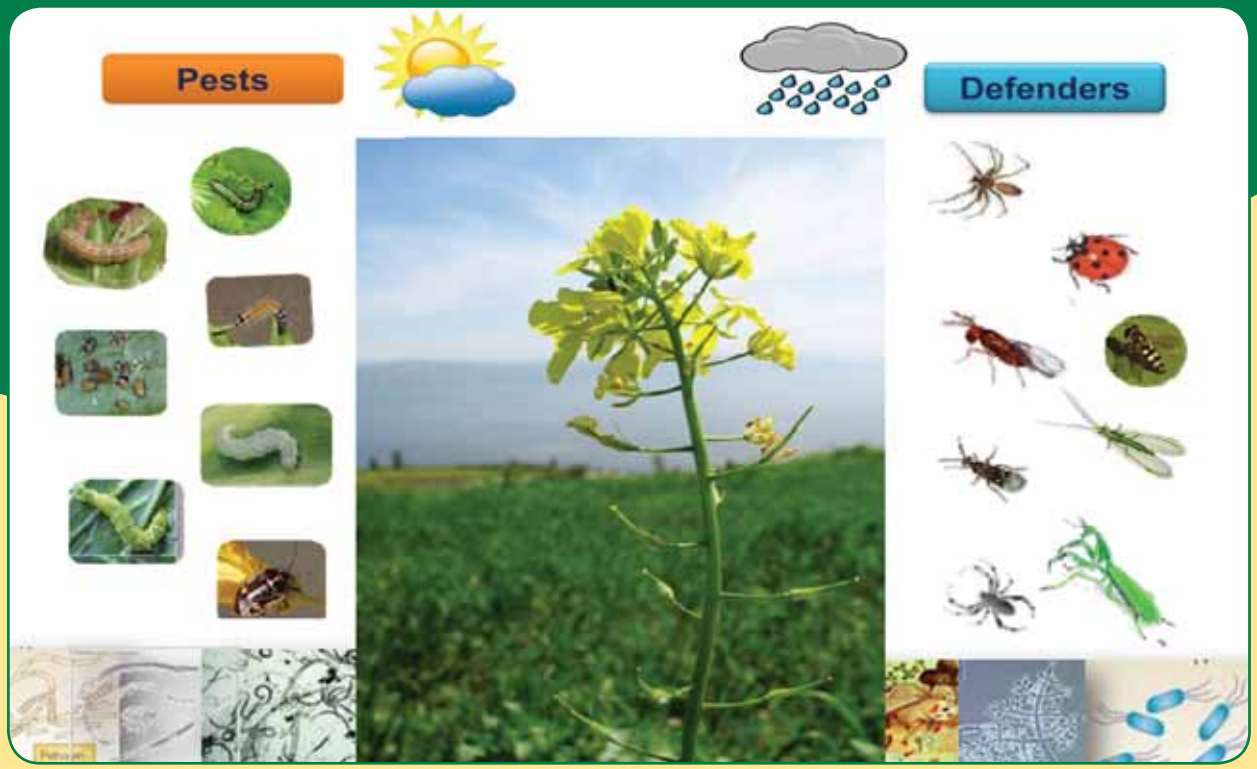
सत्यमेव जयते

AESA BASED IPM Package

AESA based IPM – Mustard/Rapeseed



रा व स्वा प्र सं
NIPHM

National Institute of Plant Health Management
Rajendranagar, Hyderabad, Telangana

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

NCIPM

National Centre for Integrated Pest Management
LBS Building, IARI Campus, New Delhi

Department of Agriculture and Cooperation
Ministry of Agriculture
Government of India

Important Natural Enemies of Mustard/Rapeseed Insect Pests

Parasitoids

Diaeretiella rapae

Trichogramma spp.

Bracon spp.

Aphelinus abdominalis

Tachinid fly

Perilissus cingulator

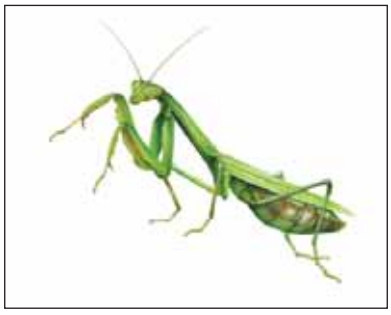
Predators

Lacewing

Ladybird beetle

Spider

Dragonfly



Praying mantis

Ground beetle

The AESA based IPM – Mustard/rapeseed, 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.

NIPHM Working Group:

Chairman : Dr. Satyagopal Korlapati, IAS, Director General
Vice-Chairmen : Dr. S.N. Sushil, Plant Protection Advisor
: Dr. P. Jeyakumar, Director (PHM)

Core Members:

1. Er.G. Shankar, Joint Director (PHE), Pesticide Application Techniques Expertise.
2. Dr. O.P. Sharma, Joint Director (A & AM), Agronomy Expertise.
3. Dr. Satish Kumar Sain, Assistant Director (PHM), Pathology Expertise.
4. Dr. Dhana Raj Boina, Assistant Director (PHM), Entomology Expertise.
5. Sri D. Chattopadhyay, Assistant Director (PHM), Pathology Expertise.

Contributions by DPPQ & S Experts:

1. Shri Ram Asre, Additional Plant Protection Advisor (IPM),
2. Dr. K.S. Kapoor, Deputy Director (Entomology),
3. Dr. Sanjay Arya, Deputy Director (Plant Pathology),
4. Dr. Subhash Kumar, Deputy Director (Weed Science)
5. Dr. C.S. Patni, Plant Protection Officer (Plant Pathology)

Contributions by NCIPM Expert:

1. Dr. C. Chattopadhyay, Director

Contributions by External Experts:

1. Prof. Anil Pandey, University Professor (Oil Seed) Rajendra Agriculture University Bihar
2. Dr. R. Pachori, Professor of Entomology, Department of Entomology, College of Agriculture, Jabalpur (MP)
3. Dr. A.Y. Thakare, Asso. Professor (Ento), Dr. PDKV, Akola
4. Dr. K. Basavanagoud, Professor and Head, Department of Entomology, UAS, Dharwad
5. Dr. A.S. Halepyati, Professor of Agronomy, College of Agriculture, Raichur
6. Dr. M.B. Patil, Professor of Plant Pathology, College of Agriculture, Raichur
7. Dr. A.G. Sreenivas, Associate Professor (Ag. Entomology), College of Agriculture, Raichur

Citation Satyagopal, K., S.N. Sushil, P. Jeyakumar, G. Shankar, O.P. Sharma, D. Boina, S.K. Sain, D. Chattopadhyay, Ram Asre, K.S. Kapoor, Sanjay Arya, Subhash Kumar, C.S. Patni, C. Chattopadhyay, A. Pandey, R. Pachori, A.Y. Thakare, K. Basavanagoud, A.S. Halepyati, M.B. Patil and A.G. Sreenivas. 2014. AESA based IPM package for Mustard/Rapeseed. pp 49.

Front cover picture Model AESA chart for Mustard/Rapeseed

Back cover picture Mustard/Rapeseed field

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

Copies: 2000

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

अपर सचिव
भारत सरकार
कृषि मंत्रालय
(कृषि एंव सहकारिता विभाग)
कृषि भवन, नई दिल्ली - 110001

Avinash K Srivastava
Additional Secretary
Government of India
Ministry of Agriculture
(Department of Agriculture & Cooperation)
Krishi Bhawan, New Delhi - 110 001

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)

संयुक्त सचित
भारत सरकार
कृषि मंत्रालय
(कृषि एवं सहकारिता विभाग)
कृषि भवन, नई दिल्ली - 110001

Joint Secretary
Government of India
Ministry of Agriculture
(Department of Agriculture & Cooperation)
Krishi Bhawan, New Delhi - 110001

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)

National Institute of Plant Health Management
Department of Agriculture & Cooperation
Ministry of Agriculture
Government of India

Dr. K. SATYAGOPAL, IAS
Director General
Telephone : +91-40-24015346,
E-mail : dgniphm@nic.in
Tele-Fax : +91-40-24015346

राव स्वाप्रसं
NIPHM
Rajendranagar
Hyderabad-500030
http://niphm.gov.in

PREFACE

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

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

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

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

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

(K. SATYAGOPAL)

CONTENTS

AESA BASED IPM PACKAGE FOR MUSTARD/RAPESEED

Mustard/rapeseed plant description:

Mustard (Brassica nigra L.; Family: Brassicaceae) and rapeseed (*Sinapis* spp. L.; Family: Brassicaceae) plants are annual shrubs, leaves are compound and alternate. The edge of the leaf blade has lobes, or it has both teeth and lobes the edge of the leaf blade has teeth. Flowers are radialy symmetrical and consist of four green sepal and 4 yellow or white petals. Both the petals and sepals are separate and not fused. Stemens are 6. The fruit is a peculiar kind of capsule named siliqua. It opens by two valves, which are the modified carpels, leaving the seeds attached to a framework made up of the placenta and tissue from the junction between the valves

The plant is believed to be native to the southern Mediterranean region of Europe and possibly South Asia where it has been cultivated for thousands of years. India is the third largest rapeseed-mustard producer in the world after China and Canada with 12 per cent of world's total production (2006-07). This crop accounts for nearly one-third of the oil produced in India, making it the country's key edible oilseed crop. Due to the gap between domestic availability and actual consumption of edible oils, India has to resort to import of edible oils. Rapeseed-mustard is the major source of income especially even to the marginal and small farmers in rainfed areas Since these crops are cultivated mainly in the rain-fed and resource scarce regions of the country, their contribution to livelihood security of the small and marginal farmers in these regions is also very important. By increasing the domestic production substantial import substitution can be achieved. Due to its low water requirement (80-240 mm), rapeseed-mustard crops fit well in the rainfed cropping system. Cultivated in 26 states in the northern and eastern plains of the country, about 6.8 mha is occupied under these crops (2006- 07). Nearly 30.7% area under rapeseed mustard is under rainfed farming. Indian mustard (*Brassica juncea*) is predominantly cultivated in the states of Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh, and Gujarat which contribute 81.5% area and 87.5% production (2001-02 to 2005-06). During 2006-07, more than 84 % of the total rapeseed-mustard acreage and production in the country is accounted for by these states, out of which more than 47.0% contributed by Rajasthan state alone.

The spice is generally made from ground seeds of the plant, with the seed coats removed. The small (1 mm) seeds are hard and vary in color from dark brown to black. They are flavorful, although they have almost no aroma. The seeds are commonly used in Indian cuisine, for example in curry, where it is known as *rai*. The seeds are usually thrown into hot oil or ghee, after which they pop, releasing a characteristic nutty flavor. The seeds have a significant amount of fatty oil. This oil is used often as cooking oil in India.

I. PESTS

A. Pests of National Significance

1. Insect pests

1.1 Mustard aphid: *Lipaphis erysimi (*Kaltenbach) (Hemiptera: Aphididae)

1.2 Painted bug: *Bagrada hilaris* (Burmeister) (Hemiptera: Pentatomidae)

1.3 Mustard saw fly: *Athalia lugens proxima (*Klug) (Hymenoptera: Tenthredinidae)

1.4 Mustard leaf miner: *Chromatomyia horticola* (Goureau) (Diptera: Agromyzidae)

2. Diseases

2.1 *Alternaria* blight: *Alternaria brassicae* (Berk.) Sacc*, A. brassicicola* (Schwein. Wiltshire)

2.2 White rust: *Albugo candida* (Pers.) Kuntze

2.3 Powdery Mildew: *Erysiphe cruciferum* Opiz ex L. Junnell

3. Weeds

Broad leaf weeds

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

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

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

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

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

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

3.7 Wild Onion : *Asphodelus tenuifolius* Cav. (Liliaceae)

3.8 Burcloveru: *Medicago denticulata* Willd. (Fabaceae)

3.9 Common vetch: *Vicia sativa* L. (Fabaceae)

3.10 Yellow pea: *Lathyrus aphaca* L. (Fabaceae)

Grassy weeds

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

3.12. Canary Grass: *Phalaris minor* Retz. (Poaceae)

Sedges

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

Parasitic weed

3.14 Broomrape: *Orobanche aegyptiaca* L. (Orobanchaceae)

B. Pests of Regional Significance

1. Insect pests

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

1.2 Cabbage head borer: *Hellula undalis* Fabricius (Lepidoptera: Crambidae)

1.3 Diamondback moth: *Plutella xylostella* L. (Lepidoptera: Plutellidae)

1.4 Larger moth (leaf webber): *Crocidolomia binotalis* Fabricius (Lepidoptera: Pyralidae)

2. Diseases

2.1 Sclerotinia stem rot: *Sclerotinia sclerotiorum* (Lib.) de Bary

2.2 Downy mildew: *Hyaloperonospora parasitica* Pers.

2.3 Club root: *Plasmodiophora brassicae* Woronin

2.4 Bacterial Leaf spot/ blight: *Xanthomonas campestris* pv. *campestris* Pammel (Dowson)

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
- Treat the seed/planting material with recommended pesticides especially biopesticides
- Select healthy seeds/seedlings/planting material
- 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 situations at least once a week (soil, water, plants, pests, natural enemies, weather factors etc.)
- Make decisions based on the field situations 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.The specificity of compensation by mustard was investigated for herbivory by biting and chewing herbivores. These types of herbivory were simulated in the field, and post defoliation compensation by the plants was quantified: leaf length, relative growth rate of foliage, and seed production were measured. Plants were unable to compensate completely for meristem defoliation combined with highly dispersed cotyledon defoliation, and compensated better as cotyledon defoliation became less dispersed. Because compensatory responses to artificial defoliation were similar to and usually indistinguishable from those of insect herbivory, it has found that the specificity of compensation is caused by the type of defoliation. Other interaction-specific processes such as transfer of growth-affecting chemicals from insect to plant need not be invoked (Gavloski and Lamb, 2000).

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):

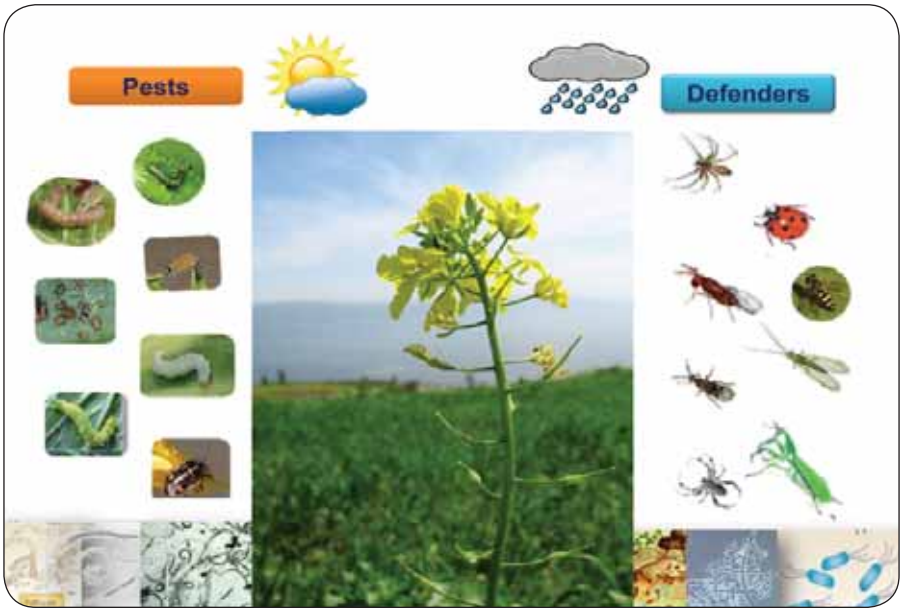
Identifying the number of pests and beneficial insects helps the farmers to make appropriate pest management decisions. Sweep net, visual counts etc. can be adopted to arrive at the numbers of pests and defenders. The P: D ratio can vary depending on the feeding potential of natural enemy as well as the type of pest. The natural enemies of mustard/rapeseed pests can be divided into 3 categories 1. parasitoids; 2. predators; and 3. pathogens. The important natural enemies of mustard/rapeseed pests are given in ecological engineering table on page 13

Model agro-ecosystem analysis chart

Date:

Village:

Farmer:



Decision taken based on the analysis of field situations

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

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

Feeding/egg laying potential of different parasitoids/predators

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

Predators/ Parasitoids	Feeding potential/ Egg laying capacity
 Spider	5 big larvae/adults per day
 *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, 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.
    - 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 problems? How can we avoid it? How can we be prepared?
- Summarize the actions to be taken.

Advantages of AESA over ETL

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

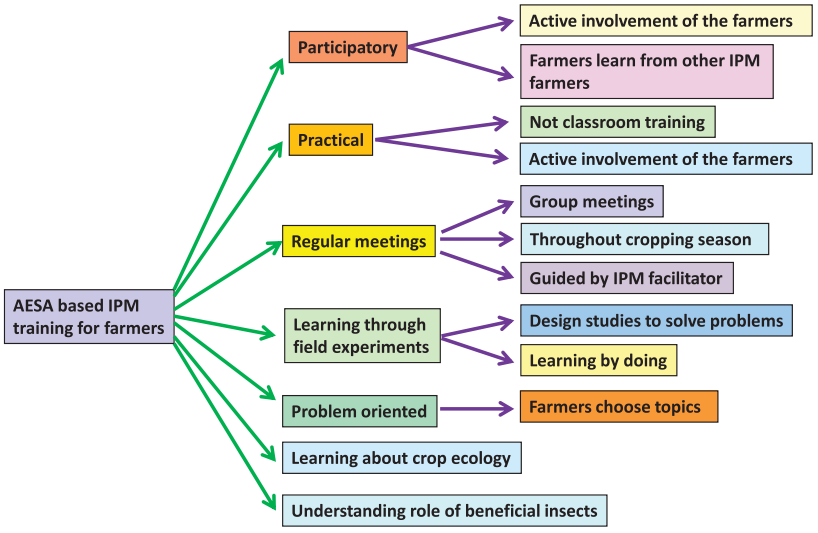
AESA and farmer field school (FFS)

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

Farmers can learn from AESA

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

FFS to teach AESA based IPM skills



B. Field scouting

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

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

least 5 feet inside of the field borders, and one in the centre). Select five random plants at each spot for recording counts of insects as per procedure finalized for individual insects.

For insect pests:

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

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

Defoliator/ borers: Count the number of young and grown up larvae on each plant and record.

For diseases:

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

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

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

Stem, flower and pod sampling: Carefully examine the stem, flower and pod of plants for symptoms and signs of fungal or bacterial diseases. The stem, flower and pod should be split or taken apart and examined for discoloration caused by fungi and bacteria. Count the number of stems, flowers and pods 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 diamondback moth, leaf webber and leaf miner

Pheromone traps for diamondback moth, leaf webber and leaf miner @ 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 water pan/sticky traps

Set up yellow water pan/sticky traps 15 cm above the canopy for monitoring aphids @ 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 as yellow sticky trap.

E. Light traps

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

III. ECOLOGICAL ENGINEERING FOR PEST MANAGEMENT

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

Natural enemies may require

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

Ecological engineering for pest management – Above ground:

- Raise the flowering plants / compatible cash crops along the field border by arranging shorter plants towards main crop and taller plants towards the border to attract natural enemies as well as to avoid immigrating pest population
- Grow flowering plants on the internal bunds inside the field
- Not to uproot weed plants those are growing naturally like *Tridax procumbens, Ageratum* sp *Alternanthera* sp etc. which act as nectar source for natural enemies

- Not to apply broad spectrum chemical pesticides, when the P: D ratio is favourable. The plant compensation ability should also be considered before applying chemical pesticides.

Ecological engineering for pest management – below ground:

- Crop rotations with leguminous plants which enhance nitrogen content.
- Keep soils covered year-round with living vegetation and/or crop residue.
- 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 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, Graminaceae, Brassicaceae, Asteraceae etc. families

***Crotalaria* sp**

Castor

Cowpea

Sunflower

Corn

Sorghum

Bindweed

Brassica rapa

French bean

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
Mustard aphids	
Parasitoids: *Aphelinus* spp. *Aphytis* spp., *Diaeretiella rapae* (nymphal and adult) **Predators**: Ladybird beetles viz., *Coccinella septempunctata, Menochilus sexmaculata, Hippodamia variegata* and *Cheilomones vicina* Syrphid fly: *Sphaerophoria* spp., *Eristallis* spp., *Metasyrphis* spp., *Xanthogramma* spp. and *Syrphus* spp., Lacewing: *Chrysoperla zastrowi sillemi*, aphid midge: *Aphidoletes aphidimyza*, predatory bird: *Motacilla cospica* **Entomopathogenic fungi** : *Cephalosporium* spp., *Entomophthora* and *Verticillium lecanii*	• Attractant plants: Wild mustard (*Sinapis arvensis*), white mustard (*Sinapis alba*)
Painted bug	
Parasitoid: *Alophora* spp. (Tachinid fly) (eggs).	• Early sowing. Irrigate the crop in IV week after sowing. • **Alternate hosts**: Weeds: Lambsquarters, purple nutsedge, *Euphorbia* spp., perennial sowthistle and field bindweed. • Crop - corn, Sudan grass, sorghum, sunflowers, papaya, potato, cotton, and some legumes
Mustard saw fly	
Parasitoids: *Perilissus cingulator* (larvae) **Entomopathogen**: Bacterium *Serratia marcescens*	• Summer ploughing to destroy the pupae. • Irrigation in seedling stage to destroy larvae by drowning. • Use of bitter gourd seed oil emulsion as an antifeedant • **Attractant plants**: Wild mustard (*Sinapis arvensis*), white mustard (*Sinapis alba*), wild radish, (*Rhaphanus rhaphanistrum*), wild turnip(*Brassica rapa)*
Bihar hairy caterpillar	
Parasitoids: Different species of braconids, trichogrammatids, **Predators**: Spiders, long horned grasshoppers, praying mantid, , ants, green lace wing, damsel flies/dragon flies, shield bugs, ladybird beetles, ground beetle, predatory cricket. **Entomopathogen**: NPV, Bt.	• Pre-monsoon deep ploughing (two/three times) to expose the hibernating pupae to sunlight and predatory birds. • Trap crop : Jatropha , papaya, cowpea, castor, *Crotalaria* in field bund
Mustard leaf miner	
Parasitoids: *Gronotoma micromorpha* (larval and pupal), *Diglyphus isaea* (larval), *Halticoptera circulus, Opius phaseoli* (pupal) *Chrysocharis pentheus*(larval), *Neochrysocharis formosa* (larval). **Predators:** Lacewings, ladybird beetle, spiders, fire ants.	• **Attractant plants :** Wild mustard (*Sinapis arvensis*), white mustard (*Sinapis alba*), wild radish (*Rhaphanus rhaphanistrum*), wild turnip(*Brassica rapa),* • French bean(predatory thrips)

Diamondback moth	
Parasitoids: *Cotesia plutellae* (larval), *Apanteles* sp (larval), *Diadegma insulare* (larval), *Microplitis plutellae* (larval)	• **Attractant plants :** Wild mustard (*Sinapis arvensis*), white mustard (*Sinapis alba*), wild radish (*Rhaphanus rhaphanistrum*), wild turnip(*Brassica rapa),* hedge mustard (*Sisymbrium officinale)*

A. Resistant/tolerant varieties of mustard/rapeseed

Pest	Tolerant/ Resistant Varieties*
White Rust	Pusa Karishma (LES-39), Jawahar Mustard-1, PBR 91
Alternaria blight and aphids	Coral-432, NRCHB 5-6, NPJ 112 (Pusa Mustard 25), NRCDR 601, RYSKS-2 and DMH-I
Alternaria blight	Saurabh
White rust, Alternaria blight, Powdery mildew	Indian mustard-91, Toria-16, Yellow sarson-11; Gobhi sarson-11; Brown Sarson-3; Karan Rai-4; Taramira-5 and Black mustard-1
Aphids	RH-7846, RH-7847, RH-9020 and RWAR-842

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

IV. CROP STAGE-WISE IPM

Management	Activity
Pre planting*	
Nutrients	• Apply FYM @ 4.0 t/acre or vermicompost @ 2.0 t/acre. • Incorporation of mustard residue (1 t/acre) + Sesbania green manuring enhances the mustard yield in the long run. • Seed treatment should be done with *Azotobactor* culture @ 240 g/acre.
Weeds	**Cultural control:** • Deep ploughing during summer. • At the time of field preparation, adopt stale seed bed technique to minimize the weeds menace in field. • In stale seed bed technique field is irrigated prior to sowing and weed seeds are allowed to germinate. Then the weed seedlings are turned into soil by ploughing before sowing.
Defoliators/soil borne pathogens	**Cultural control:** • Deep ploughing to expose the soil borne pathogens and hibernating stage of defoliators.
	• Prepare the level and well drained field to reduce the incidence of *Sclerotinia* rot. • Destruction of plant debris. • For club rot management, soil amendment with lime (@ 1 Kg/m^2) to raise soil pH to 7.2 or apply Neem cake @ 0.5 Kg/m^2.
Sowing/seedling*	
Nutrients	• Basal application of NPK is done on soil test basis. Generally, 32 Kg N, 16 Kg P and 16 Kg K per acre is required by mustard crop. • Half of the N dose should be applied at the time of sowing. • Basal application of 16 Kg Sulphur /acre is also recommended for mustard. • Under alkaline conditions, S should be applied through Gypsum

Weeds	**Cultural control:** • Adopt crop rotation, if there is infestation of *Orobanche* in previous season, pulse crop should be sown in place of mustard in that field. • Early sowing in line with weed free certified seeds. • Adopt recommended agronomic practices with respect to row spacing, plant spacing, fertilizers application, water management etc. to obtain the healthy plant stand. • Adopt intercropping with wheat/pulses/ sugarcane. **Chemical control:** • Apply oxadiargyl 6% EC @ 600 ml in 200 l of water/acre 0-3 days after sowing. As pre-emergence herbicide followed by one hand weeding at 30 days after planting, if required.
Aphids	**Cultural control:** • Early sowing to avoid damage due to mustard-aphid, and major diseases. • Use tolerant varieties. • Early planting to escape the damage. • Use yellow sticky traps. **Mechanical control:** • Destroy the affected part along with aphid population in the initial stage. **Biological control:** • 2 per cent Neem oil and 5 per cent Neem Seed Kernel Extract (NSKE) effective against the mustard aphid • Ladybird beetles viz., *Coccinella septempunctata, Menochilus sexmaculata, Hippodamia variegata and Cheilomones vicina* are most effcient pradators of the mustard aphid. Adult beetle may feed an average of 10 to 15 adults/ day. • Several species of syrphid /hover fly i.e., *Sphaerophoria* sp., *Eristallis* sp., *Metasyrphis* sp., *Xanthogramma* sp and *Syrphus* spp. • The braconid parasitoid, *Diaeretiella rapae*. • The lacewing, *Chrysoperla zastrowi sillemi*. • Predatory bird *Motacilla cospica*. • A number of entomogenous fungi, *Cephalosporium* spp., *Entomophthora* and *Verticillium lecanii* infect aphids **Chemical control:** • Chlorpyrifos 20 % EC @ 200 ml in 200-400 l of water/acre • Dimethoate 30% EC @ 264 ml in 200-400 l of water/acre • Malathion 50% EC @ 400 ml in 200-400 l of water/acre • Methylparathion 2% DP @ 6000 g/acre • Monocrotophos 36% SL @150 ml in 200-400 l of water/acre • Oxydemeton–methyl 25% EC @ 400 ml in 200-400 l of water/acre • Phorate10% CG @ 4000 g/acre • Phosphamidon 40% SL @ 200 ml in 200 l of water/acre • Thiamethoxam 25% WG @ 20-40 g in 200-400 l of water/acre
Painted bug	**Cultural control:** • Deep ploughing the soil to destroy eggs of painted bug. • Early sowing is needed to avoid pest attack.

	• Irrigate the crop in IV week after sowing to reduce pest attack. • Quick threshing of the harvested crop should be done. **Mechanical control:** • Burn the remains of mustard crop so that the stages of insect do not reach the next year crop. • The bugs usually congregate on the leaves and stem which can be jerked to dislodge them and killed in kerosin water **Biological control:** • Conserve bio-control agents such as *Alophora* spp. (tachinid fly) parasitizing eggs of painted bugs. **Chemical control:** • Dichlorvos76% EC @ 250.8 ml in 200-400 l of water/acre • Imidacloprid 70% WS @ 700 g/100 Kg seed • Phorate10% CG @ 6000 g/acre
Mustard sawfly	**Cultural control:** • Summer ploughing to destroy the pupae. • Early sowing should be done. • Maintain clean cultivation. • Apply irrigation in seedling stage for sawfly management because most of the larvae die due to drowning effect. **Mechanical control:** • Collection and destruction of larvae of saw fly in morning and evening. **Biological control:** • Conserve *Perilissus cingulator* (parasitoids of the larvae), and the bacterium *Serratia marcescens* which infect the larvae of sawfly. • Use of bitter gourd seed oil emulsion as on anti- feedant **Chemical control:** • Dimethoate 30% EC@264 ml in 200-400 l of water/acre • Quinalphos2 5% EC @ 480 ml in 200-400 l of water/acre • Imidacloprid 70% WS @ 700 g/100 Kg seeds • Malathion EC 50% EC @ 600 ml in 200-400 l of water/acre • Methylparathion 2% DP@ 6000 g/acre
Bihar hairy caterpillar**	**Cultural control:** • Pre-monsoon deep ploughing (two/three times) will expose the hibernating pupae to sunlight and predatory birds. • Removal and destruction of alternate wild hosts which harbour the hairy caterpillars. **Mechanical control:** • Collection and destruction of egg masses and the gregarious stages of early instar larvae twice a week. **Biological control:** • Conserve the natural bio control population of spiders, long horned grasshoppers, praying mantid, robber fly, ants, green lace wing, damsel flies/dragon fly, flower bugs, shield bugs, lady bird beetles, ground beetle, predatory cricket, earwig, braconids, trichogrammatids, green muscardine fungus.

White rust/ Downy mildew**	**Cultural control:** • Use certified seeds of resistant/tolerant variety • Follow timely sowing of crop. • Adopt proper field sanitation. • Follow proper crop rotation. • Destruct crop debris particularly stag heads of previous year crop. • Avoid over irrigation or water stagnation. • Apply potash in recommended dose **Botanical control:** • Treat the seeds with freshly prepared garlic bulb extract @ 2% (w/v). **Chemical control:** • Metalaxyl 35% WS @ 0.75- 1.0 Kg/100 Kg seed • Metalaxyl M 4% + mancozeb 64% WP @ 1000 g in 400 l of water/acre • Metalaxyl 8% + mancozeb 64% WP @1000 g in 400 l of water/acre (white rust)
* Apply *Trichoderma* spp. and *Pseudomonas fluorescens* as seed/seedling/planting material treatment and soil application (if commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).	
Vegetative	
Nutrients	• Top dressing of N @ 16 Kg per acre at 45 days after sowing. • Foliar application of thiourea (0.1%) at 50% flowering to enhance mustard productivity.
Weeds	• Applications of two drops of soybean oil per young shoot of *Orobanche* reduced infestation. • Hand tool weeding at 25 and 45 days after sowing.
Painted bug	• Collection and destruction of nymphs & adults • Others cultural, biological and chemical same as sowing stage
Mustard sawfly	**Cultural control:** • Collection and destruction of grubs of saw fly in morning and evening. • Others cultural, biological and chemical same as sowing stage. • Sow crop before 20 october
Diamondback moth**	**Mechanical control:** • Installing pheromone traps @ 4/acre to monitor the adult activity. • Collection and careful destruction of the larvae.
	Biological control: • Conserve *Cotesia plutellae*, as it is an important parasitoid for diamond back moth. • *Diadegma insulare* is the most important parasitoid of the diamondback moth. • Application of 4% NSKE.

Leaf miner	**Cultural control:** • Yellow sticky traps or cards may reduce the density of leaf miners **Biological control:** • **Parasitoids :** *Gronotoma micromorpha* (larva and pupa), *Diglyphus isaea* (larva) *Halticoptera circulus* and *Opius phaseoli* (pupal) *Chrysocharis pentheus*, *Neochrysocharis formosa* (westwood) • **Predators :** Lacewings, ladybug beetle, spiders, fire ants **Chemical control:** • Dimethoate 30% EC @ 264 ml in 200-400 l of water/acre • Methyl parathion 2% DP @10000 g/acre • Carbofuran 3% CG @ 26,640 g/acre
Cabbage head borer & larger moth (leaf webber)**	**Mechanical control:** • Collection and careful destruction of the larvae at gregarious stage at least twice a week. **Biological control:** • Conserve parasitoid *Pteromalus puparium*. • Application of 4% NSKE.
Bihar hairy caterpillar**	**Cultural control:** • Same as in sowing stage.
***Alternaria* leaf spot**	**Cultural control:** • Use certified/resistant/tolerant variety of seeds • Adopt timely sowing between10-25 October. • Follow proper field sanitation. • Remove weeds particularly collateral host plants. • Apply recommended dose of potash to reduce disease incidence. **Chemical control:** • Metalaxyl 8% + mancozeb 64% WP @1000 g in 400 l of water/acre
White rust and downy mildew**	• Same as sowing stage
Bacterial blight**	**Cultural control:** • Follow proper crop and field sanitation. • Follow proper crop rotation.
Powdery mildew	**Cultural control:** • Follow timely sowing of seeds. • Adopt proper field sanitation. • Destruct crop infected crop residues. • Apply potash in recommended dose
Flowering	
Weeds	• Uproot *Orobanche* plants and burn them to reduce spread of *Orobanche* seeds.
Aphids	• Set yellow sticky trap before onset of flowering
Bihar hairy caterpiller**	• Same as sowing stage

Diamondback moth**	• Same as vegetative stage
Leaf miner	• Same as vegetative stage.
***Alternaria* blight**	• Same as vegetative stage
White rust, downy mildew**	• Same as sowing stage
Club root**	**Cultural control:** • Follow long term crop rotation. • Destroy all cruciferous weeds. • Follow timely crop sowing between 10-25 October. • Improve the drainage system.
Powdery mildew	• Same as vegetative stage
Sclerotinia* stem rot*	**Cultural control:** • Implement deep ploughing during summer. • Use certified seeds of resistant/tolerant varieties. • Follow timely sowing of crop. • Use proper field sanitation practices • Follow crop rotation with non host crops like, rice and maize.
Pod formation	
Aphids	• Same as sowing stage
Powdery mildew	• Same as vegetative stage
Reproductive /Maturity	
Weeds	• Left over weeds before shading of seeds may be removing to reduce the weed seed bank/spread.

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

** Pests of regional significance

V. INSECTICIDE RESISTANCE AND ITS MANAGEMENT

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

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

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

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

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

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

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

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

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

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

VI. NUTRITIONAL DEFICIENCIES

Iron: Chlorosis starts from the base and spreads towards the apical part of the lamina. In case of severe deficiency, leaves become bleached and puckered. Newly emerging leaves are completely bleached, those subtending these also develop pigmentation. Flowering, pod number and size of pods is reduced and pods appear chlorotic.

Correction measure: Spray 0.5% ferrous sulphate solution 3-4 times at weekly intervals.

Manganese: Chlorosis in apical part of the middle leaves, followed by developing small greyish-brown spots which coalesce to form large necrotic lesions. Leaf margins also turn necrotic and the lamina curl downwards. Later, these symptoms spread to old and young leaves. Flowering is also reduced and large percentage of flowers shed prematurely, resulting in poor fruit set and pod formation.

Correction measure: Spray 0.2-0.3 % manganese sulphate 2-3 times at weekly intervals.

Copper: Young leaves develop interveinal chlorosis. Chlorotic areas later turn papery and necrotic. Growth of plants is also reduced which is more pronounced at the time of flowering and thereafter. Inflorescence is very poorly developed and large percentages of the floral buds of the plants wither before opening. Pod formation and seed setting are also reduced.

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

Zinc: There is retardation of growth, deficiency symptoms appear after 20 days of sowing, the first true leaf is also affected. Leaves are small in size with pinkish margin. Interveinal tissues turn yellowish white to papery white, with veins remaining green. There is upward or downward cupping of leaves. Severely affected leaves die. Flowering and fruiting is delayed.

Correction measure: Application of 8-10 Kg/acre at sowing time of zinc sulphate overcomes zinc deficiency. Zinc sulphate should be placed in the seed row adjacent to the seed at the time of sowing to attain its higher utilization efficiency. Zinc deficiency can also be corrected by foliar spray of 0.5 per cent zinc sulphate solution along with 0.25 per cent slaked lime.

Sulphur: Deficiency symptoms are shown on younger leaves. Chlorosis formation from leaf margins, spreading inward and/or develop purple pigmentation. Inward curling of young leaf lamina giving these leaves a cupped appearance followed by scorching and withering. Flowering is delayed, lacking normal pigmentation. Pods are borne on short peduncle and their development is restricted. Seed setting is poor and their maturity is delayed. Sulphur deficient plants show marked retardation in height, thickness of stem and size of leaves.

Correction measure: Apply gypsum@ 100 Kg/acre in soil. Use sulphur containing fertilizers

Molybdenum: Mustard is very susceptible to molybdenum deficiency. Growth is markedly reduced and plants develop foliar symptoms like cupping, marginal scorching and loss of lamina.

Correction measure: Use Sodium molybdate 37 - 39%

VII. DESCRIPTION OF COMMON WEEDS

Broad leaf weeds:

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

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

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

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

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

It is a sweet-smelling erect herb, up to 10-60 cm height with hairless, spreading or erect stem. Leaves odd-1-pinnate; leaflets 1-2.5 cm, inverted, lance-shaped to wedge-shaped, generally sharply toothed on the broader part. Flowers 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.

4. 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.

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

A diffuse annual herb. Stem branched from the root, grooved. Leaves are in pseudo whorls, fleshy, linear-subulate, spreading. Flowers 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.

6. 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 anticlockwise, 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.

7. Wild Onion: *Asphodelus tenuifolius* Cav. (Liliaceae)

An annual, slender herb with a short root stock. Erect, hollow, cylindrical stem up to 50 cm height. Leaves numerous, all basal, hollow, slender, gradually acuminate to a point, 10 to 40 cm long the base sheathing, smooth to minutely hairy, seeming to rise as a 'bunch' from the soil. Flowers laxly racemose, light purple, with white fading. Fruits capsule globose, having triangular, pitted, black grayish 2-3 mm long seeds.

8. Burcloveru: *Medicago denticulata* Willd. (Fabaceae)

It is an annual decumbent herb, 20-60 cm tall. Glabrous or pubescent; branches up to 40 cm long. Leaves are 3-foliolate; leaflets obovate to obcordate; terminal leaflets 8–27 mm long, 7–20 mm wide, entire or toothed towards apex, sometimes with darker flecks or a basal darker patch; stipules deeply incised, glabrous or hairy on lower surface. Inflorescences 1–3-flowered; Flowers yellow. A pod; spirally coiled two to three turns with two rows of curved prickles along its sharp edges. The pod is about 8 mm in diameter, brown or slight straw colored. 1.5 mm long, 3.0 mm wide, kidney shaped, yellowish or tan, smooth.

9. Common vetch: *Vicia sativa* L. (Fabaceae)

An annual herb. Decumbent-ascending, up to 60 cm tall. Leaflets 3-8 pairs, 1.5 - 2.5 x 0.2 - 0.4 cm, linear lanceolate or oblong, mucronate, base obtuse. Flowers solitary or paired, axillary, purplish. Pods 3 - 4.2 x 0.4 - 0.6 cm, narrowly oblong, beaked, pubescent. 3-4 mm across, blackish.

10. Yellow pea: *Lathyrus aphaca* L. (Fabaceae)

It is a sub-erect annual herb. Scrambling or trailing, glabrous. Leaflets modified into long tendrils; stipules ovate-rounded, 0.5-3 X 1-2 cm, appressed to stem. Yellow, axillary, solitary, on long peduncles. Pods are glabrous, straight or incurved, 2-3.5 cm long and 0.3-0.8 cm wide, with 6-8 seeds. Ellipsoid to globose, usually flattish with a glossy, smooth, dark purple-brown to black surface, sometimes spotted to marbled.

Grassy weeds

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

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

12. Canary Grass: *Phalaris minor* Retz. (Poaceae)

A tufted annual bunchgrass, up to 1.8 metres in height. Erect or decumbent, caespitose. Leaves long, linear, acuminate. Ligule is an oblong hyaline membrane, about 2-5 mm long, often truncate and/or fringed; auricles absent, sheath smooth. Panicle more or less protruding or entirely protruding from the uppermost swollen leaf sheath, ovate to oblong, 5-8 cm long, green. Sikelets green, broadly lanceolate on short pedicels, shining, 4 -6 mm long, strongly laterally compressed.

Sedge weed

13. 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.

Parasitic weed

14. Broomrape: *Orobanche aegyptiaca* L. (Orobanchaceae)

Broomrape is an annual root parasites lacking chlorophyll, upto 1 m tall. Usually parasitize solanaceae and fabaceae hosts reducing crop yield severely. Seeds germinate in response to host root exudates and the seedlings must come in contact with host root immediately after germination. Some species may produce flowers within a week of emergence from the soil. Seeds of orobanche are irregular wedge shaped oblong, tiny dust like 0.2 to 0.5 mm long black to brown coloured.

1. Plant 2. Seeds

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 PESTS

1) Bihar hairy caterpillar:

Biology:

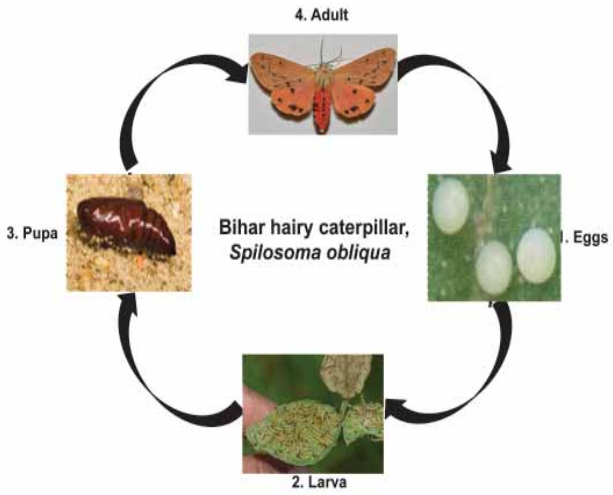
Egg: Eggs are laid in clusters of 50-100, on the lower side of leaves.

Larva: The larvae are covered with long yellowish to black hairs and are up to 5 cm long.

Pupa: Pupation takes place in the soil under dry.

Adult: The adult is a brown moth with a 40-50 mm wing span and a red abdomen.

Life cycle:



http://14.139.61.86/ebook_mustard_pest/lepidopterans.htm

Damage symptoms:

- Young larvae feed gregariously mostly on the under surface of the leaves.
- Caterpillars feed on leaves and in severe infestation the whole crop is defoliated

Scrapping of leaf

https://www.google.co.in/search?q=damage+symptoms+of+bihar+hairy+caterpillar&espv=210&es_sm=

*For management refer to page number 17

Parasitoids of bihar hairy caterpillar:

Egg parasitoid:

1. *Trichogramma* spp.

Larval parasitoid:

1. *Bracon* spp.

Predators of bihar hairy caterpillar:

1. Lacewing

2. Ladybug beetle

3. Spider

4. Fire ant

5. Dragonfly

6. Praying mantis

7. Ground beetle

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

2) Mustard aphid:

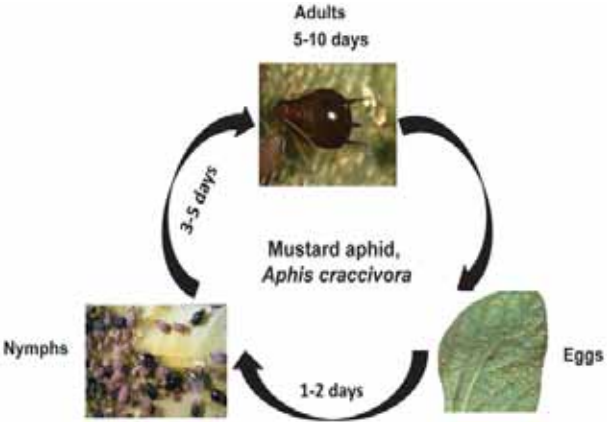
Biology:

Egg: Eggs are white in colour and laid along the veins of leaves.

Nymph: There are four nymphal stages (instars). The general appearance of each stage is similar except for increase in size during subsequent instars. The first, second, third and fourth nymphal stages last 1-2, 2, 2, and 3 days respectfully.

Adult: Aphids are small, soft-bodied, pear-shaped insects that have a pair of cornicles (wax-secreting tubes) projecting out from the fifth or sixth abdominal segment. Wingless, female, aphids are yellowish green, gray green or olive green with a white waxy bloom covering the body. The winged, female, adult aphids have a dusky green abdomen with dark lateral stripes separating the body segments and dusky wing veins. Male aphids are olive-green to brown in color. The aphid attacks generally during 2nd and 3rd week of December and continues till March.

Life cycle:



1,2,3: https://www.google.co.in/search?q=life+cycle+of+mustard+aphid&espv=210&es_sm

Damage symptoms:

- Both nymph and adults suck the sap from leaves, buds and pods.
- Curling may occur for infested leaves and at advanced stage plants may wither and die.
- Plants remain stunted and sooty molds grow on the honey dew excreted by the insects.

Aphids feeding on mustard pods

https://www.google.co.in/search?q=mustard+aphids&espv=210&es_sm =93&source=lnms&tbm=isch&sa=X&

Parasitoids of mustard aphid:

1. Nymphal parasitoid: ***Diaeretiella rapae***

2. Adult parasitoid: ***Aphelinus abdominalis***

1. https://www.google.co.in/search?q=Diaeretiella+rapae&espv=210&es_sm=93&source=lnms&
2. https://www.google.co.in/search?q= Aphelinus+ &espv=210&es sm=93&tbm=isch&i

*For management refer to page number 15 & 16

Predators of mustard aphid:

1. Hover fly

2. Ladybird beetle

3. Lacewing

4. Dragonfly

5. Spider

3) Painted bug:

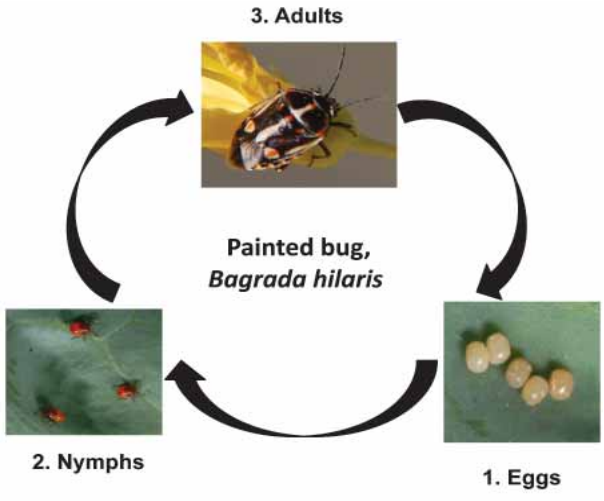
Biology:

Egg: Painted bug lays its eggs in clusters on leaves or on the soil underneath host plants. Eggs are barrel shaped, initially white and turn orange with age. A single female can lay as many as 100 eggs within 2 to 3 weeks. The incubation period is 5 to 8 days

Nymph: Nymph pass through five stages changing colour from bright orange to red with dark markings, gradually acquiring the colouration of the adult. Initially they do not have wings; wings are gradually developed as the nymphs grow. Wing pads are visible in the last instar nymph.

Adult: The adult bug is typically shield-shaped, 5 to 7 mm long and 3 to 4 mm broad at its widest area. The upper surface has a mixture of black, white and orange markings, which gives the insect its common names harlequin bug or painted bug. The life cycle lasts 3 to 4 weeks and several generations may occur in a year. Period of activity of painted bug starts from September.

Life cycle:



https://www.google.co.in/search?q=painted+bug+of+mustard&oq=painted+ bug+of+mustard&aqs=chrome.

Damage symptoms:

- Adults and nymphs suck sap from all parts of the plant.
- Young plants wilt and wither as a result of the attack.
- Adult bugs excrete a resinous substance which spoils the pods.
- Quality and quantity (31% losses) of yield is affected when grown up plants are infected.
- Harvested crop in threshing floor is also infested.

Painted bug feeding on mustard flowers & stem

https://www.google.co.in/search?q=painted+bug+of+mustard&oq =painted+bug+of+mustard&aqs=chrome..

*For management refer to page number 16

Parasitoid of painted bug:

Egg parasitoid:

1. Tachinid fly

https://www.google.co.in/search?q=Tachinid+flies&espv= 210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=MJb4

4) Mustard saw fly:

Biology:

Egg: Eggs are spherical, about 0.5 mm in diameter, light bluish green in colour.

Larva: Larva is greenish black with wrinkled body and eight pairs of pro-legs. On slightest touch the larva falls to round and feigns death. The larvae had 6 instars, fed on the leaves, and pupated after 14-16 days.

Pupa: Pupae are look like sand particle and have salivary secretions; the pupal stage lasted 11-12 days.

Adult: Adults are orange bodied with smoky transparent wings. The pest is active during seedling stage of the crop i.e. October - November.

Damage symptoms:

- Initially the larva nibbles leaves, later it feeds from the margins towards the midrib.
- The grubs cause numerous shot holes and even riddled the entire leaves by voracious feeding.
- They devour the epidermis of the shoot, resulting in drying up of seedlings and failure to bear seeds in older plants.
- The yield losses up to 5 to 18 %. In severe case at the seedling stage, the crop have to be resown.

https://www.google.co.in/search?q=mustard+saw+fly&espv=210&essm=93&source=lnms&tbm=isch&sa=X&ei=fJf4Ur2rKsW

*For management refer to page number 16 & 17

1. Larva

2. Adult

1,2: https://www.google.co.in/search?q=mustard+saw+fly&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=fJf4U

Parasitoid of mustard saw fly:

Larval parasitoid:

1. Perilissus cingulator

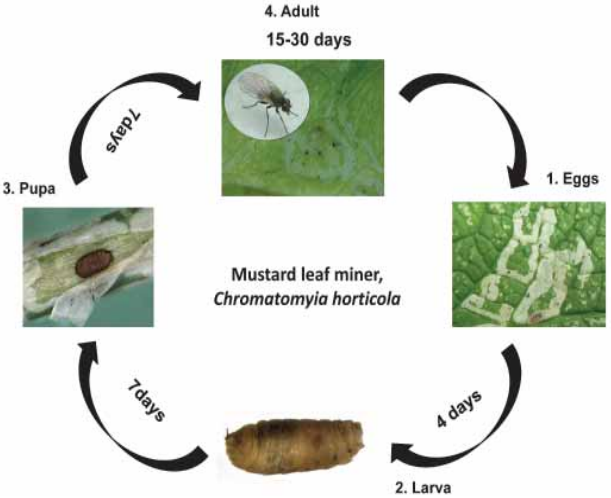
https://www.google.co.in/search?q=Perilissus+cingulator&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=lZr4UvapIYHqrQet0YHwDg&ved

5) Mustard leaf miner:

Biology:

- Mine linear, whitish, both upper and lower surface. Pupation internal, at the end of the mine with the anterior spiracles projecting through the epidermis.
- Upper-surface, less often lower-surface corridor. Pupation within the mine and soil; pupal chamber in a, usually lower-surface.
- A long whitish upper surface corridor, which eventually goes lower surface

Life cycle:



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

Damage symptoms:

- Leaves with mines; the attacked leaves wither; vigour of the plant gets reduced. Its damage is often more prominent on the older leaves.

Mines on leaves

https://www.google.co.in/search?q=leaf+minor+symptom s+on+mustard&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=dq

Parasitoids of mustard leaf miner:

Larval parasitoid: :
1. *Diglyphus isaea*

Pupal parasitoid:
1. *Halticoptera circulus*

Larval and pupal parasitoid:
1. *Gronotoma micromorpha*

1. http://www.evergreengrowers.com/diglyphus-isaea-114.html
1. https://www.google.co.in/search?q=Halticoptera+circulus&espv=210&es_sm=93&source=lnms&tbm=isch&sa
1. http://www.ento.csiro.au/science/Liriomyza_ver3/key/Eucoilidae_Key/Media/Html/ gronotoma_sp.html

Predators of mustard leaf miner:

1. Lacewing

2. Ladybug beetle

3. Spider

4. Fire ant

*For management refer to page number 18

6) Diamondback moth:

Biology:

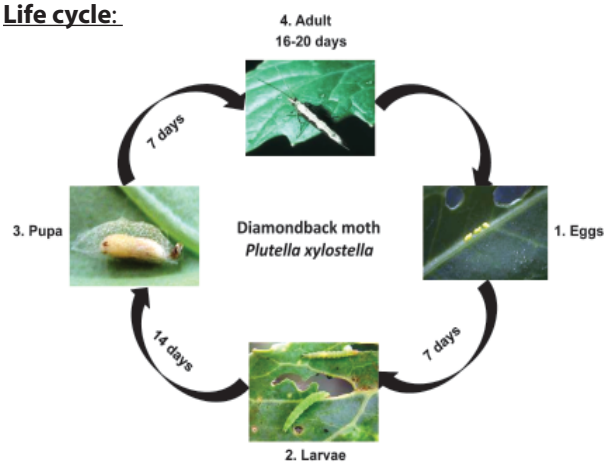
Egg : Minute yellow coloured eggs. Eggs laid singly or in groups – upper surface of leaves. Egg hatches in about 7 days.

Larva: Pale yellowish green caterpillar. Larval period is 14 days

Pupa: Pupation takes place on the foliage in a transparent cocoon. Pupal period is about 7 days.

Adult: Small greyish brown moth with three white triangular spots along the inner-margin which give diamond shape at rest position. Hind wings with fringe of long fine hairs

Life cycle:



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

Damage symptoms:

- Caterpillars feed on the foliage.
- The leaves give a withered appearance but in later stages larvae bore holes in the leaves may be eaten up completely.
- It also bores into pods and feeds developing seed.

Pod damage symptoms

https://www.google.co.in/search?q=life+cycle+of+diamondback+moth&

*For management refer to page number 18

Parasitoids of diamondback moth:

Larval parasitoid:

1. *Cotesia plutellae*

Pupal parasitoids:

1. *Microplitis plutellae*

2. *Diadegma insulare*

1. https://www.google.co.in/search?q=Cotesia+plutellae&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=D6n4UvK
1. https://www.google.co.in/search?q=Microplitis+plutellae&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=vKf4Up
2. https://www.google.co.in/search?q=Diadegma+insulare,&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=R6f

7) Cabbage head borer:

Biology:

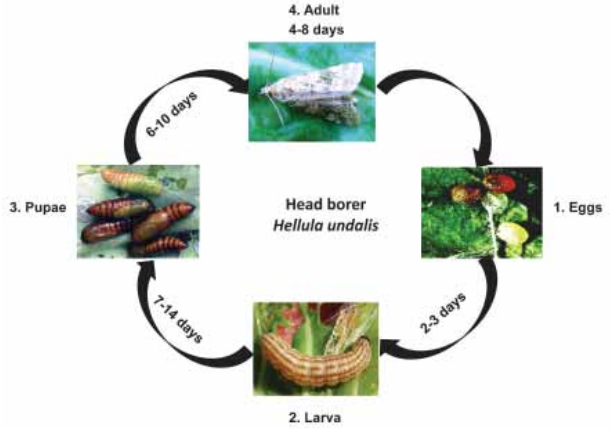
Egg: Female moth lays yellowish shiny eggs on leaves. Eggs hatch in about 4 days.

Larva: The caterpillar becomes full grown in about 9 days. Full grown caterpillar is 12-15 mm, greyish yellow with seven purplish brown longitudinal stripes on the body

Pupa: Full grown larva pupates in the larval burrow itself or in the soil. Pupal period is about 6 days.

Adult: Adult is pale yellowish-brown moth having grey wavy lines on the forewing.

Life cycle:



1,2,3,4: https://www.google.co.in/search?q=cabbage+head+borer&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=krD4Up3n

Damage symptoms:

- Caterpillars initially mine the leaves and make it white papery.
- Later they feed on leaves and bore into stems, entrance hole is covered with silk and excreta.

Different stages of damage symptom

http//:symptoms%20of%20Hellula%20undalis&tbm=isch&facrc=_&imgdii=_&

*For management refer to page number 18

8) Larger moth (leaf webber):

Biology:

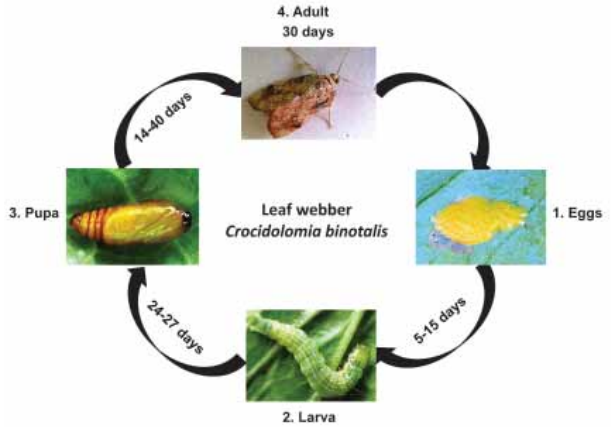
Egg: Female moth lays eggs in masses of 40 -100 on underside of leaves. They hatch in 5 -15 days.

Larva: Caterpillar webs together the foliage and feeds on leaves. It also feeds on flowers and pods in the case of mustard and flower heads in cabbage and cauliflower. Caterpillar bears red head with brown longitudinal stripes and rows of tubercles on the body. Larval period is 24-27 days.

Pupa: Pupation takes place in a cocoon within the webbed leaves. Pupal period is 14-40 days.

Adult: Adult is small with light brownish forewings.

Life cycle:



1. http://ecoport.org/ep?SearchType=pdb&PdbID=38333
2,3,4 http://infohamapenyakittumbuhan.blogspot.in/2012/04/crocidolomia-binotalis-zell.html

Damage symptoms:

- Newly hatched larvae feed initially on the chlorophyll of young leaves and later on older leaves, buds and pods, make webbings and live within.
- Severely attacked plants are defoliated.
- Seeds in the pods are eaten away.

https://www.google.co.in/search?q=Hellula+undalis&espv=210&es_sm=93&source=lnms&tbm=isch

*For management refer to page number 18

IX. DESCRIPTION OF DISEASES

1) *Alternaria* blight:

Disease symptoms:

- The disease attacks on the lower leaves as small circular brown necrotic spots which slowly increase in size.
- Many concentric spots coalesce to cover large patches showing blightening and defoliation in severe cases.
- Circular to linear, dark brown lesions also develop on stems and pods, which are elongated at later stage.
- Infected pods produce small, discoloured and shriveled seeds.


https://www.google.co.in/search?q=alternaria+blight+of+mustard&espv=210&es_sm=93&source=lnms&

Survival and spread:

- The disease is externally and internally seed born.
- The pathogen survives through spores (conidia) or mycelium in diseased plant debris or weed.

Favourable conditions:

- Moist (more than 70% relative humidity) coupled with warm weather (12-25 °C) and intermittent rains favours disease development.

*For management refer to page number 19

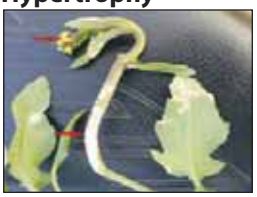
2) White rust:

Disease symptoms:

- Both local and systemic infections are observed.
- In case of local infection, white creamy yellow raised pustules appear on the leaves which later coalesce to form patches.
- In systemic infection and during humid weather, mixed infection of white rust and downy mildew cause swelling and distortion of the stem and floral parts due to hypertrophy and hyperplasia and develop "stag head" structure.

Disease symptoms **Hypertrophy**



https://www.google.co.in/search?q=white+rust+of+crucifers&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=YLL4UtG

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

Survival and spread:

- The pathogen survives through oospores in affected host tissues andsoil.
- Secondary infection is carried out by sporangia and zoospores which produce new infection.

Favourable conditions:

- Moist (more than 70% relative humidity) coupled with warm weather (12-25 °C) and intermittent rains favours disease development.

*For management refer to page number 17

3) Downy mildew:

Disease symptoms:

- Grayish white irregular necrotic patches develop on the lower surface of leaves.
- Later under favourable conditions brownish white fungal growth may also be seen on the spots.
- The most conspicuous and pronounced symptom is the infection of inflorescence causing hypertrophy of the peduncle of inflorescence and develop stag head structure.



https://www.google.co.in/search?q=downy+mildew+of+mustard&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=uLP4Urmk

Survival and spread:

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

Favourable conditions:

- Atmospheric temperature in the range of 10-20 °C and relative humidity>90% RH favours disease development.

*For management refer to page number 17

4) Powdery mildew:

Disease symptoms:

- Symptoms appear as dirty white, circular, floury patches on either sides of the leaves.
- Under favourable environmental conditions, entire leaves, stems, floral parts and pods are affected.
- The whole leaf may be covered with powdery mass.

https://www.google.co.in/search?q=powdery+mildew+of+mustard&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=uLP4Urmk

Survival and spread:

- The pathogen survives through cleistothecia present in the crop debris in the field.

Favourable conditions:

- High temperature (15-28 ºC) coupled with low humidity (<60% humidity) and low or no rainfall with wind favours disease development.

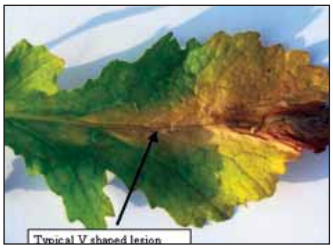
*For management refer to page number 19

5) Bacterial blight/ black rot:

Disease symptoms:

- The leaf tissue turns yellow and chlorosis reach towards the centre of the leaf and form V shaped area with base of V towards the midrib. The veins show brown to black discoloration.

  Dark coloured streaks are formed on the stem from the ground level and Gradually these streaks enlarge and girdle the stem.
- Stem become hollow due to internal rotting.
- Midrib cracking of lower leaves, browning of veins and withering is observed.
- In severe cases, the vesicular bundles of the stem also turn brown and the plant collapses.



https://www.google.co.in/search?q=bacterial+blight+of+mustard&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=Brf4

Survival and spread:

- The pathogen survives in infected plant residue in soil and seed.
- The pathogen spreads by soil and irrigation water.

Favourable conditions:

- Warm and humid climate favours the disease development

*For management refer to page number 19

6) Club root:

Disease symptoms:

- Affected plants remain stunted.
- Tiny nodules to large club shaped outgrowths develop in root system.
- Leaves turn pale green or yellow followed by wilting and under severe conditions the plants die.


https://www.google.co.in/search?q=club+root+of+crucifer&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=ebj4Uol

Survival and spread:

- The pathogen survives in the soil as resting spores and these spores act as primary source of inoculum.

Favourable conditions:

- Humid weather and high soil moisture favour disease development.

*For management refer to page number 19

7) *Sclerotinia* stem rot:

Disease symptoms:

- Elongated water soaked lesions appear on stem near to the crown region, covered with cottony mycelial growth later on.
- Plant looks like whitish from distance at internodes or base.
- Premature ripening and shredding of stem, wilting and drying.
- Brown to black sclerotial bodies may also be seen in the later stage on the infected plant parts.


https://www.google.co.in/search?q=sclerotinia+stem+rot+of+mustard&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=CLr4U

Survival and spread:

- The pathogen survives as mycelium in dead or live plants and as sclerotia in infected plant parts or on the soil surface or with seed as contaminant.

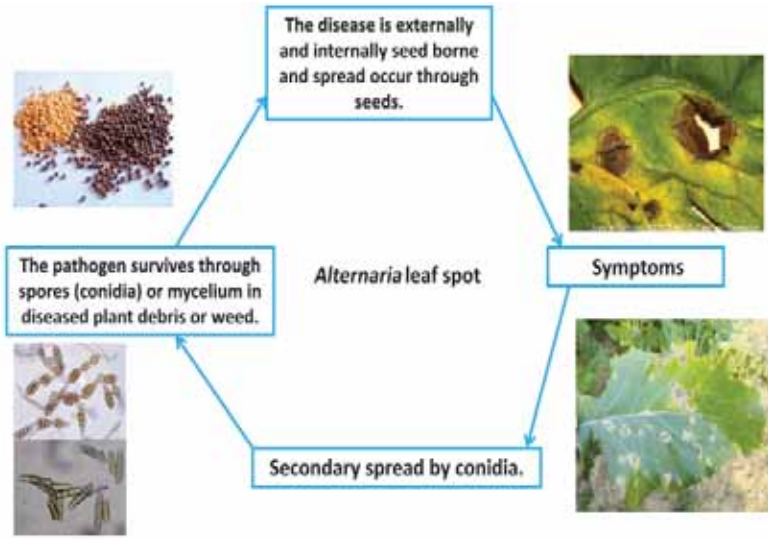
Favourable conditions:

- High humidity (90-95%) and average temperature (18-25 °C) along with wind current favours the disease development.

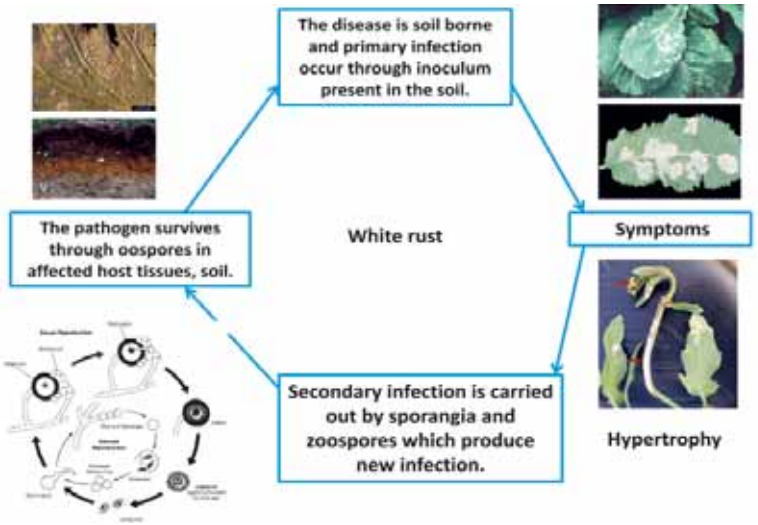
*For management refer to page number 19

Disease cycles:

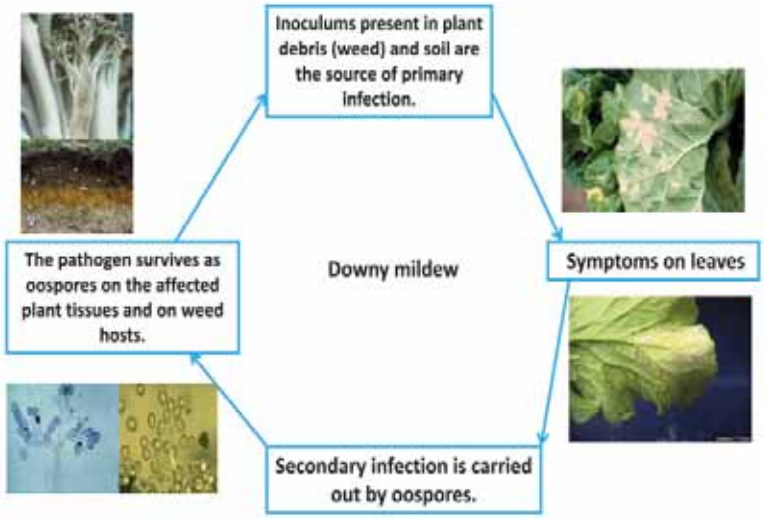
1. *Alternaria* leaf spot:



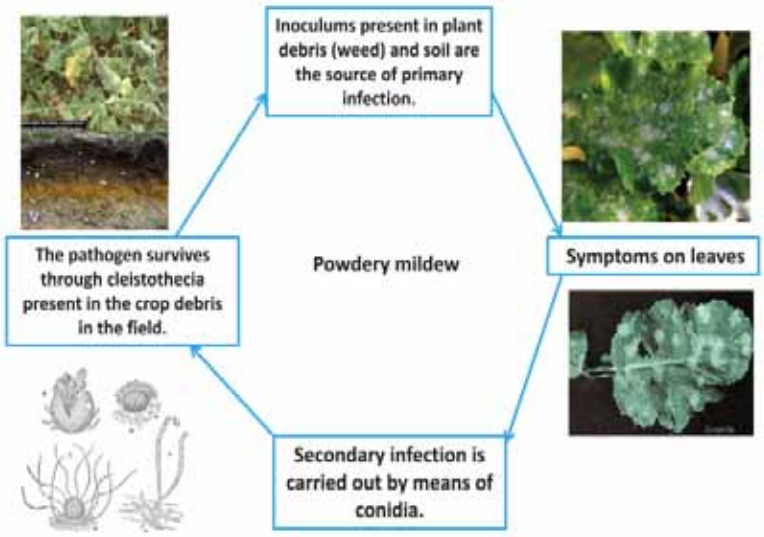
2. White rust:



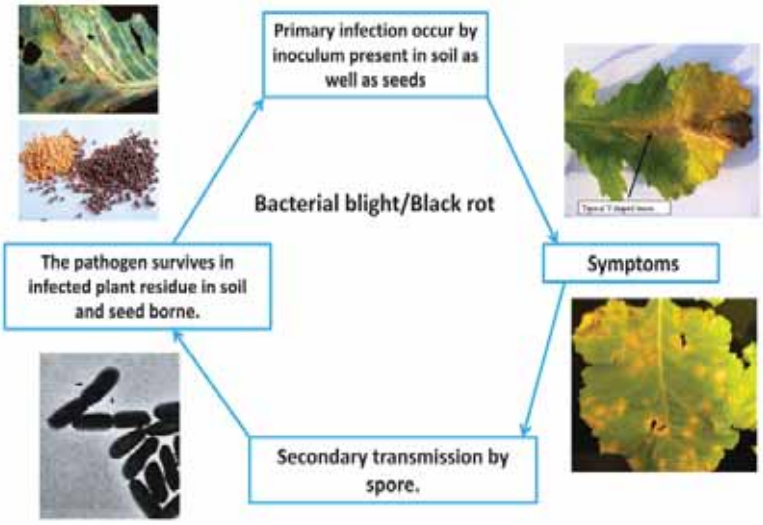
3. Downy mildew:



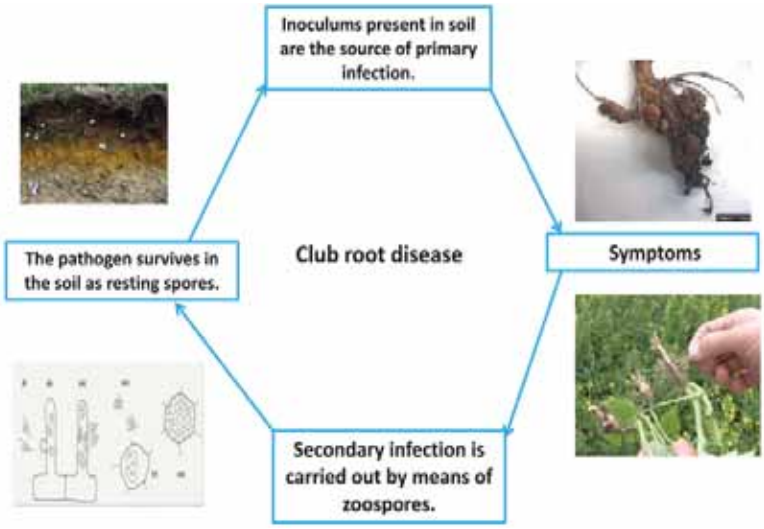
4. Powdery mildew:



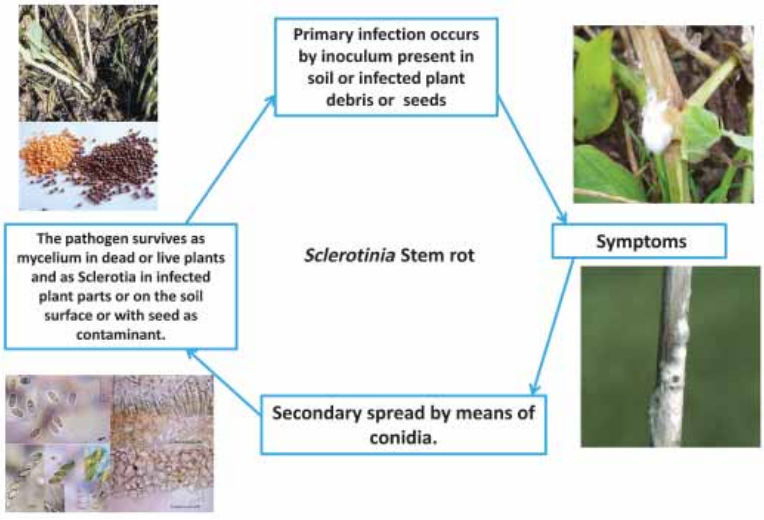
5. Bacterial blight/ black rot:



6. Club root:



7. *Sclerotinia* stem rot:



X. SAFETY MEASURES

A. At the time of harvest:

The crop should be harvested early in the morning when 75-85 per cent siliqua have turned golden yellow in colour. Amongst the types 'toria' is the earliest maturing variety that takes about 75-90 days time, 'Rai' needs 110-180 days, Yellow sarson 130-160 days and Brown sarson needs 105-145 days for maturity. The crop is harvesting with hand-sickles. The average yield from a good crop can go up to 18-20 q/ha.

B. During post-harvest storage:

After harvesting the crop bundles are made and sacked them in sun for 7 to 8 days. Threshing is done by beating the pods with wooden sticks or by trampling the plants by bullocks. Seeds are separated by winnowing, with the help of natural air currents but the wind velocity should not be very high as the seeds, being very small, are blown with the air. Store the produce after its moisture content is about 8 per cent approximately. Mustard is usually used as edible oil, as condiment, as medicine and for seasoning pickles. Rape oil is used in the manufacture of greases. Oil cake is used for feeding cattle and manures. The oil cake contains 4-5% Nitrogen. Oil content of rape seed-mustard varies from 30-48 per cent.

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 susceptible varieties.
4.	Sow early in the season	Avoid late sowing as this may lead to reduced yields and incidence of white grubs and diseases.
5.	Always treat the seedlings with approved chemicals/bio products for the control of seed borne diseases/pests 	Do not use seedlings without seed treatment with biocides/chemicals.
6.	Sow seeds in rows at optimum depths under proper moisture conditions for better establishment.	Do not sow 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 planting based test recommendations.	Do not apply any micronutrient mixture after planting without test recommendations.
11.	Conduct AESA weekly in the morning preferably before 9 a.m. Take decision on management practice based on AESA and P: D ratio only. 	Do not take any management decision without considering AESA and P: D ratio
12.	Install pheromone traps at appropriate period.	Do not store the pheromone lures at normal room temperature (keep them in refrigerator).
13.	Release parasitoids only after noticing adult moth catches in the pheromone trap or as pheromone trap or as per field observation 	Do not apply chemical pesticides within seven days of release of parasitoids.
14.	Apply NPV of respective Lepidopteran moth if available 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 spray recommended biopesticides/chemicals at the time of their appearance in the evening.	Do not spray pesticides at midday since, most of the insects are not active during this period.
16.	Spray pesticides thoroughly to treat the undersurface of the leaves, particularly for sucking pests harbouring the lower side of leaves. 	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	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.	Monocrotophos	Extremely toxic		Class I b Highly Hazardous		Do	Do	-
3.	Oxydemeton-methyl	Highly toxic	Yellow	Class Ib- Moderately hazardous		Do-	Do-	-

4	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	--
5	Phorate	Extremely toxic		Class Ia- Extremely hazardous	emove 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 R– Carry the person to the open fresh air, loosen the clothings around neck and chest, and (d) Indigestion – If the victim is fully conscious, 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	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.	- 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. 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.	-

					obstruction. Victim's head should be little lowered and face should be turned to one side in the lying down position. In case of breathing difficulty, give mouth to mouth or mouth to nose breathing. Medical aid: Take the patient to the doctor/Primary Health Centre immediately along with the original container, leaflet and label	Severe – diarrhea, 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 (eye wash with isotonic saline). Wear rubber gloves while washing contact areas. 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, barbituaratesofrphenothiazines. Do not give atropine to a cyanotic patients. Give artificial respiration first then administer atropine.	
6.	Quinalphos	Highly toxic		Class II Moderately Hazardous	Do	Do	Do	-
7.	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.	-

8.	Dimethoate	Highly toxic		Class II Moderately hazardous		Mild-anorexia, headache, dizziness, weakness, anxiety, tremors of tongue and eyelids, miosis, impairment of visual acuity	For extreme symptoms of OP poisoning, injection of atropine (2-4 mg for adults, 0.5-1.0 mg for children) is recommended. Repeated at 5-10 minute intervals until signs of atropinization occur.	--
9.	Malathion	Moderately toxic		Class III slightly hazardous		Mild-anorexia, headache, dizziness, weakness, anxiety, tremors of tongue and eyelids, miosis, impairment of visual acuity	For extreme symptoms of OP poisoning, injection of atropine (2-4 mg for adults, 0.5-1.0 mg for children) is recommended. Repeated at 5-10 minute intervals until signs of atropinization occur.	--
10.	Thiamethoxam				Have person sip a glass of water if able to swallow. Do not induce vomiting unless told to do so by a poison control center or doctor. Do not give anything by mouth to an unconscious		No specific antidote. Treatment is essentially symptomatic.	21
11.	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	-
12.	Methyl Parathion	Extremely hazardous		Hazard Class Ia	Atropine sulfate and Pralidoxime chloride.	Early symptoms of poisoning may include excessive sweating, headache, weakness, giddiness, nausea, vomiting, hypersalivation, stomach pains, blurred vision and slurred speech. If these symptoms occur, the	Persons who have been poisoned (accidentally or otherwise) must be transported immediately to a hospital and put under surveillance of properly trained medical staff.	At infestation

						person should remove contaminated clothes and wash the affected skin with soap and water, and flush with large quantities of water. If in the event of collapse artificial resuscitation is used, vomit may containt oxic amounts of the substance. In case of ingestion, the stomach should be emptied as soon as possible by careful gastric lavage. Do not induce vomiting if the formulation contained hydrocarbon solvents.		
13.	Phosphamidon	Do		Hazard Class Ib	Do	Do	Do	-
Fungicides								
1.	Metalaxyl MZ	Moderately toxic		Class III slightly hazardous	-	Headache, palpitation, nausea, vomiting, flushed face, irritation of nose, throat, eyes and skin etc.	No specific antidote. Treatment is essentially symptomatic	60
2.	Iprodione	Slightly toxic	Colourless	-	-	-	-	50
Herbicide								
1.	Oxadiargyl	-		(Obsolete as pesticides) not classified	-	-	If on skin or clothing: In case of contact with skin, remove contaminated clothes and carefully wash affected areas of skin with water. If in eyes: In case of contact with eyes, rinse immediately with plenty of water for 20 minutes.	35

If swallowed: If swallowed, seek medical advice immediately and show this container or label If you feel unwell, seek medical advice (show the label where possible) Keep the victim under medical control. If inhaled: Move person to fresh air. If person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably by mouth-to-mouth, if possible. Call a poison control center or doctor for further treatment advice.								

XIII. BASIC PRECAUTIONS IN PESTICIDES USAGE

A. Purchase

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

B. Storage

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

C. Handling

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

D. Precautions for preparing spray solution

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

E. Equipment

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

F. Precautions for applying pesticides

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

G. Disposal

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

XIV. PESTICIDE APPLICATION TECHNIQUES

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

XV. OPERATIONAL, CALIBRATION AND MAINTENANCE GUIDELINES IN BRIEF

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

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- https://www.google.co.in/search?q=downy+mildew+of+mustard&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=uLP4Urmk
- https://www.google.co.in/search?q=powdery+mildew+of+mustard&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=uLP4Urmk
- https://www.google.co.in/search?q=bacterial+blight+of+mustard&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=Brf4
- https://www.google.co.in/search?q=club+root+of+crucifer&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=ebj4Uo
- https://www.google.co.in/search?q=sclerotinia+stem+rot+of+mustard&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=CLr4U
- Gavloski J. E. and R. J. Lamb (2000) Compensation by Cruciferous Plants is Specific to the Type of Simulated Herbivory. *Environmental Entomology.* 29(6):1273-1282.
- Gurr Men SD, Altieri MA (2004) Ecological Engineering for Pest Management Advances in Habitat Manipulation for Arthropods. CSIRO PUBLISHING, Collingwood, Australia.
- http://www.pesticideinfo.org/

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

***Crotalaria* sp**

Castor

Cowpea

Sunflower

Corn

Sorghum

Bindweed

Brassica rapa

French bean

रा व स्वा प्र सं
N I P H M

National Institute of Plant Health Management
Rajendranagar, Hyderabad, Telangana

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

NCIPM

National Centre for Integrated Pest Management
LBS Building, IARI Campus, New Delhi

Department of Agriculture and Cooperation
Ministry of Agriculture
Government of India

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