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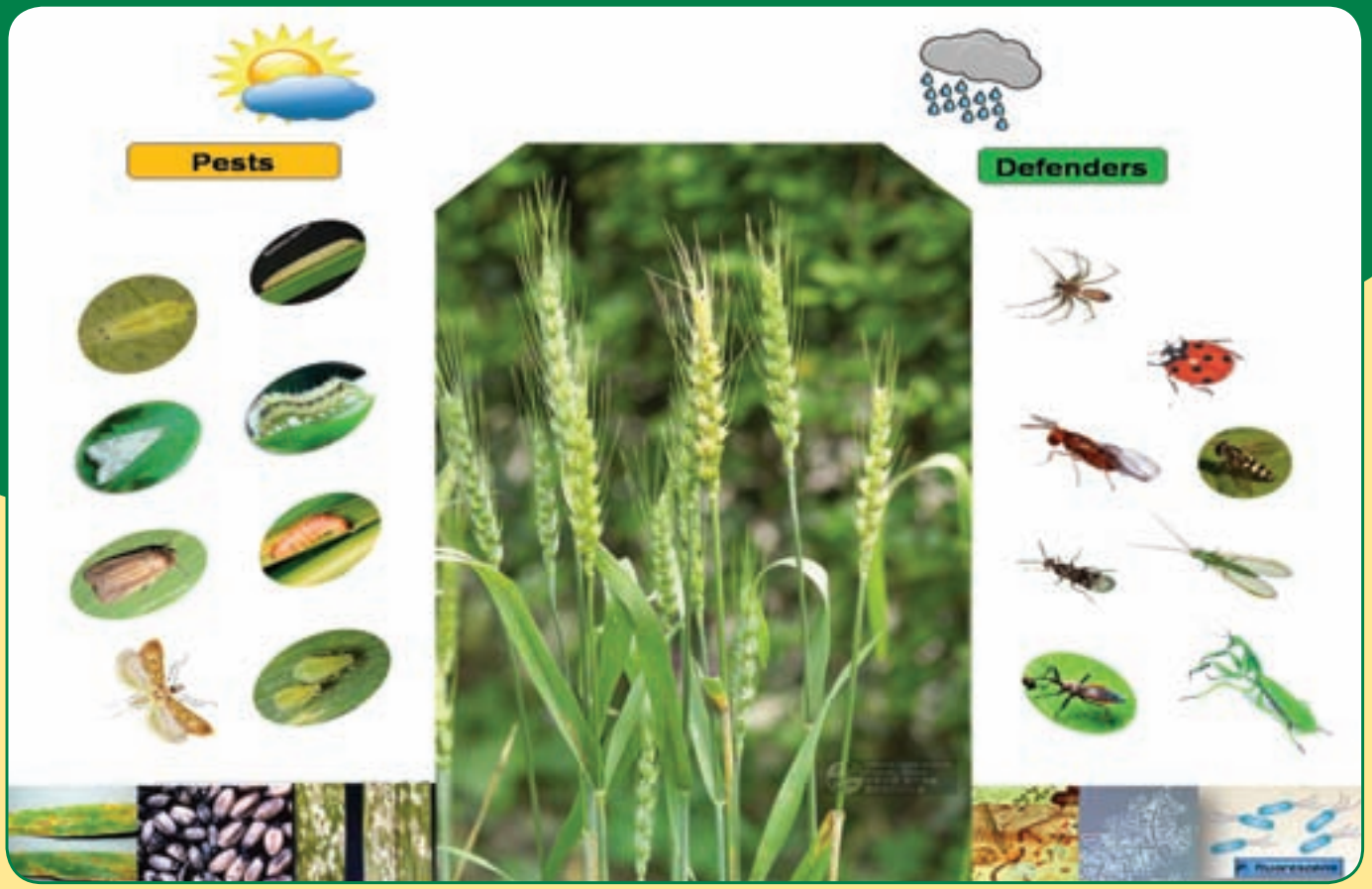
AESA BASED IPM PACKAGE

WHEAT



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

National Institute of Plant Health Management
Rajendranagar, Hyderabad, Telangana

Department of Agriculture and Cooperation

Ministry of Agriculture
Government of India

Important Natural Enemies of Wheat Insect Pests

Parasitoids

***Trichogramma* spp.**

Thripobius semiluteus

***Campoletis* spp.**

***Bracon* spp.**

***Carcelia* spp.**

***Aphidius* spp.**

Predators

Robber fly

Earwig

Pentatomid bug

Reduviid bug

Ground beetle

Black drongo

The AESA based IPM – Wheat, was compiled by the NIPHM working group under the Chairmanship of Dr. Satyagopal Korlapati, IAS, DG, NIPHM, and guidance of Shri. Utpal Kumar Singh 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), Entomology Expertise

Other Members:

1. Dr. N. Srinivasa Rao, Assistant Director (RPM), Rodent Pest Management Expertise
2. Dr. Sunanda B.S., Assistant Scientific Officer (PHM), Nematology Expertise

Contributions by DPPQ&S Experts:

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

Contributions by External Experts:

1. Dr. Indu Sharma, Project Director, Directorate of Wheat Research, Karnal, Haryana
2. Dr. H. Ravindra, Professor of Nematology, ZAHRS, Shimoga
3. Dr. B. K. Shivanna, Associate Professor, ZAHRS, Shimoga
4. Dr. M.S. Saharan (PI-Crop Protection), Directorate of Wheat Research, Karnal, Haryana
5. Dr. Damanjit Kaur, Sr. Nematologist, PAU, Ludhiana
6. Dr. Beant Singh, Entomologist, PAU, Ludhiana
7. Dr. R.K. Sharma PI(RM), PAU, Ludhiana
8. Dr. R. S. Chokar, Sr. Agronomist, PAU, Ludhiana
9. Dr. A.K. Karnatak, Dept of Entomology, G.B. Pant University of Agriculture & Technology, Pantnagar
10. Dr. Ruchira Tiwari, Dept of Entomology, G.B. Pant University of Agriculture & Technology, Pantnagar
11. Dr. Deepshikha, Dept of Plant Pathology, G.B. Pant University of Agriculture & Technology, Pantnagar
12. Dr. B.R.Patel, Prof& Head (Ento) C.P. College of Agriculture, S.D. Agriculture University Sardarkrushinagar-385506
13. Dr. Surajit Khalko, Assistant Professor (Plant pathology), Uttar Banga Krishi Viswavidyalaya Cooch Behar, West Bengal
14. Dr. Nripendra Laskar, Assistant Professor (Ento), Uttar Banga Krishi Viswavidyalaya Cooch Behar, West Bengal
15. Dr. Ayon Roy, Associate Professor (Plant Pathology), Uttar Banga Krishi Viswavidyalaya Cooch Behar, West Bengal
16. Prof. Tapan Kumar Hath, Prof (Ento), Uttar Banga Krishi Viswavidyalaya Cooch Behar, West Bengal
17. Dr. L.V. Ghetiya, Dept.of Ento, N.M. college of Agriculture, NAU, Navsari-396450

Informaton on Region-wise Distribution of Pests Provided by:

1. Dr. N. Sathyanarayana, Director, Plant Biosecurity Division, NIPHM
2. Mrs. S. Latha, Scientific Officer, Plant Biosecurity Divions, NIPHM

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Front cover picture Model AESA chart for Wheat

Back cover picture Wheat field

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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

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

सत्यमेव जयते

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

सत्यमेव जयते

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

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)

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AESA BASED IPM PACKAGE FOR WHEAT

Wheat-Plant description:

Wheat (*Triticum aestivum* L.; Family: Poaceae) is an annual grass; culms simple, erect, hollow or pithy, glabrous, up to 1.2 m tall; leaves flat, narrow, 20–38 cm long, about 1.3 cm broad; spikes long, slender, dorsally compressed, somewhat flattened; rachis tough, not separating from spikelet at maturity; spikelets 2–5-flowered, relatively far apart on stem, slightly overlapping, nearly erect, pressed close to rachis; glumes keeled in upper half, firm, glabrous, shorter than the lemmas; lemmas awned or awnless, less than 1.3 cm long; palea as long as the lemma, remaining entire at maturity; caryopsis free-threshing, soft or hard, red or white.

The total area under wheat in the world is around 225.62 million ha with a production of 685.6 million tonnes (2009-10). The normal world productivity is 3039 Kg/ha. The major wheat producing countries are China, India, USA, France, Russia, Canada, Australia, Pakistan, Turkey, UK, Argentina, Iran and Italy. These countries contribute about 76% of the total world wheat production. India stands first in area and second in production next to China in the world. The India's share in world wheat area is about 12.40%, whereas it occupies 11.77 % share in the total world wheat production. In terms of production, U.P. occupies first place followed by Punjab, Haryana, Madhya Pradesh, Rajasthan, Bihar, Maharashtra, Gujarat, West Bengal, Uttarakhand, Himachal Pradesh, Jammu & Kashmir and Karnataka. The contribution of these states in the production is about 99.5%.

Wheat is grown on more land area than any other commercial food. World trade in wheat is greater than for all other crops combined. Globally, wheat is the leading source of vegetable protein in human food, having a higher protein content than other major cereals, maize (corn) or rice. In terms of total production tonnages used for food, it is currently second to rice as the main human food crop and ahead of maize, after allowing for maize's more extensive use in animal feeds.

I. PESTS

A. Pests of National Significance

1. Insect and mite pests

- **1.1 Termite: *Odontotermis obesus* Rambur, *Microtermes obesi* Holmgren (Isoptera:Termitidae)**
- **1.2 Wheat aphid: *Sitobion avenae* (F.), *S. miscanthi* Takahashi (Hemiptera: Aphididae)**
- **1.3 Army worm/cut worm: *Mythimna separata* Walker (Lepidoptera: Noctuidae)**
- **1.4 American pod borer: *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae)**
- **1.5 Pink stem borer: *Sesamia inferens* Walker (Lepidoptera: Noctuidae)**
- **1.6 Shootfly: *Atherigona naqvii* Steyskal and *A. oryzae* Mall (Diptera: Muscidae)**
- **1.7 Brown mite: *Petrobia latens* Mull. (Acarina: Tetranychidae)**

2. Diseases

- **2.1 Brown rust: *Puccinia recondita* f. sp. *tritici* Eriks. & Henn**
- **2.2 Yellow/stripe rust: *Puccinia striiformis* var. *striiformis* Westend**
- **2.3 Black rust: *Puccinia graminis tritici* Pers**
- **2.4 Loose smut: *Ustilago tritici* (Pers.) E. Rostr.**
- **2.5 Karnal bunt: *Tilletia indica* Mitra**
- **2.6 Powdery mildew: *Blumeria graminis* (DC.) Speer**
- **2.7 *Helminthosporium* leaf spot/leaf blotch: *Helminthosporium* spp., *Cochliobolus sativus* Drechsler ex Dastur (*Helminthosporium sativum*) syn. *Bipolaris sorokiniana*, *Drechslera sorokiniana***
- **2.8 Foot rot: *Pythium graminicolum* Subraman and *P. arrhenomanes* Drechsler**
- **2.9 *Alternaria* leaf blight: *Alternaria triticina* Prasada & Prabhu**
- **2.10 Flag smut: *Urocystis agropyri* (G. Preuss) J. Schröt.**
- **2.11 Hill bunt: *Tilletia tritici* (syn. *Tilletia caries*) Bjerk. Wint. and *T. laevis* (syn. *T. foetida*). Kuhn**
- **2.12 Head scab/*Fusarium* head blight: *Fusarium graminearum* Schwabe, *Gibberella zeae* (Schwein.) Petch.**

3. Nematodes

- **3.1 Seed gall nematode: *Anguina tritici*, Tundu or yellow ear rot: *Rathaybacter tritici* + *Anguina tritici* (Tylenchida: Tylenchidae)**
- **3.2 Cereal cyst nematode: *Heterodera avenae* (Tylenchida: Heteroderidae)**
- **3.3 Root-knot nematode: *Meloidogyne* spp.**

4. Weeds

Broadleaf

- **4.1 Lambs quarter: *Chenopodium* spp. L. (Chenopodiaceae)**
- **4.2 Scarlet pimpernel: *Anagallis arvensis* L. (Primulaceae)**
- **4.3 Sweet clover: *Melilotus indica* (L.) All. (Fabaceae)**
- **4.4 Fine leaf fumitory: *Fumaria parviflora* Lam. (Fumariaceae)**
- **4.5 Corn spurry: *Spergula arvensis* L. (Caryophyllaceae)**
- **4.6 Field bindweed: *Convolvulus arvensis* L. (Convolvulaceae)**
- **4.7 Onion weed: *Asphodelus tenuifolius* Cav. (Liliaceae)**
- **4.8 Swine cress: *Coronopus didymus* (L.) Sm. (Brassicaceae)**

4.9 Jangali palak: *Rumex dentatus* L. (Polygonaceae)

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

4.11 Thistle weed: *Cirsium arvense* (L.) Scop. (Asteraceae)

Grasses

4.12 Wild oat: *Avena ludoviciana* (L.) Nees. (Poaceae)

4.13 Canary grass: *Phalaris minor* Retz. (Poaceae)

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

4.15 Rye grass: *Lolium* spp. (Poaceae)

Sedge

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

5. Rodent pests

5.1 Lesser bandicoot: *Bandicota bengalensis* (Gray)

5.2 Black rat: *Rattus rattus* L.

5.3 Field mouse: *Mus booduga* (Gray)

5.4 Soft furred field rat: *Millardia meltada* (Gray)

5.5 Indian gerbil: *Tatera indica* (Hardwicke)

B. Pests of Regional Significance:

1. Insect pests

1.1 Wheat thrips: *Anaphothrips favicinctus, Haplothrips tritici* (Kurdjumov) (Thysanoptera: Thripidae)

1.2 Ghujhia weevil: *Tanymecus indicus* Faust (Coleoptera: Curculionidae) (Uttar Pradesh)

2. Disease

2.1 Seedling blight: *Rhizoctonia solani* Kuhn and *Fusarium* sp. (Himachal Pradesh, Punjab, Tamil Nadu)

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
- Grow certified seeds
- Treat the seed with recommended pesticides especially biopesticides
- Follow proper spacing
- Soil health improvement (mulching and green manuring)
- 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 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 situation and Pest (P): Defender (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. The ability of the plant to compensate for the reduced acquisition of resources by the production of new organs or by remobilization of reserves may also mitigate biotic stress effects. Numerous examples exist in the literature. In agricultural crops, reports of plant compensation mostly are concerned with yields rather than fitness. Quantification of tolerance remains difficult because of: (i) the large number of potential mechanisms involved; (ii) different rates of

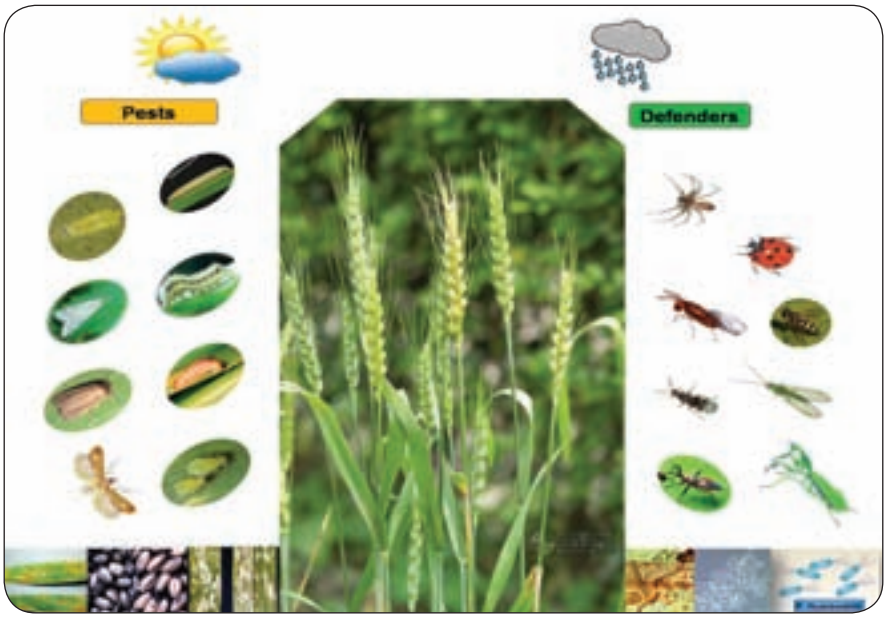
development of plants, pests and pathogens; and (iii) various compensatory mechanisms. Modelling is, therefore, a valuable tool to quantify losses, but also to prioritize the processes involved. The wheat plant can compensate for thin stands by increasing tillering, defoliation, producing more seed per head, and increasing the weight or size of each kernel. Early in the season the best compensation factor is increased tiller production. However, with late emerging wheat, high tiller production is less likely. A healthy wheat plant will typically have 3-5 tillers that contribute significantly to yield (Capinera *et al*., 1980; Walmsley *et al*., 1987; Sharrow 1990). Zuckerman *et al.* (1997) reported a 3.5-fold increase in the rate of photosynthesis in remaining green tissue of spring wheat variety Miriam compared to variety Barkai following infection by *M. graminicola*. This was associated with an apparently greater disease tolerance in Miriam and a smaller reduction in mean seed weight. However, variation in compensatory response also affects sampling strategies and economic threshold levels and provides viable tactic for breeding insect resistance to key arthropod pests into plants.

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

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	**:**

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 wheat insect pests can be divided into 3 categories 1. parasitoids; 2. predators; and 3. pathogens.

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 un-favourable, the farmers can be advised to resort to inundative release of parasitoids/predators depending upon the type of pest. In addition to inundative release of parasitoids and predators, the usage of microbial biopesticides and biochemical biopesticides such as insect growth regulators, botanicals etc. can be relied upon before resorting to synthetic chemical pesticides.

Decision making:

Farmers become experts in crop management:

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

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

AESA methodology:

- Go to the field in groups (about 5 farmers per group). Walk across the field and choose 20 plants/acre randomly. Observe keenly each of these plants and record your observations:
    - Plant: Observe the plant length, number of leaves, crop stage, deficiency symptoms etc.
    - Insect pests: Observe and count insect pests at different places on the plant.
    - Defenders (natural enemies): Observe and count parasitoids and predators.
    - Diseases: Observe leaves and stems and identify any visible disease symptoms and severity.
    - Rats: Count number of plants affected by rats.
    - Weeds: Observe weeds in the field and their intensity.
    - Water: Observe the water situation of the field.
    - Weather: Observe the weather conditions.
- 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 situations. The weather conditions, 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 the data in a notebook and drawing on a chart:

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

Data to be recorded:

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

Some questions that can be used during the discussion:

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

Advantages of AESA over ETL:

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

make the right crop management decisions. In ETL based IPM, natural enemies, plant compensation ability and abiotic factors are not considered. In AESA based IPM emphasis is given to natural enemies, plant compensation ability, abiotic factors and P: D ratio.

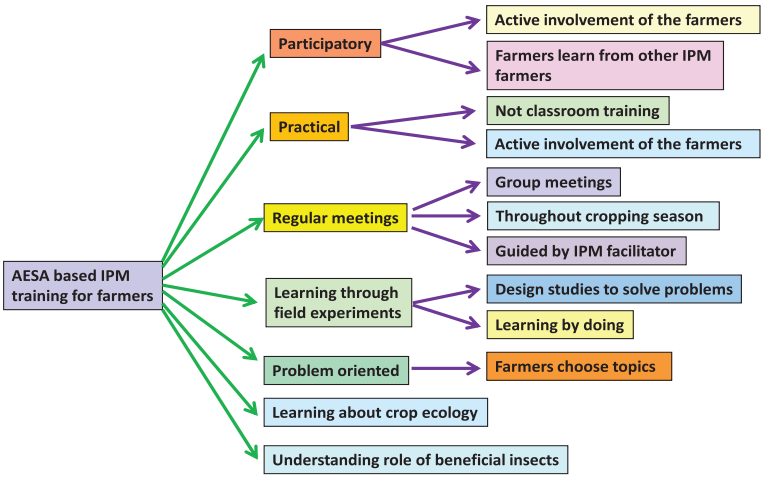
AESA and farmer field school (FFS):

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

Farmers can learn from AESA:

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

FFS to teach AESA based IPM skills:



B. Field scouting:

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

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

For insect pests:

Aphids, thrips and mites: Count and record the number of both nymphs and adults on three randomly selected leaves (top, middle and bottom) per plant.

Defoliators like *Helicoverpa, Mythimna, Sesamia*: As feeds on foliage and ear heads, per cent number of infested plants as well as number of larvae per tiller should be counted.

For diseases:

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

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

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

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

C. Surveillance through pheromone trap catches:

Pheromone traps for *Helicoverpa, Mythimna, Sesamia* @ 4-5 traps/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 should be counted and recorded. The trapped moths should be removed and destroyed after each recording.

D. Yellow/blue pan water/sticky traps:

Set up yellow & blue pan water/sticky traps 15 cm above the canopy for monitoring aphids and thrips respectively @ 4-5 traps (15 X 7.5 cm)/acre. Locally available empty tins can be painted yellow/blue and coated with grease/ Vaseline/castor oil on outer surface may also be used as yellow/blue sticky trap. Count the number of aphids and thrips on the traps daily and take the appropriate decision regarding management practices.

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 operated around the dusk time (6 pm to 10 pm).

F. Nematode extraction:

Collect 100 to 300 cm^3 (200-300 g) representative soil sample. Mix soil sample and pass through a coarse sieve to remove rocks, roots, etc. Take a 600 cc subsample of soil, pack lightly into a beaker uniformly. Place soil in one of the buckets or pans half filled with water. Mix soil and water by stirring with paddle; allow to stand until water almost stops swirling. Pour all but heavy sediment through 20-mesh sieve into second bucket; discard residue in first bucket; discard material caught on sieve. Stir material in second bucket; allow to stand until water almost

stops swirling. Pour all but heavy sediment through 60 mesh sieve to collect cysts into first bucket; discard residue in second bucket. Stir material in first bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 325-mesh sieve into second bucket; discard residue in first bucket. Backwash material caught on 325-mesh sieve (which includes small to mid-sized nematodes and silty material) into 250-ml beaker. More than 90% of the live nematodes are recovered in the first 5-8 mm of water drawn from the rubber tubing and the sample is placed in a shallow dish for examination.

III. ECOLOGICAL ENGINEERING FOR PEST MANAGEMENT

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

Ecological Engineering for Pest Management – Below Ground:

There is a growing realization that the soil borne, seed and seedling borne diseases can be managed with microbial interventions, besides choosing appropriate plant varieties. The following activities increase the beneficial microbial population and enhance soil fertility.

- 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 of beneficial microbes and insects.
- Application of balanced dose of nutrients using biofertilizers based on soil test report.
- Application of biofertilizers with special focus on mycorrhiza and plant growth promoting rhizobia (PGPR)
- Application of *Trichoderma harzianum/viride* and *Pseudomonas fluorescens* for treatment of seed/seedling/ planting materials in the nurseries and field 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).

Ecological Engineering for Pest Management – Above Ground:

Natural enemies play a very significant role in control of foliar insect pests. Natural enemy diversity contributes significantly to management of insect pests both below and above ground.

Natural enemies may require:

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

In order to attract natural enemies following activities should be practiced:

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

- Select and plant appropriate companion plants which could be trap crops and pest repellent crops. The trap crops and pest repellent crops will also recruit natural enemies as their flowers provide nectar and the plants provide suitable microclimate.

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

Plants Suitable for Ecological Engineering for Pest Management

Attractant plants


Ageratum


Carrot


Sunflower


Buckwheat


French bean


Alfalfa


Mustard


Cosmos

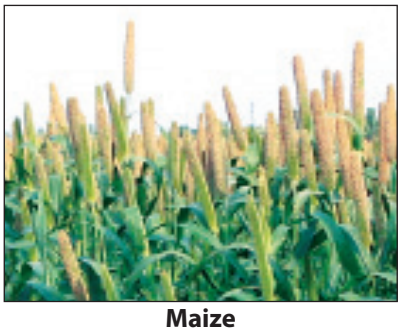

Anise

Repellent plants

***Ocimum* spp.**

Peppermint/Spearmint

Border plants



Maize

Sorghum

Rye-grass

Intercrops

Cowpea

Onion

Urdbean

Trap plant

Marigold

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

Biodiversity of natural enemies observed in Ecological Engineering field at NIPHM

Biodiversity of natural enemies: Parasitoids

Biodiversity of natural enemies: Predators

Biodiversity of natural enemies: Spiders

IV. RESISTANT/TOLERANT VARIETIES

Zone	Varieties*
Northern Hill Zone (Hills of J & K, H. P. and U. P.), North Hill Zone (High Altitude)	HS 420; HS 277; HS 295; HPW251; VL 892
North Western plain Zone (Punjab, Haryana, Western UP, Northern Rajasthan and foot hills of HP & J & K)	CPAN 3004; WH 542, HD 2687; PBW 550; WH 896; WH 1105; HD 2964; 8804
North Eastern Plain zone (Eastern UP, Bihar, West Bengal)	HP 1102; UP 262; HUW 206; HP 1102;K 8804
Central Zone (MP, Gujarat and southern Rajasthan)	WH 147; GW 190; H 1977GW273; GW322; DL 803-3; Lok 1
Peninsular Zone (Maharashtra and Karnataka)	HD 2501, MACS 2496; DWR 162; HW 971; HW 2022

• **For nematode** (Cyst nematodes) Raj MR1 (Raj Molya Rodhak)

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

V. CROP STAGE-WISE IPM

Management	Activity
Pre-sowing*	
	Common cultural practices: • Deep ploughing of fields during summer to control nematodes population, to expose pupae and resting stage of insect pests popagules of soil borne pathogens. • Soil solarization • Timely sowing should be done. • Field sanitation, roguing. • Destroy the alternate host plants • Growing marigold as a repellent crop for the management of root-knot nematode. • Grow 4 rows of maize/sorghum/bajra around the field as a gourd guard/barrier crop. • Crop rotation with non-cereals. • Adopt ecological engineering by growing the attractant, repellent, and trap crops around the field bunds.
Nutrients	• At the time of field preparation, apply FYM @ 4.0 t/ acre 2-3 week before sowing or vermicompost @ 2.0 t/acre at one week before sowing. • Grow suitable green manure crop to improve soil health.
Weeds	**Cultural control:** • At the time of field preparation, adopt stale seed bed technique to minimize the weeds menace in field. • Zero till practice is also minimize the weed seed germination.
Soil and seed borne pathogens, nematodes, foot rot, termites, resting stages of insects	**Cultural control:** • Apply well rotten FYM only to discourage termite infestation. • Avoid late sowing of crops. • **For nematode:** Non host crops such as gram, mustard, cumin, carrots, onion etc. are suggested for 3 years.

	• For others follow common cultural, mechanical and biological practices (See page no. 17). **Chemical control:** **For nematode:** • Carbofuran 3% CG @ 26640 g/acre **For termite:** • Thiamethoxam 30% FS @ 1.32 Kg per 40 Kg seeds or chlorpyrifos 20% EC @ 3 – 4 ml/ Kg seed and 0.8-1.2 l/acre as soil application
Sowing/seedling*	
Wheat is a Rabi crop that is grown in the winter season. Sowing of wheat takes place from October to December and harvesting is done during the months of February to May. The wheat crop needs cool winters and hot summers, that is why the fertile plains of the Indo-Gangetic region are the most conducive for growing it. Though well-drained loams and clayey loams are considered the ideal soil for wheat, good crops of wheat have also been raised on sandy loams and black soils of the peninsula region. India is broadly divided into 5 wheat zones based on agro-climatic conditions 1. **The North-Western Plains Zone**: This is the most important zone and comprises the plains of the States of Punjab, Haryana, Jammu, Rajasthan and western Uttar Pradesh. The wheat here is planted in late October - November and the harvesting usually begins by middle of April. 2. **The North Eastern Plains Zone**: This zone consists of eastern Uttar Pradesh, Bihar, West Bengal, Assam, Odisha, Manipur, Tripura, Meghalaya, Nagaland, Mizoram, Arunachal Pradesh and Sikkim. Since rice is harvested later in this area, wheat can be sown only in late November or early December. Harvesting is done by March - April. 3. **The Central Zone**: This zone consists of Madhya Pradesh, Gujarat, southeastern Rajasthan and the Bundelkhand area of Uttar Pradesh. Almost 75 per cent of the wheat cultivated here depends on rain for irrigation. The best quality Durum wheat is produced in this zone. 4. **The Peninsular Zone**: The peninsular zone consists of the southern States of Maharashtra, Andhra Pradesh, Karnataka, and Tamil Nadu. Sowing is usually completed by early November and harvesting begins in the second half of February. Wheat is produced the earliest in this zone. 5. **The Northern Hill Zone**: This zone includes the hilly areas of Kashmir, Himachal Pradesh, Uttar Pradesh, West Bengal, Assam and Sikkim. Wheat is sown in October and harvested in May-June. The crop remains dormant in the cold months of November to March and starts growing as the temperature rises in April. For good and uniform germination, the wheat crop requires a well pulverised but compact seedbed. The wheat seeds should be healthy and have a good germination capacity. Make sure the seeds for sowing don't contain any seeds of weeds. Experts suggest the use of certified seeds obtained from a reliable seed agency. Seeds need to be planted on time to conserve moisture for a good crop.	
Nutrients	• Seed treatment should be done with *Azotobactor* culture @ 200 g/acre. • Fertilizers should be applied on soil test basis. Generally, 60 Kg N, 25 Kg P_2O_5 and 20 Kg K_2O per acre are recommended for wheat. • Apply 1/3 of N and full dose of P & K at the time of sowing.
Weeds	• Hand weeding
Soil and seed borne pathogens, nematodes, resting stages of insects	**Cultural control:** • **For loose smut:** The seed is soaked in cold water during hot summer months in the morning hours and kept in hot sun from 8 am -12 noon and then dried in the afternoon. This kills the fungus inside the seed and provides a good disease measure without use of fungicides. However, precautions to be taken so that there is no damage to the viability of seeds. • Use resistant/tolarent varieties.

	• **For seed gal nematode** use certified seed of resistance varieties only and clean seed by sieving or by using 2% salt water floatation to remove galls and prevent ear cockle diseases. • Use the tolerant varieties such as C-306 for brown mite. • Dry cleaning: Galls can be separated by coarse sieve from the healthy seeds. • Winnowing or fanning • Brine floatation: 2% salt solution in place of plain water removes almost 100 % galls. **Biological control:** • *Pseudomonas fluorescens* 1.75% WP (in house isolated Strain Accession No. MTCC 5176) @ 5 g/Kg seed (seed treatment) • *Pseudomonas fluorescens* 1.75% WP (in house isolated Strain Accession No. MTCC 5176)@ 5 g/l (foliar spray) • Apply neem cake@ 80 Kg/acre. **Chemical control:** **For nematode:** • Carbofuran 3% CG @ 26640 g/acre **For loose smut:** • Benomyl 50 % WP @ 2g/Kg seeds or carbendazim 50% WP @ 2 g/ Kg seeds or carboxin 75% WP @ 2 -2.5 g/Kg seeds or tebuconazole 2% DS @ 0.2 Kg/10 Kg seed or carboxin 37.5% + thiram 37.5% DS @ 3.0 g/Kg **For flag smut:** • Carboxin 75% WP@2 -2.5 g/ Kg seed or tebuconazole 2% DS@0.2 Kg/10 Kg seed **For bunt:** • Carboxin 75% WP@ 2 -2.5 g/ Kg seed **For termite:** • Thiamethoxam 30% FS @ 1.32 Kg/40 Kg seeds or chlorpyrifos 20% EC @ 3 – 4 ml/Kg seed and 0.8-1.2 l/acre as soil application
Termites	**Cultural control:** • Deep ploughing of fields during summer. Three summer ploughings at 10 days interval reduce juvenile population. • Apply well rotten FYM only to discourage termite infestation. • Avoid late sowing of crops. • For termite and shoot fly destroy the crop residues which form the sources of infestation. • Use of crude oil emulsion to destroy the termite colony in the termatorium. **Mechanical control:** • Dismantle termitaria (termite mounds) around field and kill the termite queen. **Biological control:** • Apply neem cake@ 80 Kg/acre. • Entomopathogenic nematodes (EPNs) can be sprayed at the rate of 100 million nematodes per acre in termite infested fields. **Chemical control:** • Same as pre sowing stage

Application of *Trichoderma harzianum/viride* and *Pseudomonas fluorescens* for treatment of seed/seedling/ planting materials in the nurseries and field application (if commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).	
Vegetative stage	
	Common cultural practices: • Collect and destroy crop debris • Provide irrigation at critical stages of the crop • Avoid water logging • Avoid water stress during flowering stage • Judicious use of fertilizers • Enhance parasitic activity by avoiding chemical spray, when 1-2 larval parasitoids are observed • Field sanitation **Common mechanical practices:** • Collection and destruction of eggs, and larvae • Collect and destroy disease infected and insect infested plant parts • Use yellow pan water/sticky traps for aphids and blue sticky traps for thrips @ 4-5 traps/acre. • Use light trap @ 1/acre and operate between 6 pm and 10 pm • Install pheromone traps @ 4-5/acre for monitoring adult moths activity (replace the lures with fresh lures after every 2-3 weeks) • Erect bird perches @ 20/acre for encouraging predatory birds such as King crow, common mynah etc. • Set up bonfire during evening hours at 7-8 pm **Common biological practices:** • Conserve natural enemies through ecological engineering • Augmentative release of natural enemies.
Nutrients	• Apply 1/3 of N as top dressing with 1st irrigation and remaining 1/3rd N with second irrigation.
Weeds	**Chemical control:** • To control wide range of broad leaf weed, post emergence application of metsulfuron methyl 20% WP @ 20 g in 500-600 + surfactant (iso-octyl phenoxyl-poloxethanol 12.5%) @ 200 ml/acre or 2,4-D dimethyl amine salt 58% SL @ 0.344-0.416 l in 200-240 l of water / acre or 2,4-D sodium salt technical @ 0.25-0.40 Kg in 200 l of water / acre • To control wild oat, *Poa anua*, *Phalaris* and many broad leaf weeds apply isoproturon 50% WP @ 0.8 Kg in 300 l of water / acre as pre and post emergence spray.
Aphid	• Follow common cultural, mechanical and biological practices (See page no. 17). **Cultural control:** • Regular field monitoring for pest & defender population. • Grow 4 rows of maize/sorghum/bajra around the field as a gourd guard/barrier crop. **Chemical control:** • Quinalphos 25% EC @ 400 ml in 200-400 l of water/acre or thiamethoxam 25% WG @ 20 g in 200 l of water/acre.
Pink borer (leaf eating caterpillar)	• Follow common cultural, mechanical and biological practices (See page no. 17). **Cultural control:** • Bird perches @ 10/ acre should be erected for facilitating field visits of predatory birds. **Chemical control:** • Dichlorvos 76% EC@ 112.8-150.4 ml in 200-400 l of water/acre

Shoot fly	• Follow common cultural, mechanical and biological practices (See page no. 17). **Cultural control:** • Regular field monitoring for pest & defender population. • Plant barrier crops such as maize, sorghum or millet around the field to reduce pest population. • For monitoring fish meal traps can be used. **Chemical control:** • Cypermethrin 10% EC@ 220 ml in 200-320 l of water/acre or phorate 10% CG @ 7500 g/acre
Brown mite	• Follow common cultural, mechanical and biological practices (See page no. 17). **Biological control:** • Use neem oil (2%) or NSKE (5%) **Chemical control:** • Quinalphos 25% EC @ 640 ml in 200-400 l of water/acre
Army worm / Cutworm	• Follow common cultural, mechanical and biological practices (See page no. 17). **Cultural control:** • Regular field monitoring of pest & defender population. **Mechanical control:** • Pheromone traps @ 4-5/acre can be installed for monitoring cutworm activity. Replace the lures with fresh lures after every 20-25 day interval. ETL for fruit borer is 8 –10 moths /day/trap. • Bird perches @ 10/ acre should be erected for facilitating field visits of predatory birds. **Chemical control:** • Carbaryl 50% WP @ 800 g in 200 l of water/acre or trichlorfon 5% GR @ 300 g/acre or trichlorfon 5% D @ 300 g/acre or trichlorfon 50% EC@ 300 ml/acre or dichlorvos 76% EC @ 112.8-150.4 ml in 200-400 l of water/acre
Ghujhia weevil, wheat bug, wheat thrips****	• Follow common cultural, mechanical and biological practices (See page no. 17).
Black, brown and yellow rust	• For resistant / tolerant varieties consult ICAR Institute / KVK's / SAU's. • Follow common cultural, mechanical and biological practices (See page no. 17). **Cultural control:** • Follow mixed cropping and crop rotation • Avoid excess application of "N". **Chemical control:** • Propiconazole 25% EC @ 200 ml in 200 l of water/acre or tebuconazole 25% EC @ 200 ml in 200 l of water/acre or zineb 75% WP @ 6-8 Kg in 300-400 l of water/acre or mancozeb 75% WP @ 6-8 Kg in 300 l of water/acre
Powdery mildew	• For resistant / tolerant varieties consult ICAR Institute / KVK's / SAU's. **Cultural control:** • The disease severity is more in some pockets and most of the present varieties do not have adequate resistance. **Chemical control:** • Triadimefon 25% WP @ 200 g in 300 l of water/acre

Foliar blight, seedling blight, leaf spot, leaf blight**	• For resistant / tolerant varieties consult ICAR Institute / KVK's / SAU's. **Cultural control:** • Only use certified seed /resistance varieties timely sowing seed & crop rotation. • Plantation of tall plant crop as a barrier for air borne diseases **Chemical control:** • Zineb 75% WP @ 6-8 Kg in 300-400 l of water/acre or mancozeb 75% WP @ 6-8 Kg in 300 l of water/acre
Ear head stage	
Nutrients	• Foliar application of deficient micronutrient should be done as and when the symptoms are observed.
Weeds	• Remove left over weeds to check the weed seed spread.
***Helicoverpa* (American pod borer), armyworm**	• Follow common cultural, mechanical and biological practices (See page no. 17). **Cultural control:** • Growing intercrops such as cowpea, onion, maize, coriander, urdbean in 1:2 ratio • Sow / plant sorghum / maize / pearl millet in 4 rows all around wheat crop as a guard / barrier crop. • Rotate the wheat crop with a non host cereal crop such as cucurbit, or cruciferous vegetable. • Bird perches @ 4-8/ acre should be erected for facilitating field visits of predatory birds. **Mechanical control:** • Pheromone traps @ 4-5/acre can be installed for monitoring borer activity. Replace the lures with fresh lures after every 20-25 day interval. ETL for borer is 8 to10 moths /day/trap. **Biological control:** • Inundatively release of *T. pretiosum* @ 0.4 lakh/acre 4-5 times from flower initiation stage at weekly intervals. **Chemical control:** • Quinalphos 25% EC @ 640 ml in 200-400 l of water/acre. • For army worm same as in vegetative stage.
Kernal bunt	• For resistant / tolerant varieties consult ICAR Institute / KVK's / SAU's. **Cultural control:** • Low-lying areas of the field accumulate water and are more prone to kernal bunt. Effective land leveling and drainage can reduce disease incidence. • Decrease seed rate during sowing. • Increase row spacing during sowing. • Delayed sowing. • Avoiding irrigation during the period of awn emergence and end of flowering may hinder disease development. • Avoid lodging by using balance dose of Nitrogen and Potash. • Plastic mulching or solarization reduces the chance of teliospore germination. • Burn the stubble after harvesting. • Crop rotation with non-host crop. **Chemical control:** • Propiconazole 25% EC @ 200 ml in 300 l of water/acre or bitertanol 25% WP @ 896 g in 300 l of water/acre or thiram 75% WS @ 10-12 g in 400 ml of water/acre

Loose smut, hill bunt and head scab, flag smut	• For resistant / tolerant varieties consult ICAR Institute / KVK's / SAU's. **Cultural control:** • **For loose smut:** In the standing crop, the plants showing yellowing of the boot leaf tip normally are the ones which will give smutted ear heads on emergence. Uproot such plants before ear emergence to reduce the infestation of healthy seeds at later stage. • Use disease free seeds in the healthy field. For seed production, disease free field/areas to be identified for having crop without considerable inoculum load. **Chemical control:** **For flag smut:** • Carboxin 75% WP @ 2 -2.5 g/ Kg seed or tebuconazole 2% DS @ 0.2 Kg/10 Kg seed or thiram 75% WS @ 10-12 g in 400 ml of water/acre **For bunt:** • Carboxin 75% WP@ 2 -2.5 g/Kg seed or triadimefon 25% WP @ 200 g in 300 l of water/ acre **For loose smut:** • Same as pre-sowing stage

Note: The pesticides dosages and spray fluid volumes are based on high volume sprayer. The recommended pesticides are as per CIBRC list updated on 31.10.2014.

**Pests of regional significance

VI. RODENT PEST MANAGEMENT

- ❖ Disturb and destroy the habitat (burrows) of the rodents by practicing clean cultivation
- ❖ Minimize the alternate food sources and secured habitation by removing the weeds and crop residues in/ around the fields
- ❖ Practice burrow smoking using paddy straw or other natural smoking materials in 'ANGRAU/ NIPHM burrow fumigator' for 2-3 minutes for each burrow.
- ❖ Encourage the establishment of natural predator like barn owls by establishing barn owl perches/ wooden boxes in and around the crop fields.
- ❖ Practice burrow smoking as individual and community, preferably on a campaign approach.
- ❖ Organize community rodent control campaigns using rodenticide poison baits through packeting and pocketing, before crop entering into reproductive phase (i.e. before P.I.). The optimum time for organizing mass rodent control campaigns will be 6 weeks after transplanting.

Action Plan for rodent pest management using rodenticide poison baits:

- ❖ Practice poison baiting with anticoagulant, bromadiolone @0.005% (96 parts of broken rice + 2 parts of edible oil + 2 parts of 0.25% CB bromadiolone) on community approach.

  DAY – 1: Close all the burrows in the fields, field bunds, canal bunds and surrounding barren lands etc.

  DAY – 2: Count the re-opened burrows and treat the burrows with Bromadiolone chemical bait packets @ 10 g/burrow.

  DAY – 10: Observe the re-opened burrows and repeat baiting

- ❖ In cases of high level of infestation (>20 live burrows/acre) practice poison baiting with zinc phosphide @ 2.0% on community approach. PRACTICE PRE-BAITING TO AVOID BAIT SHYNESS

DAY – 1: Close all the burrows in the fields, field bunds, canal bunds and surrounding barren lands etc.

DAY – 2: Count the re-opened burrows and practice pre-baiting @ 20 g/burrow (98 parts of broken rice + 2 parts of edible oil)

DAY – 4: Observe the re-opened burrows and treat the burrow with zinc phosphide poison bait (96 parts of broken rice + 2 parts of edible oil + 2 parts of Zinc phosphide) @ 10g/ live burrow. Collect the dead rats, if found any outside and bury them.

If any residual population is found, practice anti-coagulant poison baiting.

❖ Non chemical poison bait: Boil handful of wheat with pieces of bark of *Gliricidia sepium* and allow them to ferment overnight. Use the wheat grains as rat poison. Wheat grains may be wrapped in cloth dipped in the container for boiling. For a few minutes & may be taken out the next day.

VII. 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.

VIII. NUTRIENT DEFICIENCIES

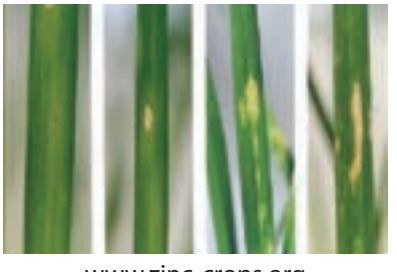
1. Nitrogen (N): Plants are pale green to yellow with chlorosis beginning on lower leaves and progressing upwards as the deficiency intensifies; plants have spindly stems and growth is slow.

2. Phosphorus (P): Phosphorus deficient plants may remain darker green than normal plants and develop purple discoloration first on the underside and later throughout. Leaf tips may die back when P deficiency is severe. Plants grow slowly, stems are thin and shortened and maturity is delayed. P deficient plants also exhibit poor tillering.

3. Potassium (K): Potassium deficiency is initially manifested as chlorosis on the older leaves and progresses upwards as the deficiency intensifies. The leaves eventually become streaked and take on a scorched appearance along the leaf margins. Chlorotic areas may develop throughout the leaf. Deficiency symptoms can occur in young leaves of some fast-maturing high-yielding varieties. Stems of deficient plants are weak and tend to lodge.

4. Zinc (Zn):

Zinc deficiency in wheat appears as intervenial chlorosis on the most recently developed leaves; plants are stunted and produce few tillers; if the deficiency is severe the leaves may turn white and die. The most characteristic reactions of wheat plants to zinc deficiency are reductions in plant height and leaf size. These symptoms are followed by the development of whitish-brown necrotic spots on middle-aged leaves. As the severity of zinc deficiency intensifies, the necrotic spots spread on leaves, and the middle parts of the leaves are often collapsed, showing a "scorched" appearance.



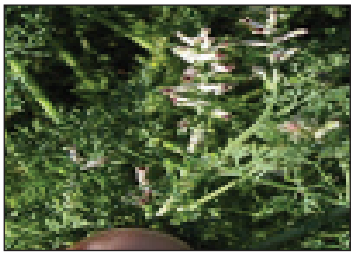
www.zinc-crops.org

IX. COMMON WEEDS

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

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

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



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

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

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

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

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

9. Jangali Palak: *Rumex dentatus* L. (Polygonaceae)

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

11. Thistle weed: *Cirsium arvense* (L.) Scop. (Asteraceae)

12. Wild oat: *Avena ludoviciana* (L.) Nees. (Poaceae)

13. Canary grass: *Phalaris minor* Retz. (Poaceae)

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

15. Rye grass: *Lolium* spp. (Poaceae)

Source: http://www.feedipedia.org/node/625 http://keys.lucidcentral.org/keys/v3/eafrinet/weeds/key/weeds/Media/Html/images/Lolium_temulentum_(Darnel_Ryegrass)Naidu, (2012)
1. https://encrypted- tbn1.gstatic.com/images?q=tbn: ANd9GcS G4MuoFs 9OR2DVI1k Yn4zGBww3 0cu TCuflmyN7cq49wTYFIFJTjg http://www.feedipedia.org/node/625

X. DESCRIPTION OF INSECT, MITE AND NEMATODE PESTS

1) Termite:

Biology:

Egg: Eggs are dull, kidney shaped and hatches in 30-90 days.

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

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

Life cycle:

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

Damage symptoms:

- Termites damage the crop soon after sowing and sometimes near maturity. They feed on roots, stem of growing plants, even dead tissues of plant feeding on cellulose. The damaged plants dry up completely and are easily pulled out. The plants damaged at later stages give rise to white ears. Infestation is heavy under unirrigated conditions and in the fields where un-decomposed FYM is applied before sowing.

Damage symptom

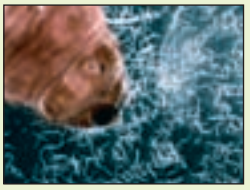
https://www.google.co.in/search?q=wheat+damage+by+termites&espv=210&es_sm=93&source=lnms&tbm=is

Biological control of termites through EPNs:

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

Mass multiplication of EPNs

Emergence of EPNs



Termite killed by EPNs

*For management refer to page numbers 14-16.

2) American pod borer:

Biology: It is a polyphagous, infesting gram, lablab, safflower, chillies, groundnut, tobacco, cotton etc.

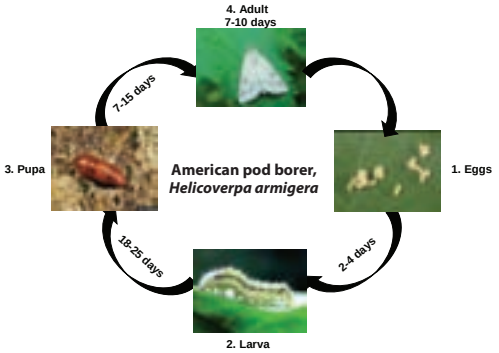
Egg: The spherical, yellowish eggs are laid singly on tender parts and buds of plants. The egg period lasts for 2-4 days.

Larva: Caterpillars are of varying colour, initially brown and later turn greenish with darker broken lines along the side of the body.

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

Adult: Moth is stout, medium sized with brownish/greyish forewings with a dark cross band near outer margin and dark spots near costal margins, with a wing expanse of 3.7cm.

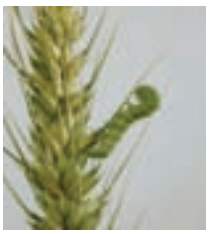
Life cycle:



1. http://www7.inra.fr/hyppz/RAVAGEUR/6helarm.htm
2. http://www.infonet-biovision.org/default/ct/120/crops
3. http://www.invasive.org/browse/subinfo.cfm?sub=9408
4. http://en.wikipedia.org/wiki/Helicoverpa_armigera

Damage symptoms:

- Young larva feeds on the leaves for some time and then attacks earheads. Internal tissues are eaten severely and completely hollowed out. While feeding, the caterpillar thrust its head inside leaving the rest of the body outside.
- Fed leaves, awns, and earheads.



Damage symptom

Natural enemies of American pod borer:

Parasitoids: *Tricogramma chilonis*, *Tetrastichus* spp., *Chelonus* spp., *Telenomus* spp. (egg), *Bracon* spp., *Ichneumon promissorius*, *Netelia* product, *Carcelia* spp., *Campoletis chlorideae* (larval), *Lissopimpla excels*, (pupal) etc.

Predators: Coccinellids, King crow, green lacewing, dragonfly, spider, robber fly, reduviid, praying mantis, red ants etc.

*For management refer to page number 19.

3) Aphid:

Biology:

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

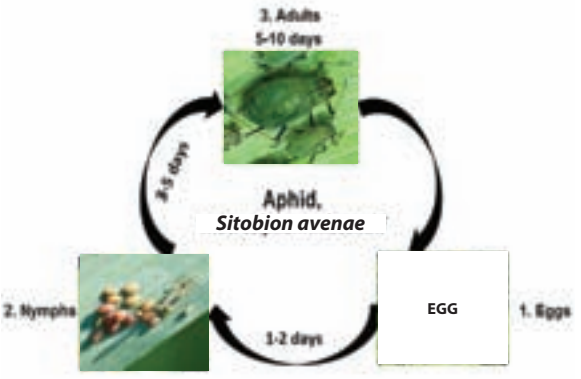
Nymph: There are four nymphal stages (instars). The general appearance of each stage is similar except for increase in size during subsequent instars. The first, second, third and fourth nymphal stages last 1-2, 2, 2, and 3 days respectively. The nymphs and the females look alike, except that the latter are larger. It breeds at a fast rate during cold weather and reaches the height of its population in February-March when the ears are ripening and the nymphal period ranges from 5-7 days.

Adult: Both apterous (wingless) and alatae (winged) forms pass through 4-5 nymphal instars in their development. Aphids are small, soft-bodied, pearl-shaped insects that have a pair of cornicles (wax-secreting tubes) projecting out from the fifth or sixth abdominal segment.

Both the forms mate within a day or two after the final moult and start reproducing young ones. The apterous forms produce significantly more number of young ones than alatae but their life-period is shorter than that of alatae.

In the field, generally viviparous apterous forms are observed in large number.

Life cycle:



Damage symptoms:

- Like other aphids, the nymphs and adults suck the sap from plants, particularly from their ears. They appear on young leaves or ears in large numbers during the cold and cloudy weather.
- The damage is particularly severe in years of cloudy weather. A heavily manured, well-irrigated and succulent crop will harbour the pest for a longer period and suffer greater damage.

1. **2.**

Damage symptoms

1,2: https://www.google.co.in/search?q=damage+of+wheat+by+aphids&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=mYENU53CA8Op

Natural enemies of aphid:

Parasitoids: *Aphidius* spp., *Aphelinus* spp. etc.

Predators: Syrphid fly, lacewing, minute pirate bug, damsel bug, ladybird beetle, predatory thrips, rove beetle etc.

*For management refer to page number 17.

4) Brown mite:

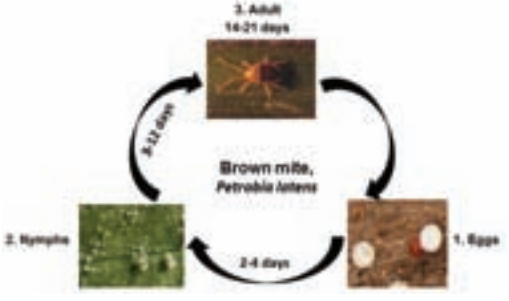
Biology:

Egg: Eggs are hyaline, globular in shape and laid in mass. Eggs are generally laid beneath clods and are either active i.e. red in colour and not visible to the naked eye or dormant i.e. white eggs. Clearly visible on the underside of clods

Nymph: Yellowish in colour

Adult: The mites are very small measuring about 0.5 mm in length, metallic brown to black with pale yellow legs and their forelegs are distinctively longer than the other three pair of legs.

Life cycle:



Damage symptoms:

- They feed on leaves by sucking sap by inserting two needle like stylets into the leaf there by withdrawing nutrients from the plants.
- Affected leaves become whitish and under severe conditions become reddish brown and bronzy
- Leaves wither and dry

1,2,3: https://www.google.co.in/search?q=Petrobia+lateen&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=dYINU6btCMK-rgetp

Damage symptom

Natural enemies of brown mite:

Predators: *Oligota* spp., *Anthrocnodax occidentalis*, *Feltiella minuta*, green lacewings (*Mallada basalis* and *Chrysoperla zastrowii sillemi*), lady bugs, predatory mite (*Amblyseius alstoniae, Phytoseiulus persimilis)* and pedatory coccinellid beetle (*Stethorus punctillum*) etc.

*For management refer to page number 18

5) Army worm/cut worm:

Biology:

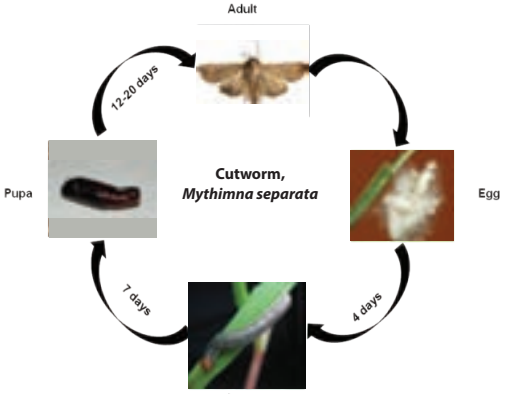
Egg: Eggs are laid in cluster, consisting of approximately 500 eggs

Larva: The young caterpillars hatch from the eggs in 4-5 days. After hatching the caterpillars start feeding on the leaves of the seedlings. The caterpillars are fully grown in about 15 days and measures 3-5 cm in length. Larvae usually have 6 instars (very seldom 7 instars), reaching 40 mm in length at older age. Larva with 2 wide black-brown and one intermediate light dorsal stripe, with black-brown lateral stripe along spiracle line; spiracles brown with black rim.

Pupa: Larvae pupate in soil at depths of 2 cm, under lumps of ground or under tussocks. Pupal phase lasts 13-21 days. Pupae are yellowish-brown, shiny. Body length is about 15-20 mm. It has a cremaster on last segment bearing 2 bent and crossed spines and 4 thin hooked setae.

Adult: Adult is brownish white in colour. Forewings are grayish-yellow, with dark-gray or reddish-yellow tint. Round and reniform spots are light or yellowish with indistinct edges; reniform spot with white point at lower margin. External wing margin blackened obliquely from top backward, with dark stroke and with a row of dark points. Hind wings are gray, with dark external margin. Antennae are thread-like.

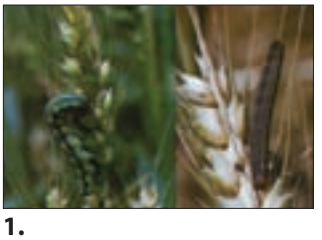
Life cycle:



http://en.wikipedia.org/wiki/Agrotis_ipsilon

Damage symptoms:

- The primary symptom is defoliation of the plant. Larvae feed on leaves, chewing from the edges to the midrib, or on the heads of cereal plants.
- Heavy infestations can be very destructive; larvae may climb the plant and sever the neck just below the head. Some species may be found feeding at the soil surface, others underground feeding on roots, and still others feeding inside the stem.
- The armyworm feeds during dawn and dusk period as it is shy of sun light.



1.

2.

Damage symptoms

1,2: https://www.google.co.in/search?q=Mythimna+separata&espv=210&es_sm=93&tbm=isch&tbo=u&source=univ&sa=X&ei=rIMNU_qRN4aCrgfujQE&ved=0CCkQsAQ&biw=1280&bih=699#facrc

Natural enemies of armyworm / cutworm: Parasitoids and predators are same as in American pod borer

*For management refer to page number 19

6) Shoot fly:

Biology:

Egg: The eggs hatch in 1 - 3 days and the maggots which are yellow in colour migrate to the dorsal surface of the leaf, enter the space between the leaf sheath and the axis and make a clean cut at the base of the leaf. The growing point of the plant dies and decays on which the maggots feed.

Larva: The larval period lasts for 6 - 10 days.

Pupa: Pupation takes place inside the stem itself and the adults emerge in about a week.

Adult: The adult is a small dark fly. It deposits whitish eggs singly on the central surface of the leaves. Each female fly is capable of laying 30 eggs during its life time. Life cycle occupies 17 - 20 days.

Damage symptoms:

- The maggots bore into the shoot of young plants, a week after germination to about one month and as a result the central shoot dries up resulting in 'dead hearts'. If it is a little later the mother plant may produce side tillers. But the tillers also may be attacked. The infestation often goes as high as 60%.

Larva

Adult

https://www.google.co.in/search?q=Atherigona+ata&espv=210&es_sm=93&tbm=isch&tb

*For management refer to page number 18.

7) Wheat thrips:

Biology:

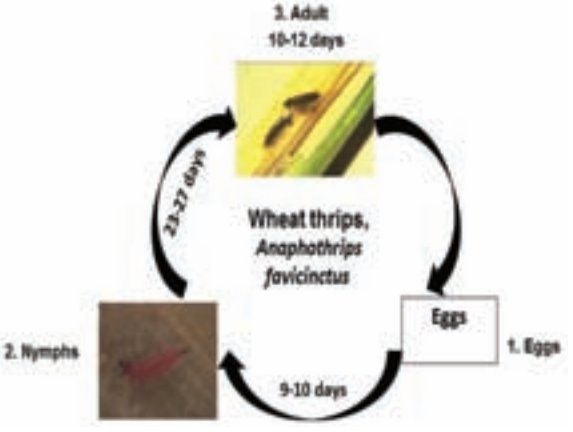
Egg: Embryonic development lasts 9-10 days.

Nymph: There are 2 instars; nymphal development lasts 23-27 days. The young nymph feeds on the lemmae and then penetrates the flower which may become sterile due to the nymph's feeding damage. When the grain has reached the milky-ripe stage, the nymph moves into the furrow of the grain and attacks the pericarp. Once it has completed its development, the nymph vacates the lemmae and falls to the ground.

Pupa: There are 3 stages, 1 'pre-pupal' and 2 'pupal', lasting only a few days.

Adult: Adults are very small, brown or black insects with a tapering, segmented abdomen, elongated and fast moving measuring 2 mm in length with four narrow fringed wings and live for about 10-12days.

Life cycle:



Damage symptoms:

- They are usually infecting the sheath of the flag leaf, feeding on the stem. However, leaves, stems, and heads may be attacked. Adults and nymphs both can cause damage and, if present in large numbers, may cause the tissue to form silver on which they are feeding.

1. **2.**

Damage symptoms

Natural enemies of wheat thrips:

Parasitoid: *Thripobius semiluteus*

Predators: *Franklinothrips,* predatory mite, hover fly etc.

*For management refer to page number 18.

1. http://www7.inra.fr/hyppz/IMAGES/7032313.jp
2. https://www.google.co.in/search?q=wheat+thrips&espv=210&es_sm=93&tbm=isch&tbo=u&source=univ&sa=X&ei=LqkeU_nDL4HVrQeso4DIDg&ved=0C

8) Pink stem borer:

Biology:

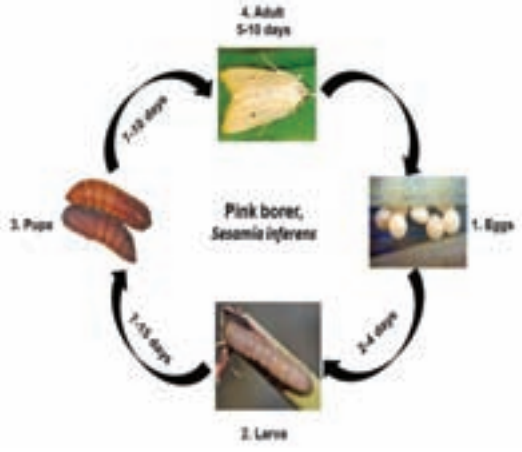
Egg: Round pearl like yellowish eggs ranging 80-300 are layed in 2-3 longitudinal rows usually within the sheaths of bottom leaves of young plant of two to three weeks old. As the time for hatching approaches, eggs become brown or shy grey.

Larva: Newly hatched larvae remain in group behind the leaf sheath and begin chewing on the stem and epidermal layer of the sheath. Full grown larvae are stout, smooth about 25 to 30 mm in length purplish pink on the dorsal side and white on ventral side.

Pupa: Pupa is dark brown in colour.

Adult: The adult moth is straw-coloured with white wings. Life cycle is completed in 6-7 weeks with 4-5 generations in a year.

Life cycle:



Damage symptoms:

- Severe damage causes the stem to break. Severely infected plants due to stunting may appear to have some times the cob and tassel at one place. Whorl feeding of larvae results in rows of oblong holes in unfolding leaves unlike round shot holes produced by *Chilo partellus.*
- Later they bore into central shoot resulting in the drying up of the growing point and formation of "dead heart" in young plant as a result of larval feeding sometimes the bottom internodes show circular ring like cuts. At ear head stage "white ears" are produced.

1,2,3: http://www.nbaii.res.in/insectpests/Sesamia-inferens.php;3. http://www.chemtica.com/site/?p=3065

Courtesy: Dr. Beant Singh
Damage symptoms

Natural enemies of pink borer:

Parasitoids: *Apanteles, Tetrastichus, Telenomus, Trichogramma japonicum* , *T. chilonis, Bracon* sp etc.

Predators: Spiders, drynids, mirid bugs, damselflies, dragonflies, meadow grasshoppers, staphylinid beetles, carabids, coccinellids etc.

*For management refer to page number 17.

9) Ghujhia weevil:

Biology:

Eggs: Insect mate frequently and lay 6-76 eggs in 5-11 installments in the soil under clods or in crevices in the ground. The egg period is 6-7 weeks.

Larvae: Young grubs enter the soil. Grub period is 10-18 days.

Pupae: Larvae pupate in earthen chambers at a depth of 15-60 cm. The pupal stage lasts 7-9 weeks.

Adults: Weevils are earthen grey and measure about 6.8 mm in length and 2.4 mm in width. Forewings are oblong and hindwings are more or less triangular, but they cannot fly. The pest is active from June to December and undergoes larval or pupal diapause during rest of the year in the soil.

Adults

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

Damage symptoms:

- Only adults feed on leaves and tender shoots of the host plants. They cut the germinating seedlings at the ground level. Often the crop is resown. The damage is particularly serious during October-November when the *rabi* crops are germinating.

*For management refer to page number 18.

Damage symptoms

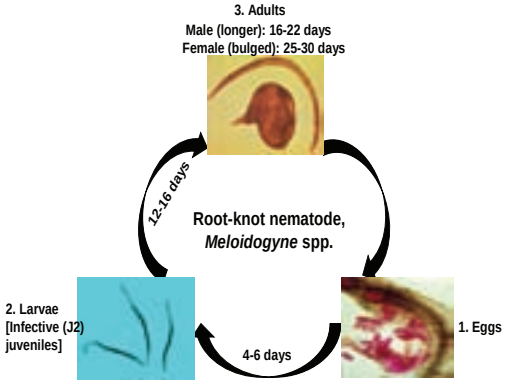
10) Root-knot nematode:

Biology:

- Most species of plant parasitic nematodes have a relatively simple life cycle consisting of the egg, four larval stages and the adult male and female.
- Development of the first stage larvae occur within the egg where the first molt occurs. Second stage larvae hatch from eggs to find and infect plant roots or in some cases foliar tissues.
- Under suitable environmental conditions, the eggs hatch and new larvae emerge to complete the life cycle within 4 to 8 weeks depending on temperature.

- Nematode development is generally most rapid within an optimal soil temperature range of 70 to 80°F.

Life cycle:



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

Damage symptoms:

- Infected plants in patches in the field
- Formation of galls on host root system is the primary symptom
- Roots branch profusely starting from the gall tissue causing a '**beard root**' symptom
- Infected roots become knobby and knotty
- In severely infected plants the root system is reduced and the rootlets are almost completely absent. The roots are seriously hampered in their function of uptake and transport of water and nutrients
- Plants wilt during the hot part of day, especially under dry conditions and are often stunted
- Nematode infection predisposes plants to fungal and bacterial root pathogens

https://www.google.co.in/search?q=damage+symptoms+of+wheat+by+nematode&espv=210&es_sm=122&source=lnms&tbm=isch&sa=X&ei=xs8BU9DHGoOJ

Damage symptom

Survival and spread:

Primary: Egg masses in infected plant debris and soil or collateral and other hosts like Solonaceous, Malvaceous and Leguminaceous plants act as sources of inoculum.

Secondary: Autonomous second stage juveniles that may also be water dispersed.

Favourable conditions: Loamy light soils.

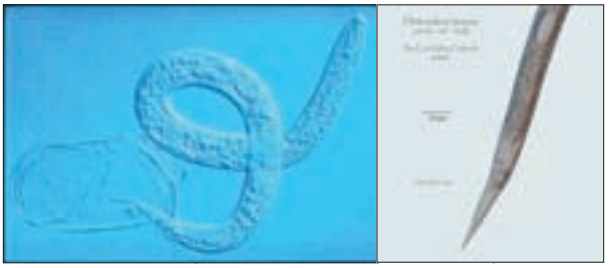
*For management refer to page numbers 14, 15.

11) Molya nematode / cyst nematode:

Biology:

- This nematode passes unfavourable season in the form of cysts, mostly in the soil. A cyst consists of the dead body of a female containing a large number of eggs.
- When the conditions are favourable, eggs hatch within the cysts and the larvae are set free into the soil in the second stage of growth.
- The larvae may invade any underground part of a susceptible plant but most of them enter it at or near the root tips.
- After moving a short distance through the cortex, they assume a position, more or less parallel to the main axis of the root, with the head away from the tip.
- Male has capability to metamorphosis, increase in girth 1/5th of its length. The female does not undergo such metamorphosis, but after the second and third moultings it continues to increase in girth until it becomes ovate. It then undergoes the fourth or final moulting and emerges as a full grown adult.

- After mating, the eggs mature inside the body of the female and it dies, the body being converted into a cyst.

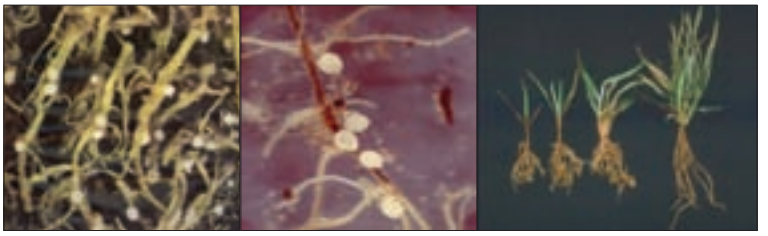


Adults of *Heterodora avenae*

1,2: https://www.google.co.in/search?q=heterodera+avenae&espv=210&es_sm=122&source=lnms&tbm=isch&sa=X&ei=bmg

Damage symptoms:

- Attacked plants remain stunted and give a shriveled unhealthy appearance.
- Presence of nematodes stimulates the formation of branched rootlets.
- The main root remains short or bunchy, bearing small galls. In case of severe infestation, the seedlings may fail to come out of the soil.
- The plants that escape the early damage produce short stalks and ears, yielding a poor harvest.



1. **2.** **3.**

Symptoms

1,2,3: https://www.google.co.in/search?q=heterodera+avenae&espv=210&es_sm=122&source=lnms&tbm=isch&sa=X&ei=bmg

Secondary: Autonomous second stage juveniles that may also be water dispersed.

Favourable conditions: Loamy light soils.

*For management refer to page numbers 14, 15.

11) Wheat-gall nematode:

Biology:

- Seed galls are dispersed along with seed during planting and harvest. In moist soil, seed galls release thousands of larvae.
- Wet weather favors larval movement and the infestation process.
- The nematode invades the crown and basal stem area, finally penetrating floral primordia. There they mature and produce large numbers of eggs.
- Seed galls develop in undifferentiated floral tissues.
- In the developing galls, the larvae mature into males and females, as the case may be. A single gall at this stage may contain 40 females and an equal number of males.
- They mate within the gall and the gravid females lay a large number of eggs. The young larvae on emerging from the eggs develop up to the second stage and then become dormant. They remain in that state in the dry galls till the next sowing season. There is only one generation in a year.

Damage symptoms:

- Basal swelling of stem, crinkling, twisting and diverge leaves & stunted growth and increased tillering
- Diverge nature of spikes and reduce ear head.
- Presence of damaged grain (cockels)

  Tundu : (*A. tritici* + *Rathaybacter tritici*)
- Yellow slimy ooze on ear head.
- At later stage production of blight yellow bacterial mass on the abortive ear. Complete destruction of ear head.

Adults

https://www.google.co.in/search?q=anguina+tritici&espv=210&es_sm=122&source=lnms&tbm=isch&sa=X&ei=bmg

1.

2.

3.

Symptoms

1,2,3: https://www.google.co.in/search?q=disease+anguina+tritici&espv=210&es_sm=122&source=lnms&tbm=isch&sa=X&ei=bmg

Secondary: Autonomous second stage juveniles that may also be water dispersed.

Favourable conditions: Loamy light soils.

*For management refer to page numbers 14, 15.

Natural Enemies of Wheat Insect and Mite Pests

Parasitoids

Egg parasitoid

***1. Trichogramma* sp**

Larval parasitoids

2. *Bracon* sp

3. *Carcelia* sp

4. *Campoletis* sp

Pupal parasitoid

5. *Ichneumon* sp

Nymphal and adult parasitoids

6. *Aphidius* sp

7. *Thripobius semiluteus*

8. *Aphelinus* sp

3. http://72.44.83.99/forum/viewthread.php?thread_id=40633&pid=178398; 4. http://www.nbaii.res.in/Featured%20insects/Campoletis.htm; 5. http://www.organicgardeninfo.com/ichneumon-wasp.html; 6 http://biobee.in/products-and-services/solutions/bio-aphidius/; 7. https://www.google.co.in/search?q=Thripobius+semiluteus&espv=210&es_sm=93&sour; 8 http://australianmuseum.net.au/image/Aphelinus-wasp-stings-aphid-Denis-Crawford/

Predators


1. Lacewing


2. Ladybird beetle


3. Reduviid bug


4. Spider


5. Robber fly


6. Red ant


7. Black drongo


8. Common mynah


9. Big-eyed bug

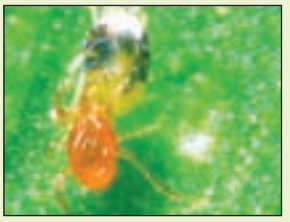

10. Earwig


11. Ground beetle


12. Pentatomid bug


13. Preying mantis


14. Mirid bug


15. Predatory mite


16. Predatory thrips


17. *Oligota* spp.


18. *Orius* spp.


19. Hover fly

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

XI. DESCRIPTION OF DISEASES

1) Powdery mildew:

Disease symptoms:

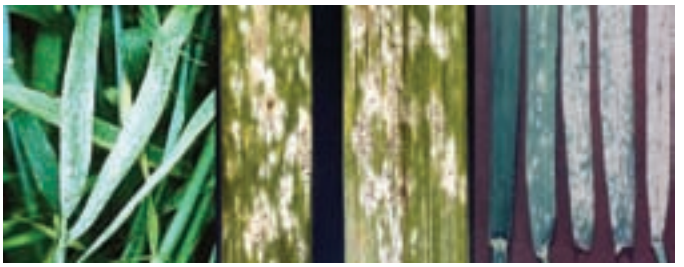
- Powdery mildew can easily be diagnosed by the white, powdery patches that form on the upper surface of leaves and stem.
- Greyish white powdery growth appears on the leaf, sheath, stem and floral parts.
- Powdery growth later become black lesion and cause drying of leaves and other parts.

Survival and spread:

- Fungus remains in high hills during summers in infected plant debris as dormant mycelium and asci. Primary spread is by the asciospores and secondary spread through airborne conidia.

Favourable conditions:

- The disease infects plants during periods of high humidity (not necessarily rain) and cool to moderate temperatures (20-21°C).



1. 2. 3.

Disease symptoms

1,2,3: https://www.google.co.in/search?q=powdery+mildew+of+wheat&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=kVoMU8H7G9HyrQfrwoCADw&ved=0CAkQ_AUoAQ&biw=1280&bih=656#facrc=_&imgdii=_&imgrc=xTEFAJmuRAg

*For management refer to page number 18.

2) Loose smut:

Disease symptoms:

- It is a seed borne disease; infection occurs during loose smut flowering through wind-borne spores.
- The infection remains dormant inside the otherwise healthy looking seed but the plants grown from such seeds bear infected inflorescence.
- At this time, infected heads emerge earlier than normal heads. The entire inflorescence is commonly affected and appears as a mass of olive-black spores, initially covered by a thin gray membrane.
- Once the membrane ruptures, the head appears powdery.

Survival and spread:

- The disease is internally seed borne, where pathogen infects the embryo in the seed.
- Primary infection occurs by sowing infected seeds.

Favourable conditions:

- Infection is favored by cool, humid conditions during flowering period of the host plant.

1. 2. 3.

Disease symptoms

1,2,3: https://www.google.co.in/search?q=loose+smut+of+wheat&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=kVoMU8H7G9HyrQfrwoCADw&ved=0CAkQ_AUoAQ&biw=1280&bih=656#facrc=_&imgdii=_&imgrc=xTEFAJmuRAg

*For management refer to page numbers 15, 16.

3) Brown rust:

Disease symptoms:

- The most common site for symptoms is on upper leaf blades, however, sheaths, glumes and awns may occasionally become infected and exhibit symptoms.
- The pustules are circular or slightly elliptical, smaller than those of stem rust, usually do not coalesce, and contain masses of orange to orange-brown Urediospores.

Survival and spread:

- Pathogen over-summers in low and mid altitudes of Himalayas and Nilgiris. Primary infections develop from wind deposited urediospores in eastern Indo-gangetic plains in middle of January where it multiplies and moves westwards by March
- Alternate host is *Thalictrum* sp.

Favourable conditions:

- Temperatures of 20-25° C with free moisture (rain or dew) cause epidemics. Severe infection causes upto 30 percent yield losses.

1. 2.

Disease symptoms

1,2:https://www.google.co.in/search?q=brown+rust+of+wheat&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=JFwMUWiA4bqrAfN4oCwCA&ved=0CAcQ_AUoAQ&biw=1280&b

*For management refer to page number 18.

4) Stripe rust /yellow rust:

Disease symptoms:

- Mainly occur on leaves than the leaf sheaths and stem. Bright yellow pustules (Uredia) appear on leaves at early stage of crop and pustules are arranged in linear rows as stripes.
- The stripes are yellow to orange yellow. The teliospores are also arranged in long stripes and are dull black in colour.
- The pustules of stripe rust, which, contain yellow to orange-yellow urediospores, usually form narrow stripes on the leaves.
- Pustules also can be found on leaf sheaths, necks, and glumes.

Survival and spread:

- The inoculum survives in the form of uredospores /teliospores in the northern hills during off season on self sown crop or volunteer hosts, which provide an excellent source of inoculums and primary spread occur through uredospores from hills

Favourable conditions:

- Disease is prominent when temperature is 10-20°C and high humidity.

1. 2. 3.

Disease symptoms

1,2,3: https://www.google.co.in/search?q=black+rust+of+wheat&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=uF0MU5fJB8X_rQf6moAw&ved=0CAcQ_AUoAQ&biw=1280&bih=656#facr

*For management refer to page numbers 18.

5) Black rust:

Disease symptoms:

- Symptoms are produced on almost all aerial parts of the wheat plant but are most common on stem, leaf sheaths and upper and lower leaf surfaces.
- Pustules (containing masses of urediospores) are dark reddish brown - occur on both sides of the leaves, on the stems, and on the spikes.
- Pustules are usually separate and scattered, heavy infections -coalesce.
- Prior to pustule formation, "flecks" may appear. Before the spore masses break through the epidermis, the infection sites feel rough to the touch.
- As the spore masses break through, the surface tissues take on a ragged and torn appearance.

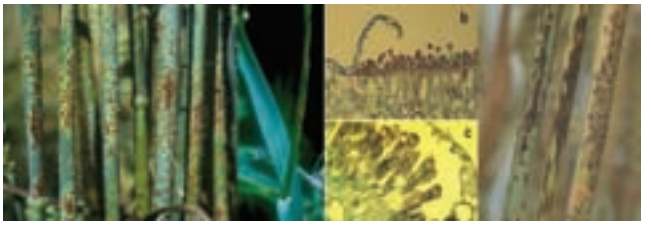
Survival and spread:

- Both survive on stubbles and volunteer crops, alternate host: *Berberis* spp. and primary spread occur through uredospores from southern hills

Favourable conditions:

- Moisture and temperature above 20° C favours the development of disease.

*For management refer to page number 18.



1. 2. 3.

Disease symptoms

https://www.google.co.in/search?q=black+rust+of+wheat&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=uF0MU5fJB8X_rQf6moAw&ved=0CAcQ_AUoAQ&biw=1280&bih=656#facr

6) Flag smut:

Disease symptoms:

- Symptoms can be seen on stem, clum and leaves from late seedling stage to maturity.
- The seedling infection leads to twisting and drooping of leaves followed by withering.
- Grey to grayish black sori occurs on leaf blade and sheath. The sorus contains black powdery mass of spores.

Survival and spread:

- The disease is seed and soil borne. Smut spores are viable for more than 10 years.
- Primary infection occurs by sowing infected seeds or by resting spores present in the soil.

Favourable conditions:

- Temperature of 18-24°C.
- Relative humidity 65% and above.

1. 2.

Disease symptoms

1,2: https://www.google.co.in/search?q=flag+smut+of+wheat&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=5WYMU5S_M8PrrQfBpYGoCw&ved=0CAkQ_AUoAQ&biw=1280&bih=656#

*For management refer to page numbers 15, 16.

7) Hill bunt or stinking smut:

Disease symptoms:

- The fungus attacks seedling of 8-10 days old and become systemic and grows along the tip of shoot.
- At the time of flowering hyphae concentrate in the inflorescence and spikelets and transforming the ovary into smut sorus of dark green color with masses of chlamydospores.
- The diseased plants mature earlier and all the spikelets are affected.

Survival and spread:

- The pathogen survives in seeds and sowing such seeds are source of primary infection.

Favourable conditions:

- Temperature of 18-20°C.
- High soil moisture.

1. **2.**

Disease symptoms

1,2: https://www.google.co.in/search?q=hill+bunt&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=W2YMU82XIYeMrQe3iI DoBw&ved=0CAkQ_AUoAQ&biw=1280&bih=656#facrc=_&i

*For management refer to page number 20.

8) Karnal bunt:

Disease symptoms:

- Symptoms of Karnal bunt are often difficult to distinguish in the field due to the fact that incidence of infected kernels on a given head is low.
- There may be some spreading of the glumes due to sorus production but it is not as extensive as that observed with common bunt.
- Symptoms are most readily detected on seed after harvest.

Survival and spread:

- The disease is seeds borne and sowing of infected seeds is the source of primary infection.

Fabourable conditions:

- Temperature of 18-20°C.
- High soil moisture.

1. **2.** **3.**

Disease symptoms

1,2,3: https://www.google.co.in/search?q=karnal+bunt+of+wheat&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=k2I MU_StOM6ErAey9oD4Cw&ved=0CAcQ_AUoAQ&biw=1280&bih=699#facrc=_&imgdii=

*For management refer to page number 19.

9) *Alternaria* leaf blight:

Disease symptoms:

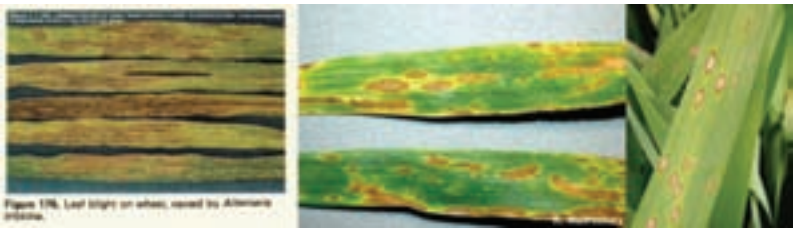
- Reddish brown oval spots appear on young seedlings with bright yellow margin. In severe cases, several spots coalesce to cause drying of leaves.
- It is a complex disease, having association of *A. triticina, B. sorokiniana* and *A. alternata.*

Survival and spread:

- Primary spread is by externally seed-borne and soil borne conidia. Secondary spread by air-borne conidia.

Favourable conditions:

- Temperature of 25°C and high relative humidity.



1. **2.** **3.**

Disease symptoms

1,2,3: https://www.google.co.in/search?q=leaf+blight+of+wheat&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=aGMMU_IJMGNrgeOoIDQCw&ved=0CAkQ_AUoAQ&biw=1280&bih=699#f

*For management refer to page number 19.

10) Foot rot:

Disease symptoms:

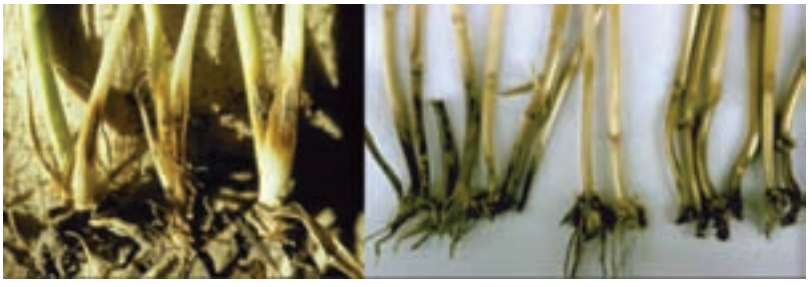
- The disease mainly occurs in seedlings and roots and rootlets become brown in colour.
- Seedlings become pale green and have stunted growth.
- Fungus produces sporangia and zoospores and oospores.

Survival and spread:

- The disease is soil borne, pathogens survives in soil.
- Primary spread occurs through soil and irrigation water.

Favourable conditions:

- Wet weather and high rainfall.



1. **2.**

Disease symptoms

1,2: https://www.google.co.in/search?q=foot+rot+disease+of+wheat&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=YGQMU9yXL4q0rAf1q4

*For management refer to page number 14.

11) Head scab/ *Fusarium* leaf blotch (snow mold):

Disease symptoms:

1. Leaf blotch:

- The blotching caused by this organism becomes evident on leaves at about late-joint to early-boot growth stage.
- Young lesions occur as oval to elliptical, greyish green mottled areas, usually located where the leaf bends. The lesions enlarge rapidly, developing into large, "eyespot" blotches with bleached or light grey centers; the leaves tend to split or shred, beginning at the centers of the lesions.

2. Head Scab:

- The fungus also can cause head scab.
- Symptoms of *Fusarium* head blight include tan or light brown lesions encompassing one or more spikelets. Some diseased spikelets may have a dark brown discoloration at the base and an orange fungal mass along the lower portion of the glume.
- Grain from plants infected by *Fusarium* head blight is often shriveled and has a white chalky appearance.
- Some kernels may have a pink discoloration.
- Infected florets (especially the outer glumes) become slightly darkened and oily in appearance.

Survival and spread:

- The disease is soil borne and inoculum of fungi survive in soil. Spores are produced on crop debris left on or near the soil surface. These spores are transmitted to leaves by the wind or by splashing rain.

Favourable conditions:

- Disease development is favored by cool, moist weather.

1. 2. 3.

Disease symptoms of head scab

1,2,3: https://www.google.co.in/search?q=head+scab+disease+ofwheat&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=lWUMU66TJsanrgfaxYGYBw&v

*For management refer to page number 19.

12) *Helminthosporium* leaf spot/leaf blotch (spot blotch):

Disease symptoms:

- Lesions caused by this disease are elongated to oval in shape and are generally a dark brown color.
- As lesions mature, the centers often turn a light brown to tan color, surrounded by an irregular dark brown rin (21 on leaf g; 22 on spike).
- Primary infections tend to be on the lower leaves, beginning as chlorotic flecks or spots. These infection sites enlarge, turn dark brown, and often coalesce. When the disease is severe, affected leaves or leaf sheaths may die prematurely.

Survival and spread:

- The disease is seed as well as soil borne and inoculums present in the seeds and soil are the source of primary infection.

Favourable conditions:

- Disease is prevalent in more humid and higher rainfall areas.

1. **2.**

Disease symptoms

1,2: https://www.google.co.in/search?q=helminthosporium+leaf+spot+disease+ofwheat&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=lWUMU66TJsanrgfaxYGYBw&v

*For management refer to page number 19.

13) Seedling blight:

Disease symptoms:

- This symptom is seen when ears become infected during the early flowering stages. Later infections may result in infection of the grain but without obvious bleaching of the ears.
- *Fusarium* lesions often begin in the leaf sheath at the stem base where crown roots split the leaf sheath when emerging. This infection can then spread up the leaf sheath causing long dark brown streaks at the stem base
- The ear blight phase of the disease can cause yield loss but is most important as it can result in mycotoxin production in the grain.

Survival and spread:

- The most important source of *Fusarium* for wheat crops is the seed but the fungus can also survive on debris in the soil.

Favourable conditions:

- Relatively high soil moisture and soil temperature are favourable for the infection.

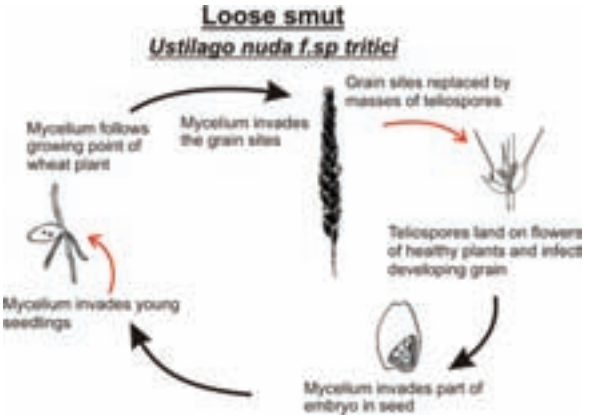
Disease symptoms

*For management refer to page number 19.

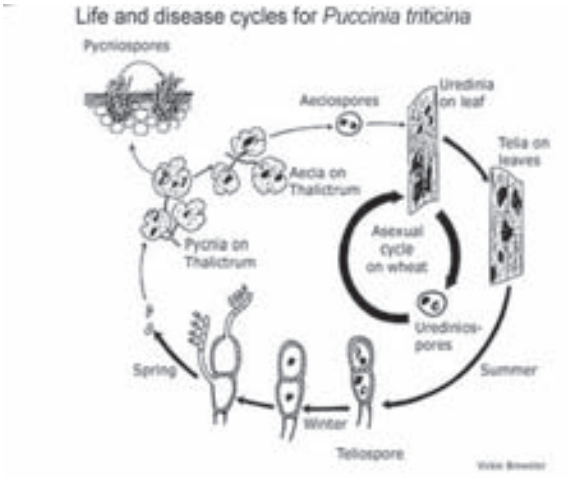
Disease cycles:

1. Powdery mildew:

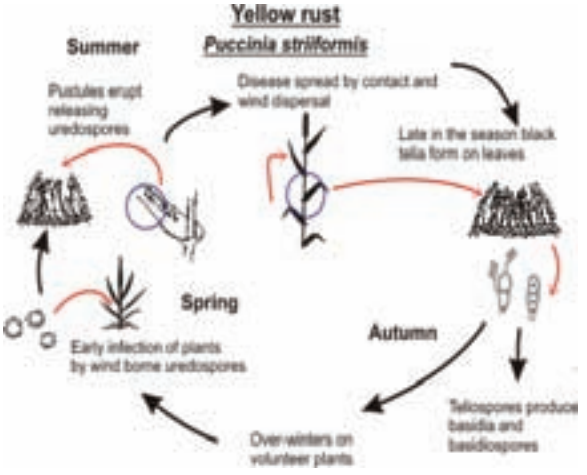
2. Loose smut:



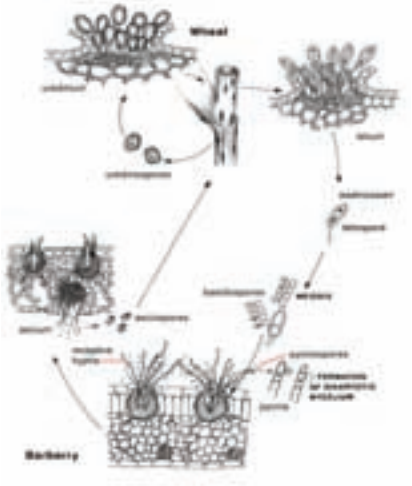
3. Brown rust:



4. Stripe rust /Yellow rust:

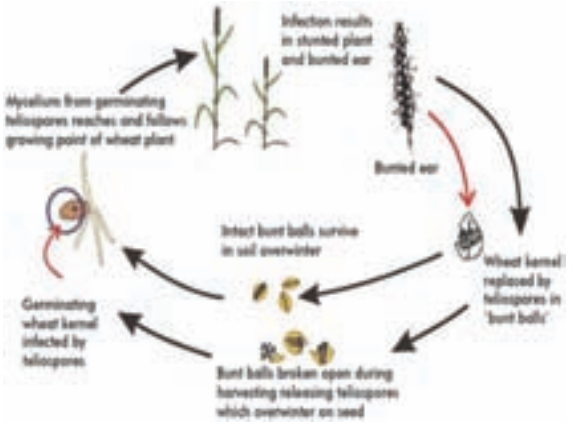


5. Black rust:

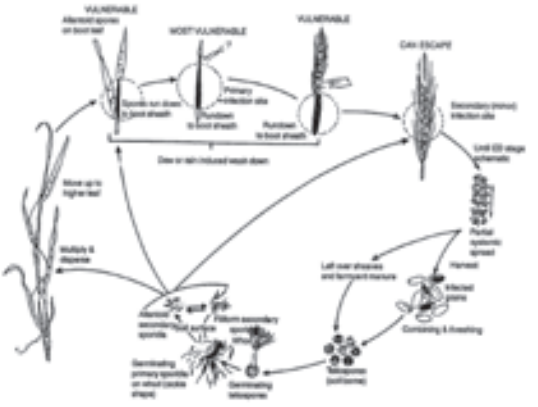


6. Flag smut:

7. Hill bunt or stinking smut:

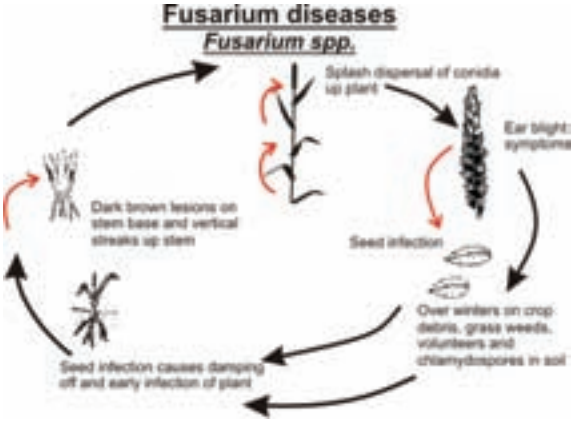


8. Karnal bunt:

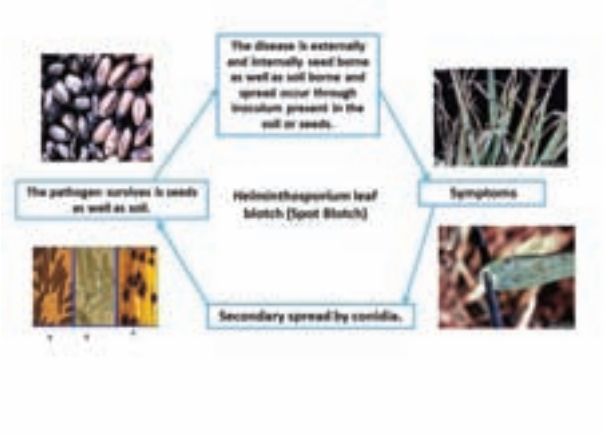


9. *Alternaria* leaf blight:

10. Head scab:



11. *Helminthosporium* leaf blotch/leaf spot (spot blotch):



XII. DESCRIPTION OF RODENT PESTS

1) Lesser bandicoot:

- Distributed throughout India and infests almost all crops.
- Robust rodent (200 to 300 g body weight) with a rounded head and a broad muzzle. Dorsum covered with grey-brownish rough hairs. Tail is naked, shorter than head and body.
- Breeds throughout the season and litter size 6-8 in normal conditions.
- Nocturnal and fossorial. Burrows are characterized by the presence of scooped soil at the entrance and mostly burrow openings are closed with soil.
- It is a major pest in irrigated rice crop
- *Rattus rattus*

*For management refer to page numbers 20, 21.

2) Field mouse:

- Distributed in peninsular India to cutch in Punjab, Uttar Pradesh, Bihar, Odisha and in North east.
- Habitats especially irrigated crop fields.
- Tiny mouse (10g) with slender, short, naked and bicolor tail
- Nocturnal and fossorial.
- Breeds throughout the year
- Individually it is a minor pest but, accumulated losses will be more.

*For management refer to page numbers 20, 21.

3) Soft furred field rat:

- Distributed in Punjab, Uttar Pradesh southwards to western and southern India, also finds in foothills of eastern Himalayas. Found mostly in semi arid areas.
- Small rodent (40-60g) with soft fur, dorsum light grey and bicolored tail equal to the head and body.
- It is associated with *T. indica* and *Musboodga* in northern part and with *Bandicotabengalensis* in southern part.
- Nocturnal and tonsorial with simple burrows.
- Found majorly in rain-fed paddy and rice-sugarcane ecosystem.

*For management refer to page numbers 20, 21.

4) Indian gerbil:

- Distributed throughout the India. Inhabits rain-fed crop fields/ fallow/ wastelands
- Medium sized (100-250 g.) with light brownish dorsum and longer tail than head and body
- Earmarked enlarged eyes, rounded ears and bicolour tail with terminal black tuft.
- Nocturnal and fossorial, with semi circular openings in burrows with zigzag shape and 2 to 4 openings and emergency exits.
- Inhabits dry land crop fields, fallow and wastelands in ruderal, sandy, gravel plains habitats.
- Minor pest in rice fields.

*For management refer to page numbers 20, 21.

Rodent damage at various growth stages

- Wheat is an important cereal crops grown throughout the India. The crop is highly vulnerable to rodent attack from sowing to harvesting stage.
- The average loss due to rodents is 3-5%. They cut the tillers by making a slant cut in vegetative and at earhead stage and feeds on the developing earhead
- The tiller damage by rodents can be diagnosed with 45^{O} angle cut at the base of the tillers at 5-10 cm above the ground level. They make the burrows in both fields bunds and inside the field. The *B. bengalensis* hoard the mature grains (ear-heads) inside their burrows.

XIII. SAFETY MEASURES

A. At the time of harvest:

1. Grain must be harvested in a timely manner before shattering, pre-harvest sprouting, bird damage or weathering, to minimize pre-harvest losses, yet must be dry enough for storage.
2. During threshing, cracking and breaking the grain should be avoided since damaged grain invites greater damage from storage moulds and insects, and reduces marketability.
3. Harvesting at the proper time can minimize shattering or pre-harvest sprout damage, but untimely harvests are often beyond the control of the farmer. Grain that shatters before and during harvest not only yields no return, but may cause additional expense as a volunteer crop.
4. Pre-harvest sprouting reduces seed viability and may result in milled flour with inferior baking properties due to an excess amount of alpha-amylase that causes excessive liquefaction of dough and results in a wet and sticky crumb (Bloksma and Bushuk, 1988).
5. Alternately, grain may be harvested at moisture content higher than is safe for storage, by reaping or swathing the grain and allowing it to dry in windrows, sheaves, stooks, shocks or stacked.
6. Wheat may be reaped or swathed with no loss of yield at any time after the completion of the maximum-weight phase of grainfill, which occurs when the moisture content of the kernel has declined to about 35 percent. These procedures allow wheat to dry more quickly, prevent harvest damage due to the presence of late weed growth and protect the otherwise standing grain from weathering.

B. During post-harvest storage:

Grain deterioration in storage can be minimized or prevented by keeping the grain dry (less than 12.5 percent grain moisture), cool (less than 10°C) and free from insects. Concerted efforts should be made to eliminate grain storage insects from remnant grain left in the storage bin. A small number of resident insects in a bin, or introduced with the grain, can lead to a serious infestation if the grain is warm, or if the grain remains in storage a long time. Alternately, brief, high-temperature treatment of grain has been found to disinfest all stages of *Rhizopertha dominica*, *Sitophilus oryzae, S. granaries, Tribolium castaneum* in wheat (20 minutes at 70°C; Zewar, 1993) and other storage insects (two minutes at 55°C; Lapp *et al*., 1986).

Follow customary pest control techniques such as

- Controlled climate, including cooling and aeration to reduce insect reproductive rate and humidity
- Controlled and airtight storage atmospheres
- Heat treatment (more than 60°C) to disinfest grain
- Physical barriers to protect uninfested grain
- Fumigation with penetrating gases
- Contact insecticides to control flying insects
- Admixing an insecticide or grain protectant

- Trapping to control rodents;
- Resistant crop cultivars;
- Statutory regulations affecting the quarantine or control of storage insects.

Monitoring insect infestations

1. Frequent monitoring of grain storage conditions to identify possible problems associated with storage moisture and temperature and pest infestation is important. Due to their small size, visual assessment of insect infestation in grain stores is often difficult or ineffective, unless large numbers of insects are present.
2. Traps baited with synthetic aggregation pheromones have been developed for detection and monitoring of stored grain insect pests.
3. Low cost, combined with species specificity, makes pheromone-baited traps ideal monitoring tools in developing countries (Campion et al., 1987).
4. Grains should be also kept along with, insecticides (chemical, botanical) to control the infestation of grains from storage pests.

XIV. DO'S AND DON'TS IN IPM

S. No.	Do's	Don'ts
1	Clean the area from all existing vegetation, stumps, roots and stones	Don't select plain area for nursery bed.
2	Prepare bed with 1 meter width, 20 cm height and of required length	Don't make too wide nursery bed
3	Fumigate the beds with 2% formalin (2 l/100 l of water) under polythene cover for 48 hrs (10 l/bed) or do solarization.	Don't sow seed within week of fumigation
4	Grow only recommended varieties.	Do not grow varieties not suitable for the season or the region.
5	Collect ripened bold capsules from disease free mother clumps from 2nd and 3rdharvests for seed extraction.	Don't collect unripened capsules for seed
6	Sow the seed in September preferably	Avoid sowing before September
7	Always treat the seeds with approved biopesticides/ chemicals for the control of seed borne diseases/ pests.	Do not use seeds without seed treatment with biopesticides/chemicals.
8	Cover the bed with mulch material either with pot grass or paddy straw	Don't throw away the topsoil
9	Once sprouting is observed, remove the mulch and cover the bed with thinly sliced mulch materials.	Avoid the contact of mulch materials with the soil by supporting twigs laid across the bed.
10	Keep plant base mulched (5-10 meter thick) except during June-Sept.	Don't use spade for weeding, as it will cause soil erosion
11	Apply proper manure, fertilizer and irrigation	Avoid imbalance fertilizer.
12	Do hand weeding during May, Sept. and Dec./Jan..	Avoid too much shade and too much openness.
13	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.

14	Use NPK fertilizers as per the soil test recommendation.	Avoid imbalanced use of fertilizers.
15	Use micronutrient mixture after sowing based on soil test recommendations.	Do not apply any micronutrient mixture after sowing without soil test recommendations.
16	Conduct weekly AESA in the morning preferably before 9 a.m. Take decision on management practice based on AESA and P: D ratio only.	Do not take any management decision without considering AESA and P: D ratio
17	Install pheromone traps at appropriate period.	Do not store the pheromone lures at normal room temperature (keep them in refrigerator).
18	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.
19	Apply pesticides on need basis	Avoid calendar based application of pesticides and avoid dust formulation
20	Spray pesticides in afternoon only.	Spray should not be done in morning hours especially between 7 to 11 am to protect bees.
21	Spray pesticides thoroughly to treat the undersurface of the leaves, particularly for sucking pests.	Do not spray pesticides only on the upper surface of leaves.
22	Apply short persistent pesticides to avoid pesticide residue in the soil and produce.	Do not apply pesticides during preceding 7 days before harvest.
23	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.

XV. SAFETY PARAMETERS IN PESTICIDE USAGE

S. No.	Pesticide; Classification as per insecticide rules; Colour of toxicity triangle	WHO classification of hazard	Symptoms poisoning	First aid measures; Treatment of poisoning	Waiting period from last application to harvest (days)
Insecticides					
1.	Chlorpyrifos Highly toxic 	Class II - Moderately hazardous	Severe – diarrhoea, pinpoint and non - reactive pupils, respiratory difficulty, pulmonary edema, cyanosis, loss of sphincter control, convulsions, coma and heart block.	**First aid measures:** Atrophine sulphate **Treatment of poisoning:** 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.	Carbofuran Extremely toxic 	Class I b Highly hazardous	Constriction of pupils, salivation, profuse sweating, muscle incordination, nausea, vomiting,diarrhea, epigastric pain, tightness in chest	**Treatment of poisoning:** Atropine injection-1-4 mg. repeat 2 mg when symptoms begin to recur (15-16 min interval) excessive salivation- good sign, more atropine needed	--
3.	Carbaryl Highly toxic 	Class II Moderately hazardous	do	do	

4.	Phorate Extremely toxic	Class Ia- Extremely hazardous	Nausea, vomiting, restlessness, tremor, apprehension, convulsions, coma, respiratory failure and death Mild – anorexia, headache, dizziness, weakness, anxiety, tremors of tongue and eyelids, miosis, impairment of visual acuity. Moderate- nausea, salivation, lacrimation, abdominal cramp, vomiting, sweating, slow pulse, muscular tremors, miosis. Severe – diarrhea, pinpoint and non-reactive pupils, respiratory difficulty, pulmonary edema, cyanosis, loss of sphincter control, convulsions, coma and heart block.	**First aid measures:** Remove the person from the contaminated environment In case of (a) Skin contact Remove all contaminated clothings and immediately wash with lot of water and soap. (b) Eye contamination Wash the eyes with plenty of cool and clean water; (c) Inhalation – Carry the person to the open fresh air, loosen the clothings around neck and chest, and (d) Indigestion – If the victim is fully conscious, induce vomiting by tickling back of the throat. Do not administer milk, alcohol and fatty substances. In case the person is unconscious make sure the breathing passage is kept clear without any obstruction. Victim's head should be little lowered and face should be turned to one side in the lying down position. 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 **Treatment of poisoning**: 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. - 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.	
5.	Quinalphos Highly toxic 	Class II Moderately hazardous	Do	Do	-
6.	Cypermethrin Highly toxic 	Class II Moderately hazardous	Headache, palpitation, nausea, vomiting, flushed face, irritation of nose,throat, eyes and skin, allergic manifestation etc.	**Treatment of poisoning** : No specific antidote. Treatment is essentially symptomatic.	

7.	Dichlorvos Extremely toxic 	Class I b Highly hazardous	Moderate nausea, salivation, lacrimation, abdominal cramp, vomiting, sweating, slow pulse, muscular tremors, miosis	**Treatment of poisoning**: Speed is imperative. Atropine injection-1-4 mg. repeat 2 mg when symptoms begin to recur (15-16 min interval) excessive salivation- good sign, more atropine needed	-
8.	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	**Treatment of poisoning**: No specific antidote. Treatment is essentially symptomatic.	21
Fungicides					
1.	Mancozeb Slightly toxic 	Unlikely produce acute hazard	Headache, palpitation, nausea, vomiting, flushed face, irritation of nose,throat, eyes and skin etc.	**Treatment of poisoning**: No specific antidote. Treatment is essentially symptomatic	

2.	Carbendazim Slightly toxic 	Unlikely to present acute hazard in normal use	Headache, palpitation, nausea, vomiting, flushed face, irritation of nose, throat, eyes and skin etc.	**Treatment of poisoning**: No specific antidote. Treatment is essentially symptomatic.	
3.	Propiconazole Moderately toxic 	Class III Slightly Hazardous	do	do	30
4.	Zineb Slightly to moderately toxic 	-	Early symptoms from exposure of humans to inhalation of zineb include tiredness, dizziness and weakness. More severe symptoms include headache, nausea, fatigue, slurred speech, convulsions and unconsciousness	-	
Rodenticide:					
1.	Bromadiolone Extremely toxic	Class I b- Highly hazardous	Headache, palpitation, nausea, vomiting, flushed face, irritation of nose, throat eyes and skin etc.,	**Treatment of poisoning**: No specific antitode. Treatment is essentially symptomatic.	-

Herbicides					
1	2,4-D Sodium salt technical lesser extent, toxicity White powder  		Symptoms of acute oral exposure to 2,4-D include vomiting, diarrhea, headache, confusion, aggressive or bizarre behavior. A peculiar odor is sometimes noted on the breath. Skeletal muscle injury and renal failure may also occur.18 Systemic toxicity is mainly associated with suicide attempts. Dermal exposure may include irritation, and inhalation exposure may lead to coughing and burning sensations in the upper respiratory tract and chest.18 Prolonged exposure may result in dizziness.18 Chlorophenoxy compounds such as 2,4-D are quickly absorbed when swallowed, but absorption from dermal or inhalation exposure is low.		

XVI. BASIC PRECAUTIONS IN PESTICIDE USAGE

A. Purchase

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

B. Storage

1. Avoid storage of pesticides in house premises.
2. Keep only in original container with intact seal.
3. **Do not** transfer pesticides to other containers; **Do not** store expose to sunlight or rain water; **Do not** 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. Equipments

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

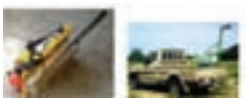
F. Precautions for applying pesticides

1. Apply only at recommended dose and dilution
2. **Do not** apply on hot sunny day or strong windy condition; **Do not** apply just before the rains and after the rains; **Do not** apply against the windy direction
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 spraying
7. Avoid tank mixing of different pesticides

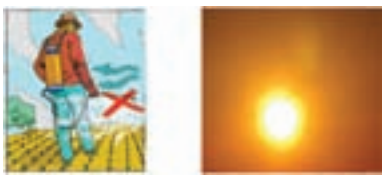
G. Disposal

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.

XVII. PESTICIDE APPLICATION TECHNIQUES

Equipment			
Category A: Stationary, crawling pest/disease			
Vegetative stage i) For crawling and soil 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	 
ii) For small sucking leaf borne pests			
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)	

XVIII. 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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Plants Suitable for Ecological Engineering in Wheat Field

Onion

Sunflower

Ocimum spp.

Urdbean

Spearmint

Mustard

Marigold

Carrot

French bean

Cowpea

Buckwheat

Maize

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

National Institute of
Plant Health Management
Rajendranagar, Hyderabad, Telangana

Department of Agriculture and Cooperation
Ministry of Agriculture
Government of India

Balaji Scan Pvt. Ltd., Tel : 040-2330 3424