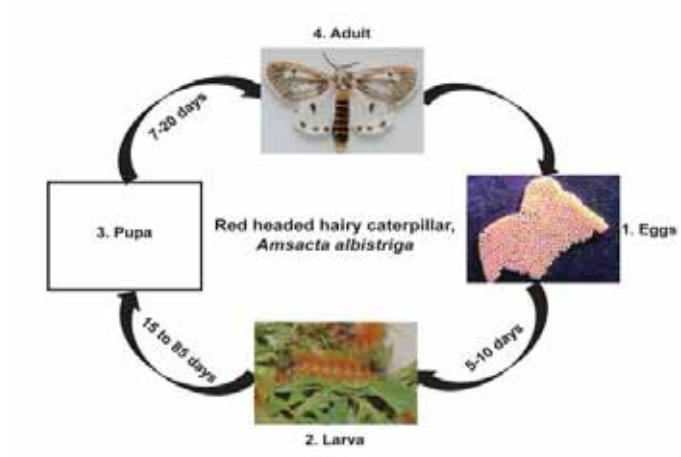
Egg: The female moth lays its eggs in clusters on the under-sides of leaves and covers them with pale brown hairs. The incubation period lasts from 5 to 10 days.

Larva: The newly hatched larvae feed gregariously and after a few days feed on the leaves independently. Larva has red head, body covered with long dense, reddish brown hairs. Both anterior and posterior ends have black broad bands (hairs) with a reddish area in the middle.

Pupa: The pupa resembles is mostly darker in color, although it sometimes is yellowish in color. The pupa bears spiny hairs on the posterior end. Pupa undergoes diapause during winter. The larval period varies from 15 to 85 days and the pupal period 7 to 20 days.

Adult: The pest is active throughout the year and has several generations. Adult moths have dirty white forewings and milky white hindwings with black spots . Forewings have a reddish brown band along coaster margin. The peak period of activity is August-September

Life cycle:



Damage symptoms:

- Scrap under surface of leaves when they are in neonate stage. The scrapped patches of the leaves becomes thin and papery
- Full grown larvae devours entire foliage and flowers causing defoliation and affecting fruit setting and often migrate from one field to another devastating whatever crops come their way.
- After about 30-40 days of feeding the larvae burrow into soil, usually in the undisturbed soil of field or non-cropped areas and pupate.

1. http://tnau.ac.in/eagri/eagri50/ENTO331/lecture08/groundnut/ 004.html
2,4. http://www.nbaii.res.in/insectpests/Amsacta-albistriga.php

Natural enemies of red headed hairy caterpillar:

Parasitoids: *Trichogramma* spp., *Enicospilus* sp

Predators: *Chrysoperla zastrowi sillemi*, ladybird beetle, reduviid bug, spider, red ant, robber fly, black drongo (King crow), common mynah, big-eyed bug (*Geocoris* sp), earwig, ground beetle, pentatomid bug (*Eocanthecona furcellata*), preying mantis etc.

*For management refer to page number 15

2) Castor semilooper:

This is a serious pest of the oilseed crop and is distributed throughout the Indian Union, wherever castor is grown. It occurs during July to September

Biology:

Egg: The female moth lays around 450 blue green rounded eggs singly on the leaves of the castor plant at night. The eggs are laid singly on both sides of the leaves. Four to six eggs have been observed on each leaf. The egg when freshly laid is round, pale green in colour and measures about 0.9 mm in diameter. The chorion is full of ridges and furrows. The egg is convex on the upper surface and concave below. The incubation period of the egg varies from 2 to 5 days from July to September.

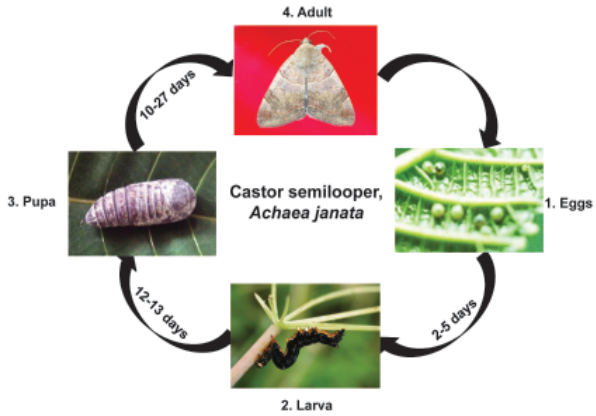
Larva: The newly hatched caterpillar is yellowish green in colour with light brown head and thorax and measures 3.5 mm long. The full grown larva is dull greyish brown and measures 60 to 70 mm long. Five distinct larval instars are present. The larval period lasts from 12 to 13 days in July, August and September.

Pupa: Pupation takes place either in the soil amidst the fallen leaves or sometimes amidst the folded leaves on the plant. The pupal period lasts from 10 to 27 days.

Adult: Adults are grayish-brown in colour. Forewings have pale reddish brown patch. Black hind wings have white stripes in the middle and 3 large white spots on outer margin.

A generation is completed in about 28 to 45 days

Life cycle:



Damage symptoms:

- Freshly hatched larvae feed gregariously, scraping the chlorophyll, soon disperse.
- Sometimes the feeding is so heavy that only petioles and branches are left behind.
- Caterpillars feed on the leaves and cause sometimes complete devastation of the crop.
- Damage to defoliation.

1. http://pikul.lib.ku.ac.th/insect/007-013%20INSECTS%20of%20 Thailand/011%20Charernsom%20Pics/Charernsom%209,205%20pics/
2,3,4. http://oilseeds.agropedia.in/content/semilooper-achaea-janata

Natural enemies of castor semilooper:

Parasitoids: *Trichogramma achaea, T. minutum, T. evanescens*, *Microplitis* spp.

Predators: *Chrysoperla zastrowi sillemi*, ladybird beetle, reduviid bug, spider, red ant, robber fly, black drongo (King crow), common mynah, big-eyed bug (*Geocoris* sp), earwig, ground beetle, pentatomid bug (*Eocanthecona furcellata*), preying mantis etc.

*For management refer to page numbers 15, 17

3) Tobacco caterpillar:

The pest has a wide distribution throughout the Indian Union and occurs as a sporadic pest. Active during August to October.

Biology:

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

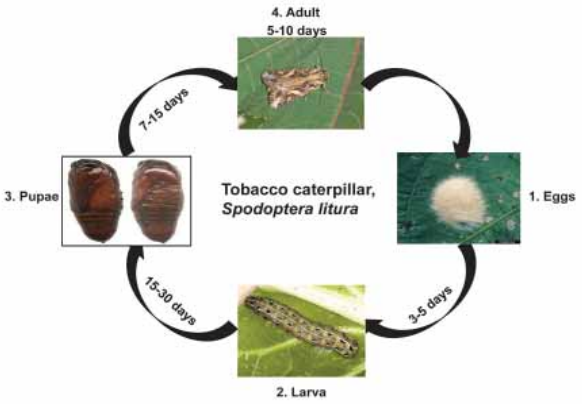
Egg: Female lays about 300 eggs in clusters. The eggs are covered over by brown hairs and they hatch in about 3-5 days.

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

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

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

Life cycle:



Damage symptoms:

- The early instar larvae feed gregariously on the under surface of the leaf by scrapping off the chlorophyll leading to appearance of papery membranes
- Later they disperse, become solitary and nocturnal and cause complete defoliation
- They also feed on the flower buds, flowers.

1. http://commons.wikimedia.org/wiki/File:Spodoptera_litura_egg_ mass.jpg
2. http://lepidoptera.butterflyhouse.com.au/lynf/lynf.html
3. http://www.ccs-hk.org/DM/butterfly/Noctuid/Spodoptera-litura.html
4. http://www.nbaii.res.in/insectpests/images/Spodoptera-litura11.jpg

Natural enemies of tobacco caterpillar:

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

Predators: *Chrysoperla zastrowi sillemi*, ladybird beetle, reduviid bug, spider, red ant, robber fly, black drongo (King crow), common mynah, big-eyed bug (*Geocoris* sp), earwig, ground beetle, pentatomid bug (*Eocanthecona furcellata*), preying mantis etc.

*For management refer to page numbers 15, 17

4) Shoot and capsule borer:

The pest is distributed throughout the plains and the hills of the Indian Union. Infestation starts from flowering stage. Usually active during Nov-March

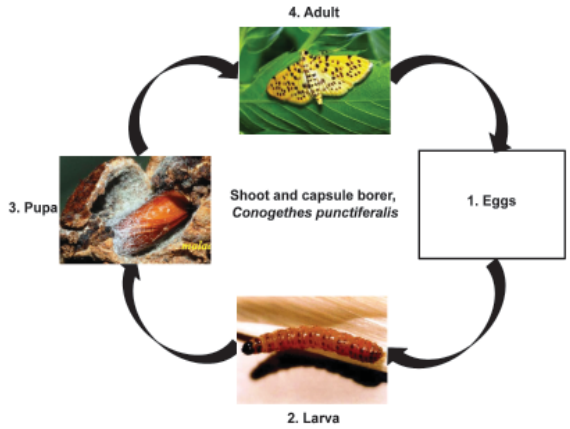
Biology:

Egg: The female moths lay eggs on the tender parts of the plant.

Larva: Pale greenish with pinkish tinge and fine hairs with dark head and prothoracic shield. The caterpillar that hatches out bores into the shoot if the plant is young and knit the seed capsules if the plant is old. The full-grown caterpillar is stout, reddish brown in colour and measures 15 to 25 mm. long. It pupates in a silken cocoon.

Adult: Adults have yellow wings with black dots

Life cycle:



Damage symptoms:

- The caterpillars bore into shoot and seed capsules and cause extensive damage to the crop and characteristic webbing of capsules along with excreta is seen.
- Capsules with bore holes
- Damaged capsules webbed together
- Peduncle and capsules having galleries made of silk and frass.

1. http://lepidoptera.butterflyhouse.com.au/spil/punctif.html
2. http://www.malaeng.com/blog/?p=4444
3. http://natural-japan.net/?cat=28&paged=6

Natural enemies of shoot and capsule borer:

Parastioids: *Bracon brevicornis*, *Brachymeria euploeae*

Predators: *Chrysoperla zastrowi sillemi*, ladybird beetle, reduviid bug, spider, red ant, robber fly, black drongo (King crow), common mynah, big-eyed bug (*Geocoris* sp), earwig, ground beetle, pentatomid bug (*Eocanthecona furcellata*), preying mantis etc.

*For management refer to page numbers 16, 17

5) Bihar hairy caterpillar:

This pest occurs during October to December and of late it is also occuring from July. In recent years, it has become an important pest on groundnut also.

Biology:

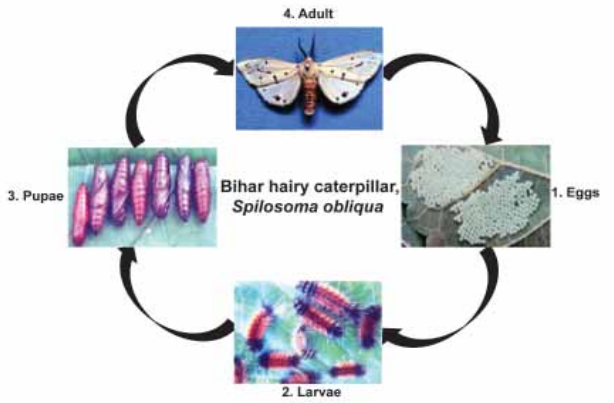
Egg: Female lays eggs in masses on lower surface of leaves.

Larva: The larvae are pale yellow coloured with yellow hair over the body. They are polyphagous, feed on leaves and cause loss by way of defoliation. In severe cases only stems are left behind. In defoliated crops it also feeds on capsules.

Pupa: Pupates in leaf litter close to the plants. There are several generation per year.

Adult: Adult moth is reddish brown with black spots. Both the wings are pinkish and posses black spots

Life cycle:



Damage symptoms:

- Young larvae feed gregariously mostly on the under surface of the leaves.
- Feed on leaves and cause loss by way of defoliation.
- In severe cases only stems are left behind.
- In defoliated crop it also feed on capsules.

1,2,3, http://kssrdi.org/technology/technology_view.asp?id=343
4. http://agropedia.iitk.ac.in/content/groundnut-bihar-hairy-caterpillar

Natural enemies of bihar hairy caterpillar:

Predators: *Chrysoperla zastrowi sillemi*, ladybird beetle, reduviid bug, spider, red ant, robber fly, black drongo (King crow), common mynah, big-eyed bug (*Geocoris* sp), earwig, ground beetle, pentatomid bug (*Eocanthecona furcellata*), preying mantis etc.

*For management refer to page number 16

6) Jassid:

The castor jassid occurs on castor as a minor pest. It has been recorded from Bihar, Tamil Nadu and Assam. Outside India it has been recorded in Burma. Besides castor it infests tea. Peak infestation of jassid is during November to January. Mostly seen at seedling stage, sometimes found almost throughout the year.

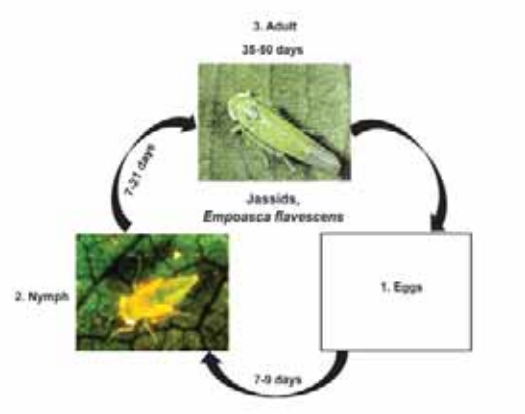
Biology:

Egg: Female inserts eggs into leaf veins on the underside. Eggs hatch in 6-10 days and nymphal period is 7-9 days.

Nymph: Nymphs are pale greenish almost translucent and walk diagonally. Nymph stage lasts for 7-21 days.

Adult: Adults are greenish yellow, wedge shaped with a pair of black spots on vertex and a black spot on each of the forewings. Adult stage lasts for 35-50 days. There are a total of 7-8 generations in a year.

Life cycle:



Damage symptoms:

- Nymphs and adults suck sap usually from the under surface of the leaves and inject toxin causing curling of leaf edges and leaves turn red or brown. The leaves dry up and shed.
- Leaf margins become yellow
- Curling of leaf edges and leaves turn red or brown
- Leaves dry up and shed.

2. http://jpkc.szpt.edu.cn/2007/sylzw/diyjingpinke/bingchonghai/yechongtu/c305ycl.htm
3. http://www.shouragroup.com/carantine-79.html

Natural enemies of jassid:

Predators: *Dicyphus hesperus, Chrysoperla zastrowi sillemi*, ladybird beetle, big-eyed bug (*Geocoris* spp.) etc.

*For management refer to page numbers 16, 17

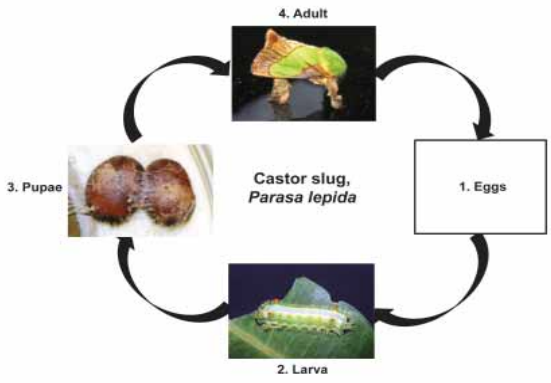
7) Castor slug:

It is most common in the southern regions of the country especially Madras and has been recorded from Ceylon also. This pest damages the castor plant sporadically.

Biology:

- The female moth lays flat scaly eggs on the tender parts of the plant in small clusters.
- The full-grown caterpillar measures 15-25 mm in length.
- Thick short spiny hairs out of rows of warts on the body.
- It is bright green in colour and has interrupted blue stripes on the dorsum.
- It moves like a slug.
- Pupation takes place in a hard greyish cocoon on castor stem or the trunks of its other host plants.
- The pupal period lasts from three to five weeks or longer.

Life cycle:



Damage symptoms:

- The caterpillars are spiny and when touched, cause irritation to the skin.
- To begin with, they feed gregariously on the leaves of castor and later spread over to the entire plant.

2,3,4. http://www.nbaii.res.in/insectpests/Parasa-lepida.php

Natural enemies of castor slug:

Predators: *Chrysoperla zastrowi sillemi*, ladybird beetle, reduviid bug, spider, red ant, robber fly, black drongo (King crow), common mynah, big-eyed bug (*Geocoris* sp), earwig, ground beetle, pentatomid bug (*Eocanthecona furcellata*), preying mantis, *Dicyphus hesperus* etc.

*For management refer to page number 16

8) Whitefly:

The castor whitefly is a pest of castor in some regions of our country. It is more commonly found in Bihar, Bombay, Andhra and Madras. Sometimes the damage caused by this pest to castor crop is serious. More serious in summer months (March to May). Temperature of 30 °C with high relative humidity favours multiplication of the pest

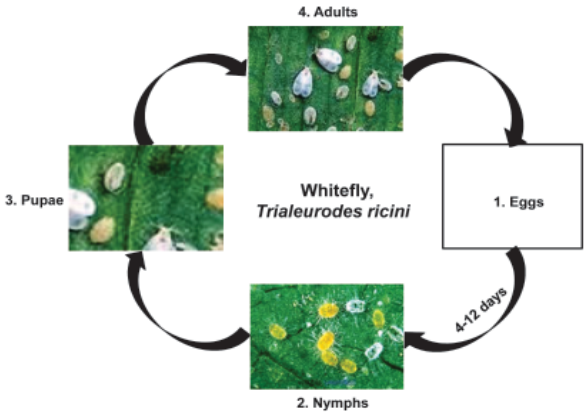
Biology:

Egg: The female lays shining white long eggs in small clusters or scattered about on the underside of tender leaves.

Nymph: The eggs hatch into nymphs which settle on the leaves and along with the adults suck the sap from the leaves. Both the nymphs and the pupa are yellowish in colour.

Adult: The adult fly has white wings, yellow body and pale white legs and antennae. It is a tiny insect a little less than a millimeter in length.

Life cycle:



Damage symptoms:

- Both nymphs and adults suck sap from leaves.
- This makes the leaves appear sickly and sooty mould is developed a whitefly infestation is severe.
- Water soaked spots on the leaves and become yellow and dry up
- Leaves appear sickly and get coated with sooty mold
- Stunted plant growth, shedding of fruit bodies.

2. http://dwpicture.com.au/picture.asp?picture=110301
3,4. http://www.ppis.moag.gov.il/ppis/insect_gallery/images/01ALEYRODIDAE/images/P.spp_F01.htm

Natural enemies of whitefly:

Parasitoids: *Encarsia formosa, Eretmocerus* spp., *Chrysocharis pentheus*

Predators: *Chrysoperla zastrowi sillemi*, ladybird beetle, reduviid bug, spider, red ant, robber fly, black drongo (King crow), common mynah, big-eyed bug (*Geocoris* sp), earwig, ground beetle, pentatomid bug (*Eocanthecona furcellata*), preying mantis etc.

*For management refer to page number 16

9) Thrips:

Adult and nymph: Very tiny pinkish nymphs and black adults with fringed wings

Damage symptoms:

- Both adults and nymphs feed on the upper and lower surfaces of the leaves.
- The terminal leaves crinkle and appear silvery.
- If infestation is severe, stunted growth results.
- The injury results in development of dull yellowish green patches on the upper surface as brown necrotic areas of the lower surface
- Leaves gets curl and plant get stunted.

Natural enemies of thrips:

Predators: Predatory mite, predatory thrips, *Oligota* spp., *Orius* spp. (pirate bug), hover fly, mirid bug etc.

*For management refer to page number 16

Natural Enemies of Castor Insect Pests

Parasitoids

Egg parasitoids

1. *Trichogramma achaea*

2. *T. minutum*

3. *T. evanescens*

4. *Tetrastichus* spp.

5. *Telenomus* spp.

Egg-larval parasitoids

6. *Chelonus* spp.

Larval parasitoids

7. *Enicospilus* sp

8. *Microplitis* spp.

9. *Bracon* spp.

10. *Ichneumon* spp.

11. *Carcelia* spp.

12. *Campoletis* spp.

Pupal parasitoid

13. *Brachymeria euploeae*

Nymphal and adult parasitoids

14. *Encarsia formosa*

15. *Eretmocerus* spp.

16. *Chrysocharis pentheus*

1. http://www.nbaii.res.in/Featured_insects/Trichogrammatids.php; 2. http://www.veroniquemartel.com/ResearchProjects.html; 3. http://www.nbaii.res.in/Introductions/Insects/Trichogramma%20evanescens.htm; 4. http://www.pbase.com/image/135529248; 5. http://baba-insects.blogspot.in/2012/02/telenomus.html; 6. http://www.nbaii.res.in/Featured%20insects/chelonus.htm; 7. http://www.pbase.com/stuartwilson/image/111751079; 8. http://www.pbase.com/image/117861010; 10. http://www.organicgardeninfo.com/ichneumon-wasp.html; 11. http://72.44.83.99/forum/viewthread.php?thread_id=40633&pid=178398; 12. http://www.nbaii.res.in/Featured%20insects/Campoletis.htm; 13. http://www.nhm.ac.uk/researchcuration/research/projects/chalcidoids/database/media.dsml?IMAGENO=chalc519&VALGENUS=Brachymeria&VALSPECIES=euploeae; 14. http://www.buglogical.com/whitefly-control/encarsia-formosa/; 15. http://www.dongbufarmceres.com/main/mboard.asp?strBoardID=c_product01_en; 16. http://baba-insects.blogspot.in/2012/05/blog-post_21.html

Predators


1. Lacewing


2. Ladybird beetle


3. Reduviid bug


4. Spider


5. Robber fly


6. Red ant


7. Black drongo


8. Common mynah


9. Big-eyed bug


10. Earwig


11. Ground beetle


12. Pentatomid bug


13. Preying mantis


14. *Geocoris* spp.


15. Predatory mite


16. Predatory thrips


17. *Oligota* spp.


18. *Orius* spp.


19. Hover fly


20. Mirid bug

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

IX. DESCRIPTION OF DISEASES

1) Seedling blight:

Disease symptoms:

Dead seedling

- The disease first makes its appearance on both the surfaces of the cotyledonary leaves in the form of roundish patch of dull green colour which soon spreads to the point of attachment causing the leaf to rot and hang down.

Spots on older leaf

- The infection further spreads to the stem with the result that the seedling is killed either due to the destruction of growing point or by the collapse of stem.
- The true leaves of seedlings and the very young leaves of older plants may also be affected; but ordinarily not much injury is caused.
- The leaf spots turn yellow and then brown and concentric zones of lighter and darker brown colour are formed.
- The disease spots coalesce at a later stage and cover almost the entire leaf.
- The affected leaves shed prematurely. Under moist conditions, a very fine whitish haze is found on the under-surface of the leaf spots.

1.

Spot on older leaf

2.

3.

Leaf blight symptom

1,2,3 http://www.ikisan.com/crop%20specific/eng/links/ap_castor

Survival and spread:

- The pathogen survives in soil or collateral or alternative hosts.

Favourable conditions:

- High humidity and warm conditions favour the development of disease.

*For management refer to page number 16

2) *Alternaria* blight:

Disease symptoms:

***Alternaria* leaf spot with concentric rings.**

- All the aerial parts of the plant, i.e., stem, leaves, inflorescence and capsules are liable to be attacked.
- These may appear on any portion of the leaf and are irregular, scattered, and have concentric rings.
- These are brown and later become covered with bluish-green or sooty growth.
- When the attack is severe the spots coalesce and form big patches resulting in premature defoliation of the plant which gradually wilts away.
- In one case the capsules, when half mature, wilt suddenly, turn brown and due to collapse of the pedicel the capsules fall or hand down.
- They are smaller in size and have under-developed and wrinkled seeds with little oil content.

***Alternaria* leaf spot with concentric rings**

http://oilseeds.agropedia.in/content/castor-alternaria-leaf-spot

Survival and spread:

- Fungus is seed borne and survives in seeds

Favourable conditions:

- High humidity and low temperature (16-20 °C) favours the development of diseases.

*For management refer to page number 16

3) *Cercospora* leaf spot:

Disease symptoms:

- The disease appears as minute black or brown points surrounded by a pale green ring.
- These spots are visible on both the surfaces of the leaf.
- As the spots enlarge, the centre turns pale brown and then greyish-white surrounded by a deep brown band which may be narrow and sharp or broad and diffused.
- The fructifications of the fungus appear as tiny black dots in the white centre.
- The diseased spots often occur in great numbers scattered over the leaf and are roundish when young but may become irregularly angular when mature.
- When the spots are close together, the intervening leaf tissue withers and large brown patches of dried leaf may result.

***Cercospora* spots on leaf**

http://www.ikisan.com/crop%20specific/eng/links/ap_castorDisease%20Management.shtml

Survival and spread:

- The fungus survives in soil debris which is cause of primary infection. Secondary infection occurs by conidia through rain splash or wind.

Favourable conditions:

- High humidity and warm weather conditions responsible for the disease

*For management refer to page number 16

4) Powdery mildew:

Disease symptoms:

Powdery mass covering entire leaf

- It is characterised by typical mildew growth which is generally confined to the under-surface of the leaf.
- When the infection is severe the upper-surface is also covered by the whitish growth of the fungus.
- Light green patches, corresponding to the diseased areas on the under surface, are visible on the upper side especially when the leaves are held against light.

Survival and spread:

- The pathogen survives as oospores on the affected plant tissues and on weed hosts.

Favourable conditions:

- Cool (10-20° C) and wet weather (90% RH) favours disease development

*For management refer to page number 16

5) Wilt:

Disease symptoms:

- Leaves droop and drop off leaving behind only top leaves.
- Diseased plants are sickly in appearance.
- Wilting of plants, root degeneration, collar rot, drooping of leaves and necrosis of affected tissue and finally leading to death of plants.
- Necrosis of leaves starts from margins spreading to interveinal areas and finally to the whole leaf.
- Spilt open stem shows brownish discolouration and white cottony growth of mycelia much prominently in the pith of the stem.

Wilt affected castor field

https://www.google.co.in/search?q=wilt+of+castor+2JXoUtyeCMr4rQei8oDoCA%26ved%3D0CAcQ_AUoAQ%26biw%3D1280%26bih%3D699%23facrc%3

Survival and spread:

- The fungus is soil-borne and remains in the soil as saprophyte for 2-3 years. The disease is primarily transmitted through infected seed pieces.
- The secondary spread is aided by wind, rain and irrigation water.

Favourable conditions:

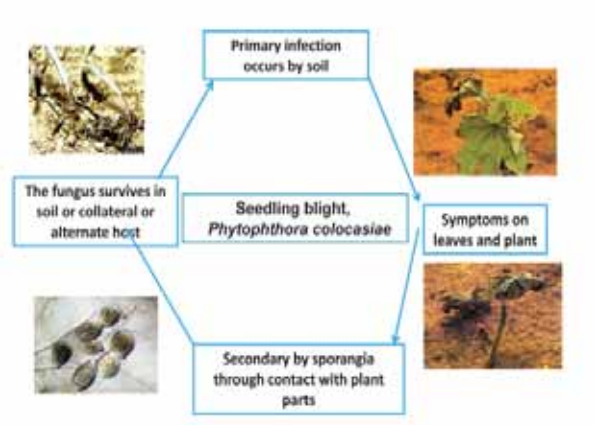
- High day temperature (30-35˚C).
- Low humidity (50-60%).

Low soil moisture and alkaline soils.

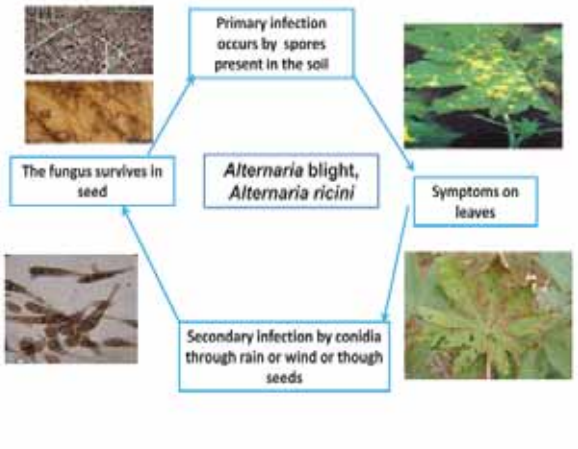
*For management refer to page number 17

Disease cycles:

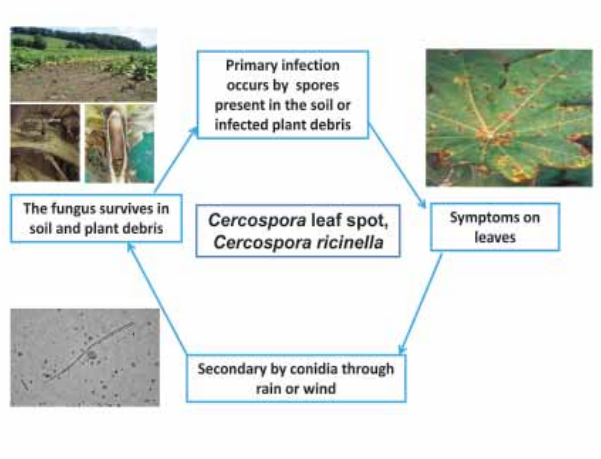
1. Seedling blight



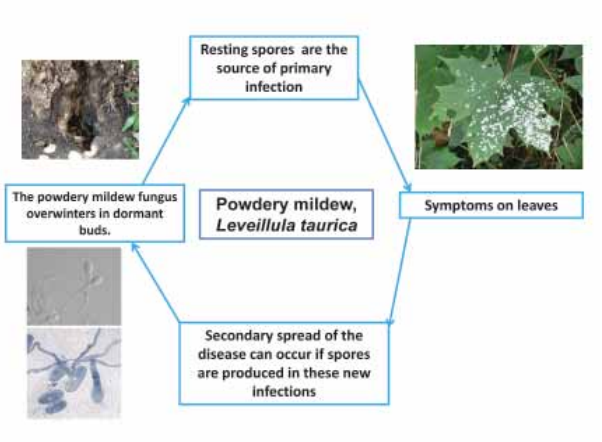
2. *Alternaria* blight



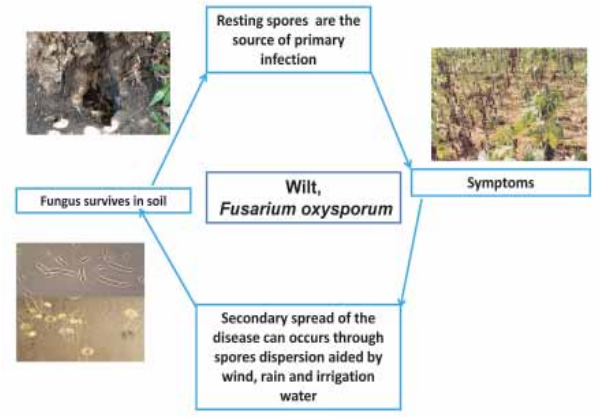
3. *Cercospora* leaf spot



4. Powdery mildew



5. Wilt



X. SAFETY MEASURES

A. At the time of harvest: Castor, on an average, produces 4-5 sequential order spikes over a span of 180-240 days at an interval of 30 days. The main spike can be harvested within 90-120 days after planting. The subsequent harvestings can be made at an interval of 30 days. Physiological maturity is attained when some of the capsules in a spike turn brown in colour. Harvest the spikes at physiological maturity and dry under sun for easy threshing. Harvest capsules when they turn yellow and start drying for good seed filling, oil content, and germinability.

XI. DO'S AND DON'TS IN IPM

S. No.	Do's	Don'ts
1	Deep ploughing is to be done on bright sunny days during the months of May and June. The field should be kept exposed to sun light at least for 2-3 weeks	Do not plant or irrigate the field after ploughing, at least for 2-3 weeks, to allow desiccation of weed's bulbs and/or rhizomes of perennial weeds.
2	Adopt crop rotation.	Avoid monocropping.
3	Grow only recommended varieties.	Do not grow varieties that are 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 seeds with approved biopesticides/ chemicals for the control of seed borne diseases/ pests.	Do not use seeds without seed treatment with biopesticides / chemicals.
6	Sow/plant in rows at optimum depths Under proper moisture conditions for better establishment.	Do not sow/plant seeds beyond 5-7 cm depth.
7	Apply only recommended herbicides at recommended dose, proper time, as appropriate spray solution with standard equipment along with flat fan or flat jet nozzles.	Pre-emergent as well as soil incorporated herbicides should not be applied in dry soils. Do not apply herbicides along with irrigation water or by mixing with soil, sand or urea.
8.	Maintain optimum and healthy crop stand which would be capable of competing with weeds at a critical stage of crop weed competition.	Crops should not be exposed to moisture deficit stress at their critical growth stages.
9	Use NPK fertilizers as per the soil test recommendation.	Avoid imbalanced use of fertilizers.
10	Use micronutrient mixture after sowing based on test recommendations.	Do not apply any micronutrient mixture after sowing without test recommendations.
11	Conduct weekly AESA in the morning preferably before 9 a.m. Take decision on management practice based on AESA and P: D ratio only.	Do not take any management decision without considering AESA and P: D ratio
12	Install pheromone traps at appropriate period.	Do not store the pheromone lures at normal room temperature (keep them in refrigerator).
13	Release parasitoids only after noticing adult moth catches in the pheromone trap or as pheromone trap or as per field observation	Do not apply chemical pesticides within seven days of release of parasitoids.
14	Apply *SI* NPV at recommended dose when a large number of egg masses and early instar larvae are noticed. Apply NPV only in the evening hours after 5 pm.	Do not apply NPV on late instar larva and during day time.
15	In case of pests which are active during night such as *Spodoptera* spray recommended biopesticides/ chemicals at the time of their appearance in the evening.	Do not spray pesticides at midday since, most of the insects are not active during this period.
16	Spray pesticides thoroughly to treat the under surface of the leaves, particularly for mites, whiteflies, *Spodoptera* etc.	Do not spray pesticides only on the upper surface of leaves.
17	Apply short persistent pesticides to avoid pesticide residue in the soil and produce.	Do not apply pesticides during preceding 7 days before harvest.
18	Follow the recommended procedure of trap crop technology.	Do not apply long persistent pesticides on trap crop, otherwise it may not attract the pests and natural enemies.

XII. SAFETY PARAMETERS IN PESTICIDE USAGE

S. No	Pesticide Classification as per insecticide rules 1971 Colour of toxicity triangle	WHO classification of hazard	Symptoms of poisoning	First aid measures and treatment of poisoning	Harvest interval (days)
1.	Dimethoate Highly toxic 	Class II Moderately hazardous	Mild-anorexia, headache, dizziness, weakness, anxiety, tremors of tongue and eyelids, miosis, impairment of visual acuity	**First aid measures:** Rush to the nearest physician. **Treatment of poisoning:** For extreme symptoms of OP poisoning, injection of atropine (2-4 mg for adults, 0.5-1.0 mg for children) is recommended. Repeated at 5-10 minute intervals until signs of atropinization occur.	7 days
2.	Malathion Moderately toxic 	Class III slightly hazardous	-do-	-do-	3 days

3.	Phenthoate Moderately toxic 	Class II, Moderately Hazardous	Excessive salivation, sweating, rhinorrhea and tearing. Muscle witching, weakness, tremor, incoordination. Headache, dizziness, nausea, vomiting, abdominal cramps, diarrhea. Respiratory depression, tightness in chest, wheezing, productive cough, fluid in lungs. Pin-point pupils, sometimes with blurred or dark vision. Severe cases: seizures, incontinence, respiratory depression, loss of consciousness. Cholinesterase inhibition.	**First aid measures:** Ingestion: Seek medical assistanc. Eyes: Irrigate exposed eyes with copious amounts of tepid water for at least 15 minutes. Skin: Systemic effects can occur from dermal exposure to organophosphates. Remove contaminated clothing, wash skin, hair and nails vigorously with repeated soap washings. Inhalation: Move patient to fresh air. Monitor for respiratory distress. If cough or difficulty breathing develops, evaluate for respiratory tract irritation, bronchitis, or pneumonitis. **Treatment of poisoning:** Antidote: atropine	--
4.	Dichlorvos Extremely toxic 	Class I b highly hazardous	Moderate nausea, salivation, lacrimation, abdominal cramp, vomiting, sweating, slow pulse, muscular tremors, miosis	**First aid measures:** Rush to the nearest physician. **Treatment of poisoning:** 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	--

XIII. 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** apply just before the rains and after the rains; **Do not** apply against the windy direction

XIV. PESTICIDE APPLICATION TECHNIQUES

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

XV. OPERATIONAL, CALIBRATION AND MAINTENANCE GUIDELINES IN BRIEF

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

XVI. REFERENCES

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Ecological Engineering Plants for Castor

Dill

Sunflower

Carrot

***Ocimum* sp**

Cluster bean

Mustard

Parsley

Alfalfa

French bean

Cowpea

Buckwheat

Maize

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