ISBN: 978-93-88901-25-3

INSECT PESTS OF CROPS AND THEIR ECO-FRIENDLY MANAGEMENT

Manoj Kumar Gurjar
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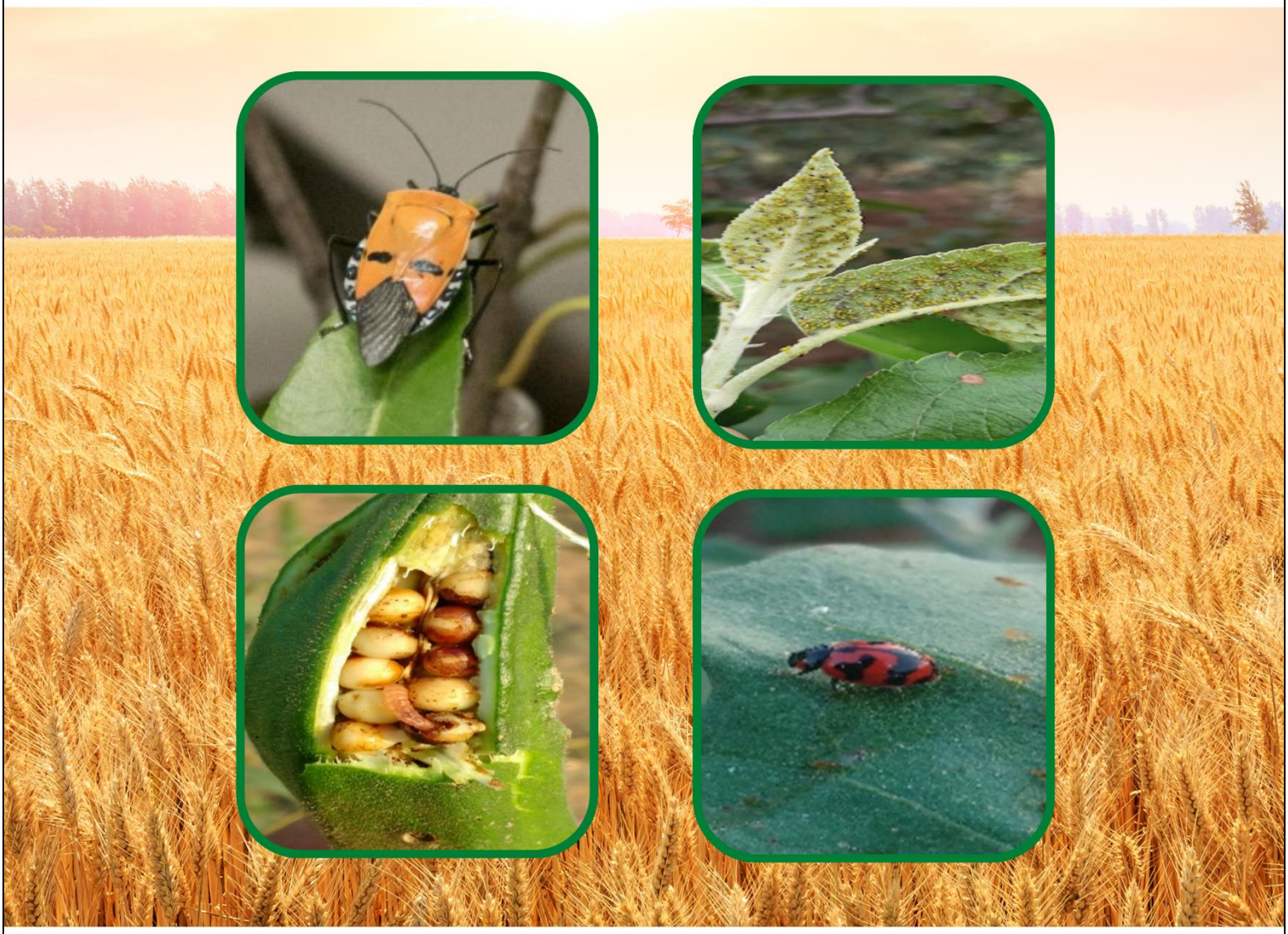
Nanda Ram
Rohit Kumar Nayak



BHUMI PUBLISHING

Insect Pests of Crops and Their Eco-friendly Management

(ISBN: 978-93-88901-25-3)

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Bhumi Publishing

2022

First Edition: December, 2022

ISBN: 978-93-88901-25-3

Published by:

Bhumi Publishing,

Nigave Khalasa, Kolhapur 416207, Maharashtra, India

Website: www.bhumipublishing.com

E-mail: bhumipublishing@gmail.com

Book Available online at:

https://www.bhumipublishing.com/books/

PREFACE

Entomology is a biological science dealing with a specific group of organisms, the insects. Insect constitute the largest class of the whole living organism. The general understanding of the subject of entomology is must and till date though there is lot of literature and reviews available, enormous effort is required to arrive at correct conclusions. So this way, I have tried to put my level best to put the information in the book related every aspect of competitive examination of entomology. This book has been prepared on the persistent demand of the student who to require themselves to adopt entomology as a professional carrier.

Ecofriendly pests control methods are generally less environmentally damaging, and less toxic to non-targeted insects, mammals and aquatic life. Unfortunately, in our time-starved world, many people simply want the most potent, one application product—no matter what the consequences. Pest control strategies in the eco-friendly garden seek to use the least toxic method first. There are some very effective natural control treatments available. The good news is, with the proper preparation, and cultural practices, rarely if ever will you need to get beyond these measures.

This book furnishes a detailed account of basic applied entomology as well as insect pests of crops and their ecofriendly management. The book provides an outline of various aspects of the science of entomology in subjective form. The Book would have useful to students' preparation for various examinations conducted by state Agricultural Universities (B.Sc Ag., M.Sc and Ph.D. Entomology examination), Indian Council of Agricultural Research (M. Sc. and Ph.D. examination), Agriculture research Institute (Ph.D. entrance), University Grant commission, other agencies and also useful to teachers to keep them abreast with recent developments in entomology and guide their students to a better future.

Manoj Kumar Gurjar

H. L. Deshwal

Nanda Ram

Rohit Kumar Nayak

Acknowledgment

Writing a book is harder than I thought and more rewarding than I could have ever imagined. None of this would have been possible without my co-authors Dr. H L Deshwal, Dr. Nanda Ram and Dr. Rohit Kumar Nayak. These helped and supported me through out in compiling such an excellent book.

My special thanks to Bhumi Publishing for his friendly behavior and nice book publication. I am grateful to Dr. Jaipal Singh Choudhary, Scientist, ICAR, RCER Ranchi and my seniors Bhagchand Yadav, Om Prakash Gurjar, and classmates Kunal Narwal, Shubham Pareek and Sunil Tailor for their help, infusing love and joyful company throughout the study. Sincere appreciation is due to junior Nanu Ram Sharma, Sourabh Dadhich, Dinesh Kumar Yadav, Devendra Saini and Laxman Choudhary for their regular support, motivation and inspiration and also i wish to express my deep sense of gratitude and indebtedness to those who helped me directly or indirectly during the preparation of the manuscript of this book.

Eloquence seems inadequate in expressing my deepest feeling and regards to my grandfather Shri Mahadev Prasad Gurjar and grandmother Gyarsi Devi, father Ram Chandra Gurjar and mother Patasi Devi, Uncle Ramawtar Gurjar and Aunti Prem Devi, elder brother Umbrav, Hetram, Dataram (Banty), Dr. Dinesh and younger brothers and sisters Lokesh, Prashant, Rakesh, Vikas, Raju, Neelam, Sapna whose consistent encouragement and blessings are beyond my expression that brought me here upto dream without which it could not be sketched.

Lastly, but the greatest of all, a million thanks to God, the almighty who made me able to do this task and made every job a success for me.

- **Manoj Kumar Gurjar**

CONTENT

POLYPHAGOUS INSECT PESTS OF CROPS AND THEIR ECOFRIENDLY MANAGEMENT

Manoj Kumar Gurjar, H. L. Deshwal and Nanu Ram Sharma
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Introduction:

Polyphagous insect pests are primarily agricultural pests that feed on economically important agricultural and horticultural crops of wide taxonomic diversity across the globe. Polyphagous pests are those which feed on plants belonging to diverse taxonomic groups. Generally, these pests multiply in large number are voracious feeders and cause considerable damage to agricultural crops. They cause immense damage across different crop varieties owing to their generalist and voracious food habits. The advent of mono-crop culture in a huge area and the massive use of pesticides post green revolution have massively increased pest outbreaks all over the world. The Middle Eastern countries, African continent and even the Indian subcontinent is increasingly facing resurgences of polyphagous pests.

Traditionally synthetic pesticides have been the most effective means of pest control but, continuous and indiscriminate use of insecticides over the years has resulted imbalance in our agro ecosystem (Pavela, 2012). The risk to human health and environmental side effects have force to look for greener alternatives like botanicals (Koul *et al*., 2008; Yadav *et al.*, 2015). Today, crop production must also ensure healthy, ecofriendly and sustainable food supply to us. The use of botanical resources for agrochemical purpose is one of the important alternatives to manage insect-pests in place of synthetic insecticides (Isman, 2006; Pavela, 2007).

The most important polyphagous pests are locusts, termites, hairy caterpillars, white grubs etc.

Polyphagous insect pests

Polyphagous pests are primarily agricultural pests that feed on economically important agricultural and horticultural crops of wide taxonomic diversity across the globe.

They cause immense damage across different crop varieties owing to their generalist and voracious food habits.

1 Locust
2 Termite
3 Hairy caterpillars
4 White grub

1. Locust

This is the most destructive of all locusts. It invades 30 million square kilometer areas spreading over 60 countries from the west and north of Africa to Assam in India and in 50 per cent of this area, breeding can occur.

Three species are found in India of which desert locust is predominant all over the country.

a. *Schistocerca gregaria* (Forskal) (Desert locust, Orthoptera Acrididae)
b. *Locusta migratoria* (Linnaeus) (Migratory locust, Orthoptera, Acrididae)
c. *Patanga succincta* Linnaeus (Bombay locust, Orthoptera, Acrididae)

Host plant- All varieties of agriculture crops, forests, fodders etc. Do not feed on aak, neem, jamun.

Distribution- Widely distributed throughout the world, Asia, Africa and Europe. In India, the desert locust is found almost around the year.

Life history- The desert locust passes through three stages its life cycle, egg, nymph and adults.

Egg- The eggs are laid in patches of 60 to 150 at a depth of 8 to 14 cm in moist sandy or loamy soil. Female may lay about 500 eggs in her whole life. The eggs are yellow in colour and resemble to rice grain about 78 mm long and 1 mm girth. Egg hatched in 14-20 days in summer and 4 weeks during winter. At this stage a suitable amount of soil moisture is most essential for the proper development of eggs. If this prerequisite is provided by timely rainfall the eggs hatch into a vermiform larva with membranous covering in which they are enveloped and they enter in the hopper stage of their life.

Nymph (Hopper)- The colour, size and habit of hoppers depend upon the phase of locust. Generally, there are two types of phases namely solitary and gregarious.

Solitary phase- In this type, the hoppers are inactive and the individual nymph lives solitary or scattered. They are restricted in desert breeding areas namely Rajasthan, parts of Saurashtra and Baroda, Cutch, Hissar and Mahindargarh district in Punjab. This permanent desert home of locust undergoes certain changes in phase. The hoppers of solitary phase are of green colour and behave like a common grasshopper.

Gregarious phase- In this phase, the hoppers are very active and gregarious i.e., the individuals tend to remain together. They breed rapidly and form swarms which leave the breeding areas and March in group to longer distances crossing the many countries. The hoppers of this phase are generally of black colour with pink markings when young, developing black and yellow markings as they grow old. The gregarious hoppers settle into bands, which sometimes extend over several square kilometers. They move in large numbers and devastate field after field thus leaving no green vegetation which comes across their way. As there are some individuals which are intermediate in habits, therefore they have been put into a separate phase known as transient phase. The hoppers moult 5 times and after 3-4 weeks they change into adults. During rainy

season the main breeding grounds of desert locust in India are located in and around the desert of Rajasthan. With the end of monsoon i.e., by September, the desert areas get drought affected accompanied by a rise of air temperature which generally the locust avoids. Therefore, the new hoppers leave the area and are carried partly eastward by the westernly winds into Punjab, U.P., Bihar and Bengal and sometimes southward into the peninsular areas including south India. Although these flights may find till December and January and most of them are destroyed by birds. Those which survive breed in spring in Punjab and adjoining areas of U.P. The swarms that are carried westward by north- easternly winds in the direction of Pakistan and Iran breed during winter rainfall in these areas. The next generation produced in these western areas during the spring months is carried eastward into the Indian desert areas by the westernly winds prevalent in May and June. With the advent of rainfall, the summer breeding occurs in the desert and thus breeding continues year after year. They generally fly at 18-24km per hour and can travel long distances without resting.

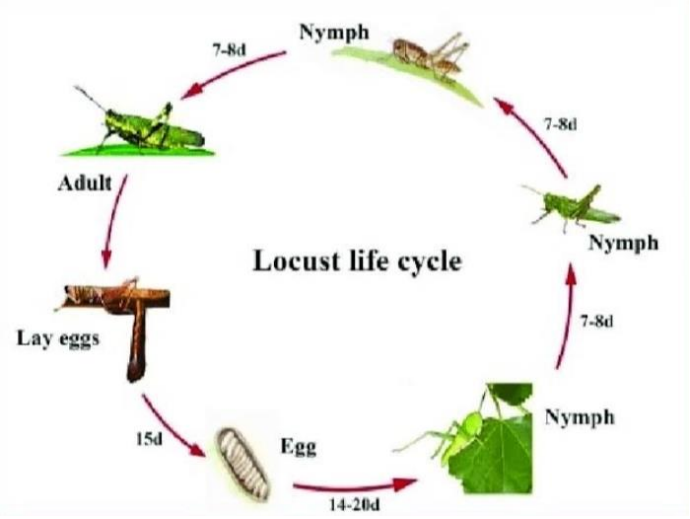
Adults-

The description of adults of different species is given below:

1. Desert locust-The young ones are bright pink in colour, but older ones turn into bright yellow. They have 6-7 stripes on each eye. The legs are hard and head and legs are of yellow. Colour. The pink locusts are very active and are likely to cause great damage to crops.

2. Migratory locust-The adults of this species come from Pakistan in summer and generally mate in Rajasthan and Gujarat. The hind wings are of yellow colour and the stripes are absent in eyes. They are now under Management and may be seen in small number here and there only.

3. Bombay locust-It is found in India, Cylone and Malaya. It is generally found in sporadic form and never in swarms. The hind wings are of pink colour and stripes are found in each eye. The adults of this species are found in quescent stage from October to July. In India, it is found in Mumbai, Gujarat and Tamilnadu and only one generation is found in a year.



Management-

The Indian Government has a permanent locust warning organization as a part of Central Directorate of Plant Protection Quarantine and Storage. The staff of which is posted in the breeding areas for constant watching and receiving information regularly about locust population.

The following methods may be used in Managementling the swarms of locust:

1. The eggs can be destroyed by digging them. But this method is not economical.
2. The trenches may be dug at some distance in the way of marching hoppers and after falling in them may be burried alive.
3. The hoppers as well as adults may be killed by using flame throwers or with kerosene oil torches.
4. Poison bait may also be used to kill them, the same is spread around the bushes, where hoppers est at night or on the way of marching hoppers in the day time.

The following bait mixture has been found effective:

Wheat bran	95 parts
BHC dust	5 parts
Molasses	Little quantity

5. Dusting of 10% carbaryl at the rate of 20-25 kg/ha has been found effective and cheap.
6. Spraying the crop with 0.1% neem seed kernel powder was found very promising and it protects the crop for 3 weeks.
7. Encourage predatory birds viz. crow, common myna and starlings birds.
8. Use bio-Management agent Nosema locustae, Bacillus thuringiensis.

Termite:

The termites are found practically all over the world and popularly known as white ants. There are two distinct categories of termites.

(a) Subterranean-Their colony is always partly underground and starts by a pair of reproductive forms which enter the wood or earth at the time of swarming. The common Indian species belonging to this category are as follows:

(i) *Odontotermes obesus* Holmgren.

(ii) *Microtermes obesi* Holmgren.

(b) Dry wood termites-Their colony is confined entirely to wood and starts by a pair of reproductive forms which enter the wood above the ground at the time of swarming.

The following are the important species:

(i) *Coptetermes fletcher* Holmgren.

(ii) *Eutermes sp*.

Since *O. obesus* is the species mostly associated with cultivated crops, hence its description is given here.

Host plants- This is a polyphagous pest and feeds on variety of forest trees and agricultural crops. Among the crops grown, wheat, maize, sorghum, groundnut and sugarcane etc. are severely damaged. The other species destroy wood in its various forms viz., wooden building structure, wooden furniture and all articles containing cellulose like paper even decaying matter like cow dung.

Distribution- The pest is prevelant in all warmer parts of the world but commonly found in the tropical regions.

Damage-

The food of termite includes cellulose and they eat almost everything which contains this substance. Though it is a polyphagous pest, but mainly feeds on sugarcane and wheat. Termites attack both sugarcane stalks and setts. As result of their attack, the young canes even the shoots of older canes dry up and finally the growth is adversely affected. The cane setts are eaten up from the cut ends and are rendered hollow; their eye buds are damaged resulting the poor germination of crop. In unirrigated areas the young wheat crop is damaged badly, as they destroy the roots of seedlings and finally the plants are dried off completely. Termites destroy the crop at night and remain hidden in their nest during day time. The attacked plants can easily be distinguished by irregular cuttings and adhering the soil particles. Th fruit trees are also attacked and on branches and stem the soil channels are formed under which they live.

Life history-

Three developmental stages viz., egg, nymph and adult are found. They are social insects and live in colony. There is polymorphism in adult stage and king, queen, soldiers, workers are found. The members of the colony may be divided into (i) reproductive forms which include queen, king, complimentary forms (substitute caste) and colonizing forms (macropterous forms winged), (ii) sterile forms which include the workers and soldiers.

Egg- The winged reproductives come out in swarms from the nest generally in the beginning of monsoon. Swarming usually takes place in day time and most of the individuals of the swarms are destroyed by birds etc. The survivals mate, shed their wings and burrow in the ground to form a new colony of which include the king and queen. Their flight is known as nuptial flight. The queen lays first batch of 10-130 eggs about a week of swarming, but later on may be five years. Eggs are small kidney-shaped and yellowish in colour. The individual egg is 1/2 mm long and hatch out in a week or so depending upon the environmental conditions.

Nymph- The newly hatched nymphs are yellowish white in colour and about 1 mm long. They eat for some time the excreta of the king and queen and later search the food. Nymphs develop into different castes in 6-13 months after 4-10 moultings.

Adults-

1. Reproductive forms

(a) Queen- The queen is the largest individual ranging 6.6-8 cm in length and 1 cm in thickness. This high dimension of the queen as compared to other members is mainly due to the enlargement of the abdomen which is full of eggs. She is the mother of the colony and lives in a specially prepared royal chamber which is situated in the centre of the nest at a depth of 1-6 feet below the ground surface. The queen is wingless, creamy white in colour and her abdomen is marked with transverse dark brown bands. The queen lives much longer (5-10 years normally though 20 years on records) and lays thousands of eggs, 70 to 80 thousand, per day, a real egg-laying machine. The queen develops from a fertilised egg.

(b) King- The winged male which remains with queen after nuptial flight is known as king. There is generally a single king in each colony which is smaller than queen and remains with her in royal chamber. The king develops from unfertilized egg. (c) Complimentary forms-

These are the apterous or brachypterous forms of both the sexes which maintain the numerical strength of colony in absence of macropterous forms. In a single colony their number may be in hundreds.

(c) Colonizing forms-

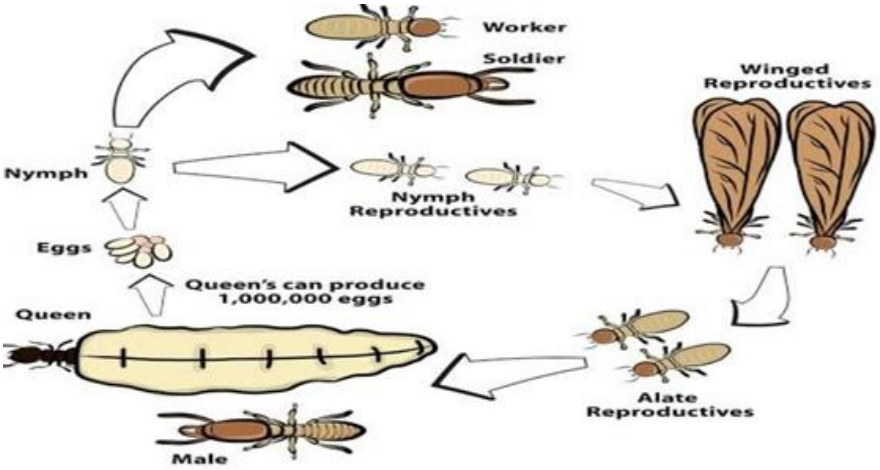
They are generally produced in rainy season and attracted by light. They are brownish in colour with two pairs of slender, dark brown, long narrowed wings which are used for nuptial flight and after which they are shed. These forms emerge in millions from the parent colony during monsoon and after finding their mate they crawl into soil and start the new colony. They are thus the kings and the queens of future colonies.

2. Sterile forms-

(a) Workers- Among the sterile castes the workers constitute the main labour force of the colony and represent 90% of the whole colony. They are about 6-8 mm long, dirty white in colour with brown head and eyes are small or absent. Their mous parts are fairly strong and used as the working tools for all types of odd-jobs. They work for the whole colony by storing food, looking after the young ones and building up the termitarium. The workers develop from fertilised eggs but remain smallest in size as they are reared on ordinary food. They are basically females rendered sterile due to suppression of reproductive organs under the influence of pheromones produced by the queen.

(b) Soliders- They are slightly bigger than workers. Their mouth parts are well developed and used for very active defence and offence, particularly the mandibles are very large, projecting and shaped for a variety of uses. Their main function is to protect Colony, but also help the workers in keeping the colony neat and clean by removing dead and sickly members. Both

workers and soldiers contain sterile individuals of th the sexes. They develop from unfertilised eggs.



Management-

1. The removal of dead or decaying matter or dry stubbles from the field is useful because they attract the termite.
2. The use of partially decomposed manure should be avoided.
3. Irrigation water with crude oil emulsion may be used to avoid the termite attack. Mixing of any one of the following insecticide before sowing in soil has been found very effective.
4. (a) Endosulfan 4% dust @ 30 kg/hec.
   (b) Lindane 1.6% dust @ 50 kg/hec.
   © Heptachlor 3% @dust 35 kg/hec.
5. In standing crops any one of the following insecticides may be used with irrigation water.

(a) Chlorpyriphos 20 EC @ 3.75 lit/hec.

(b) Gamma BHC 20 EC @ 3.75 lit/hec.

© Heptachlor 20 EC @ 3.75 lit/hec.

6. Cane setts before planting can also be dipped in solution of 0.25% lindane or chlorpyriphos emulsion.
7. The seed treatment of wheat with chlorphyriphos 20 EC has also been very effective: for this, use 400 ml per quintai of sced. Before application, the insecticide should be diluted with 5 litres of wate: and the emulsion be sprayed over the seed. The seed should be turned over to ensure proper mixing and the treated sced should be left over night for drying before sowing.
8. In buildings, an insecticidal barrier between the ground and wood work should be made by treating the soil beneath the building and around the foundations with 0.05 chlorpyriphos or lindane @ 5 lit/m^2.

Hairy caterpillars:

A number of species of hairy caterpillars occur in India which have dense tufts of hair on their body. They are the young ones of generally moderate sized moths which have often

conspicuous colouration and are nocturnal in habit. A common characteristic of this group is that the moths as well as the larvae appear in large numbers during certain fixed seasons when climatic conditions are best suited to them. There are about 10 species of hairy caterpillars found in India, out of which following are the common species.

1. Family-Arctiidae

(i) *Amsacta moorei* Butler-Red hairy caterpillar

(ii) *Spilosoma obliqua* Walker-Bihar hairy caterpillar

(iii) *Utetheisa pulchella* Linn. Sunhemp hairy caterpillar

(iv) *Pericallia ricini* Fabar. Black hairy caterpillar

2. Family-Lymantriidae

(i) *Euproctis lunata* (Walker)

(ii)*Euproctis fratema* (Moore) Castor hairy caterpillar

(iii) *Porthesia scintillans* W.

(iv) *Lymantria dispar*

Among this whole group of insects, the red hairy caterpillar and Bihar hairy caterpillar are the most injurious to agriculture throughout India.

Red hairy caterpillar:

Hindi Name- Kutru, Kamla, Lal bhurti, Katr

Scientific Name- *Amsacta moorei* Butler

Host plants – It is a serious and polyphagous pest which generally feeds on jowar, bajra, maize. urd, mung, tii, groundnut cowpea, cotton, guar sunhemp etc.

Distribution- This species is distributed throughout Northern India and another species A. albistriga Moore is found in southern parts of India.

Nature of damage- The caterpillar is damaging stage which has chewing and biting type of mouth parts. Among the whole group of hairy caterpillars, this is the most injurious to agriculture. The newly hatched larvae prefer to feed on the growing parts of plants gregariously and after few days they disperse in the whole field. When vegetation of the field is finished, they march in large bands to neighbouring fields and continue to migrate from field to field. In years of severe outbreak, fields may have to be resown in the beginning of the season and later on it becomes too late even for resowing. In July, 68 they appeared in epidemic form in eastern parts of U.P. covering more than 14,000 hectares of land. Authors experience has shown that out breaks of this are generally associated with the seedling stage of the crop. Further, their epidemics are positively co-related with the intermittant shower of rains followed by bountiful supply of food material.

Life history-

Four developmental stages viz, egg, larva, pupa and adult are found in its life cycle.

Egg- Female moth starts saying eggs after 6 to 9 hours of mating. The eggs are generally laid preferably on the under surface of leaves. They are creamy in colour and laid in prominent clusters. These egg masses look like clusters of poppy seeds specially conspicuos against the green back ground. An egg is 0.65 mm long, oval and dark brown in colour at the time of hatching. A female moth lays as many as 100-750 eggs during its life time. The incubation period (hatching time) lasts for 6-9 days and generally occurs early in the morning or late at night.

Larva- The dark-coloured tiny caterpillars begin to feed immediately after hatching. They remain congregated for a few days and then disperse. Newly hatched caterpillar measures 1.5 to 2 mm long and 0.75 mm wide. It contains two black spots on dorsal side of Ist abdominal segment. The larva moults (-7 times and become full grown which measures 40-50 mm in length and 5-7 mm in breadth. They are dark brown or deep orange in colour covered with reddish brown tuft. Of dense hairs. At the posterior and anterior ends of some larvae, a band of black airs is also found. The larval period lasts for 34-45 days depending upon the environn ental conditions.

Pupa- Generally full-grown caterpillars begin to go down into the soil for pupation at the end of September. Before pupation a large number of larvae migrate from cultivated fields to the neighboring uncultivable, area. Here they pupate in the soil and remain there till the onset of monsoon gain the following year. Pupation takes place in soil in a cocoon made from larva hairs. The pupal colour is light brown which turns to dark brown after some time. The pupa is 16-17 mm ieng and 7-8 mm wide. A timely rain on the eve of pupation is a pre- requisite for successful pupation for the caterpillars which require a loose wet soil for burrowing to a depth of 15 cm. The failure of runs at this critical stage will result in whole sale annihilation of the pest. The pupa remains in soil for about 9-10 months general from October to July. During active period of life cycle pupal con varies 16-22 days.

Adult- The adult is a medium size moth with white wings and black bands and spots or the body. The female is larger than the male. Female is 25 mm long with wing expansion of 42 mm white male is 17 mm, long expansion of 34 mm. The wings Crops Pests and Their Management have red stripe at the margin of coastal region and there are black spots on hind wings. The moths are nocturnal in habit and positively phototrophic in nature. They survive on/ for 3-5 days. The moths start laying eggs after one or two days of emergence and life cycle is thus completed within 59-76 days. Generally, 1-2 generations are found in a year.

Management-

1. Since the moths are attracted to light, the light traps should be set-up as soon as rains start.
2. Collect the egg masses and young caterpillars in the early stage and destroy them.
3. The chemical Management operation should be reported as quickly as possible i.e., before larvae develop the migratory tendency. The following dusts have been found
4. Effective: (a) Lindane 2% dust @ 40 kg per hectare. (b) Methyl parathion 2% dust @ 25 kg./hectare.
5. The following emulsifiable concentrates have been found quite effective when used at the rates given per hectare: (a) Endosulfan 35 EC—1. 875 lit. (b) D D V P 76 EC @ 625 ml. (c) Quinalphos 25 EC @ 1.25 lit. (d) Chlorpyriphos 20 EC-1.5 lit.
6. Spraying of neem seed kernel powder suspension (1%) makes the larvae unable to feed on the crop.
7. Thuricide (formulation of Bacillus thuringiensis, Berl) spray has also proved very effective in killing the larvae of this pest.
8. Following micro- organisms are the effective parasites of this insect:
9. For the, first time isolated a nuclear polyhedrosis virus from the larvae of *A. albistriga*. (Jacob and Subramaniam 1972)

   (a) Aspergillus fumigatus Frs. (Fungi).

   (b) Nuclear polyhedrosis and pox-like-virus; use of NPV @ 250 LE/ha. Hindi name-Safed gidar

White grub:

Scientific name- *Holotrichia consanguinea* Blanch.

H. semata Fabr Anomala

Host plants- White grubs are polyphagous pest and feed on almost all the kharif crops like jawar, bajra maize. Groundnut, sesamum, sunflower, chilles, cotton, sugarcane, tobacco, brirjs cucurbit and bhindi etc.

Distribution- They are of worldwide importance as noxious crop bests and cosmopolitan in occurrence White grub ha status of major devastating pest of a variety of rain season crops in India particulate states Rajasthan. Gujarat, Maharashtra, Karnataka, Tamilnadu, Bihar. U.P and Orissa

Nature of damage-

The damage caused by white grubs has been estimated to the tune of 40-80%. At times, the damage caused by grubs is so much so that entire stand of the crop is destroyed thereby necessitating resowing in the field. During the last few years, white grub has posed such a serious and alarming situation in the country that it has been designated as a National pest.

The losses are inflicted by grub and the beetle, the former feeds on fine rootlets, nodules in case of leguminous crops and then girdles of the main root, whereas the latter (adult) feeds on shrubs and the tress growing nearby the cultivated fields. The plants damaged by the grub give a wilted appearance and finally dries out, while in case of bectles the attacked plants get defoliated. In case of severe grub infestation, the entire crop is destroyed.

Life history-

The life cycle of this pest passes through the four stages viz., egg. Grub, pupa and adult.

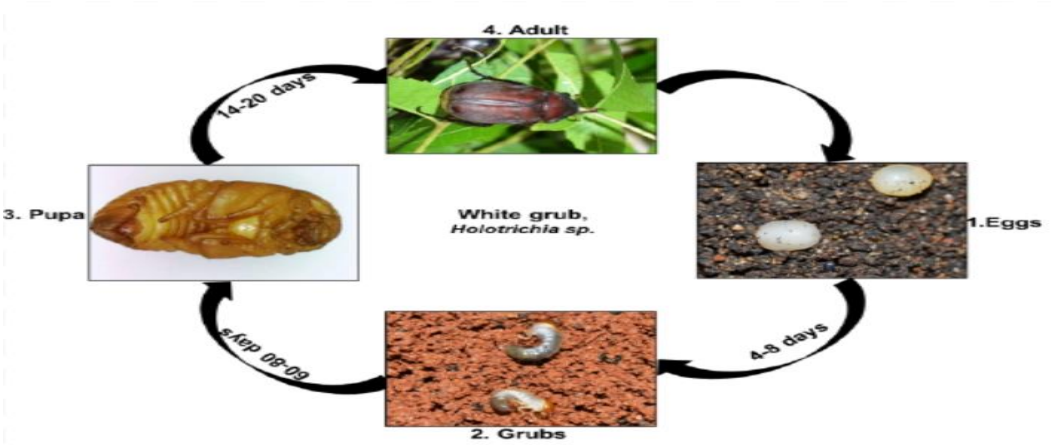
Egg- The beetles emerged from soil after dusk (7.30-8.00 p.m.) followed by good premonsoon rains, which may occur from April to June. The emergence, movement and distribution of adults are mainly governed by rainfall, temperature and atmospheric humidity. Generally, mating takes place, soon after the emergence of adults. After feeding and mating, the beetles get back to the soil in early morning hours and lay eggs. The eggs are generally laid singly in loose soil or in an earthen cell inside the soil upto the depth of 10 cm. The eggs are oval, creamy white when fresh and later turn to brown in colour. The number of eggs laid by single female ranges from 30-120. And hatching period varies from 4-8 days depending upon the per valuing conditions.

Grub- The newly hatched grub is creamy white and measures 10-12 mm in length and 2 mm in width. They feed on organic matter. There are three larval instars of the pest and the mean body length and width are 11.75 mm and 2.91 mm for the first instar, the second instar and 32. 23 mm and 7. 71 mm, respectively of the third instar. The full grown grub is curved, C-shaped and dirty white in colour, its posterior abdomen is shiny black devoid of folds through which the intestinal contents are visible. The head is dark brown with strong mandibles and prominent thoracic legs. The larval period for the first and second instar ranges from 9.12 days and 3.4 weeks, respectively, while in case of third instar it lasts for 6 weeks. Thus total larval period varies from 60 to 80 days.

Pupa- The full grown grubs move down deeper in the soil in search of moisture and for pupation. The grub constructs an earthen cell in which it passes a quiescent or pre pupal stage which lasts for one to 6 weeks. The freshly formed pupa is light yellow and extremely tender, but

as it grows older it turns brown and becomes some what hardened. It is of execrate type i.e., the appendages are free from the body. The pupal duration ranges from 14-20 days depending upon the type of soil.

Adult- The freshly formed beetle is cream coloured with soft white elytra and with the lapse of time its colour changes to brown and elytra gets hardened. Generally, adults are lamellate and males being smaller than females. These newly emerged beetles remain within the earthen cell and do not come out of soil until the onset of summer rains. The total life cycle Is completed from 90 to 108 days and all the known species in India have one generation in a year.



Management-

1. Plough the fields twice during May-June. It would help in exposing the beetles resting in the soil.
2. The repeated ploughings, preferably soon after the summer rains (May-June) help in exposing the various stages of grubs to their natural enemies.
3. Light trap be set up in endemic areas to collect the beetles with the onset of monsoon in June July coinciding with emergence of beetle and the trapped beetles be destroyed.
4. Treat the seed before sowing with 15 ml of Chlorpyriphos 20 EC or 15 ml Quinalphos 25 EC per kg of kernels and this seed treatment will also Management the termites in groundnut crop.
5. Sprayed with imidacloprid 17.8 SL at 1.5 ml/L water.
6. Kill the beetles by spraying the trees @ 0.05% Carbaryl 50 WP or 0.05 % Quinalphos 25 EC in 250 litres of water.
7. Bio –Management agent *Bacillus spp. Beuveria bassiana* Managementled the grubs.
8. Indian toad *Bufo melanostictus* feeds on the bettles.

The following micro-organisms are found parasitising the grubs:

(a) *Bacillus thuringiensis* (bacteria)

(b) *Bacillus popillae* (bact)

(c) *Beuveria bassiana* (fungus)

(d) *Aspergillus parasiticus* (fungus)

(e)*Metarhizium anisopliae* (fungus parasiting the adults).

7. Indian toad Bufo melanostictus feeds on the beetles.

8. Seed treatment of groundnut kernels with chlorpyriphos @ 15-20 ml/kg of seed has been found very effective in protecting groundnut crop against white grub.

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INSECT PESTS OF RICE AND THEIR ECO-FRIENDLY MANAGEMENT

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Abstract:

The most essential food for humans is rice. Numerous bug species find the rice plant to be an excellent host. From planting to harvest, all plant sections are susceptible to insect nutrition. There are about 800 bug species that harm rice in some way, yet most of them cause relatively little harm. It is crucial to correctly identify and comprehend the biology and ecology of insect pests and the arthropods that aid in population control in order to build efficient pest management solutions. In order to promote human health, global peace and stability, and rice production, insect pests must be safeguarded and increased. The Integrated Pest Management (IPM) is the only way to regulate the pest by using various tactics as cultural methods, mechanical methods, physical methods, biological methods, by using botanicals, host plant resistance, chemical methods and biotechnological approaches.

Keywords: Rice, management, pest, IPM

Introduction:

India's main dietary staple is rice. Although rice production has so far kept up with population growth, significant research support aimed at boosting rice productivity and maintaining the production can meet future demand for the expanding population. Weeds and insect pests are the two main biotic stressors that limit productivity. The development of techniques to control their populations is based on an understanding of the bio-ecology of the major insect pests. In India, it has been documented that more than 100 different insect species feed on rice plants throughout the course of their life cycles. In order to produce rice cultivars resistant to significant pests, host plant resistance has been utilised. Modern molecular and biotechnological technologies are being used to generate multiple pest resistance, persistent resistance, and resistance against pests like stem borers in order to solve the limitations of this approach. Another environmentally beneficial strategy is biological control, which combines appropriate augmentation with natural biological control by preserving existing natural enemies. In order to keep the pest population below levels that result in monetary loss without harming the environment, rice integrated pest management employs all of the available treatment strategies in a blended manner.

List of insect pest of rice

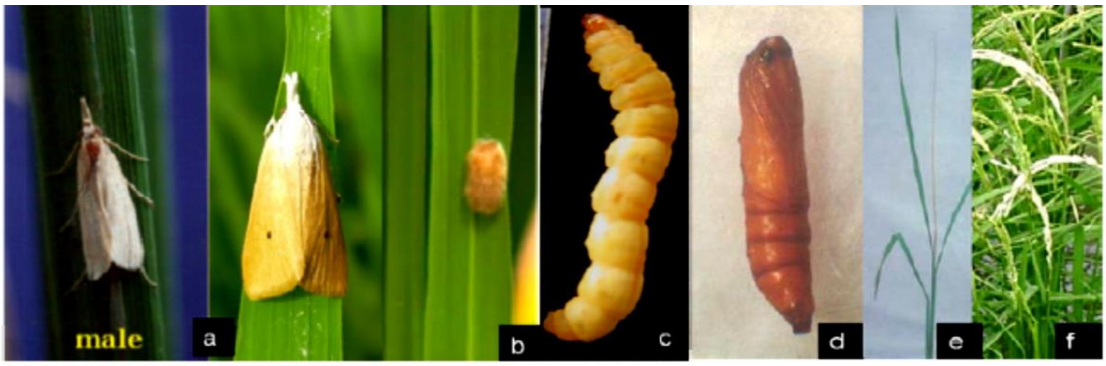
Sr.no.	common name	scientific name	family	order
Stem borers				
1.	Yellowq stem borer	*Scirpophaga incertulas*	Pyralidae	Lepidoptera
2.	White stem borer	*S.fusciflua*	Pyralidae	Lepidoptera
3.	Pale headed striped borer	*Chilo suppressalis*	Pyralidae	Lepidoptera
4.	Gold-fringed stem borer	*Chilo auricilius*	Pyralidae	Lepidoptera
5.	Pink stem borer	*Sesamia inferens*	Noctuidae	Lepidoptera
Sap suckers				
6.	Brown plant hopper	*Nilaparvata lugens*	Delphacidae	Hemiptera
7.	White-backed plant hopper	*Sogatella furcifera*	Delphacidae	Hemiptera
8.	Green leafhopper	*Nephotettix nigropictus* *N. virescens*	Cicadellidae	Hemiptera
9.	White leafhopper	*Cofana spectra*	Cicadellidae	Hemiptera
10.	Zig-Zag leafhopper	*Recilia dorsalis*	Cicadellidae	Hemiptera
11.	Gundhi bug	*Leptocorisa acuta*	Alydidae	Hemiptera
Leaf feeders				
12.	Whorl maggot	*Hydrellia philippina*	Ephydridae	Diptera
13.	Case worm	*Nymphula depunctalis*	pyralidae	Lepidoptera
14.	Gall fly	*Orseolia oryzae*	Cecidomyiidae	Diptera
15.	Hispa	*Dicladispa armigera*	Chrysomelidae	Coleoptera
16.	Leaf folder	*Cnaphalocrocis medinalis*	Pyralidae	Lepidoptera
17.	Skipper	*Pelopidas mathias*	Hesperiidae	Lepidoptera
18.	Phadka grasshopper	*Hieroglyphus nigrorepletus*	Acrididae	Orthoptera
19.	Paddy grasshopper	*Hieroglyphus banian*	Acrididae	Orthoptera
Root feeders				
20.	Root weevil	*Echinocnemus oryzae*	Curculionidae	Coleoptera
21.	White grub	*Leucopholis irrorata*	Scarabaeidae	Coleoptera
22.	Paddy black beetle	*Heteronychus lioderes*	Scarabeidae	Coleoptera
23.	Oriental mole cricket	*Gryllotalpa orientalis*	Gryllotalpidae	Orthoptera

1. Rice stem borer: *Scirpophaga incertulas* (Pyralidae/Crambidae: Lepidoptera)

Identification: Eggs are a clear colour. They are oblong, flattened, arranged in a clump, and coated with the female moth's brownish anal hairs. The larva has a small, orange head and a body that is pale yellow and hairless. Puberty takes place in the stem. Inside the white silken cocoon, Papa is hidden. The colour of the female ranges from white to yellowish. Each forewing

contains a pair of distinct, black spots in the centre. The male has two rows of black dots at the tip of the forewings but is smaller and duller in colour.

Nature of damage: A brown egg clump can be seen close to the leaf tip. The paddy seedling's and tiller's central stalk was pierced by a caterpillar. The centre stalk, known as the "dead heart" in young plants, or the panicle, known as the "white car" in older plants, both dry out as a result of larva feeding inside the stem. It has been shown that the insect may multiply most easily between October and December. Late planting of fields and the persistence of stubble in the field are factors that favour insect development.



Source: Bewke, G.B. (2018)

Life history: The female covers the 15–18 eggs with buff-colored scales and hairs before depositing them in a pile near the tip of the fragile leaf blade. The incubation phase lasts between 5-8 days, and a female typically lays two to three egg masses. The freshly emerged pale white larva burrows into the leaf sheath, feeds there for two to three days, and then bores into the stem close to the nodal area. Typically, a stem will only contain one larva, although on rare occasions, 2-4 larvae may be observed. The larva grows to adult size in 33–41 days and is 20 mm long. It has a well-developed prothoracic shield and is white or yellowish white in colour. It produces a white silken cocoon in which it pupates before covering the exit hole with fine webbing. The pupa is 12 mm long and dark brown in colour. The length of the papal term ranges between 6 and 10 days and might be affected by the weather. The life cycle is finished in 50 to 70 days.

Management:

- Removal and destruction of rice stubbles from field.
- Clipping the tip of the seedlings prior to transplantation to eliminate egg masses
- Avoid close planting and continuous water stagnation
- Pull out and destroy the affected tillers Set up light traps to attract and kill the moths
- Harvest the crop upto the ground level and disturb the stubbles
- Release the egg parasitoid, Trichogramma Japonicum on twice@5 card/ha.
- Apply *Becillus thuringiensis* var *kurstaki* and neem seed kernel extract.
- Apply any of the insecticides as per need alternatively viz, acephate 75% SP @ 1kg/ha, bifenthrin 10% EC 500 ml/ha, cartap hydrochloride 50% IL/ha, chlorantraniliprole 18.5%

@150 ml/ha, chlorpyrifos 10% G @10gha, deltamethrin 18% EC 625 ml/ha, fipronil 5% SC @IL/ha, flubendiamide 19.35% 50ml/ha, lambda-cyhalothrin 5% EC @250ml, chlorpyrifos 50% cypermethrin 5@625ml/ha.

2. Rice gall midge: *Orseolia oryzae* (Diptera: Cecidomylidae)

Description: Egg is near the ligule of the leaf blade are reddish, elongated, tubular eggs. The maggot, which is light to dark red, feeds inside the gall. At the base of the gall, the larva pupates before moving to the tip of the gall. An adult orange mosquito-like fly. Damages' types Maggot faeces create a tube-like gall that resembles an onion leaf or "Silver-shoot" at the base of the developing shoot. Even in the nursery, it infests the rice, yet tillers are typically favoured. No panicles are produced by infected tillers. A crop that is severely infested may see a yield loss of up to 50%.

Source: http://www.knowledgebank.irri.org/

Life history: The yellowish brown fly, which is active at night, deposits 100–300 reddish elongate tubular eggs just under or above the leaf blade's ligules, either singly or in groups of two to six. The maggots hatch in three to four days and descend to shoot primordia in six to twelve hours. The apical meristem is suppressed and radial ridges are formed as a result of the maggot feeding on the shoot primordia. In the shoot apex, just one larva grows, and it spends the entirety of its development inside the tubular gall that its feeding has created. The modified leaf sheath is called gall. After 15-20 days of feeding on the developing point, the pale red maggot pupates inside the gall. The pupal stage lasts for two to eight days, and as the adult emerges, the pupa wriggles up to the tip and extends halfway out. Normally, the life cycle takes 19–21 days, but in the winter, it might reach 32–39 days.

Management:

- Early ploughing
- Early planting
- Use early maturing varieties
- Setup light trap and monitor the adult flies

- Seed treatment with chlorpyriphos 0.2% emulsion for 3 hours or seed mixing with either chlorpyriphos (0.75 kg a.i/ 100 kg seeds) or imidacloprid (0.5 kg a.i/100 kg seeds) provide protection for 30 days in the nursery.
- Seedling root dip in 0.02% chlorpyriphos emulsion before transplanting for 12-14 hours gives protection for 30 days.

3. Green rice leaf hoppers: *Nephotettix nigropictus* and *N. virescens* (Cicadellidae: Hemiptera)

Description: Eggs are round, yellowish, or pale in colour. Nymphs start out as a light yellow colour, eventually developing brown eyespots and tiny spines on the dorsal surface of their abdominal segments. Adults are slim, green, and may have black head patterns and black patches on their wings. They often inhabit the leaf blade in tiny groups and eat the uppermost layer of the rice canopy.

Nature of damage: Both nymphs and adults sucking plant sap cause the leaves to turn brown or yellow from the tip downward. It is well recognised that both species can spread viruses that cause diseases such the "rice tungro virus", rice yellow dwarf, and transient yellowing. Grasses near irrigation canals, rice ratoons, lots of sunshine, little rain, and high temperatures, as well as rain-fed and irrigated wetland settings, excessive nitrogen consumption, are factors that favour bug development.

Source: http://www.knowledgebank.irri.org/

Life history: The male of *N. nigropictus* has two black dots that reach all the way to the forewings' black distal region, while the female of the species is green. It features a submarginal black band on the summit of the head and a black tinge along the anterior pronotal border. The black submarginal band is lacking, and the black spots on the forewings do not reach the black distal area in *N. virescens*. On some grasses, they can also reproduce. The female can lay up to 53 eggs, which are inserted in rows under the epidermis of the leaf sheath. The egg and nymphal periods are 6-7 and 18 days, respectively, during the course of the life cycle, which lasts about 25 days.

Management:

- Apply neem cake @ 12.5 kg/20 cent.

- Set up light traps.
- Spray application of phosalone or etofenprox or cartap hydrochloride or monocrotophos or acephate or chlorpyriphos or carbaryl, at 0.5 kg a.i/ ha

4. Brown plant hopper: - *Nilaparvata lugens* (Delphacidae: Hemiptera)

Description: - White describes eggs. Nymphs are light brown and creamy white. The two kinds of adults—long-winged (macropterous) and short-winged (brachypterous) are distinguished by their ochraceous brown dorsal and brown ventral surfaces. The dry season typically has higher levels of BPH than the wet season. It is frequently observed in areas that receive irrigation and rainfall when the rice plant is in its reproductive stage.

Life history: Rows, one on either side of the leaf sheath's midrib. Between 250 and 350 eggs are typically deposited by each female. The nymphal phase lasts 10–18 days, while the incubation period is 6–9 days. The entire life cycle lasts 16–27 days.

Source: Patrick Garcia and K.L. Heong

Nature of damage: Plants quickly wilt and turn yellow as a result of feeding by both nymphs and adults near the base of the tillers. Early infestations cause spherical yellow patches to emerge, which quickly turn brownish as a result of the plants' drying out. This condition is known as "hopperburn." *N. lugens* feeds on phloem. Crop lodging caused by extremely high infestation results in yield losses of between 10 and 70%. The plants are at risk for bacterial and fungal infections because of the feeding. The ragged stunt and grassy stunt viruses are spread through BPH. At every stage of plant development, it attacks the rice crop. Rainfed and irrigated wetland habitats, persistent submerged conditions in the field, high levels of shade and humidity, densely sown crops, and excessive nitrogen use are all characteristics that favour bug development.

Management:

Alternate wetting and drying of the field.

Removal of grasses from the field.

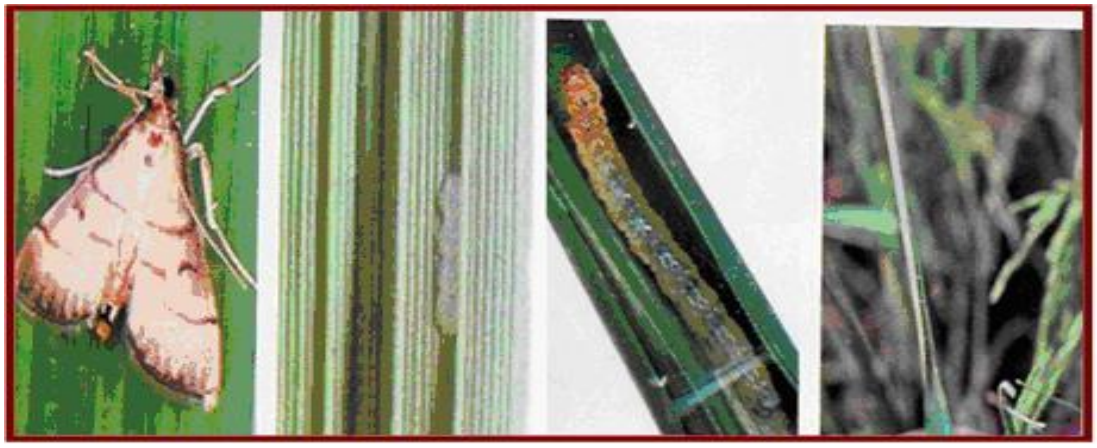
Conserve natural enemies.

Spray monocrotophos@0.005% and thiamethoxam @2g/10l.

5. Rice leaf folder: *Cnaphalocrocis medinalis* (Pyraustidae: Lepidoptera)

Description: Larvae are roughly 12 to 25 mm long and start out as yellow before turning yellowish green with brown heads as they become older. Every larva can fold up to four leaves. The 9–12 mm long pupa is located inside the coiled leaf. Adults have a yellow-brown coloration. Typically, adults come out in the evening. Women give birth at night.

Nature of damage: - The larva coils the leaf blade by stitching its edges together, glueing it with silk fibres, and then feeds by scraping the green tissue from inside the leaf. Longitudinal white and translucent streaks are produced on the blade by larval feeding. In a field that has been heavily infested, the entire crop has white blotches that give it a sickly aspect. Infestation during the crop's boot leaf stage can occasionally cause a significant decrease in grain output. Insect development is favoured by heavily fertilised fields, high humidity, and shaded places; by the presence of grassy weeds from rice fields; and by the neighbouring borders.



Source: Akanksha (2009), Agropedia

Life history: Small and with two and one prominent black wavy lines on the brownish fore and hind wings, respectively, the brownish-orange coloured moth is brownish in colour. A stripe of dark brown to grey runs around the outer edge of each wing. On the underside of sensitive leaf blades, the eggs are placed singly or in pairs. There is a 4–7 day incubation period. Within the leaf roll, the pale yellowish-green larva pupates after growing to full size in 15–27 days. The papacy lasts 6 to 8 days. The length of the life cycle is 25 to 42 days.

Management:

- Removal of grass from field bunds
- Need based spraying of phosalone or carbaryl or monocrotophos or etofenprox or cartap hydrochloride or quinalphos or fenthion at 0.5 kg a.i/ha or spray of fipronil 5 SC at 1 litre/ha.

6. Rice earhead bug: *Leptocorisa acuta* (Coreidae/ Alydidae: Hemiptera)

Distribution: In India, this is one of the most significant rice pests, typically beginning to show before the blooming stage and persisting into the milky stage. In addition to rice, it also reproduces on several grasses.

Nature of damage: Both nymphs and adults consume the milky grains that become chaffy as well as the sap of the peduncle, delicate stem, and grains. The grains form black marks where the feeding puncture was made. In the rice field during the milky stage, there is an insect odour.

Source: http://www.knowledgebank.irri.org/

Life history: The female lays 250–300 eggs on leaf blades in rows that are each 10–25 eggs long. The eggs take about a week to hatch. In about two weeks, the thin, greenish nymphs mature into adults. The adult life span is 3–4 months.

Management:

- Dust carbaryl 10%, and repeat it depending upon the severity of infestation.

7. Whorl maggot: *Hydrellia philippina* (Ephydridae: Diptera)

Distribution: It happens in several Asian nations that farm rice. Certain high yielding types in Andhra Pradesh, Tamil Nadu, and Orissa exhibit it in a severe form. Additionally, it reproduces in the following species*: Fimbristylis miliacea, Eleusine indica scrobiculatum*, *Cynodon* and *Paspalum dactylon, Echinochloa crusgalli* and *E. colona*.

Description: It is semi-aquatic, produces elongated, white eggs, legless juvenile larvae that range in colour from clear to light cream, and yellow mature larvae.

Source: http://www.knowledgebank.irri.org/

Nature of damage: It is semi-aquatic, produces elongated, white eggs, legless juvenile larvae that range in colour from clear to light cream, and yellow mature larvae.

Life history: On either side of the leaves, a female lays 3–7 batches of roughly 100 cigar-shaped eggs. 2 to 6 days pass during incubation. The larva goes through three instars and has a lifespan of 8–17 days. Pupation occurs between the leaf sheath and lasts between 5 and 9 days. There are 10 to 15 generations that overlap.

Management:

- Use of natural egg parasitoid *Trichogramma minutuan*
- Use of field drainage on vegetative stage of rice
- Spraying of quinalphos or fenthion at 0.5 kg a.i/ha. Alternatively application of granules of carbofuran or fenthion at 0.75 kg a.i/ha.

8. Rice caseworm: *Nymphula depunctalis* (Lepidoptera: Pyralidae)

Description: - Adults are a tiny, delicate moth with a 16 mm wing span. White spots can be seen on the wings. Digestive tracts are evident in the translucent, yellowish green larvae.

Nature of damage: At the seedling and tillering stages, the nature of the injury entails cutting the leaves at a straight angle with a pair of scissors. The upper leaf surface seems papery, and the ladder-like appearance of the injured leaf tissue. Plants can appear stunted in severe cases. Case worm favour rice in the seedling and vegetative stages. Only the middle rib remains after the leaf blades have totally disappeared. Additionally, they build tubular cases inside leaves, where they stay and eat the foliage.

Source: http://www.knowledgebank.irri.org/

Life history: Little eggs are placed in rows and batches on leaves and leaf sheath. About 150 eggs are laid by a female, and they hatch after about a week. Young larvae consume food by scraping the surface of leaves. A piece of the leaf cut is used by the larva to create a cylindrical, tubular casing, which it then uses to move along the leaves. It actively consumes the leaves, growing to a length of 10–12 mm in about 20 days. The caterpillar goes through six instars and is recognised by the tubular gills that are present on its body. The branching of the gills coincides with the increase in caterpillar size. In the final situation, the larval stage pupates. Before pupation the case is attached to the leaf sheath above the water level and its both ends are

plugged. The pupal stage lasts for about a week before the insect transforms into an adult. There may be two or three broods in a season because the pest is active during the monsoon. The life cycle takes roughly 35 to 40 days to complete.

Management:

- Use of biological control agents such as spiders, dragonflies, and birds.
- Larvae are parasitized by tabanid fly (Tabanus sp.) and braconid wasp (Dacnusa sp)
- Eggs of case worm are parasitized by Trichogramma minutum.

9. Rice root weevil: *Echinocnemus oryzae* (Coleoptera: Curculionidae)

Nature of damage: *E. oryzae* grubs and adults both eat on rice plants, but often the grub stage reduces production. From July to September, white, legless grubs can be found in the soil eating roots. The plants that have been attacked turn yellow, and overall growth is hindered, yielding few tillers. In flooded or unflooded rice fields, adults feed on young paddy leaves, creating the distinctive feeding scars that run nearly parallel to the venation of the leaves.

Life history: The mature weevil is glossy black, with an oblong body coated in scales that are greyish. In the dirt close to grass roots, the female deposits her eggs. Three to four days pass during incubation. The watery, creamy-white worm consumes the hairs on roots. The 11-month larval stage is the longest. After September, the grub spends the winter in soil at a depth of 25–30 cm. May is the pupation month. The pupal stage lasts for 10–12 days.

Management:

- treatment of seedlings with chlorpyriphos 20Ec at 3 ml/L of water followed by a soil application prior to transplanting with cartap hydrochloride 4% G at 750 g/ai or 18.75kg of the formulation/ha

10. Paddy black beetle: *Heteronychus lioderes* (Coleoptera: Scarabaeidae)

Description: Black on the dorsum, deep reddish brown on the ventral side, smooth and shiny Beetles have a longate-oval form with little convexity. Except for the vertex, the head is transversely rugose. The clypeus has two moderately spaced reflexed teeth that are separated from the forehead by a tiny carina that is interrupted in the middle. The pronotum and scutellum are completely shiny and smooth. Throughout its length, the elytra is irregularly and profoundly punctate, with large subsutural interstriae; heavily and irregularly punctate at the apical edges coufluently punctate: Pygidium. The anterior angles of the metasternum are gently punctured, while the ventral surface is almost totally smooth. Males have thick protarsus bones with inner claws that have expanded into convex plates that are as wide at their extremities as they are long. Females lack a thick protarsus and an inner claw that hasn't expanded into a convex plate.

Nature of damage: Between June and August, the adult beetles eat the subterranean stems and roots of maize and rice plants. The impacted plants wilt and pass away. Upland rice is severely under attack.

Management:

- Deep summer ploughing of field exposes grubs and pupae to sun drying as well as predation to birds.
- Apply chlorpyriphos 20EC @ 400 gai/ha.

11. Grasshoppers: *Hieroglyphus banian* and *Hieroglyphus nigrorepletus* (Orthoptera: Acrididae)

Distribution: In India, paddy grasshoppers are common and are regarded as a serious pest of the crop. Afganistan, Burma, China, Pakistan, Sri Lanka, Thailand, and Vietnam are also home to this species.

Description: The adults are medium-sized insects that are nearly spotless and consistently green in colour. They are approximately 5 cm long.

Source: http://www.knowledgebank.irri.org/

Nature of Damage: The leaves and shoots of paddy are consumed by both the juvenile and adult stages. The ear heads were also amputated. In marshy and humid environments, these grasshoppers are particular pests that can occasionally become economically significant. Newly sprouted rice seedlings are eaten by the nymphs, which causes them to wither. Adult grasshoppers consume the leaves, shoots, and occasionally the ear heads while feeding.

Life history: Each egg pod contains about 35 eggs and is placed in the soil. Between 100 and 150 eggs are generally deposited by each female. Eggs are placed on the soil surface in dry sandy soil, while they are buried 3-5 cm deep in wet sandy soil. Oviposition takes place between October and December, and the eggs stay in the soil until the following June or July when rains start. Each egg is yellowish and has a sticky coating that eventually solidifies into a waterproof layer. After the first monsoon rain in the month of June, the hoppers come out. The hoppers reach sexual maturity after 70 days for males and 80 days for females. The male and female adult grasshoppers are both medium-sized, measuring 28 to 40 mm and 34 to 54 mm respectively. It is either yellow-brown or drab green. The surface of the lower body is brownish black. The brachypterous type of *H. nigrorepletus* is more frequently observed than the macropterous form in adults. Nymphs emerge not long after the start of the rainy season. Poor rains prevent eggs from hatching, while temperatures above 40 degrees Celsius cause a significant amount of egg mortality. Hopper larvae start out brownish yellow and subsequently turn dull green. Nymphs

hide from birds during the day, just like adults do, and eat rice leaves at night. Males often have 5 to 6 instars, whereas girls typically have 7 instars. Each year, there is only one generation.

Management:

- The egg masses are destroyed by ploughing the field and exposing them to birds.
- Flooding the stubbles, trimming the bunds, sweeping along the bunds
- Common baits contain carbary! (2.0-5.0%). Baits should be spread evenly throughout the field. Baits containing the protozoan Nosema locustae is a biological control option that may be considered for treating grasshopper breeding sites
- Dust the crop with methyl parathion 2% dust @ 25-30 kg/ha or malathion 5% dust @ 20 kg/ha.
- Foliar sprays of insecticides such as fipronil, alpha-cypermethrin, lamda-cyhalothrin, bifenthrin and also biopestcide Metarhizium anisopliae and Nosema locustae can also control grasshoppers.

12. Rice Hispa: *Dicladispa armigera* (Coleoptera: Chrysomelidae)

Nature of Damage: Heavy crop losses are caused by the insect in many Asian nations, particularly Bangladesh. It occurs most frequently in wetlands. Numerous regions of India have experienced sporadic outbreaks. Hispa infestations have grown in recent years. Rice plants are consumed by both grubs and adult beetles. Grubs tunnel into the tissue in the direction of the leaf's main axis, moving toward the leaf sheath, while feeding on the mesophyll between the veins. Adults initially remove the chlorophyll that appears as parallel white streaks on the leaves between the lamina's veins. They generally start feeding from the apical portions of leaves and go downward. Early in the morning when beetles are most active and feeding on leaves, later white, erratic spots emerge on the leaves as a result of eating on the veins. In extreme circumstances, the field appears dried up and the leaves turn brown. The dorsal side of the leaf is where mature beetles like to feast on delicate leaf tissues. Each day, a single adult beetle eats around 25 mm of leaf surface.

Description: Adult beetles are 5.5 mm long, shiny black, and have spines on the undersides of their wings.

Source: **http://www.knowledgebank.irri.org/**

Life history: Adult beetles emerge in the morning and spend the day sleeping on the lower portions of the plant. In tiny openings on the sensitive leaves, usually near the tip, eggs are placed. The grub is flattened and whitish yellow in colour. It feeds by mining into the tissue of the leaf. In there, it pupates. Males only survive for two weeks, whilst females live for 20 days. After emerging, the beetles mate 3–4 days later. The epidermal layers on the ventral surface of rice leaves are where the eggs are placed individually. On average, a single female lays 55 eggs. The tiny eggs are typically located around the leaf tips. The incubation phase lasts between four and five days. The freshly hatched larvae are around 2-4 mm long, pale yellow, and dorso-ventrally flattened. From the leaf tip toward the leaf blade's base, they begin mining. When held up to light, larval movement inside the leaf may be seen clearly. Typically, the grub stage lasts 7–12 days. The pupae are exaggerated, flat, and brown. Within the leaf mines, the pupal stage is finished in 4-5 days. Cut through the rice leaf, the adult beetles emerge to become external feeders.

Management:

- Close plant to plant spacing results in greater leaf densities which can tolerate higher hispa numbers.
- Leaf tip containing blotch mines should be destroyed.
- Manual collection and killing of beetles.
- Leaf clipping and burying in the mud controls 75-90% of grubs.
- Spray malathion 50% EC @ 2ml per litre water a.i 0.1% or quinalphos 0.05% when 1 adult or 1-2 damaged leaves per hill are seen.

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MAJOR INSECT PESTS OF MAIZE AND SORGHUM AND THEIR MANAGEMENT

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Abstract:

Maize and Sorghum are important cereal crops grown in India and world. The productivity of these crops is greatly reduced by attack of insect pests. Excessive use of chemical and synthetic pesticides may lead to human health hazards as well as environmental pollution. To overcome such problem, various eco-friendly methods have been developed for the management of insect pests.

Keywords: Maize, Sorghum, Insect pest management.

Introduction:

Maize (*Zea mays* L.) also known as 'the queen of cereals' plays a significant role in global agriculture (FAO, 1995). Maize in India ranks fifth in total area and third in total production and productivity. To fulfil the rising demand for maize for human consumption, animal and poultry feed, as well as industrial processing, the level of production of maize must be significantly increased. On the other hand, sorghum which is grown for grain and many of which are utilised as fodder plants, either as part of pasture or in cultivation ranks 5th in cereals for global production. The majority of varieties of sorghum are heat and drought tolerant, which is crucial in dry places where the grain provides a staple food for the underprivileged and rural populations.

Among the factors adversely affecting productivity of these two crops, prevalence of diseases and insect pests in the pre harvest stage are prominent. The chemical control is the most common method used to provide protection to crop against insect pests and diseases. By using pesticides, cropping systems may be made simpler, yields could be raised, and more intricate crop protection techniques could be avoided. However, an excessive reliance on chemical management is linked to ecosystem contamination and unfavourable health impacts. The development of insect resistance and the dwindling supply of active ingredients both pose threats to crop output in the future. Therefore, agricultural methods need to be created that are less reliant on synthetic pesticides (Barzman *et al*., 2015). Eco-friendly pest management which includes IPM, biopesticides, natural enemies, etc. replaces the toxic, non-degradable ingredients/ adjuvants of the conventional formulations. This article gives the eco-friendly strategies for the management of major pests of two important crops: maize and sorghum.

1. **Stem Borer (*Chilo partellus*; Crambidae: Lepidoptera)**

Identification: The yellowish, flat, oval eggs are laid in overlapping clusters. The larva has a reddish brown head and is creamy pink to yellowish brown in colour with 4 rows of dotted

stripes running along the back. The larval stage lasts between 14 and 28 days. Adult female moths have brownish-yellow forewings with darker scale patterns that resemble longitudinal stripes. In males, the hind wings have a light straw colour, whereas in females, they are white. The life cycle is finished in roughly 5 to 6 weeks (Dhillon and Hasan 2017; Khokhar *et al*., 2019; Dhillon *et al*., 2022).

Damage symptoms: The 3-5 leaf stage of maize is preferred by the adult moth for egg laying and is typically laid on the lower surface of leaves. The eggs hatch in 3–4 days, and the newly emerged larvae crawl inside the leaf whorl and feed in groups. The first signs of a spotted stem borer attack are visible pinholes and papery windows in the unfurled rolled leaves of the whorl. After a week, larvae emerge from the whorl and bore upward along the growing stalk, frequently reaching the meristem, which leads to the formation of dead hearts (Sharma *et al.*, 2010; Mohyuddin and Attique, 1978; Ajala *et al*., 1994).

Management:

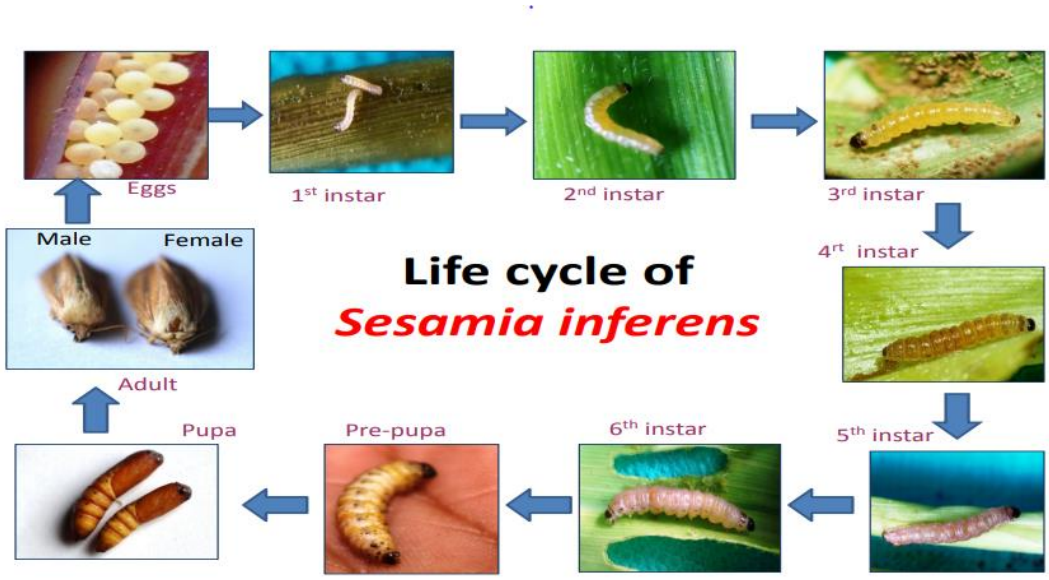
- Collection and destruction of the stubbles before sowing.
- Deep summer ploughing.
- Use of Napier grass as a trap crop.
- Intercropping maize with cowpea in 2:1 ratio.
- Release of *Trichogramma chilonis* 8 cards/ha (1,50,000 parasitized eggs/ha) at 7 and 15 days after germination.
- Removal and destruction of dead hearts.
- Spray Chlorantraniliprole 18.5 SC @150ml/ha when infestation crosses 10%.
- Natural enemies: *Trichogramma chilonis, Cotesia flavipes, Xanthopimla stemmator, Chrysoperla carne* and *coccinellid.* (Minja *et al*., 1990; Sallam *et al*., 1999; Neupane *et al*., 2016**)**

2. **Pink stem borer (*Sesamia inferens;* Noctuidae: Lepidoptera)**

Identification: Eggs are bead like, creamy white in colour and are laid inside the sheath of lower leaves in 2-4 longitudinal rows. Larva is light pink in colour with a purplish undertone. The larval stage lasts for 22 to 36 days. The mature female is a medium-sized, robust straw-coloured moth with coppery toned shiny scales and brown stripes. On the dorsal side of the forewings, three tiny black dots and in the middle a brown strip is present. The hind wings are white in colour. The antennae are filiform in female moths and pectinate in male moths. The lifespan is between 40-53 days (Patel and Verma, 1980; Sharma *et al*., 2017; Viswajyothi *et al*., 2019; Jeevanadham *et al*., 2020).

Damage symptoms: The larvae hide inside the leaf sheath in groups and feed on the epidermal layer of the leaf sheath generally on first three leaf sheaths. In young plants, the larvae bore into the central shoot which results in dead heart symptoms (drying and of growing point of maize). The larva form circular shaped tunnels inside the stem and fill them with excreta. Sometimes

circular ring like incisions are observed on the lower internodes due to larval feeding (**B**aladhiya *et al.*, 2018).



Source: Sharma *et al.*, 2017

Management:

- Collect and destroy the stubbles before sowing.
- Deep summer ploughing.
- Remove and destroy the dead hearts.
- Spray chlorantraniliprole 18.5 SC @150ml/ha in case infestation crosses 10%.
- Natural enemies: *Trichogramma chilonis, Cotesia flavipes, Chrysoperla carnea, coccinellid, reduviid bug* and *robber fly.*

3. **Fall armyworm (*Spodoptera frugiperda;* Noctuidae: Lepidoptera)**

Identification: The eggs are laid by the female moths on the upper or lower surface of the leaf and are covered with tan scales. 50–150 eggs are present in each egg mass. The incubation period ranges from 4-5 days. The larvae are smooth skinned and have three creamy yellow dorsal and lateral lines on their bodies. The colour of the larvae ranges from light tan or green to dull grey. The head of the larva is reddish brown with a white, inverted Y-shaped suture predominating between the eyes. The larval period ranges from 15 to 18 days with 6 instars. Four dark spots forming a square are present on the second last segment. Pupa is a reddish brown colour. Adults emerge from pupae after 7-9 days. Female moths are less sharply defined, varying from uniform greyish brown to a fine mottling of grey and brown. The forewing of an adult male moth consists of a fawn coloured spot and a white patch at the apical margin of the wing. Adult life expectancy ranges from 4 to 7 days. Total lifespan ranges from 30-35 days which may vary depending on climatic conditions (Kalleshwaraswamy *et al*., 2018; Navik *et al*., 2021).

Spodoptera frugiperda **Source: Georgen *et al.*, 2016**

Damage symptoms: All stages of maize growth, from seedling emergence to ear development, are targeted by fall armyworm. The young larvae feed on the whorl leaves by scraping and skeletonizing the upper epidermis leaving a silvery transparent membrane that develops into papery patches. Pinhole symptoms on the leaves are other symptoms of the injury. Inside the whorl, older larvae continue to live and feed. Large numbers of faecal pellets are seen in whorls and the leaves are severely defoliated as a result of the damage caused by late instars. Damage that occurs during the vegetative stage results in leaf damage, but damage that occurs during the reproductive stage may result in tassel damage. The whorl damage results in both quality and quantity losses.

Management:

- Deep ploughing in the maize fields to expose pupae to sun light and predatory birds.
- Clean the field bunds and plant flowering plants such as marigold, sesame, niger, sunflower, coriander, fennel etc. to attract natural enemies.
- Ridge and furrow planting method should be adopted.
- Naiper grass as a trap crop should be planted in 3–4 rows around maize fields.
- Intercrop maize with legumes such as pigeonpea, cowpea, black gram, kidney bean etc. in 2:1 to 4:1 ratio.
- Destruction of egg masses and larvae by crushing.
- Application of sand or soil mixed with lime in 9:1 ratio into whorl of maize plants.
- Two release of egg parasitoids such as *Telenomus remus* @ 4000/ ac*re* or *Trichogramma pretiosum* @ 16,000/acre at weekly intervals.
- Hand picking and destruction of larvae boring into ears.
- Application of *Bacillus thuringiensis* v. *kurstaki* formulations (400g/acre) @ 2g/litre or *Metarhizium anisopliae* or *Beauveria bassiana* with spore count of1×10^{8}cfu/g (1 kg/acre) @ 5g/litre or SfNPV (600ml/acre)@3ml/ litre or entomopathogenic nematode (EPN) (4kg/acre) @20g/litre of water is recommended at 10% ear damage (Firake *et al.*, 2019; Shylesha *et al*., 2021).

4. **Shootfly (*Atherigona orientalis;* Muscidae: Diptera)**

Identification: Eggs are elongate, milky white in colour with two wing-like projections and looks like a small rice grain. The incubation period ranges from 1-3 days. Larval period ranges from 7-10 days with 3-4 instars. Full grown maggot is yellow in colour. Pupation occurs inside the stem. The pupa is barrel-shaped and dark brown in colour. The pupal period lasts for about a week. The adult longetivity is 3-4 days. The total life cycle is completed in about 3 weeks (Grzywacz and Pape. 2014).

Damage symptoms: Eggs are laid on the abaxial surface of basal leaves, shoots and soil near the base of the plant. Within two weeks following germination, a central shoot begins to wither as a result of maggots boring into the shoot while feeding, progressively killing the growing point, resulting in the formation of dead hearts.

Management:

- Sowing must be done by the first fortnight of February.
- Seed treatment should be done using Imidacloprid 600 FS @ 6 ml/kg seed or Thiamethoxam 30 FS @ 8.0 ml per kg seed
- Remove and destroy dead hearts.
- Natural enemies: Coccinellid, spider, robber fly, pentatomid bug, earwigs.

5. **Cutworm (*Mythimna separata* and *Agrotis ipsilon;* Noctuidae: Lepidoptera*)***

Identification: About 300 dome-shaped, creamy white eggs are laid by the female. The freshly hatched larva has a black head and is yellowish in colour. The fully grown larva is dark brown in colour with a red head and looks greasy and plump. The larval stage lasts for roughly 4-5 weeks. The pupal stage lasts for approximately 10 days. Pupation occurs underground, and the pupa is reddish brown in colour. Forewings of adults are darker than the hind wings and are long, narrow and marked with black dashes. The basal two-thirds of the forewing is dark with the outer third pale grey to brown; orbicular is tear-shaped; reniform has a distinct black wedge or dagger shaped black marking on its outer margin. In the sub terminal region, there is a zigzag pattern of light scales on a dark background. The females have filiform antennae and males have plumose antennae. The life cycle is completed in about 8 to 12 weeks (Sharma and Davies, 1983).

Damage symptoms: The damage is done by the larvae. Stems are chewed near the soil level during night. After hatching the tiny larvae feed gregariously on the leaves. During day time they hide in the soil and come out at night and cut the plant at ground level. Larva drags the cut seedlings near its hideouts where the leaves are eaten up.

Management:

- Digging close to damaged seedlings and destroying larvae.
- Frequent raking of soil helps in exposing hiding larvae to birds and sun.
- Hand picking of larvae using flash light.
- Collection and destruction of larvae after flooding of fields.

6. **Aphid *(Rhopalosiphum maidis;* Aphididae: Hemiptera)**

Identification: The aphids have 2 mm body length, bluish green bodies, black antennae, legs, and cornicles. The females produce apterous forms that undergo four moults before becoming adults. Aphids produce winged adults under crowded or stress conditions, which undergo five stages of development before becoming adults. In 12–15 days, nymphal development is completed.

Damage symptoms: During the vegetative stage of the crop, aphids suck the sap from the whorl leaves. Additionally, it feeds on the panicles and produce honeydew on which sooty moulds develops. Maize mosaic virus is also transmitted through it. The yellowing, darkening, and drying of leaves are signs of damage. The surrounding leaves and the growing tassels are sometimes totally covered by the aphid colony, blocking their emergence. The infested ears and shoots may lead to poor seed set. The heavily infested tassel can become infertile.

Management:

- Mechanical removal of infested shoots.
- Conservation of natural enemies such as coccinellids, chrysopids and syrphids that feed on the aphids can significantly reduce the population without any insecticidal spray (**Alam *et al*. 2020**).

7. **Earhead bug *(Calocoris angustatus;* Miridae: Hemiptera)**

Identification: The adult male is green in colour whereas, the female is green in colour with a brown margin. The blue coloured, cigar shaped eggs are laid under the glumes or into the middle of the florets. The incubation period is seven days. Nymphs are slender in shape and green in colour. The first instar is orange in colour. The nymphal period lasts 10 days. Total life cycle is completed in 15-17 days.

Damage symptoms: The adults and nymphs feed on the earheads thereby damaging them. They suck the juice from the grains when they are in milky stage. The sucked out grains shrink, turn black in colour and chaffy. Older grains shows distinct feeding holes that reduce grain quality. (Goswamy *et al*., 2020)

Management: Use light traps till midnight to monitor, attract and kills adults of the pest. The sowing of sorghum should be completed in as short time as possible to avoid a continuous flowering.

8. **Sorghum midge (*Contarinia sorghicola;* Cecidomyidae: Lepidoptera)**

Identification: The fly is small, delicate with a bright orange coloured abdomen and a pair of transparent wings.

Damage symptoms: The maggots feed on the developing grains and cause the developing grains to shrivel and severe infestation has a substantial impact on the overall production of grains. White pupal cases are also found protruding out from the grains as well as chaffy grains with holes. The loss varies from 20-50%.

Management: Use light traps till midnight to monitor, attract and kills adults of the pest. The sowing of sorghum should be completed as quickly as possible to avoid a continuous flowering. Moulya and her co-workers suggested chemicals such as lambda cyhalothrin 5EC, Carbosulfan 25 EC and Fipronil 5 SC for efficient control of sorghum midge (Moulya *et al.*, 2022).

9. **Armyworm (*Mythimna separate;* Noctuidae: Lepidoptera)**

Identification: The lustrous, greenish-white eggs are spherical in shape and covered in fine reticulations that turn black before hatching. The colour of mature larvae ranges from green to greyish brown, and they have a white inverted Y-shaped suture on their heads and dorsal or subdorsal longitudinal light grey to black stripes or clear yellow stripes along the length of their bodies. The larva can be found in top layer of soil or in the whorl of leaves. The pupa is deep brown in colour. The mature moth is light brown in colour with dark specks on its body. Hind wings are pale brown with dark exterior margins. In males, paired tufts on the basal segment of the abdomen are absent. The life cycle of this pest is completed in one month.

Damage symptoms: The damage causing stage of this pest is the larvae. Larvae feed on tender leaves and skeletonize them. In case of severe attack, leaves including midribs are eaten away and the fields appears to have been grazed by the cattle. Larvae excrete faecal matter in the form of pellets which are seen in the plant whorls. Larvae also damage developing ears.

Management:

- Larvae should be hand-picked and destroyed.
- Installation of light traps.

10. **Cob borer (*Helicoverpa armigera;* Noctuidae: Lepidoptera)**

Identification: Eggs are laid singly on silk of the cob and are round in shape and creamy white in colour. The colour of larva varies from greenish to brown. The body of the pest have dark brown-grey lines with lateral white lines. Pupa is brown in colour and two tapering parallel spines are present at posterior tip. Forewings of adult moth have seven to eight blackish spots arranged in a line on the margin and a black comma shaped marking in the middle underside of each forewing. Males have greenish-grey forewings that eventually turn straw yellow and the hind wings are cream to light yellow in colour with a dark brown outer marginal band. The forewings of the females are light brown in colour and the hind wings ranges from cream to light yellow in colour with distinct dark brown bands. Females can also be distinguished from the male by the presence of tuft of hairs on the tip of the abdomen.

Damage symptoms: It is an emerging pest of maize usually attacking sweet corn. The larvae of this pest first feed on silk and then bore into ears, especially if the ear tip is open and covered loosely.

Management:

- Handpicking and destroying larvae before it enters the ear.
- Pheromone traps @4/ha should be installed for monitoring purpose.

- In case of heavy infestation, application of BtK formulations @ 2g/l or HaNPV @500LE/ha directed into ears.

11. **Leaf hoppers** (***Pyrilla perpusilla;*** **Lophopidae: Hemiptera)**

Identification: The female lays elongate, pale white to slightly bluish coloured eggs which are loosely arranged in elongated clusters of 20-50 and are covered with white waxy filaments of the caudal tuft. The nymphs emerge from eggs and start sucking the plant sap, developing to adult through five nymphal instars. The egg and nymphal stages completes in 7-12 days and 24-65 days respectively during April-October.

Damage symptoms: The nymphs suck the cell sap, turning the leaves yellow and covered in black sooty mould. Top leaves get dried up and lateral buds start germinating.

Management:

- Avoid excessive use of nitrogenous fertilizers.
- Setting up light traps.
- Release natural enemies of the pest such as *Epiricrania melanoleuca* @8000-10,000 cocoon/ha or 8-10 lakhs egg/ha.

12. **Chafer beetle** (***Chiloloba acuta;*** **Cetonidae: Coleoptera)**

Identification: The adults have prominent eyes, a striking metallic green colour, and are covered with yellow coloured hair. Males are often smaller than females. The females lay a tiny, oval-shaped egg of creamy white colour in the soil. The larvae feed on the humus and are dull white to greyish white in colour. There are three instars of the larva. In the month of June, pupation takes place in the soil by constructing an earthen cage. Pupa is a bright yellow in colour.

Damage symptoms: This pest poses a major threat to maize because it attacks the crop at the time of flowering. The adult beetles feed on the pollen which results in poor seed set.

Management:

- Deep ploughing of infested field to eradicate the grubs in the soil.
- Hand picking of adults.
- Remove dead and decomposing matter present in the nearby surroundings.

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INSECT PESTS OF SUGARCANE AND THEIR ECO-FRIENDLY MANAGEMENT

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Introduction:

One of the principal sources of sugar production in the world, sugarcane is a major cash crop in many tropical and subtropical nations. With a global harvest of 1.83 billion tonnes, sugarcane is grown on over 26.0 million hectares in over 90 countries. The two nations that produce the most sugarcane on a global scale are Brazil and India. In modern agriculture, insect pests reduce the yield of sugarcane. As a result, entomologists are now more interested than ever in biocontrol. The most destructive pests are borers, which lower sugar recovery rates at sugar companies by 15-20% and farmer cane yields by 8-10%. In addition to the 288 insects that impact this crop, which is affected by roughly 76 non-insect pests, nearly 24 of these insects are known to significantly reduce the quality and yield of the crop sugarcane. India is one of the world's major producers of sugarcane and has the largest area dedicated to its cultivation. From seed germination until harvest, a large number of insect pests cause crop harm. Insect damage to sugarcane reduces output and reduces sugar recovery.

The world's most popular geological sweetener and energy source is sugar. The beneficial use of sugar is an issue that is frequently discussed in the home countries. It provides work for millions of people and is essential to the cost-effective growth strategy of nations that produce sugar. The remaining 20% comes from sugar beet (*Beta vulgaris*: Amaranthaceae), whereas around 80% of the world's sugar is produced from sugarcane. One of the most important useful crops in the world is sugarcane (*Saccharum officinarum*; Poaceae). Worldwide, 121 nations are increasing their sugarcane production, and they are joined by Pakistan, Australia, Argentina, Bangladesh, Brazil, China, Columbia, Cuba, India, Mexico, Myanmar, Philippines, South Africa, Thailand, and the United States, who together account for 86% of the field and 87% of the production. It is the second-most important cash crop in Pakistan after cotton, contributing to new cultivation and GDP by 3.4% and 0.7%, respectively.

Sugarcane is also used to make ethanol, bagasse, molasses, and lobby mud in addition to sugar. For sectors like the manufacture of paper and chipboard, sugarcane serves as a basic supply of raw materials. Additionally, it serves as the primary source of income and employment for Pakistan's agrarian society (Food and Agriculture Division, 2009). This is a strategically important crop with a large economic impact on social and political issues in many nations throughout the world. 1.89 billion tonnes of sugarcane were produced globally in 2016,

according to estimates. It thrives in areas with extended periods of sunlight (12–14 hours), high temperatures (20–35 degrees Celsius), and high moisture levels (80–85%). A new era in sugarcane culture was ushered in by Soltwedel's naked sugarcane fertility in Java in the late 1880s. For hot regions of the country, wider clamour spacing of 150 cm is optional in order to provide top-notch harvests and enable automated harvesting. More than 50 plant diseases, several weeds, and other arthropods make up the sugarcane flora and fauna (phytobiome).

Since it is a crop with a long shelf life, a variety of biotic and abiotic factors, such as insect pests, viruses, bacteria, fungi, nematodes, invertebrates, and weeds, reduce its yield. Generally speaking, illnesses and insect pests have the potential to reduce its production by 19 and 20%, respectively.

Alongside the expansion of the sugar business, sugarcane acreage, production, and productivity figures have constantly increased over the years. The estimated crop area for 2013–14 in all of India was 4.99 M ha, with an average cane yield of 70.50 t/ha and a sugar recovery of 10.23%. In the country, there are currently 513 operational sugar mills, up from 29 in 1930–1931. Sugarcane will continue to be a significant agro-industrial crop in the nation despite a number of drawbacks. It is grown in two major agro-climatic zones of the nation, the tropics and subtropics, which are both characterised by moderate or ideal and extreme climatic conditions.

Biotic stresses were left behind by the sugar industry's enormous expansion and the increase of sugarcane farming. Although they are in second place to diseases among these, insect pests cause significant losses in cane yield and sugar production. Different pest profiles are seen on sugarcane in subtropical and tropical India. Subtropical India has an unfavourable environment marked by seasonal extremes that promotes moderate crop growth but considerable insect abundance. In contrast, tropical India's temperate climate encourages good agricultural growth but few pests. From planting to harvest, sugarcane is attacked by borers, sucking pests, defoliators, and underground pests. Many different types of illnesses and insect pests damage the sugarcane crop. Arthropod pests that affect crops all throughout the world include complexes of branch-eating insects, sap-sucking insects (like aphids, thrips, and mealy bugs), root-eating insects (like white grubs and stem borers), and spider mites.

In this chapter, we are discussing different pests of sugarcane and their symptoms and management practices.

Major Insect-Pests of Sugarcane:

1. **Early Shoot Borer *Chilo infuscatellus* Snellen (Crambidae: Lepidoptera)**

Identification: The eggs were placed in clusters of 10 to 30 on the underside of the leaves by the side of the midrib by a straw-colored adult moth. The eggs have a scale-like shape and are a creamy white colour. The larvae are dull white in colour with several longitudinal brownish red stripes on the back, and they repeatedly bore, either in the same stalk or in stalks nearby. In the

tunnel inside the sugarcane stalk where they had been feeding before, the larvae pupate after spending about three weeks in the larval stage.

Source: Satyagopal *et al.* (2014)

Symptoms:

Pre-monsoon season (April to June) is when shoot borer infection is at its peak since ambient temperatures are often high and relative humidity is low. Before internode formation and during the early stages of cane growth, the crop is attacked by the borer. In order to eliminate the developing point, larvae tunnel downward as well as upward into the cane through one or more holes in the stalks (shoot) immediately above the ground level. This causes gaps in the field. As a result, the central leaf spindle is cut off, eventually drying to form a "**dead heart**."

Dead heart, which can be easily plucked out of a crop that is one to three months old, exudes an unpleasant odour. Before pupating, a single caterpillar may devour three or four shoots. With the arrival of the monsoon, borer activity significantly diminishes.

Management:

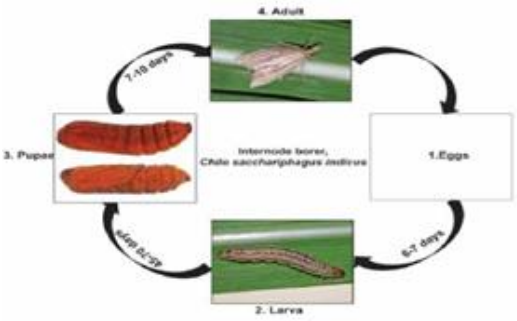
- The incidence is decreased by lightly earthing up the tillers in the early stages of the crop.
- The gathering and disposal of egg masses.
- Removing and destroying hearts that have died.
- Planting before the peak oviposition time to avoid it.
- Early-stage mulching with cane garbage has also been shown to lower incidence and aid in moisture conservation.
- Cutting and destroying the impacted tillers as close to the ground as is practical.
- Applying 25 kg/ha of Cartap hydrochloride granules to the soil at planting, followed by another treatment 45 days later for crops that were planted later.
- From the first month of planting, inundative releases of the egg parasitoid Trichogramma chilonis at 50,000/ha at intervals of 7–10 days.

2. Internode Borer: *Chilo sacchariphagus* indicus (Kapur) (Crambidae: Lepidoptera)

Identification:

Moths that are adults are straw in colour and average size. Four violet-colored strips on the body of fully grown caterpillars serve as a distinguishing feature. The prolegs' crochets create a complete circle, and the tubes are completely black.

Life cycle:



Source: Satyagopal *et al.* (2014)

Symptoms:

After three months of planting, caterpillars attack sugarcane plants (June-December). causes damage to the crop shortly after internode development and persists until harvest. They drill into the canes close to the nodes, seal the entry pores with excrement, and tunnel upward in a distinctive spiral pattern. Entry is typically limited to the first five truncated internodes. Reddening occurs in the tissues affected. The larvae feed on and grow in the water shoots. One larva detected in one cane causes harm to one to three internodes. The presence of water shoots, lodging, a high nitrogen dose, and soggy conditions all encourage the growth of pest.

Management:

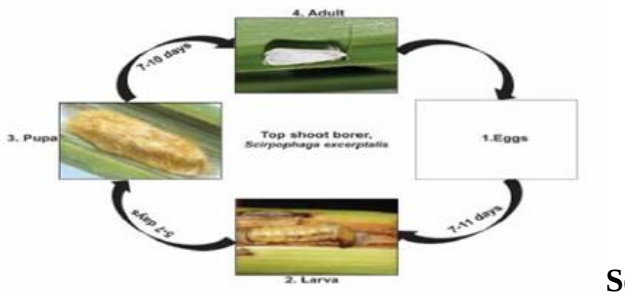
- Collecting and destroying egg masses
- In order to eliminate the larvae and pupae clinging to the leaf sheaths, canes must be destroyed and rubbish burned. Egg masses must also be collected and destroyed.
- Trichogramma chilonis, an egg parasite, will be released in an inundative manner at a rate of 50,000 parasites per hectare every week beginning in July.
- Dimethoate will be sprayed at a rate of 2ml/ litre of air if serious incidents are seen.

3. Top Borer *Scirpophaga excerptalis* Walker (Pyralidae: Lepidoptera)

Identification:

Caterpillars, which are typically found in a cane's top section, are the cause of damage. Caterpillars are slow-moving and creamy white in colour. The moths are completely white in colour, and at the tip of their abdomens, they have a crimson tuft of silky hairs.

Life cycle:



Source: Satyagopal *et al.* (2014)

Symptoms:

Caterpillars are primarily found in the apical region of the canes. They bore through the growth point and through the higher joints until they reach the sap-filled area of the stem, where they feed on the tissues and kill the cane. Additionally, they drilled into opened leaves, especially into the midrib, mining their way down to the base. After the sixth month of adulthood, an adult cane with a dead heart emerges that is difficult to pull. But as the disease progresses, its attack only affects the tops of the sugarcane plants, leading to the characteristic symptom known as bunchy top.

Management:

- During the brood emergence stage, it is possible to collect and destroy the egg masses as well as the infected plant parts.
- The release of the parasites Trichogramma japonicum and Isotima javensis was successful.
- For the third brood, it is advised to apply 33 kg of carbofuran 3G to the soil, followed by irrigation, in the first week of July.

4. Root Borer, *Emmalocera depressella* (Swinhoe) (Pyralidae: Lepidoptera)

Identification: The colour of fully grown caterpillars is milky white. Roots are not eaten by caterpillars, although they do consume the upper surface of the roots.

Symptoms:

Although they are known as root borers, they hardly ever penetrate the root. This bug only attacks the portion of the stem that is above ground. The caterpillars of this insect are mostly responsible for the harm done to the cane crop. After hatching, caterpillars descend the plant and burrow into the soil to feed on plant tissue below the soil's surface. The typical signs of an infestation by this pest are the inner whorl of leaves drying up and the production of dead hearts.

Management:

- Using Regent (Fipronil) 0.3 (granular formulation) at 75 g a.i/ha, E. depressella was successfully eradicated.
- Intercropping cowpea and sugarcane decreased infestation. Other crops, such green and black grammes, were discovered to lessen infestation.
- Field flooding decreased infestation.

5. Stalk borer *Chilo auricilius* Dudgeon (Crambidae: Lepidoptera)

Identification:

First and second instars of the moths feed inside the top leaf sheaths after the females had laid their eggs in clusters on the bottom surface of sugarcane leaves. Dead hearts are caused by later larval instars' drill holes inside cane stalks. In clusters of 2 to 6, eggs were found in equal densities on dried cane leaves, green leaves, and ground debris.

Symptoms:

On the underside of the leaves, eggs are placed in groups. Young larvae consume the upper leaf sheaths before boring into the cane stalks and killing the Page | 9 hearts. Holes appear on or near the buds as a result of infestation. Infested setts shouldn't be utilised for planting in the field because this impairs germination and tillering.

Management:

- Reducing occurrence is achieved by burning waste materials, removing plant remains, and cutting off "water shoots" in ratoon crops.
- Earthing up in May and June and fertiliser application in the months before monsoons.
- 1.5 kg a.i. of carbofuran 3-G per hectare.

6. Plassey Borer: *Chilo tumidicostalis* (Hampson) (Crambidae: Lepidoptera)

Identification: Four pinkish-brown stripes on the back and a full circle of the crochet on the prolegs help identify a typical larva. A pest's life cycle takes 39–64 days to complete in August–September; the egg stage lasts 7 days, the larval stage is 26–46 days, and the pupal stage is 6–11 days. On both plant and ratoon canes, *C. tumidicostalis* has six larval instars, with the lengths of the larval and pupal stages being longer in December and February than they are in July and August. Duration of the larval stage (53.3 days), the pupal stage (10–12 days), and the entire life cycle of *C. tumidicostalis* (61-72 days).

Symptoms:

The primary infection is caused by young larvae tunnelling gregariously into the top three to five internodes and is identified by the development of set-roots, lateral buds, and dried-out top leaves. Larvae later bore separately in different internodes during a secondary infestation, although the cane tops did not dry.

Management:

- Gathering moths from light traps;
- Cutting off cane tops that have the predominant infestation;
- Gathering and destroying egg masses
- In July and September, rogueing of afflicted shoots in combination with phosphomidon at 0.05%.

7. White grub: *Holotrichia consanguinea* **Fabricius. Scarabaeidae coleoptera**

Identification:

Egg: A female lays an average of 27 pear-shaped, white eggs that are encased in earthen cells in the soil.

Grub: A fleshy, 'C'-shaped insect with a white yellow colour that is located near the base of the clump.

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

Adult: After emerging from the pupal stage, adult beetles are rusty-red in colour before turning virtually black.

Life cycle:

Source: Satyagopal *et al.* (2014)

Symptoms:

- The wilting and yellowing of the leaves.
- The entire crown drying.
- When pulled, affected canes easily come off.
- Significantly harm the roots and base of the shoot.

Management:

Cultural control:

- Eliminating stubble and leftovers from previous crops

Physical control:

- Find and eliminate the infected setts and termite colony.
- Construct a light trap to catch adult white grubs, then kill them in kerosene-oil water.
- When the monsoon season begins, gather and kill adult beetles by shaking the tree branches where they spend the night.

Biological control:

- Entomopathogenic nematodes (EPNs) can be sprayed on sugarcane fields that are infested with termites and root grubs at a rate of 100 million nematodes per acre.
- For the management of sugarcane root grubs, four EPN-infected corpses of Galleria/Corcyra larvae per plant are implanted in the soil at the bases of the plants throughout the months of May, June, and/or September.
- Chemical control:
- Fipronil 40% + imidacloprid 40% WG@175-200 g in 400–500 l of water/acre or phorate 10% CG @ 10,000 g/acre are two chemical control options.

8. Sugarcane Leaf Hopper *Pyrilla perpusilla* Walker (Lophopidae: Homoptera)

Identification:

When a person goes through a field that is extensively infested with leaf hoppers, they make a faint noise and move around in large numbers. The adult, which is also active, has wings with dark streaks or patches and a straw-colored body. It features bright red eyes and a protruding snout-like feature on the front end.

Symptoms:

The sugarcane pest known as Pyrilla is the worst for sucking up the leaf. The nymphs and adults are both quite active, hopping from leaf to leaf in response to small disturbances. The black fungus is drawn to them because they emit honey dew and suck the cell sap from the leaves. This feeding causes the leaves to turn yellow and eventually seem withered, scorched, and covered with black encrustation. Photosynthesis is impacted by this. High temperatures (26-30 °C), frequent periods of drought, 75-80% humidity, and heavy precipitation all contribute to the rapid development of pyrilla.

A dense and luxuriant crop, excessive nitrogen application, water logging, cane lodging, and cultivars with broad and succulent leaves are other conditions that encourage pyrilla buildup. Pyrilla-related losses to cane yield have been calculated to be around 28%, with a sugar unit loss of roughly 1.6%.

Management:

- Destroying and burning rubbish (detrash) after harvest aids in eliminating egg masses and nymphs that have overwintered.
- Gathering and killing egg masses throughout the early stages, from April to May.
- Eliminating sprouts from the stubble once in April helps to lower pest buildup.
- Detrashing has been incredibly beneficial since august.
- Epiricania melanoleuca, a lepidopteran ectoparasitoid, is checked for multiplication by releasing 400–5000 cocoons, or 4-6 lakh eggs, per hectare.
- Spraying with chlorpyriphos at 2 ml per litre, phosphamidon at 0.5 ml per litre, or dimethoate at 2 ml per litre is highly successful in cases of severe infestation without the presence of the ectoparasitoid.

9. Whitefly, *Aleurolobus barodensis* (Aleyrodidae: Hemiptera)

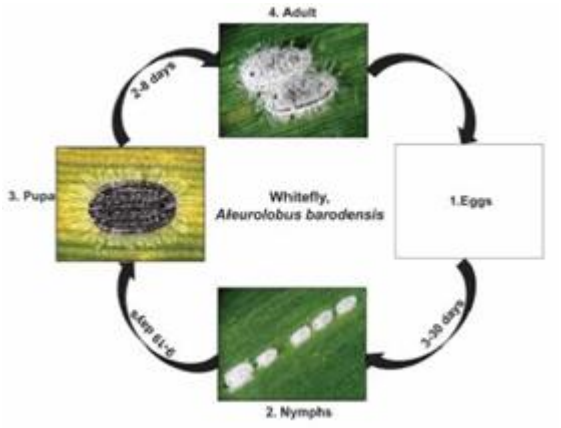
Identification:

The oval, black nymph of the whitefly has a silvery-gray waxy coating across its body. The adults are tiny, delicate, pale yellow, with a white mealy look and black spots on their moulted wings. They move quickly, although in the field it is difficult to see them.

The leaf gradually turns yellow and pinkish as a result of nymphs draining the sap, and eventually the leaf dries up. The nymphs excrete a lot of honey dew, which collects on the

afflicted leaves and makes them look black because sooty mould growth prevents photosynthesis. A major infestation of whiteflies is brought on by water logging and nitrogen deficiency. Droughts in the summer and dry spells during the monsoon season further encourage the growth of this insect. Long, broad leaf varieties are particularly vulnerable to this insect.

Life cycle:



Source: Satyagopal *et al.* (2014)

Symptoms:

The sap from the underside of leaves, which in extreme cases turn yellow and pinkish and gradually dry up, is sucked by the nymphs of white flies. The sooty mould brought on by the heavy infestation of leaves Juice quality suffers and crop growth is impeded when infection levels are high. A severe whitefly infestation may cause a loss in sugar of up to 2.9 units and a drop in cane yield of up to 24 percent.

Management:

- Prevent water logging and discourage ratooning in low lying locations. Periodically remove lower leaves that contain pupae.
- Limit your use of nitrogen.
- After removing the infected lower leaves, spray Imidacloprid 17.8 SL@ 0.01%. At least two sprays will be necessary every two weeks.

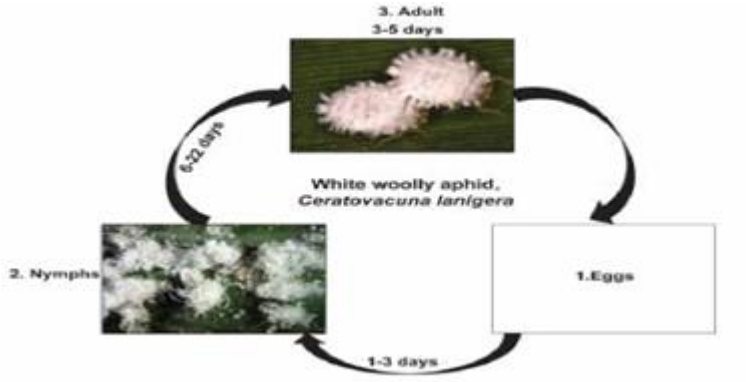
10. Sugarcane Woolly Aphid, *Ceratovacuna lanigera* (Aphididae: Hemiptera)

Identification:

Nymphs that have just emerged are a yellowish or greenish yellow colour without any fuzzy filaments. On the underside of the leaves, nymphs may be seen gathered at both sides of the midrib. There are four seen instars before they reach adulthood. On the dorsal side of the third and fourth instar nymphs, but not on the first and second instar, white coloured fuzzy filaments are seen. Adults are all-black, with two pairs of transparent wings, two cornicles, and two pairs of wings. Females with and without wings have been observed to procreate parthenogenetically all through the year.

In 20 days, each female could produce a maximum of 217 nymphs. Nymphs went through four instars, maturing into adults in 6 to 22 days. In the field, overlapping generations have been noticed. The main reason for the attack was an early wet season, and an aphid infestation was further encouraged by a dry season with high humidity. Aphid population growth was boosted by alternating rainy and hot days rather than by prolonged dry and wet seasons.

Life cycle:



Source: Satyagopal *et al.* (2014)

Symptoms:

On the bottom surface of the sugarcane leaves, nymphs and adults can be seen sucking the cell sap and excreting "honey dew," which is then dropped on the upper surface of the lower leaves. The growth of the fungus Capnodium spp., which causes a black covering known as "sooty mould" on the upper surface of leaves and interferes with photosynthesis, is aided by honey dew. The development of yellowish white spots on the leaves as a result of sap sucking causes the edges of the leaves to dry out before they completely dry out. Leaf mottling, slowed growth, and decreased sugarcane production and sugar recovery are all symptoms of severe infestation. There have been reports of losses of up to 26% in sugarcane yield and 24% in sugar content.

Source: Satyagopal *et al.* (2014)

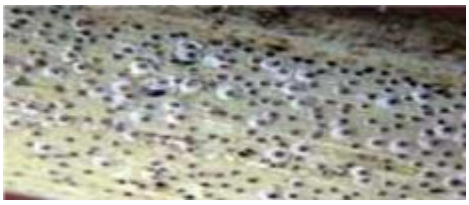
Management:

- Sugarcane that is planted in pairs or broader rows.
- Release of M. igorotus larvae at 2500/ha and Dipha aphidivora larvae at 1000/ha.
- Use of dimethoate or metasystox 0.0375% or 0.045% depending on the severity of the infestation and the absence of natural enemies.

11. Scale Insects, *Melanaspis glomerata* (Diaspididae: Hemiptera)

Identification:

The mature female is a sedentary creature without wings or legs who resides inside a white covering. The male is diminutive and unattached. It has a unique sharp organ that can cut through a woman's scale covering.



Source: Satyagopal *et al.* (2014)

Symptoms:

Infested canes' leaves exhibit evidence of tip drying and a sickly light green colour, while a severe infection results in yellowing. The leaves don't open due to severe desapping; they also turn yellow and eventually dry up. Crop that has been infested loses its vigour, canes wilt, growth is hindered, and the intermodal length is significantly reduced. Cane eventually dries up. Such canes have a reddish red appearance when cut open. In badly afflicted canes, the nodal and intermodal zones exhibit thick brown encrustations.

Management:

- Choose setts that are free of scale insects.
- Keep weeds at bay in the fields.
- Prevent prolonged water logging in the field.
- Steer clear of ongoing ratoons.
- Falling foliage
- Before planting, sets should be dipped in chlorpyrifos 20EC at a rate of 5ml per lit of water and allowed to sit for 15 minutes.
- After detrashing, spritz 2 ml of dimethoate per lit of water. The scale insect infestation was greatly decreased by 0.1% of Malathion, 0.03% dimethoate, and detrashing.

12. Mealy Bug, *Saccharicoccus sacchari* (Pseudococcidae: Hemiptera)

Identification:

Eggs: Until they are fully developed, eggs are kept in the female reproductive organs. Short incubation period. The females may parthenogenetically give birth to hundreds of offspring. Egg is smooth, cylindrical, rounded at both ends, and colourless.

Nymph: Nymphs that have just emerged have a pinkish, translucent body and are highly active.

Adult: Mealy with a pinkish covering. The insects are typically discovered trapped in a white waxy substance close to the internode joints beneath the leaf sheaths. These can occasionally be

found on the internodes' exposed areas. The waxy clump under the leaf sheath is where the eggs are placed. 400 eggs could be laid by one female.

Depending on the temperature and humidity, they hatch in 4–7 days. Young nymphs that emerge from the waxy material stay there for a day or two before starting to migrate. They quickly establish themselves on newly formed internodes close to the joints, stick their mouthparts into the plant tissue, and start sucking in plant sap. The immature nymphs are round and pink, just like the adult female, but they are flattened, considerably smaller, and free of any mealy covering. the mature wing. Unlike the female, which has no wings, the male is a very uncommon sight.

The pest's life cycle takes about a month to complete, and the broods come in quick succession. Every stage of the pest can be seen during the growing season, and generations overlap.

Source: Satyagopal *et al.* (2014)

Symptoms:

On the nodes, there are pinkish oval insects with a yellowish mealy coating under the leaf sheath. Stunned main cane also attacks roots. Honey dew canes that are attacked by black ants and develop sooty mould, giving them a blackish look, turn their leaves yellow. Because of the withering of the leaves, the affected crop appears pale and sickly and can be seen from a distance. The afflicted leaves may dry out if the infection is severe. On the internodes beneath the leaf sheaths, cavities-like depressions develop as a result of the bugs' ongoing desapping. Additionally, the buds suffer severe harm and appear atrophied.

When canes are severely infested, the juice quality suffers and there may be a 25% drop in sugar content. Varieties with loosely fitting leaf sheaths are subject to more severe assault.

Management:

- Pick wholesome setts
- Drain the land of any extra water.
- Remove crop waste in September and October
- Don't use too much nitrogen fertilisers
- Spray crop with Chlorpyriphos 20 EC @ 5 lit in 1000 lit water/ha after removing the lowermost 1-2 dry leaves from the setts for 5 minutes.

13. Termites: *Odontotermes obesus* Rhamb (Termitidae: Isoptera)

Identification:

Nymphs go through 8–9 moults before reaching maturity in 6–12 months. Nymph eggs are dull, kidney-shaped, and hatch in 30–90 days. Adults are tiny, cream-colored insects that resemble ants and have a dark-colored head. The harmed canes pass away. A loose network of tunnels and chambers beneath the ground houses highly organised societies of several hundred thousand to one million or more termites. A few winged individuals leave the colony for a nuptial flight shortly after the first monsoon rainfall. After a brief flight, mating occurs, and the male and female (Queen) then make camp. The female creates a new colony by digging in the ground.

The eggs are laid by the queen quickly. They grow into workers and make up the majority of the colony. They forage for food to eat and take back to the nest, build and maintain the nest, and tend to the young. These employees look after the colony and the queen. Inside the termitoria, queen termite eggs and nymphs can be discovered. Forms that reproduce have wings. Queens and kings, who are reproductive, give birth to the new generation while troops protect the colony from outsiders.

Adult males and females known as **swarmers** leave established colonies in an effort to found new colonies. Termites are worldwide and polyphagous insects. More severe when there is a prolonged drought and in soils with a light texture, such as sandy and sandy loam soils.

Symptoms:

More severe when there is a prolonged drought and in soils with a light texture, such as sandy and sandy loam soils. Stubbles, shoots, canes, and setts are all attacked by termites. In order to feed on the soft tissue, the termites enter through the cut ends or buds of the setts. The soil fills the tube that was dug out. This has an impact on germination, ultimately affecting the cane production and the initial crop stand. A 60% germination failure rate is possible.

Management:

- Flood irrigation while planting prevents termite attack from too much moisture and restores the ideal moisture level.
- One method to suffocate these pests is to find the termite colony and eliminate it by burning crop wastes on top of the termite mounds. By tillage or flooding, mud galleries or tunnels are destroyed, although this only provides a short-term fix.
- Gather and remove the field's termite-damaged setts.
- Spraying imidacloprid 17.8% SL at 375 ml/ha on sugarcane setts for 5 minutes or dipping the setts in Chlopyriphos 20 EC @ 5 ml/lit of water.

Future Aspects:

Finding methods to get over the ecological constraints imposed by monocultures in sugarcane, as in many other cropping systems, is the main issue in implementing ecologically oriented pest management (Altieri and Nicholls, 1999). IPM also needs to be scaled up from traditional tactics used at the field level to a more comprehensive strategy known as Area Wide Integrated Pest Management (AW-IPM) used at the landscape level (Vreyssen *et al*., 2007). Fields and farms are a part of an ecosystem where insects have no boundaries and dwell in many habitats, therefore this relatively new strategy is unquestionably the best course of action (crops, natural vegetation, weeds and forests).

Conclusion:

Sugarcane is a reliable agricultural system in tropical India since the climate there is less extreme than in the subtropical area. While holding themselves well below the harmful thresholds, a variety of local pests frequently reach levels that inflict economic impact. Invading pests occasionally start epidemics, seemingly with human assistance. The successful control of these pests depends on regular monitoring and early application of a variety of techniques, either separately or in combination as mentioned in the previous section under specific pests.

Major natural enemies of Sugarcane pests

Parasitoids

Cotesia flavipes

***Trichogramma*spp.**

***Encarsia*sp**

***Eretmocerus*sp**

Chrysocharis pentheus

***Aphytis*sp**

Predators

Lacewing

Ladybird beetle

Spider

Dragonfly

Reduviid bug

Praying mantis

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MAJOR INSECT PESTS OF OIL SEED CROPS AND THEIR MANAGEMENT

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Introduction:

Oilseeds are India's second-largest agricultural product after cereals. These crops are damaged by several pests; among these pests some are more serious. In many occasions they have been used as the principal method. Wide-spectrum insecticides are a major source for causing harmful effect to the environment and human health. The adoption of some cultural techniques and pest tolerance plant cultivars can effectively manage these pests. Based on existing knowledge, various methods for developing Integrated Pest Management (IPM) tactics against significant pests in oilseed crops have been proposed. By minimizing insect damage while having no negative effects on the agro-system or environmental devastation, such IPM technologies will help to boost the production and productivity of these crops. Pest wise information and management of major pests infesting oilseed crops are described below.

Pest of Groundnut

1. Groundnut aphids, *Aphis craccivora*, Aphididae: Hemiptera
2. Leaf hopper, *Empoasca kerri*, Cicadellidae: Hemiptera
3. Thrips, *Scirtothrips dorsalis*, Thripidae: Thysanoptera
4. Red hairy caterpillar, *Amsacta albistriga*, Arctiidae: Lepidoptera
5. Groundnut leaf miner, *Aproaerema modicella*, Gelechiidae: Lepidoptera
6. Tobacco caterpillar, *Spodoptera litura*, Noctuidae: Lepidoptera
7. Gram pod borer, *Helicoverpa armigera*, Noctuidae: Lepidoptera
8. Pod borer (Ear wig), *Anisolabis stalli*, Forficulidae: Dermaptera
9. Pod bug, *Elasmolomus sordidus*, Lygaeidae: Hemiptera
10. Bud borer, *Anarsia ephippias*, Gelechiidae: Lepidoptera
11. Stem borer, *Sphenoptera perotetti*, Buprestidae: Coleoptera
12. Termites, *Odontotermes* sp., Termitidae: Isoptera
13. White grub, *Holotrichia consanguinea*, Scarabaeidae: Coleopter

Aphids, *Aphis craccivora,* Aphididae: Hemiptera

Host Plants: Aphid is the serious pest in groundnut it also attacks beans, peas, safflower, lablab, pulses etc.,

Destructive Stage: Nymphs and Adults

Symptoms of damage: The nymph and adult sucking the sap from underside of the leaflets and young shoots up to 2 months after development of the crop. It makes young shoots wilt in hot weather. Infected plants show mottled leaves with dark green/chlorotic spots. Infestation in earlier stages causes stunted growth well as reducing their vigour. Honey dew deposits on the leaves and young shoots, it causes sooty mold. It acts as a vector for the peanut stripe virus and the complex of groundnut rosette viruses.

Management: Planting crops on time. Select a groundnut cultivar that has stiff leaves and dense hairs. Eg. Girnar1. Choose resistant/ tolerance varieties for cultivation - Gimar-2, Jawahar Groundnut-3, Prutha, Kadiri-7 and Kadiri-8. Hand picking and destroying different insect stages as well as the affected plant parts. Treat the seed with *Trichoderma viride* at 4 g/kg. Application of 5% NSKE (Neem Seed Kernel Extract) to control sap feeding pests. Release *Cheilonenes sexmaculata* at 1250/ha. Release *Chrysoperla carnea* grubs at 5000 / ha. Protect the biological agents like Anthocorids (flower bugs), Coccinellids (lady bird beetles), praying mantis, Syrphids (Hover flies), Chrysopids (Green lace wing), long horned grass hoppers and spiders.

Leaf hopper, *Empoasca kerri,* Cicadellidae: Hemiptera

Host plant: Groundnut, black gram, cow pea and green gram

Destructive Stage: Nymphs and Adults

Symptoms of damage: Nymphs and adults sucking the sap from young leaves. Leaf veins are turn into white in colour. Salivary secretion of jassids cause chlorotic (yellow) patches at the tips of leaflets. In severe infestation leaf shows 'hopper burn' symptom.

Management: Sowing of crop on time and grow tolerant varieties. Follow crop rotation using a non-host crop. Intercropping pattern groundnut + pearl millet. Avoid castor used as an intercrop, because it causes severe infestation. The damaged parts of the plant should be collected and destroyed. Protect the following bio control agents in groundnut field like long horned grass hoppers, praying mantis, dragon flies, spiders, green muscardine fungus.

Thrips, *Scirtothrips dorsalis,* Thripidae: Thysanoptera

Host plant: Groundnut, peppers, blueberry, citrus, grapevines, peanuts, tea, mango, cotton, and rose

Destructive Stage: Nymphs and Adults

Symptoms of damage: Nymphs and Adults both are sucking the sap from the leaflets' surface. White patches are present in the upper lower surface of the leaves. Necrotic patches present in the lower surface of the leaves. Damage is usually seen in young age plants.

Management: Follow the 1:4 ratios of lab lab + groundnut intercropping pattern. Introduction of border crop maize, sorghum or pearl millet 5-6 lines or intercrop 5:1 ratio. Use the following resistant/tolerance variety - Gimar-2, Girnar-3, GG-16, Durga, Kadiri Harithandhra, Pratap Mungphali-1, Pratap Mungphali-2, Vasundhara, Kadiri-7, Kadiri-8 and GG-14.

Red hairy caterpillar, *Amsacta albistriga,* Arctiidae: Lepidoptera

Host plant: Red hairy caterpillar major pest on groundnut. They also affect corn, sorghum, green gram, gingelly, pearl millet, ragi, castor and cotton.

Destructive Stage: Larva

Symptoms of damage: Young larvae scraping the lower surface of the tender leaves because mandibles are not well developed in earlier stage of the larva. Later age larva feed leaves and main stem voraciously. Severely affected field looks like grazed by cattle and sometimes it results in total loss of pods.

Management: Cowpea/red gram grows as an intercrop to attract adults to lay more eggs. The egg masses, early instar larva and pupae in the groundnut as well as intercrop should be collect and destroy. Set up light traps (3-4) and kill the attracted moths.

Leaf miner, *Aproaerema modicella,* Gelechiidae: Lepidoptera

Host plant: Groundnut, soybean and red gram.

Destructive Stage: Larva

Symptoms of damage: Leaf miner prefers rainfed and cluster groundnut varieties. Young caterpillar makes mines into the leaf and feed on green soft tissue causing in brownish dried up blotches. Later instar caterpillars folding the leaves and eat green tissues by remaining inside. Burnt up appearance presents in severely infected crop.

Management: Grow resistant cultivars like ICGS 156 (M 13), ICGV 86031, FDRS 10, ICG 57, 156, 541, 7016, 7404 and 9883. Early and synchronously sowing of peanuts during rainy season and rabi season. Maintain a 4:1 ratio of groundnut and pearl millet intercropping pattern. Install light traps in groundnut field at ground level and operate in between 8 and 11 PM. Mulch the soil with straw10 days after germination. Avoid water stress in irrigated plants to avoid insect infestation. Ensure that there are no weeds in the fields or bunds.

Tobacco caterpillar, *Spodoptera litura,* Noctuidae: Lepidoptera

Host plant: Tobacco caterpillar is the serious pest in groundnut and also attacks, soybean, citrus, cotton, millets, castor, pulses, sunflower safflower, cabbage, banana, bhendi, tomato, sweet potato, tobacco, chillies etc.,

Destructive Stage: Larva

Symptoms of damage: Early instar larva feed voraciously on leaves and appear to be grazed by cattle. It is nocturnal insect so during the day time the larvae hide under the plants, cracks and crevices of soil and debris. Faecal matters are visible on the ground and on the leaves, which indicates the presence of pests.

Management: Raise castor as a border/intercrop in groundnut, it acts as indicator/trap crop. Grow the following resistant cultivars such as ICGV 86031, FDRS 10. Setting up of light trap (1/ha) and pheromone traps (12/ha) to monitor the emergence of adult moths. Collect and destroy the egg

masses and the gregarious larvae. Digging a trench 30 cm deep and 25 cm wide in the infested fields avoid migration of larvae from one field to another.

Gram pod borer, *Helicoverpa armigera,* Noctuidae: Lepidoptera

Host plant: Besides groundnut, sorghum, cotton, lablab, safflower, soybean, chilly, tobacco, bhendi, corn, tomato, etc.,

Destructive Stage: Larva

Symptoms of damage: Larvae feed on the vegetation and flower buds. Larva makes small/large irregular holes in leaves.

Management: Expose the eggs to direct sunlight by deep summer ploughing. Grow one row of red gram for every 5/6 rows of groundnut. Set up light trap and pheromone traps (12 nos. /ha) to kill the attracting moths. Release of egg parasite and egg larval parasite of *Trichogramma* spp. and *Chelonus blackburnii*. Apply Nuclear Polyhedrosis Virus (NPV) at 250 LE/ha or B.t (*Bacillus thuringiensis*) 1 kg/ha or NSKE 5% for monitor eggs and early instar larvae**.** Combined use of SlNPV and HaNPV at 250 LE/ha with crude sugar 2.5 kg/ha on groundnut is highly effective. Release *Trichogramma chilonis* at 1 lakh/ha or *Chrysoperla carnea* at 50000 Nos./ha at 40 & 50 DAS (Days after Sowing) of groundnut. Install bird perches @ 50/ha.

Ear wig, *Anisolabis stalli,* Forficulidae: Dermaptera

Host plant: Groundnut, onion, garlic, cabbage, cotton and sorghum.

Destructive Stage: Larva and adult

Symptoms of damage: *A. stalli* makes bore holes on pods and plugged with sand particles, excreta or discoloured the pulp. Bored pods are lacking of kernels. The occurrence of earwig is confined to rainfed groundnut.

Management: A good trap can be made from cat food or tuna fish can, with 0.5 inch of oil in the bottom. Earwigs are attracted to tuna fish oil or vegetable oil with a drop of bacon fat. These traps work best when they are buried so that the neck portion of the can is level with the ground. Allow Chickens and ducks to the groundnut field because it will eat several earwigs.

Pod bug, *Elasmolomus sordidus,* Lygaeidae: Hemiptera

Host plant: Groundnut, gingelly

Destructive Stage: Nymphs and adults

Symptoms of damage: Both nymphs and adults sucking the sap from the pods. Freshly harvested pods having shrunken kernels. It will cause severe damage at pod initiation, pod harvesting stage and harvested produce in the threshing floor.

Management: Set up light traps and kill the attracted bugs. Keep the crop litter in the field along irrigation channel to attract the bugs which can be destroy/killed by dusting.

White grub, *Holotrichia consanguinea,* Scarabaeidae: Coleoptera

Host plant: All types of oil seed crops, vegetables, sugarcane, pulses, cereals, etc.,

Destructive Stage: Grub and adult

Symptoms of damage: Infected plants shows stunted growth. Severe infestation causes wilt/die. The plant roots are cut and eaten by the grubs, which causes the plants to wilt and die. Fields with severe infestations have large areas of dead vegetation. When the grubs are present at the stage of pod production, they also damage the pods.

Management: Summer ploughing helps to expose the grub in direct sunlight and kill. Adopt crop rotation with rice in irrigated endemic areas to reduce grub infestation. Ensure adequate irrigation to irrigated groundnut in endemic areas since the grub attacks roots under inadequate soil moisture condition. Set up light traps and destroy the beetles, which are attracted by light trap. Follow regular pruning of the trees present around the fields. Collect and destroy the alternate host around the field like ber, drumstick, and neem. Install light traps and destroy the beetles, which are attracted by light trap. Apply *Beauveria bassiana* or *Metarhizium anisopliae* 5 kg/ha + castor cake 300 kg/ha in soil at the time of sowing and also drenching with same powder at 40 g/ 10 lit in row after 30 days.

Pest of Sunflower

1. Leaf hopper, *Amrasca biguttula biguttula*, Cicadellidae: Hemiptera
2. Capitulum bore, *Helicoverpa armigera*, Noctuidae: Lepidoptera
3. Tobacco caterpillar, *Spodoptera litura*, Noctuidae: Lepidoptera
4. Bihar hairy caterpillar, *Spilosoma oblique*, Arctiidae: Lepidoptera
5. Semi looper, *Trichoplusia ni*, Noctuidae: Lepidoptera
6. Cutworms, *Agroitis* spp., Noctuidae: Lepidoptera
7. Stink bug, *Nezara viridula*, Pentatomidae: Hemiptera
8. Plant bug, *Dolycoris indicus*, Pentatomidae: Hemiptera
9. Black hairy caterpillar, *Estigmene lactinea*, Arctiidae: Lepidoptera
10. Ash weevil, *Myllocerus* sp, Curculionidae: Coleopter

Leaf hopper, *Amrasca biguttula biguttula,* Cicadellidae: Hemiptera

Host plant: In addition to sunflower, it also affects cotton, brinjal, potatoes, castor, cowpeas, and cluster beans.

Destructive Stage: Nymph and adult

Symptoms of damage: Nymphs and adults sucking the sap from the underside of leaves. Leaves become wrinkled and cup shaped. Infected plants shows stunted growth. Severe infestation causes "hopper burn".

Management: Early sowing and closer spacing will reduces pest damage. Apply sufficient amount of nitrogen. Mixed cropping of sunflower + cotton. Intercropping sunflower + groundnut in the ratio 1:4. Setup light trap to monitor the leaf hopper. Spray NSKE 5% at 25 kg/ha. Release predators *Chrysopa carnea* at 50000/ha.

Capitulum borer, *Helicoverpa armigera,* Noctuidae: Lepidoptera

Host plant: Capitulum borer is polyphagous in nature; besides sunflower it affects red gram, sorghum, maize, cotton, bhendi, tomato.

Destructive Stage: Larva

Symptoms of damage: The larva feeds on the developing seeds and bore the head. Head starts rotting due fungal developed. Earlier stage larva feeds on young leaves and later starts to feeds on head.

Management: Install bird perches at 50 Nos./ha. Install light trap 1No. /ha and pheromone traps 12 Nos./ha to kill the attracted moths. Inundative release of egg parasitoid *Trichogramma* spp. and egg larval parasitoid *Chelonous blackburnii* to control head borer. Release predators like Coccinellids, *Chrysoperla carnea* at 1larva/ head. Spray nuclear polyhedrosis virus (NPV) at 500 LE/ha in 0.1 % teepol. Grow inter crops like, groundnut, black gram, soybean, green gram and raising 3-4 lines of corn (or) sorghum around the sunflower crop to monitor the head borer adult. Raise marigold as a trap crop at 50plants/acre. Spray *Helicoverpa armigera* nuclear polyhedrosis virus (HaNPV) 250 LE + Bt at 0.5kg/ha for control of head borer. In the evening hours spray HaNPV 250 LE/ha +1 kg Jaggery + 200ml Sandovit/Teepal for effective control of head borer. Spray 5% Neem oil or 5% Neem Seed Kernal extract (NSKE) before egg laying.

Tobacco caterpillar, *Spodoptera litura,* Noctuidae: Lepidoptera

Host plant: Tobacco caterpillar is the polyphagous pest. Besides sunflower it also attacks citrus, soybean, pulses, millets, cotton, tobacco, groundnut, safflower, castor, banana, cabbage, tomato, chillies, sweet potato, bhendi and etc.,

Destructive Stage: Larva

Symptoms of damage: The young larvae feed tender leaves, shoots, bracts and flower petals. Later age larva causes defoliation and also feeds on the developing seeds in head. Due to its nocturnal habitat, larvae hide under the plants, cracks and crevices of soil and debris during the day time. Faecal matters are visible on the ground and on the leaves, which indicates the presence of pests.

Management: Raise castor as a border/intercrop in sunflower, it acts as indicator/trap crop. Setting up of light trap (1/ha) and pheromone traps (12/ha) and change the septa 3 weeks once to monitor the emergence of adult moths. Collect and destroy the egg masses and the gregarious larvae. Digging a trench 30 cm deep and 25 cm wide in the infested fields to avoid migration of larvae from field to field. Install bird perches at 50 Nos./ha

Bihar hairy caterpillar, *Spilosoma obliqua,* Arctiidae: Lepidoptera

Host plant: Sunflower, sesamum, linseed, groundnut, mustard and some vegetables.

Destructive Stage: Larva

Symptoms of damage: Young larvae predominantly feed underside of the leaves. In severe

infestations, the crop is completely defoliated. Drying up of infected leaves.

Management: Deep ploughing will expose the hibernating pupae to sunlight and predatory animal/birds. Use of well rotten manures. Intercropping with red gram at 2:1 ratio is effective for control the insect damage. Collect and destroy the egg masses, young larva, pupa and alternate hosts. Timely sowing and clean cultivation of crop. Conserve the natural enemies such as spiders, praying mantis, long horned grasshoppers, green lace wing, robber fly, ants, damsel flies/dragon flies, lady bird beetles, ground beetles, and earwigs. Spray NPV at 500 LE/ha. Spraying of *Bacillus thuringenesis* at 1 g/l or 400 g/ha.

Semi looper, *Trichoplusia ni,* Noctuidae: Lepidoptera

Host plant: Sunflower, castor, crucifer vegetables, pea, pepper, potato, sweet potato, tomato, and watermelon.

Destructive Stage: Larva

Symptoms of damage: Leaves contain holes, and severe damage leads to defoliation and skeletonization.

Management: Hand-pick and destroy caterpillars. Use light trap to attract and kill adults.

Cutworms, *Agroitis spp.*, Noctuidae: Lepidoptera

Host plant: Sunflower, tomato, beans, cabbage, carrots, corn, lettuce, peas, peppers and potato.

Destructive Stage: Larva

Symptoms of damage: The cutworms may be serious in fields during March - April. Caterpillars cut the seedlings at the ground level. Cutworms are feed at night during the daytime, cutworm larvae hide under the plants, cracks and crevices of soil and debris during the day time. The presence of cutworms is typically indicated by wilted or dead plants.

Management: Sowing sunflower seeds on 6-8 cm height ridges, in cutworm endemic areas. Release of *Trichogramma chilonus* at 20000/acre. Controlling weeds prior to planting will reduce cutworm infestations.

Pest of Safflower

1. Safflower caterpillar, *Perigea capensis*, Noctuidae Lepidoptera
2. Safflower bud Fly, *Acanthiophilus helianthi*, Tephritidae: Diptera
3. Safflower aphid, *Uroleucon compositae*, Aphididae: Hemiptera
4. Leaf hopper, *Empoasca punjablensis*, Cicadellidae: Hemiptera
5. Green peach aphid, *Myzus persicae*, Aphididae: Hemiptera
6. Lace wing, *Monanthia glubulifera*, Tingidae: Hemiptera
7. Stink bug, Dolycoris indicus, Pentatomidae: Hemiptera
8. Safflower caterpillar, *Spodoptera exigua*, *Helicoverpa armigera* and *Eublemma rivula*, Noctuidae: Lepidoptera
9. Leafminer, *Chromatomyia horticola*, Agromyzidae: Diptera

10. Surface weevil, *Tanymecus indicus*, Curculionidae: Coleoptera

Safflower caterpillar, *Perigea capensis*, Noctuidae: Lepidoptera

Host plant: Safflower

Destructive Stage: Larva

Symptoms of damage: The larva feed leaves, capitulum and also feeds on bracts, flowers and capsule. Plants which lose their vigour and become stunted. Enormous yield losses of 62.6 to 100% have been encountered due to excessive foliage feeding by a large number of larvae.

Management: Intercropping with non-host crop like wheat. Avoided excessive application of nitrogen to the field. Release the following parasitoid to control caterpillar *Apanteles ruficrus, Rogas percurrens, Euplectrus euplexiae, Eriborus argenteopilosus, Pteromalus* sp etc. Use the following Predators to control safflower caterpillar such as lacewing, ladybug beetle, reduviid bug, spider, red ant, robber fly, common mynah, earwig, praying mantis, ground beetle etc.,

Safflower bud Fly, *Acanthiophilus helianthi*, Tephritidae: Diptera

Host plant: Safflower, musk thistle and knapweed

Destructive Stage: Maggots

Symptoms of damage: Newly hatched young larvae feed on the soft parts of the capsules. Affected buds exhibit small bore holes. The damage is brought on by the maggots that eat the floral components, including the thalamus. The infected buds start to decay and release a foul odour. Safflower seed production is decreased as a result of the infestation.

Management: Early removal and destruction of the infected buds. Conserve the following larval parasitoids *viz.*, Ormyridae, (*Ormyrus sp*), Eurytomidae (*Eurytoma sp.*) and Braconidae (*Pachyneuron muscarum)* and predator *Chrysopa virgestes* (Chrysopidae).

Safflower aphid, *Uroleucon compositae*, Aphididae: Hemiptera

Host plant: Sunflower, Niger, Calendula, *Glyricidia maculata*, Ashwaghanda, Lactus and some weeds are the other hosts of safflower aphid.

Destructive Stage: Nymph and adult

Symptoms of damage: Nymph and adult feed on the sap of leaves, twigs, flowers, and capsules. Plants with severe infestations drastically lose height, leaves, and branches. The plants deteriorate, become stunted, and sometimes dry up. Seed production is seriously affected. The aphids secrete honeydew, gets deposited on the upper surface of the leaves, on which sooty molds develop and affect the photosynthesis, resulting in stunted growth and poor yields.

Management: Intercultural operations such as harrowing and hoeing reduce weeds. Intercropping with sorghum, wheat and coriander reduces aphid infestation. Should be avoiding niger as an intercrop. Conserve the following parasitoid *Aphidencyrtus aphidivorus* and predator *Brumoides suturalis* in safflower field. Release of *Chrysoperla carnea* larva at 2-3

Nos./plant or 70,000 larva /acre. Spray neem oil emulsion at 0.25%. Spray NSKE at 4%.

Pest of Castor

1. Capsule & Shoot borer, *Conogethes punctiferalis*, Pyraustidae: Lepidoptera
2. Castor semi looper, *Achaea janata*, Noctuidae: Lepidoptera
3. Slug caterpillar, *Parasa lepida*, Cochilididae: Lepidoptera
4. Hairy caterpillar, *Euproctis fraternal*, *Dasychira mendosa*, *Portrhesia scintillans*, Lymantriidae: Lepidoptera
5. Tussock caterpillar, *Notolophus posticus*, Lymantriidae: Lepidoptera
6. Castor butterfly / spiny caterpillar, *Ergolis merione*, Nymphalidae: Lepidoptera
7. Wooly bear, *Pericallia ricini*, Arctiidae: Lepidoptera
8. Leaf hopper, *Empoasca flavescents*, Cicadellidae: Hemiptera
9. White fly, *Trialeurodes ricini*, Aleyrodidae: Hemiptera
10. Thrips, *Retithrips syriacus*, Thripidae: Thysanoptera
11. Castor gallfly, *Asphondylia ricini*, Cecidomyidae: Diptera

Capsule & Shoot borer, *Conogethes punctiferalis*, Pyraustidae: Lepidoptera

Host plant: Other than Castor, it attacks mango, sorghum, guava, pear, peach, cocoa, avocado, cardamom, ginger, turmeric, mulberry, pomegranate, sunflower, cotton, tamarind and hollyhock.

Destructive Stage: Larva

Symptoms of damage: Newly hatched larva feed green coloured capsule. Caterpillar makes bore hole into the main stem of the young plant and also capsules. Affected capsules are webbed together and galleries are made. There by killing the terminal shoots. The yield is reduced considerably since the capsule and the seeds are damaged.

Management: Collect and destroy the affected shoots and capsules. Set up light trap and pheromone traps. Avoid growing varieties which are having compact inflorescence. Covering the undamaged capsule with paper bags to keep capsule and shoot borer from laying eggs and boring. Cluster bean, groundnut, cowpea and black gram as intercrops in castor with 1:2 ratio, resulted in reduction of incidence of shoot and capsule borer.

Castor semi looper, *Achaea janata*, Noctuidae: Lepidoptera

Host plant: Besides castor the insect attacks rose, pomegranate, tea, citrus, mango and some weeds.

Destructive Stage: Larva and adult

Symptoms of damage: Both caterpillar and adult moth cause the damage. The caterpillars feed castor leaves on voraciously. Caterpillar feed from the edge inwards and leaves only the mid rib and the stalk. Maximum damage is occurring in the month of August, September and October. The adult is a fruit sucking moths and cause damage to citrus crop. Seed yield is reduced due the excessive loss of foliage.

Management: Cluster bean, black gram, groundnut and cowpea as intercrops in castor with 1:2 ratios, for manage semilooper incidence. Using pheromone and light traps as well as hand picking of late instars are efficient methods for destroying of adults. Spray NSKE to destroy eggs. Release egg parasitoid *Trichogramma evanescens minutum* at 50000/acre and larval parasitoid *Microplitis maculipennis*.

Slug caterpillar, *Parasa lepida,* Cochilididae: Lepidoptera

Host plant: It feeds castor, pomegranate, citrus, rice, coconut, palm, wood apple, country almond, mango, cocoa, coffee, banana, rose and tea.

Destructive Stage: Larva

Symptoms of damage: A severe defoliation is caused by the larva's aggressive consumption of leaves, which leaves just the midrib and veins**.** Picking and destroying the gregarious caterpillars and cocoons that are found on castor tree trunks.

Management: Set up light traps to monitor and kill the adult moths. Collect all the stages of insect and destroy them.

Hairy caterpillar, *Euproctis fraterna,* Lymantriidae: Lepidoptera

Host plant: It attacks other than castor is linseed, peanut, grapevine, red gram, pomegranate, cotton, coffee, mango, rose, and pear.

Destructive Stage: Larva

Symptoms of damage: It causes severe defoliation. The pest is active throughout the year; however it is less active in the winter.

Management: Release larval parasitoids *viz*., *Helicospilus merdarius, H. horsefieldi*, *Apanteles* sp. and *Disophrys* sp.

Castor butterfly /Spiny caterpillar, *Ergolis merione,* Nymphalidae: Lepidoptera

Host plant: Castor and some weeds

Destructive Stage: Larva

Symptoms of damage: It is a serious sporadic pest. It starts attacking the crop early. Insects destroying the leaf tissue and cause defoliation.

Management: Collect and destroy the affected leaves. To control early-stage larva, spray 5% neem seed kernel extract (NSKE).

Wooly bear, *Pericallia ricini,* Arctiidae: Lepidoptera

Host plant: Castor, gingelly, cotton, banana, sunflower, maize, jute and brinjal.

Destructive Stage: Larva

Symptoms of damage: Caterpillar causes the damage. It feeds on leaves resulting in defoliation.

Management: Collect and destroy the caterpillars. *Beauveria bassiana*, *Verticillium lecanii* and *Paecilomyces fumosoroseus* and entomophagous predator (*Eocanthecona furcellata)* used as a biological control agent against wooly bear. The flower extracts of *Delonix regia* affects

oviposition, larval and pupal activities of wooly bear.

Leaf hopper*, Empoasca flavescens,* Cicadellidae: Hemiptera

Host plant: Castor, cotton, brinjal, potato, tomato, fruit trees

Destructive Stage: Nymphs and adults

Symptoms of damage: *E. flavescens* nymphs and adults suck the sap of young leaves and tender shoots. Leaf edges become crinkled and turn red or brown in colour. Leaf margins become yellow. Affected leaves dry up and cause rim blight or hopper burn.

Management: Select double or triple bloom castor cultivars are tolerant to leafhopper *viz.*, DCH-519, GCH-4, GCH-5, GCH-7 and YRCH-1.

White fly, *Trialeurodes ricini,* Aleyrodidae: Hemiptera

Host plant: Castor, cotton, brinjal, bean

Destructive Stage: Nymphs and adults

Symptoms of damage: Water-soaked spots on the leaves which become yellow and dried. Whitefly colonies can be seen on the underside of the leaves. Both nymphs and adults suck sap from leaves. Infestation is severe leaves appear sickly and sooty mould is developed. Stunted plant growth, shedding of fruits.

Management: Install yellow sticky traps, which are coated with grease or sticky oil materials. Spraying of neem oil 3% or NSKE 5% with any sticky material.

Thrips, *Retithrips syriacus,* Thripidae: Thysanoptera

Host plant: Castor, cotton, rose, avocado, mango, grape, walnut and many ornamental plants.

Destructive Stage: Nymphs and adults

Symptoms of damage: Nymphs and adults feed on the upper and lower surface of the leaves. Affected terminal leaves give a silvery appearance and also plant gets stunted.

Management: Install blue sticky traps, which are coated with grease or sticky oil materials. Spraying of Neem oil 3% or NSKE 5% with any sticky material.

Castor pest management practices

- Resistant varieties: R.C.1098 and R.C.1096 are resistant to leaf hopper (jassid) attack. R.C.1066, R.C.1067, R.C.1092, R.C.1069, R.C.1071 and R.C.1072 are resistant to mite infestation.
- Select triple or double bloom castor cultivars are tolerant to leafhopper *viz.*, DCH-519, GCH-4, GCH-5, GCH-7 and YRCH-1.
- Non-spiny capsules or semi-compact spike castor varieties/hybrids like GCH-4 and GCH-7 are less damaged by shoot and capsule borer.
- Deep summer ploughing control the larvae of semilooper, hairy caterpillar pupated in the soil will be killed due to expose the hibernating pupae to predatory birds/animals or hot sunlight.

- Cluster bean, black gram, groundnut and cowpea as intercrops in castor 1:2 ratio resulted in reduction of castor semilooper, leafhopper and shoot and capsule borer.
- Set up light and pheromone traps to kill the attracting lepidopteran moths.
- Collect and destroy the egg masses and early instar larvae of hairy caterpillar, tobacco caterpillar and slug caterpillar.
- Spray *Bacillus thuringiensis*1% (thuricide) is effective in controlling the larvae of semilooper and some other lepidopterous larvae.
- Apply neem oil 2% + NSKE 3% for the control of *A. janata* (semilooper).
- Before sowing of castor raise cucumber in the field borders it attracts the migrating red hairy caterpillar.

Pest of Gingelly

1. Leaf webber, *Antigastra catalaunalis*, Pyralidae: Lepidoptera
2. Sphinx moth, *Acherontia styx*, Sphingidae: Lepidoptera
3. Gall fly, *Asphondylia sesami*, Cecidomyiidae: Diptera
4. Leaf hopper, *Orosius albicinctus*, Cicadallidae: Hemiptera
5. Pod bug, *Elasmolomus sordidus*, Lygaeidae: Hemiptera
6. Aphid, *Aphis gossypii*, Aphididae: Hemiptera

Leaf webber, *Antigastra catalaunalis*, Pyralidae: Lepidoptera

Host plant: Sesame, dragon flower and duranta.

Destructive Stage: Nymphs and adults

Symptoms of damage: The immature larvae fold the top leaves together and feed them. The plant dies in the early stages of infestation without producing any branches or shoots. In later stage infested shoots stop growing. Larvae feed inside the flowers during flowering and then during capsule formation, they bore into the capsule and eat the growing seeds.

Management: Pearl millet, mung bean, moth bean and groundnut (6:3) as Intercrop in sesame which reduces the damage of *A. catalaunalis*. Collection and destruction of affected leaves and pods. Sesame cultivars like EH7, 57, 84,105,106, and 156 should be encouraged since they have been found to be completely resistant to *A. catalaunalis*. Neem preparations like margocide 5 ml/l and neem gold 3 ml/l were effective to manage on leaf webber. Sequential application of *Bacillus thuringiensis* at 1 kg/ha and neem seed kernels extracts 5% (NSKE) for effective and inexpensive against *A. catalaunalis*. Spray two rounds of neem oil 2%. Release larval parasites like *Bracon hebetor*, *Bracon gelechi* and *Trathala flavo-orbitalis* and predators like *Cantheconidia furcellata* for managing *A. catalaunalis.*

Sphinx moth / Hawk moth / Death's head moth, *Acherontia styx*, Sphingidae: Lepidoptera

Host plant: Sesame, potato, brinjal, lab lab and jasmine

Destructive Stage: Larva and adult

Symptoms of damage: The larvae, which feed leaves voraciously and cause defoliation. The adult moth is consuming honey from apiary honey combs.

Management: Hand-pick the larvae during early stages of the attack, then kill them by keeping in kerosene oil. Collection and destruction of caterpillars. Deep summer ploughing helps to control the insect by exposes the egg and pupae to direct sunlight or natural enemies. Spray NSKE 5%.

Gall fly, *Asphondylia sesami,* Cecidomyiidae: Diptera

Host range: Sesame, mulberry, privet and isu tree

Destructive Stage: Maggot

Symptoms of damage: Maggots feed inside the flower bud. Maggots feed on the ovary and results in the malformation of pods with improper seeds setting. Flowers and young capsules with gall like swelling is the typical symptom of attack. The gall fly remains active at the time of bud formation. The affected flower buds are withering and dropping. Gall formed flower buds are fade and dry.

Management: Pearl millet, mung bean, moth bean and groundnut (6:3) as intercrop in sesame which reduces the damage of *A. sesami*. Picking of gall formed flower buds and burning, as a prophylactic measure. Neem seed kernels extract (5%). Neem oil 2% (two rounds). Neem gold and nimbicidine (5 ml/l) to manage *A. sesami*. Use N 166 – 5 resistant variety in endemic areas. Release *Eurytoma dentipectus* and *Bracon hebetor* as larval parasites to manage *A. sesami.*

Leaf hopper, *Orosius albicinctus,* Cicadallidae: Hemiptera

Host plant: Sesame**,** sunn hemp, radish, black gram, sugar beet, lucerne, chicory and Indian rape

Destructive Stage: Nymphs and adults

Symptoms of damage: Nymph and adults sucking the sap from young parts of the sesame plants. Affected plants show curling leaf edges and leaves turn brown/red in colour. The jassid/leafhopper is a severe pest in sesame and it is transmit phyllody disease. Affected leaves become dry up and shed. The pest remains active from asexual stage to capsule formation stage.

Management: Remove sesame phyllody diseased plants from the field. Spray the following biopesticide such as mahua oil 2% or neem oil 5% are effective to control for leafhopper.

Pod bug, *Elasmolomus sordidus,* Lygaeidae: Hemiptera

Host plant: Sesame, groundnut

Destructive Stage: Nymphs and adults

Symptoms of damage: Both nymphs and adults sucking the sap from the young capsules

and seeds. This leads to the appearance of black spots on the capsule. The affected pods shrivel up and cause reduction in seed weight and oil content.

Management: Set up light traps and kill the attracted bugs. Keep the crop litter in the field along irrigation channel to attract the bugs which can be destroy/killed by dusting. Spray the following biopesticide such as neem oil 5% or mahua oil 2% are effective to control on pod bug.

Pest of Mustard

1. Mustard Aphid, *Lipaphis erysimi*, Aphididae: Hemiptera
2. Painted Bug, *Bagrada hilaris,* Pentatomidae: Hemiptera
3. Mustard Sawfly, *Athalia lugens,* Tenthredinidae: Hymenoptera
4. Green Peach Aphid, *Myzus persicae,* Aphididae: Hemiptera
5. Bihar Hairy Caterpillar, *Spilosoma obliqua,* Arctiidae: Lepidoptera
6. Cabbage butterfly, *Pieris brassicae,* Pieridae: Lepidoptera
7. Diamondback moth, *Plutella xylostella,* Plutellidae: Lepidoptera
8. Jassid, *Empoasca binotata,* Cicadellidae: Hemiptera
9. Pea Leaf-miner, *Chromatomyia horticola,* Agromyzidae: Diptera
10. Leaf webber, *Crocidolomia binotalis,* Pyralidae: Lepidoptera
11. Noctuid caterpillars, *Agrotis ipsilon*, *Mythimna loreyi* and *Helicoverpa armigera,* Noctuidae: Lepidoptera
12. Flea beetles, *Phyllotreta cruciferеae* and *Phaedon hrassicae,* Coleoptera: Chrysomelidae
13. Leaf-miner, *Chromatomyia horticola,* Agromyzidae: Diptera

Mustard Aphid, *Lipaphis erysimi,* Aphididae: Hemiptera

Host plant: Cabbage, cauliflower, knol-khol, toria, sarson, raya and taramira.

Destructive Stage: Nymphs and adults

Symptoms of damage: Nymphs and adults sucking the sap from leaves, shoots, flower buds and the developing pods. Strength of plants is greatly reduced. Infected plants show a curly leaf, flowers fail to form pods and the pods do not produce vigorous seeds. One-fourth or one-fifth of the crop yield is reduced due to *L. erysimi*. Sooty molds grow on the leaves due to honeydew excreted by the insects.

Management: Sow the crop 3rd week of October, early wherever possible. Apply recommended dose of fertilizers. Set up yellow stick trap to monitor aphid population. Conserve the following natural enemies like, *Coccinella septempunctata, Menochilus sexmaculata, Syrphus serarius, Menochilus sexmaculatus* and *Cephalosporium aphidicola*.

Painted bug, *Bagrada hilaris,* Pentatomidae: Hemiptera

Host plant: Crucifers, rice, sugarcane, indigo and coffee

Destructive Stage: Nymphs and adults

Symptoms of damage: Nymphs and adults sucking the sap from the leaves and pods, which causes gradually wilt and dry up. The nymphs and bugs secrete a resinous material which affects the pods.

Management: Irrigate the field 3-4 weeks after sowing as it reduces the bug population. Conserve egg parasitoid *Gryon sp*. and the adult parasitoid *Alophora sp*.

Mustard Sawfly, *Athalia lugens proxima,* Tenthredinidae: Hymenoptera

Host plant: Mustard, cabbage, toria, rapeseed, cauliflower, knol-khol, turnip, radish, etc.,

Destructive Stage: Grub

Symptoms of damage: The grubs alone cause damage. It prefers young plant, skeletonize the leaves and make holes and also eat epidermis of the shoot. Affected seedlings become death due to mustard sawfly. Older plants do not produce healthy seed.

Management: Collection and destruction of larva and affected plant parts. Use of an antifeedant made from bitter gourd seed oil. Release larval parasitoid *Perilissus cingulator*.

Green peach Aphid, *Myzus persicae,* Aphididae: Hemiptera

Host plant: Besides mustard it attacks peach, beans, potato, tobacco, turnip, radish, etc.,

Destructive Stage: Nymphs and adults

Symptoms of damage: Nymphs and adults sucking the sap from the plants and cause damage. After the inflorescence forms, the aphid feeds and congregates on terminal buds. As a result, flowers fall off, inadequate pod formation occurs, and grains begin to shrivel. *M. persicae* transmits virus diseases. The honeydew secretion causes sooty mould.

Management: Raise the crop in 1st week of October. Spray neem oil 3 % with 0.5 ml teepol/lit. Set up yellow stick trap to monitor aphid population

Bihar Hairy Caterpillar, *Spilosoma obliqua,* Arctiidae: Lepidoptera

Host plant: Mustard, sesamum, mash, mung bean, linseed, mustard, sunflower and some vegetables.

Destructive Stage: larva

Symptoms of damage: Caterpillars eat leaves, tender shoots and branches. In cases of severe infection, plants may lose all of their leaves.

Management: Collection and destruction of egg masses, young caterpillars as well as affected plants. Raise cowpea/red gram as an intercrop to attract adults to lay more number of eggs. Set up light traps (3-4) and kill the attracted moths. Deep summer ploughing will expose the hibernating pupae to direct sunlight and predatory birds/animal. Use of well decomposed manures. Intercropping with mustard + red gram at a ratio of 2:1 is effective to control of *S. obliqua*. Timely sowing and clean cultivation of crop. Removal and destruction of alternate hosts. Conserve the natural enemies such as spiders, long horned grasshoppers, green lace wing,

praying mantis, lady bird beetles, damsel flies/dragon flies, ground beetles, and earwigs. Use of NPV at 500 LE/ha will be effective to manage Bihar hairy caterpillar. Spraying of *Bt* at 1 g/l or 400 g/ha.

Cabbage butterfly, *Pieris brassicae,* Pieridae: Lepidoptera

Host plant: Cabbage butterfly attacks other than mustard are cabbage, cauliflower, knol-khol, turnip, radish, sarson, toria and some other cruciferous.

Destructive Stage: larva

Symptoms of damage: The caterpillars consume leaves, tender shoots, and green pods as food. Young caterpillars feed gregariously but the mature caterpillars move from one field to another. The first instar larva just scrapes the leaf because mandibles are not well developed, but the subsequent instars continue to eat the leaves, leaving just the main veins.

Management: At the earlier stage of the attack, collect and kill the caterpillars. Conserve parasitoids like *Cotesia glomeratus* and *Apanteles glomeratus* in field.

Diamondback moth, *Plutella xylostella,* Plutellidae: Lepidoptera

Host plant: *P. xylostella* attacks mustard, cabbage, cauliflower, broccoli, knol-khol, canola, kale.

Destructive Stage: larva

Symptoms of damage: Young caterpillars form little yellow mines on leaves. Scrapping of leaf epidermal making characteristic whitish patches on leaves. A full-grown larva bites and makes holes in the leaves and also feeds on curd.

Management: Collect and destroy all debris and crop stubbles after harvest of crop. Pheromone traps @12/ha. Crop rotation with cucurbits, beans, peas, tomato and melon. Release Larval parasitoid *Diadegma semiclausm* at 1,00000/ha and *Cotesia plutellae* at 20000/ha from 20 days after planting. Spray *Bacillus thuringiensis var kurstak*i 2g/lit and neem seed kernel extract 5%.

Leaf webber, *Crocidolomia binotalis,* Pyralidae: Lepidoptera

Host plant: It attacks mustard, cabbage, cauliflower, radish, mustard, turnip and other crucifers.

Destructive Stage: larva

Symptoms of damage: Young larva feeds gregariously on leaves. Later webs together the leaves feed within

Management: Webbed leaves that contain caterpillars should be removed and destroyed. Set up light trap 1/ha. To promote *Cotesia crocidolomiae* parasite activity.

Conclusion:

Single management technique could not be sufficient to combat the main insect pest of this particular crop, which would result in the development of resistance to that particular technique; therefore, the damage should be mitigated by implementing IPM solutions depending on economic threshold levels. Spraying should be done in the morning/evening or when the pollinators and biocontrol agents won't be affected. To maximize the effectiveness of pest and

disease control strategies, analytical interpretation of pest population dynamics, defenders, abiotic factors, and farmers' previous experiences is also a crucial tool for decision-making and timing of pest management treatments. To gain the greatest advantage in pest management and consequently increase crop yields, a variety of integrated management interventions, including as cultural, mechanical, biological, botanical, and less dangerous chemical treatments, are implemented singly or combined.

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MAJOR INSECT PESTS OF COTTON AND THEIR ECO-FRIENDLY MANAGEMENT

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Introduction:

Cotton is generally grown in 10 major states of India which are divided into 3 different zones *viz*., north, central and south zone based on climatic conditions and types of soil. It is investigated that cotton crop is attacked by 251 arthropod pest species. Among these, approx 12 species are considered major pests (including insects and mites) causing heavy damage and responsible for significant losses to the cotton crop. These all pests are responsible for causing economic damage to cotton crop in a range between 20-60 per cent. The pests of the cotton crop are categorized into different groups based on the nature of damage like sucking insect pests, foliar feeders and bollworm complex. The sucking insect pests are generally including leafhopper *Amrasca biguttula biguttula* (Ishida), whitefly *Bemisia tabaci* (Gennadius) aphid *Aphis gossypii* Glover, Cotton mealybug *Phenacoccus solenopsis* Tinsley, Indian cotton mirid bug *Creontiades biseratense* (Distant), thrips *Thrips tabaci* Lindeman.Papaya mealybug *Paracoccus marginatus* Williams and Granara de Willink. Another major group of insects that attack cotton is bollworm complex comprises of pink bollworm Pectinophora gossypiella (Saunders) American bollworm *Helicoverpa armigera* (Hubner), and spotted bollworms *Earias insulana* (Boisduval), *E. vitella* (F.). Other pests like stem weevil *Pempherulus affinis* Faust and tobacco caterpillar *Spodoptera litura* F., are also categorized as major pests.

Some arthropod species are also found effective against the population of insect pests and responsible to keep the pest population below the ETL level. There are approximately 368 natural enemies reported previously including 174 species of predators and 194 species of parasitoids/parasites. Among these natural enemies are used as biological control agents in the cotton ecosystem. In this chapter, we include all updated information regarding the pests of cotton, their natural enemies and the latest trends in management strategies for economically damaging cotton pests.

Cotton is considered the most important fiber crop grown by about 80 countries in the world and plays important role in textile industries and the agriculture sector. India covers almost

37 % of the area of cotton cultivation in the world. Cotton is generally a shrub with broader leaves crop plant which attacked by a wide range of various insects.

The insect pests of cotton crop basically can be divided into different categories on the basis of damage caused by insect and their nature of damage.

1. Borers (Bollworm complex)

1. Borers:

American bollworm	*Helicoverpa armigera* (Hübner)	Noctuidae	Lepidoptera
Pink bollworm	*Pectinophora gossypiella* (Saunders)	Gelechiidae	Lepidoptera
Spiny bollworm	*Earias insulana* (Boisduval)	Nolidae	Lepidoptera
Spotted bollworm	*Earias vittella* (Fabricius)	Nolidae	Lepidoptera

2. Sap feeders:

Leafhopper	*Amrasca biguttula biguttula* Ishida (syn. *Empoasca* Walsh/*Amrasca devastans* Distant)	Cicadellidae	Hemiptera
Aphid	*Aphis gossypii* Glover	Aphididae	Hemiptera
Whitefly	*Bemisia tabaci* (Gennadius)	Aleyrodidae	Hemiptera
Cotton Mealybug	*Phenacoccus solenopsis* Tinsley	Hemiptera	Pseudococcidae
Thrips	*Thrips tabaci* Lindeman	Thripidae	Thysanoptera
	Thrips palmi Karny	Thripidae	Thysanoptera
	Scirtothrips dorsalis Hood	Thripidae	Thysanoptera
Red cottonbug	*Dysdercus cingulatus* (Fabricius)	Pyrrhocoridae	Hemiptera
	Dysdercus koenigii (Fabricius)		
	Dysdercus similis Freeman		
Dusky cottonbug	*Oxycarenus hyalinipennis* (Costa)	Lygaeidae	Hemiptera

1. American bollworm: *Helicoverpa armigera*

Family: Noctuidae, Order: Lepidoptera

Description of Insect Stages The American bollworm belongs to the order Lepidoptera and there are four stages in the life cycle including Egg, larva, pupa and adult.

1. Egg: The eggs are generally creamy whitish and spherical with flattened base laid singly on the calyx, developing bolls, and on tender foliage. The incubation period of egg is generally 3 days in warm weather and 6-10 days in winter season, respectively.

2. Larva: Newly emerged larvae (Caterpillar) are generally yellowish-white with black to brown head capsules. There are six larval instars in the larval stage.

3. Pupa: The larval stage is turned into the brown pupa, with two tapering parallel spines at the posterior part of the abdomen. Pupation occurs at 2.5-12.5 cm depth in the soil. The duration of pupation is determined by temperature, taking around two weeks in summer and up to six weeks in spring and autumn. However, diapausing pupae take much longer to emerge.

4. Adult: Adults are generally nocturnal and active during night time. Forewings are basically buff-brown to dark brown and hind wings are whitish pale with dark black outer margin.

Nature of damage and symptoms

- Larvae is considered the most damaging stage and damaged bolls showing regular, circular bore holes by thrusting their heads alone inside and leaving the rest of the body outside the boll.
- A single larva can damage 30-40 bolls.
- Presence of granular faecal pellets outside the bore hole.

Life History

American bollworm is a highly polyphagous insect species. The egg period is generally 3 to 5 days. The larval and pupal stages take approximately 17-35 days and 17-20 days, respectively. The life cycle is completed in 25-60 days. They are multivoltine and have overlapping generations. The moths are highly mobile able to fly up to 200 KM and thus have wider regional distribution.

Figure 1: Nature of Damage of American bollworm

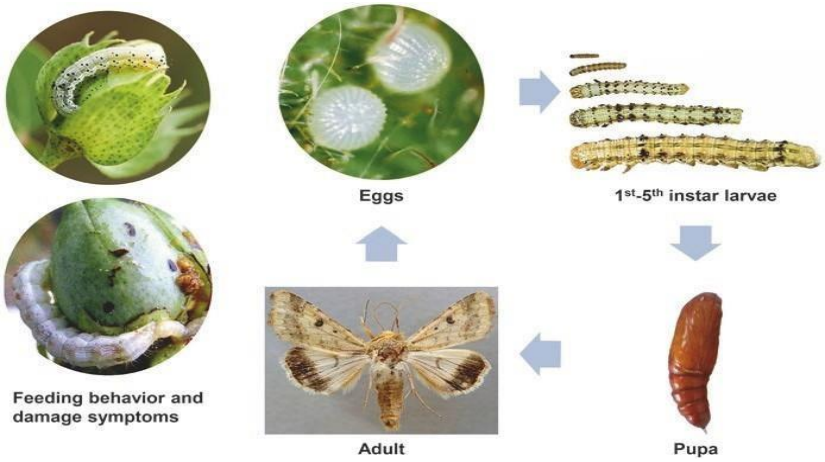

Figure 2: Life cycle and different stages of American bollworm

2. Pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechidae)

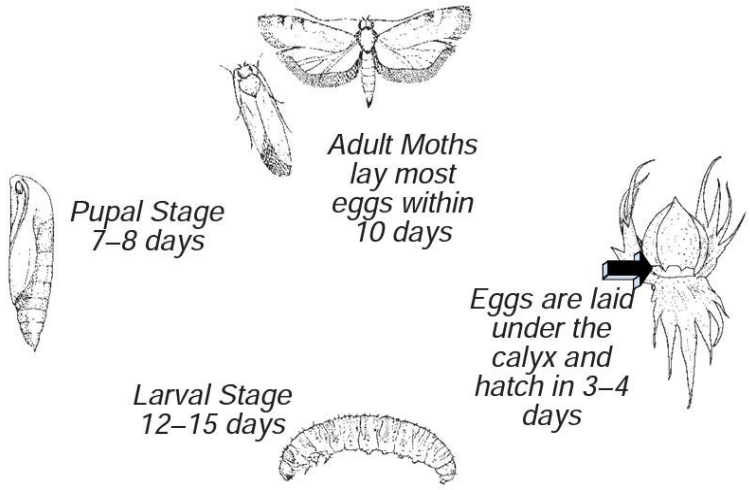

Figure 3: Life cycle and different stages of Pink bollworm

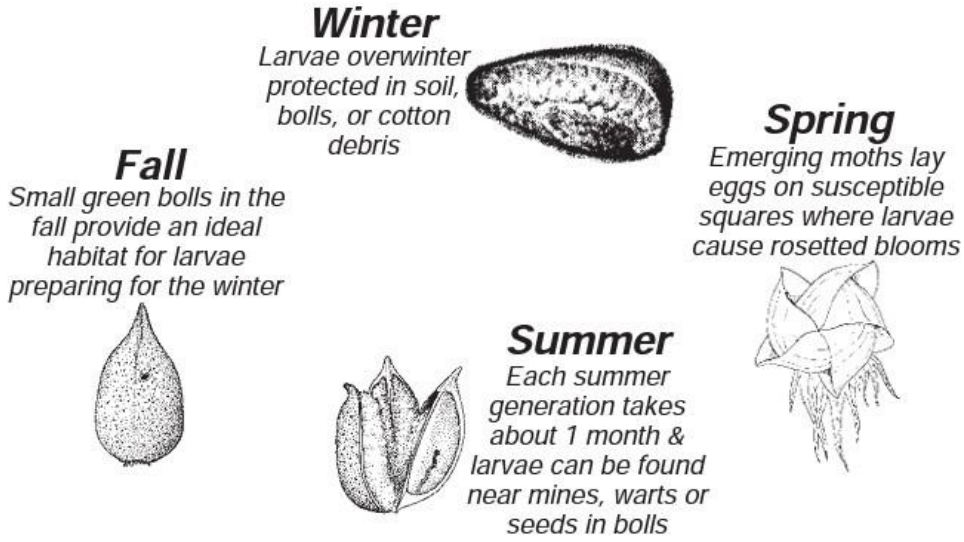

Figure 4: Pink Bollworm Seasonal Cycle

Description of Insect Stages

1. Egg: Singly laid or in small groups of three to five eggs, flattened oval eggs measuring 0.5 mm long by 0.25 mm width with sculptured longitudinal lines.

2. Larva: The larvae generally white in colour but in later stages it turns into pink colour. Larva enters in the bolls and close the entry hole and feeds internal content of the developing bolls. Average larval period takes 9-14 days in summer and 12-20 days in winter season, respectively.

3. Pupa: The fully grown larva turns into the pupa. The pupation of pink bollworm is can be divided into two categories on the basis of time period of pupation. First category is shortcycle pupa, means the larvae immediately changed into pupate, while the long-cycle ones turn to diapause. The pupation generally takes place in the soil and average pupal period ranges between 8 to 12 days. In the case of long cycle larvae entering diapause spins a tough thick walled,

closely woven, spherical cell referred as "hibernaculum" with no exit hole. Always, the long term larvae occur during end of crop season, where there are mature bolls present and larvae often form their hibernaculae inside seeds.

4. Adult: The adult moth is greyish brown with blackish bands on the forewings, hind wings are silvery grey. Moths emerge from pupae in the morning or in the evening, but are nocturnal, hiding amongst soil debris or cracks during the day.

Nature of damage and symptoms:

The attack of pink boll worm is generally starts at the time of flowering and boll formation. The larvae bore into the flower buds responsible for the rosette flower and shedding of buds in early stages. The entry hole is plugged with excreta of the pink boll worm larva which are feeding inside the boll. It is also responsible for the reduction in yield, germination quality and destruction of lint.

Figure 5: Damage of pink bollworm on cotton crop

3. Spiny Bollworm, *Earias insulana* (Boisduval), and Spotted Bollworms, *Earias vittella* (Fabricius) (Syn. *E. fabia* Stoll) (Lepidoptera: Nolidae)

Description of Insect Stage

1. Eggs: Eggs are generally sculptured, spherical bluish green in colour are laid singly on the tender parts of the plant like (flower buds, bolls, bracteoles and peduncles).

2. Larva: The larva generally brown, gray to green in colour. Last two segments and all abdominal segments are bear two pairs of fleshy tubercles, one of which is dorsal and the other lateral. The larva of *E. insulana* is generally lighter in colour, while in *E. Vittella* larval tubercles are much less prominent especially in the abdomen. Fully grown larva is about 1.3 to 1.8 cm long, spindle shaped bearing long setae on each abdominal segment.

3. Pupae: are found on plants or on fallen buds and bolls. Pupation is in a boat shaped tough silken cocoon that is dirty, white to brownish in colour.

4. Adult: There is two species of spiny bollworm, first one is *E. Insulana*, the head, thorax and forewings are generally silver green colour to straw green. The green forms are common during

summer, while yellow/brown forms occur toward the end of season. In the case of *E. vittella*, moths are quite distinctively creamy white or peach with a central green wedge running from proximal to the distal edge of the forewing.

Symptom of damage

- Drying and drooping of terminal shoots during pre-flowering stage
- Shedding of squares and young bolls
- Flaring up of bracts during square and young boll formation stage
- Holes on bolls and rotting of bolls

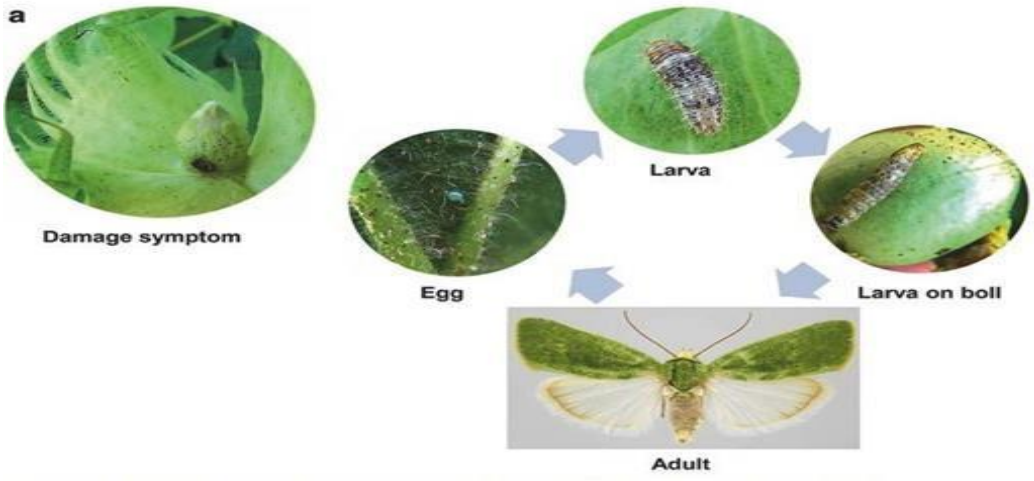

Figure 6: Life cycle of spiny bollworm, *Earias insulana* (Boisduval)

Major sucking insect pests of cotton:

These insects are specialized with piercing and sucking mouthparts. They inject saliva into the tissues and suck back the phloem substance. The undigested, excess plant sap is excreted, often called as 'honeydew' due to it containing sugars, and hence it is sweet. The excess honeydew secretion due to luxury consumption could encourage growth of black sooty mould, disrupting photosynthesis of leaves.

1. Jassids, *Amrasca biguttula biguttula* Ishida (Hemiptera: Cicadellidae) (Syn. *Empoasca* Walsh/ *Amrasca devastans* (Distant) Sucking Pests Cotton

1 Aphid: *Aphis gossypii*, Aphididae: Hemiptera

Nature of damage & symptom:

- Aphids are greenish brown small soft bodied insects. Aphids are considered the potential pest on cotton which feeds on the generally lower side of the leaves and tender parts of the plants.
- The aphids are coming in the category of sucking insect pests due to having piercing and sucking type of mouth parts.
- Both nymphs and adults are responsible for damage and they present on the plants in large numbers suck the sap and cause the stunted growth, yellowing of leaves.

- Aphids are also producing honey dew which is responsible for the development of sooty mould and fungal growth on the plant. Aphids are multiply parthenogenitically and viviparously.

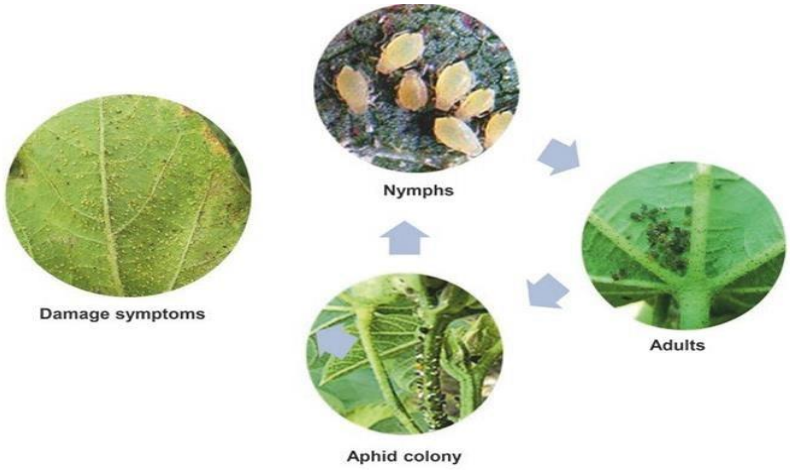

Figure 7: Life cycle of cotton aphid and damage symptoms

2. Thrips: *Thrips tabac*i, Thripidae, Thysanoptera

Nature of damage & symptom

- Thrips are generally dark brown to blackish, fringed wings, small soft bodied insects having lacerate and sucking type of mouth parts.
- Both nymphs and adults lacerate the plant tissue and suck the sap from the tender parts of the plants. The infected leaves are curl up and become crumbled.
- In the case of severe attack the yellowish lines and silvery streaks are seen on the leaves, damaged leaves become yellow and dried up resulting reduction in yield.

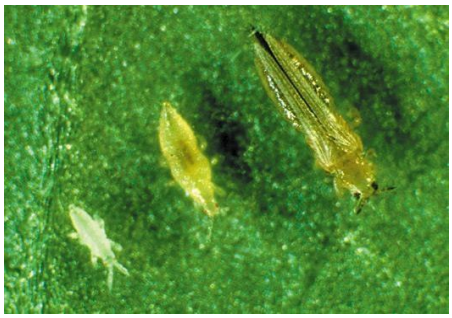

Figure 8: Life cycle of cotton aphid and damage symptoms

3. Whitefly - *Bemisia tabaci*, Aleyrodidae, Hemiptera

Nature of damage & symptom

- Whiteflies are minute whitish yellow minute soft bodied insects that considered the most serious sucking insect pest of cotton.
- Whiteflies are polyphagous in nature and feeds on the wide range of crop and weed plants. Both Nymphs and adults are suck the sap from leaves.

- In the case of severe infestation results in premature defoliation, shedding of flower squares, immature and developed bolls and development of sooty mould.
- Whiteflies are considered as vector insect and also responsible for the transmission of leaf curl disease in cotton.

Figure 9: Life cycle of cotton whitefly and damage

4. Red Cotton Bug: *Dysdercus cingulatus*, Pyrrhocoridae, Hemiptera Nature of Damage & Symptoms:

- Red cotton bugs are dark red with black marking on forewings and white strips on abdominal area.
- Both nymphs and adults are sucking the sap from developing bolls, flower buds and tender leaves.
- Due to the severe attack the water-soaked spots and wart growth observe on the developing bolls.
- The red cotton bugs also transmit the bacterium Nematopsora gossypii which is responsible for the red stained lint and rotting of developing and mature bolls.

Figure 10: Red cotton bug damage symptoms

5. Dusky cotton bug: *Oxycarenus hyalinipennis,* Lygaeidae, Hemiptera Nature of Damage & Symptoms:

- The dusky cotton bugs are generally small flat and brown in colour.
- Both nymphs and adults are suck the sap from developing seeds in open bolls and also stain the lint.
- Due to the severe attack the seeds become shrunken and reduced the germination quality of the seeds.

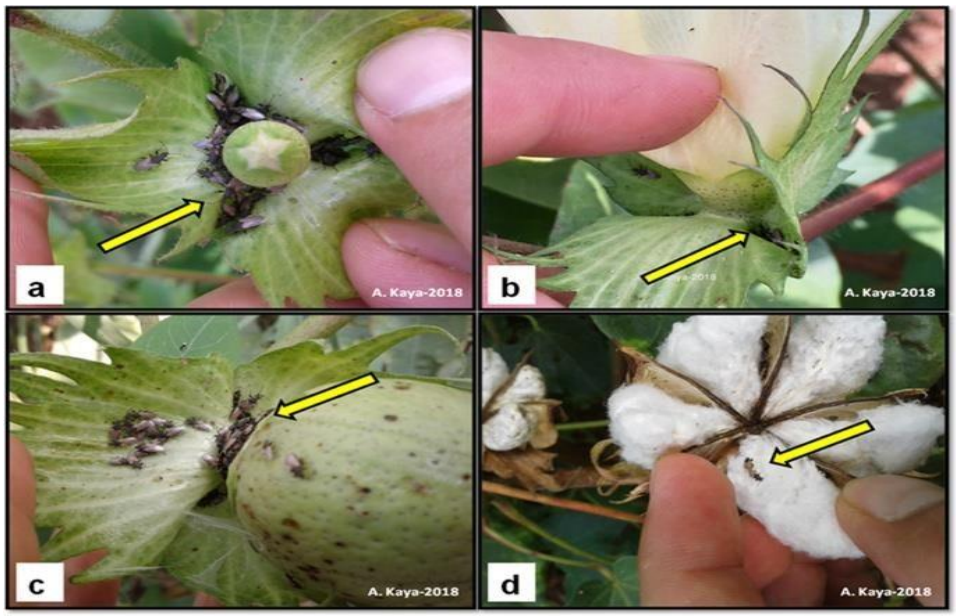

Figure 11: Dusky cotton bug damage symptoms

6. Jassids, *Amrasca biguttula biguttula* Ishida (Hemiptera: Cicadellidae) (Syn. *Empoasca* Walsh/*Amrasca devastans* (Distant) Nature of Damage & Symptoms:

- The jassids or hoppers are generally green in colour with black spot on forewings small and soft bodied insects.
- Both nymphs and adults are suck the sap from the lower side of the leaves and responsible for dark brown blotches/ spots on the leaf surface.
- In the case severe damage, the 'hopper-burn' symptoms seen due to many brown and yellow patches on the plant leaves.
- The jassids attack generally seen higher in the high nitrogenous fertilizer application areas.
- The farms look diseased when the jassid damage is severe, especially in highly susceptible cotton varieties.

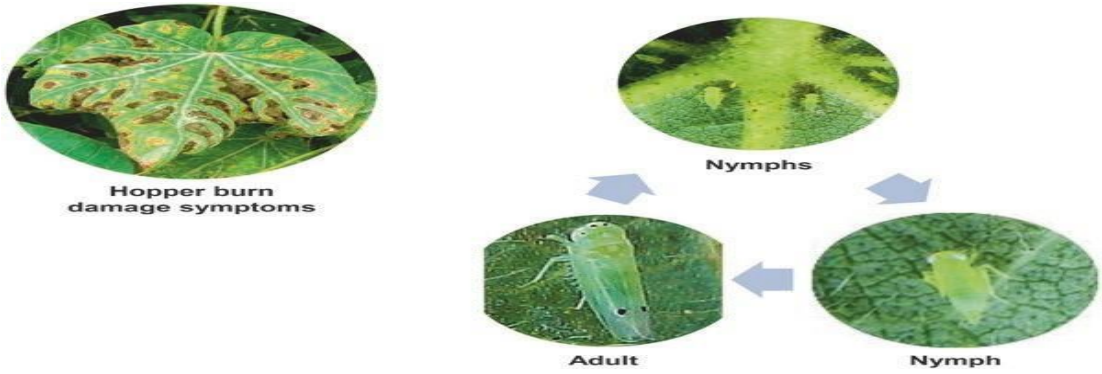

Figure 12: Jassids bug damage symptoms

Integrated Pest Management Strategies

1. Cultural Practices

- Deep summer ploughing to expose the resting stages of various insect pests, pathogen and nematodes.
- Remove the weeds plants from the field boundaries and keep the field sanitized.
- In the case of increasing the incidence of mealy bugs, bollworms and soil borne diseases, adopt proper crop rotation and avoid the growing the cotton year after year.
- Application of FYM * @ 5 tonnes/acre (* subject to availability of quality products)
- Always grow verified and suitable cotton cultivars released according to locality and region as per state government recommendations.
- Only sucking pest tolerant *Bt* cultivars for particular zones should be used.
- Seed treatment with systemic insecticides like thiamethoxam 30% FS 10 g/kg or imidacloprid 70%WS@5-7g/kg for reduce the attack of sucking insect pests in early stages of crop.
- Acid delinting should be carried out in plastic containers with commercial grade sulfuric acid @100g/kg seeds. The seeds are should properly washed 2-3 times to remove the toxic effect of the acid.
- Seed treatment with thiram 75% WS @ 2.5-3.0 gm/kg seeds for the management of seed born disease.
- Sowing should be completed by first week of May in Northern regions of India>
- Always follows the package and practices provided by state government or state agriculture universities.
- Adopt proper spacing, timely irrigation, inter-culture practices and fertilizer application to reduce the pest population and probability of diseases. Avoid the use of high doses of nitrogenous fertilizers.
- Removal and destruction of weeds that are considered the alternate host for survival of insect pests and diseases viz *Abutilon* sp, *Lagascea mollis*, *Sida* sp and other malvaceous plants surrounding the field.

- Use of trap crop/ border crops like okra (In south Indian states for shoot weevil), castor, marigold, jowar and maize, early pigeonpea crop is recommended to avoid the losses to the main crop and conserve the natural enemies.
- The following inter-cropping system is recommended for Central and South Zone to conserve and help colonize the bioagents fauna such as lady bird beetles, *Chrysoperla* and syrphid flies
- Cotton+Pigeonpea (Central Zone)
- Cotton+Groundnut (South Zone)
- Cotton+Pulses (Green gram/Blackgram/ Cowpea) (South Zone)
- Do not extend the normal crop period and avoid ratooning.
- Allowing grazing of animals after last picking is recommended for checking the carry over population of bollworms.

2. Mechanical practice

- Clipping of terminal shoots on 90-110 days in case of conventional hybrids.
- Hand picking and destruction of various insect stages viz., egg masses and gregarious larvae of Spodoptera litura, grown up larva of Helicoverpa armigera, affected plant parts, rosetted flowers due to pink boll worm and rotted bolls.
- Install 8-10 bird perches per ha after 90 days of crop growth for the benefit of predatory birds.
- Grow maize interspersed with cowpea on border to attract predators and parasitoids.

3. Biocontrol practices

- Growing of the two rows of sorghum/ maize or cowpea along the border surrounding the main crop to conserve the population of predators viz. lady bird beetles, lacewings, predatory wasps, staphylinids, syrphid flies, surface bugs like Geocoris, Anthocorid, Nabids, Reduviids and Spiders and different parasitoids species.
- Spraying of Ha-NPV 0.43% AS @ 2700 ml/ha at the time of early infestation of American bollworm.
- Spraying of azadirachtin 0.3% (3000 ppm) (Neem Seed Kernel Based EC) @ 4.0 l/ha against Helicoverpa bollworm infestation, Spraying of azadirachtin 0.15%, (Neem Seed Kernel Based EC) @ 2.5-5.0 l/ha against whiteflies and bollworms,
- Spraying of azadirachtin 0.03% (300ppm) (Neem Oil Based WSP) @ 2.5-5.0 l/ha against aphids, leaf hoppers, whiteflies and bollworms and Azadirachtin 5%w/w (Neem Extract Concentrate) @ 375 ml/ha for whiteflies, leafhoppers and Helicoverpa are recommended.
- Spraying of Bacillus thuriengiensis var kurstaki H 3a, 3b, 3c. 5% WP @ 0.50-1.00 kg/ha for Helicoverpa and spotted bollworm.

- Bacillus thuriengiensis var kurstaki strain HD-1, serotype 3a, 3b, 3.5% ES (Potency17600 IU/mg) @ 750-1000 ml/ha for control of bollworms are recommended.
- Beauveria bassiana 1.15% WP is recommended @ 2kg/ha in 400 lit water for bollworm control.
- Verticillium lecanii 1.15%WP is recommended @ 2.5 kg/ha in 500 lit water against white flies.

4. Chemical practice:

Name of the pest	Pesticide chemistry	Formulation dosage per ha
Bollworm and other caterpillars	Neonicotinoid chemistry	Thiodicarb 75 SP 750 g/ha
		Indoxacarb 15 SC at 500 ml/ha
	Avermectins	Emamectin benzoate 5 SG at 50 g/ha, abamectin 1.8 EC at 50 g/ha
	Spinosyn	Spinosad 48 SC at 150 ml/ha,
	Phthalic diamides	Flubendiamide 480 SC at 10 ml/ha
	Anthranilic diamide	Chlorantraniliprole (Rynaxypyr) 18.5 SC at150 ml/ha
Sap-sucking pests	Neonicotinoi dchemistries	Seed dressing at 5–10 g per kg cotton seedusing:
	Systemic organophosph atechemistries	Imidacloprid 70 WS
		Thiamethoxam 75
		Acetamiprid 20 SP
		Spraying of organophosphate pesticides such as methyl demeton/dimethoate/quinalphos, etc. at 2 l/ha, fipronil 5 SC at 1.5 l/ha
		Acetamiprid 20 SP at 50 ml/ha, thiamethoxam 25 WG at 100 ml/ha
Whitefly	Organophosphate and neonicotinoid pesticides	Triazophos at 2 l/ha, phosalone 35 EC 2 l/ha, thiamethoxam 25 WG at 100 ml/ha

Conclusion:

Cotton is the most important fiber crop in India and plays important role in the economy of the nation. Cotton is also source of food and shelter for a wide range of insect pests that cause high damage and reduced yield. Different technologies and strategies are developed for the eco-friendly management of cotton insect pests without affecting the agro-ecosystem. The main motto of this chapter is to provide basic information regarding the major insect pests, the nature of the damage, and management according to IPM practices. The IPM is the best method to conserve natural enemies and keep the pest population below ETL without affecting the environment.

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MAJOR INSECT PESTS OF CRUCIFEROUS VEGETABLE CROPS AND THEIR ECO-FRIENDLY MANAGEMENT

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Introduction:

The most significant member of the *Cruciferae (Brassicaceae)* family is *Brassica.* Cruciferous or cole crops are the names given to plants that belong to the *Brassica* genus. The genus includes six closely related species three of which are diploid (*B. nigra*, *B. oleracea* and *B. rapa*) and three of which are Amphidiploids (*B. carinata*, *B. juncea* and *B. napus*). Brassica plants predominate primarily in *B. oleracea* and *B. rapa*. Crucifers, which includes cabbage, cauliflower, mustard, broccoli and radish are significant winter crop. The most common temperate cruciferous crop that is grown globally in a variety of climate zones is cabbage (*Brassica oleracea* var. *capitata* L.). After China worldwide, India is the second-largest producer of cabbage. Brussel sprouts, cauliflower, broccoli, kohlrabi, Chinese kale, collard greens, cabbage, savoy cabbage, turnips, Chinese cabbage, pak choi, and komatsuna are among the vegetables found in *B. oleracea* (Cartea *et al.,* 2011) whereas Horseradish, watercress, Chinese broccoli, Japanese mustard, mustard greens, and radish are among the other species of *Brassica* (Lampe and Peterson, 2002). Vitamins, minerals, fibre and several plant compounds are abundant in crucifers. The phytochemicals in crucifers aid in the hydrolysis of glucosinolates in plant tissues, resulting in a substance that reduces oxidative stress, activates enzymes that fight against toxins and stimulates plant growth. In addition, it is regarded as a rich source of sulfur-containing chemicals that give crucifers their spicy flavor and pungent odour (Higdon *et al.,* 2007). Punjab, Haryana, Uttar Pradesh, Maharashtra, West Bengal, Assam, Gujarat, and Karnataka are India's top vegetable-producing states. Due to a variety of biotic and abiotic conditions such as insect pests, the productivity of vegetables, including cool season crops, is impacted (Hasan and Ansari, 2010). Among the most destructive insects to crucifers includes *Pieris brassicae* L. (Pieridae: Lepidoptera), *Plutella xylostella* L. (Plutellidae: Lepidoptera), *Brevicoryne brassicae* L. (Aphididae: Hemiptera), and *Trichoplusia ni* H. (Noctuidae: Lepidoptera). In general, using synthetic pesticides to protect crops from numerous insect pests is thought of as a fundamental control approach. However, prolonged use of synthetic pesticides for management has had unfavourable effects and has contributed to a number of issues, including pest resistance, toxicity to creatures other than the targets, and environmental

pollution. As a result, finding pesticide alternatives is necessary. Use of biological sources like botanical pesticides, which have less detrimental effects on the ecosystem, is an alternate strategy for pest management.

1. Diamondback moth, *Plutella xylostella* (Plutellidae: Lepidoptera)

The diamondback moth (DBM), which is responsible for 90 per cent of crop losses worldwide, is a significant insect pest of crucifers (Amoabeng *et al*., 2013). It primarily affects *Brassica oleracea* crops like turnips, cabbage, cauliflower, and broccoli. In North America, pests were first noted in 1854. Pest was supposed to be originated from Mediterranean and South Africa region through which it get distributed to the commonly grown areas of cruciferous crops in the world (Talekar and Shelton, 1993). Over 128 countries throughout the world have reported pest infestation (Gautam *et al.,* 2018).

Distribution: Cosmopolitan in nature. Found everywhere crucifers are grown and is thought to be the Lepidopteran pest with the broadest geographic distribution among crucifers (Talekar and Shelton, 1993). Lack of natural enemies in many non-indigenous locations, the capacity to travel great distances, and its high rate of fecundity are the main causes of its high pest status (Sayyed et al., 2002). In India, it is also distributed in all vegetable growing areas such as Delhi, Jammu & Kashmir, Manipur etc.

Host Range: Plants belonging to the family *Cruciferae* are infested by diamondback moth. Attacks on all cruciferous vegetable crops have been documented, including those of broccoli, Brussels sprouts, cabbage, Chinese cabbage, cauliflower, collard, kale, kohlrabi, mustard, radish, turnip and also reported from solanaceous and liliaceous plant. Also feeds on many cruciferous weeds such as yellow rocket, shepherdspurse, pepperweed and wild mustards. Before cruciferous vegetable crops are planted in the spring, these weeds play a vital role as alternative hosts (Philips *et al.,* 2014).

Biology and description of the pest: The eggs are oval-shaped, having 0.4 mm length, 0.2 mm width and yellowish white with greenish tinge. Female lays egg on the exterior side of leaf singly or in a group of 2-10. Under typical field conditions, eggs hatch in five to six days. Larvae go through four instars of development and take nine to thirty days to complete. The earliest instars contain a black head capsule and are very small, colourless to yellow. The body of late instars is covered in fine black hair that is dispersed throughout and is green in color and 8 to 12 mm length. Pupate beneath the bottom or outer leaf surface in a loose silken cocoon. The pupa measures between 7 and 9 mm in length and ranges in color from yellow to green. For the pupal stage to fully grow, 7 to 15 days are required. Adult moths are 8 to 12 mm long, thin, grayish-brown, and have pale white narrow wings with yellow inner margins. Each fore wing has three faint white triangular markings on hind margins that, when at rest, seem like three diamond-shaped spots, hence the name DBM. Adults can live for 16 to 18 days, although the average life

span is closer to two weeks. An individual female usually produces 20 to 300 eggs. (Shrivastva and Dhaliwal, 2014). In plains, pest activity occurs in the winter, whereas in hills, it occurs from March–April to October–November. The incubation period ranges from 4-8 days. According to reports, the average adult female and male longevity is about 16 and 12 days, respectively. The newly hatched moth begins to lay eggs on same day and each female can lay 20 to 288 eggs (Sarfraz *et al.,* 2011).

Nature of Damage: Crop damage is produced by larvae of DBM. Damage takes place when first-instar larvae leads to scraping of epidermal leaf tissues and produces typical white patches, whereas later instars devour the leaf tissue from the underside of leaves eventually causing holes in the leaves. Due to high infestation of insect, leaves become completely skeletonised *i.e.* complete removal of the leaf tissues except for the leaf veins. The infestation is more severe during dry season (Shrivastva and Dhaliwal, 2014).

Management:

- Plant debris and weeds should be removed and destroyed after final harvest. Before being disposed off, the plant debris should be put right away in a covered container.
- A particularly successful method of limiting the spread of pests in the greenhouse is to pinch-off injured plant parts, blooms, and leaves (as well as those with insect larvae or egg deposits) (Gautam *et al.,* 2018).
- Growing bold-seeded **mustard as a trap crop at 2:1** ratio helps to attract the DBM for oviposition at least 10 days before planting of main crop. Population can be reduced by planting marigolds as a trap crop (Silva-Aguayo, 2007).
- **Intercropping** with **tomato, garlic, dill, clover or carrot** helps to reduce the incidence of DBM. Tomato has been shown to suppress DBM egg-laying when interplanted with cabbage (Sharma *et al.,* 2017).
- Resistant cultivars like **Pusa ketki** and **Pusa deepali** against DBM (Ram and Raju, 2002).
- Recommended to install **Pheromone traps @12/ha** for adult mass collection.
- **Botanical pesticides** including *Allium sativum*, *Azadirachta indica*, Ginger, Javanese long pepper, *Solanum* spp., Sweet orange peels and *Momordica balsamina* boost plant height and yield while reducing the population of P. xylostella (Degri and Zakaria, 2015).
- Spraying of **Bt formulation at 1000g/ha** and **NSKE at 5%** (Sannaveerappanavar, 1995).
- **Hymenopteran parasitoids** such as egg parasitoids, ***Trichogramma brassicae* @ 100000/ha** found effective against the pest. **Larval parasitoids** such as *Diadegma insulare, Cotesia plutellae* and *Oomyzus sokolowskii* provides high rate of mortality (Cordero and Kuhar, 2007).

- ***Bacillus thuringiensis* var. *kurstaki* @2g/lit** is also efficient at reducing pest population. ***Diadromus*** and ***Pteromalus,*** two pupal parasitoids, might effectively control DBM (Chauhan and Sharma, 2004).
- Additionally, effective **entomopathogenic fungi** includes *Beauveria bassiana*, *Metarhizium anisopliae* and *Paecilomyces fumosoroseus* (Grzywacz *et al.,* 2010).
- **Entomopathogenic nematode,** *Steinernema carpocapsae* has been found effective by causing 100 per cent mortality of larvae after 6 h of exposure (Ratnasinghe and Hague, 1998).

2. Cabbage aphid, *Brevicoryne brassicae* (Aphididae: Hemiptera)

Name is derived from two words "*brevi"* and "*coryne"* which are informally translated as "little pipes" and known as cornicles and located near the posterior end of the body. With the exception of *Lipaphis eyrsimi*, the cornicles of cabbage aphid are often shorter than those of other aphids. Cabbage aphids can be distinguished from other aphids by their small cornicles and waxy coating (Carter and Sorensen, 2013).

Distribution: Supposed to be native of Europe but now having worldwide distribution. Present in different parts of the world such as Canada, Netherland, South Africa, India and China. Distributed throughout the U.S. and also prevalent in southern states (Carter and Sorensen, 2013).

Host Range: Pest is restricted to the plants belonging to *Cruciferae* family which includes both cultivated as well as wild cruciferous crops. Infest the crop in cool season and requires humid but free of rain and cool weather for multiplication (Gabrys *et al.*, 1997).

Biology and description of the pest: Eggs are pale yellowish in color with greenish tinge and laid at winter season in plant waste close to the soil surface (Hines and Hutchison, 2013). There are four nymphal phases in nymphs, which are 1-1.5mm long, golden green with a subtle ash grey tinge. Nymphs begin depositing eggs as soon as they are 10 to 15 days old. The adult, which is about 2mm long, has an ash grey color, a soft, pear-shaped body with a waxy coating, and two cornicles that secrete honey dew. The head and thorax seem black to dark brown. Remains active from October to April (Natwick, 2009). Aphids primarily reproduce parthenogenetically, although during particularly harsh winters, they can also reproduce sexually. Winter developed winged (alate) adults have longer life cycle when compared with parthenogenetically produced ones. Alates for migration emerge due to overcrowding, hot temperatures, and low humidity. Average life cycle lasts for 10-45 days (Kessing and Mau, 1991).

Nature of Damage: Nymphs and adults infest the crop by sucking the sap from the host plant (leaves/shoots). Yellowing, wilting and stunting of the plant are caused by continued feeding (Opfer and McGrath, 2013). Most frequently noticed on the underside of younger leaves and

plant terminal portions (Natwick, 2009). Produces honeydew, an organic waste product that is sweet and is consumed by ants. The ants in turn shield the aphids from their natural foes. A sooty mould develops due to honeydew which reduces photosynthesis (Hines and Hutchison, 2013).

Management:

- Field should be monitored every week. When aphid populations are excessive **(>50/plant)** on seedlings or on plants close to harvest, control measures should be followed (Webb, 2010).
- The most effective cultivar of cauliflower to reducing aphid populations is **Smilla** (Jahan *et al.,* 2013)
- Following harvest, the field should be immediately ploughed in order to remove any potential alternate hosts, such as mustards or other cruciferous weeds (Griffin and Williamson, 2012).
- Destroying plant debris containing aphid eggs at the end of the season (Hines and Hutchison, 2013).
- Use of nectar plant such as **sweet alyssum (*Lobularia maritime*)** helps to attract beneficial insects (Webb, 2010).
- Predators like larvae and adults of the syrphid fly and lacewing larvae can be used. Utilizing yellow sticky traps is beneficial for keeping track of the aphid population (Gharde and Mal, 2019).
- Leaf and Seed extract of the Chinaberry tree (*Melia azedarach),* peppermint (*Mentha piperita*) & seeds and flowering lantana (*Lantana camara*) proven effective (Baidoo and Adam, 2012).
- Treatment with the ***Beauveria bassiana* @ 1-3ml/litre** found effective and also increases the B:C ratio and economic yield of the crop (Basnet *et al.,* 2018).
- Treatment of the plants using **Margosom (Neem pesticide) @ 5-7.5ml/litre** is effective and also increases the number of pest repelling natural enemies (Rijal *et al.,* 2008; Basnet *et al.,* 2018).

3. Cabbage semilooper, *Thysanoplusia ni* (Noctuidae: Lepidoptera)

Distribution: Distributed throughout the world where crucifers are cultivated but mostly present in USA, India and Sri-Lanka (Capinera, 2001).

Host range: Wide range of cultivated plants and weeds are infested by this pest. Feeds on cruciferous vegetables like watercress, mustard, radish, rutabaga, Chinese cabbage, collards and broccoli. Beet, cantaloupe, celery, cucumber, lima beans, lettuce, parsnip, potato, snap beans, squash, sweet potatoes and tomatoes are some additional vegetable crops. Field crops like cotton and tobacco as well as floral crops like chrysanthemum, hollyhock and snapdragon serve as additional hosts. Agricultural weeds including *Rumex crispus, Taraxacum officinale* and *Chenopodium album* as well as wild lettuce (Soo Hoo *et al.,* 1984).

Biology and description of the pest: Eggs are hemispherical in shape. Place eggs in a single layer on the leaf's upper or lower surface. The eggs are yellowish white or greenish in color having 0.6 mm diameter. Early larvae are dark white; later, they turn pale green and swollen. Although initially moderately hairy, as the larvae mature, the quantity of hairs rapidly diminishes. *P. brassicae* caterpillars and larvae are typically seen together. Larvae have three pairs of prolegs. Pupate in a white, fragile cocoon that is created on the underside of leaves, in plant debris or in soil clods. The forewings have a mottled gray-brown colour, while the hind wings are light brown at the base and dark brown at the tips. The forewing dots serve to distinguish the pest from the majority of other noctuid moths that munch on crops. The moths range from 33 to 38 mm in length (Capinera, 2001).

Nature of Damage: Damaging stage of the pest is larvae. Larvae consume leaves by first scraping off their epidermal tissues and then biting round holes in them. At high infestation defoliation of plant occurs leaving behind midribs and main veins. (Dhaliwal and Arora, 2009).

Management:

- Egg masses and mature larvae should be manually removed and destroyed.
- **NSKE @ 5 %** and **Bt @ 1000g/ha** also found effective against the pest (Lall, 1964).
- Release of *Trichogramma* spp. in large quantity has been investigated for control (Oatman and Platner, 1971).
- Larvae of semilooper are parasitized with ***Apanteles glomerata*** as it has major mortality factor for this pest (Ayyar and Ramakrishna, 1963).

4. Crucifer leaf Weber, *Crocidolomia binotalis* (Pyralidae: Lepidoptera)

Distribution: Leaf webber is a polyphagous pest. Distributed throughout Burma, Srilanka and India (Gharde and Mal, 2019).

Host Range: All vegetables belonging to *Cruciferae (Brassicaceae)* family. Infest crops like mustard, cabbage, cauliflower, radish, and others. Additionally reported from *Thymus vulgaris* (*Labiatae*) (Gharde and Mal, 2019).

Biology and description of the pest: Moths lay several eggs on the underside of leaves. Larval bodies have a red head section and are greenish to pale violet in hue. Small body hairs in two to three rows running longitudinally range in color from amber to brick red. The pupal stage of an insect ranges from 14 to 40 days depending on the climate and incubate in earthen cocoons at a depth of 10 to 20 cm in the soil. The adult is small, pale brown in color, has wavy forewing line, and has conspicuous, large spots on it. Hind wings are semi-transparent in nature. Within five to fifteen days, the egg hatches. Larvae live for between 24 and 50 days. The average adult lives 5 to 6 days. An insect's life cycle lasts 40–80 days and have 5-8 generations. (Jain and Bhargava, 2007).

Nature of Damage: Larval stage of the pest is most destructive. Pest is well known for its gregarious feeding. Young larvae eat leaves and then later web two to three leaves together. Webbed leaves have presence of fecal matter of the pest which causes rottening of infected cabbage and cauliflower (Atwal and Dhaliwal, 2005).

Management:

- Eliminating and destroying the webbed leaves that contain larvae. Thorough summer ploughing is also beneficial in controlling the pest.
- Mass trapping of adult moth by installation of **light traps @1/ha** (Srinivasan and Krishna, 1991).
- **Mustard** can be utilised as a pest-controlling trap crop (Srinivasan and Krishna, 1991).
- Spraying of **NSKE @ 5 per cent** and other neem insecticides are found effective against the pest (Dhaliwal and Arora, 2009).
- Application of **Bt var. *kurstaki* @ 0.2 per cent** is also a effective treatment (Sailaza and Krishnnaiah, 2003).
- **Natural enemies** like *Cotesia crocidolomiae, Apanteles crocidolmiae, Enicospilus xanthocephalus, Palexorista solennis, Eocanthecona furcellata* and *Microbracon mellus* helps to reduce larval population (Dhaliwal and Arora, 2009).
- **Fresh leaf extract of thornapple, Tephrosia and galangal rhizome @ 20 per cent** also found effective (Tarigan *et al.,* 2021).

5. Cabbage butterfly, *Pieris brassicae* (Pieridae: Lepidoptera)

Distribution: Cosmopolitan in nature. Europe, North Africa, and the Himalayas are where they are most commonly found. The intensity is high in mountainous places in contrast to lowlands (Bhalla *et al*., 1997). It is also prevalent in Bihar, Himachal Pradesh, Manipur, Meghalaya, Punjab and West Bengal.

Host Range: Cruciferous crop pest. Frequently attacks vegetables such as toria, mustard, knol-khol, turnips, and cabbage. Sometimes targets weeds in the family *Cruciferae* as well as flowers like nasturtium and sweet alyssum (Ayyar and Ramakrishna, 1963).

Biology and description of pest: Eggs have a cylindrical shape and a yellow tint. Eggs are often placed in groups of 50 to 90 on the ventral surface of the leaves. Oviposition prefers clumped vegetation. Initially larvae are pale yellow eventually turn greenish yellow. The butterflies are pale white. Both wings have a smoky shade on the dorsal side of the body and range in colour from creamy white to dull yellow (Hasan *et al.,* 2008). In males and females, the wing expansion measures 6.5 cm and 6.1 cm, respectively. Males are smaller in size and have black spots on the underside of each forewing, while females have two noticeable black spots on the dorsal side of each forewing. From October until April, this pest is active. Winter is the season with the highest butterfly incidence. In winter, the eggs hatch in 11–17 days; in summer, it takes 3–7 days. When

the larvae reach maturity, they disperse throughout the plant after initially feeding in groups. Pupate in cocoon on the leaves and stem of the host. Adults live between 3 and 12 days (Capinera, 2001).

Nature of damage: Widely dispersed throughout the Himalayan area and sections of North India. Pest migrates to hilly regions in the summer after spending the winter in the lowlands. Initially larvae feed gregariously on leaves. Late instars disperse and migrate to nearby plants or fields where they gorge themselves on the leaves. Later larvae tunnel into the head of the plant, killing it completely (Verma *et al.,* 2004).

Management:

- To eliminate the leftover crop waste, deep ploughing should be done right after after the last harvest. Cole crops planted early incur less damage than those planted later (January).
- During the initial phase of an attack, collecting and destroying egg masses and caterpillars reduces the pests ability to reproduce (Capinera, 2001).
- Parasitoid such as ***Cotesia glomeratus*** can effectively control the population of *P. Brassicae* (Kumar, 2012).
- Use of botanical extract of **Chinaberry, Lemon grass, Neem leaves extract and white top weed along with cow urine @ 10 per cent** also found effective (Hussain *et al.,* 2022).
- Use of **Neem EC (1% azadirachtin)** induces high mortality of the pest by causing lethal failure (Grisakova *et al.,* 2006).

6. Cabbage head borer, *Hellula rogatalis* (Crambidae: Lepidoptera)

Distribution: Found in warmer climates of Europe, Asia and Africa as well as Hawaii (Capinera 2001).

Host range: The key cruciferous plants that the cabbage head borer eats are broccoli, cabbage, Chinese cabbage, collard, kale, mustard, radish, rutabaga, shepherd's purse, and turnips. Beet and purslane serve as additional hosts. (Nuessly and Larsen, 2013).

Biology and description of pest: Eggs are oval, somewhat flattened, and have a distinct nipple form at one end. They are reddish in color and have a tangled surface. On terminal leaves, eggs are deposited individually or in tiny clusters. While mature larvae are grayish-yellow with five longitudinal stripes of purple or black color running from head to tail, early instar larvae are yellowish-gray in color without stripes. The bodies of larvae are sparsely coated in setae (hairs), and they are yellow or light brown in hue with shiny, black heads. Larvae tunnel into the ground and then pupate. Pupate inside the tight cocoon, which is formed of earth and silk webbing. When females and males first emerge, their forewings, are, respectively grey and light brown; they eventually turn yellowish-brown In 2-4 days, the eggs hatches out. The caterpillar goes through a 4–19 day pupal stage before becoming fully fed in 6–18 days (McAvoy and Kok 1992).

Nature of damage: Younger larvae feed on the lower surface of leaves, whereas older larvae feed between the upper and lower leaf epidermis. Webs are made by larvae (Silken passage), who then feed within the webs protective covering. Additionally, because larvae feed on the midribs of leaves, the midribs may become weak and the leaves may shatter. Larvae frequently eat away at the main stem and stalk of young plants, causing the plants to wilt and eventually die. When the attack is severe, the plant's head appears distorted and is covered in caterpillars (McAvoy and Kok 1992).

Management:

- Use of **mustard** as a trap crop; collection and extermination of the early-stage larvae (Verma *et al.*, 2004).
- Cauliflower lines such as **Early Kumari, 78-IS, 234-S, Sel-916** and **Sel-1012** have been shown to be resistant to the pest (Brar *et al.*, 1993).
- Spraying of **Bt products @ 1.25kg/ha** found effective (Lall, 1964).
- **NSKE @ 5 per cent** is successful in preventing the pest (Mane *et al.*, 2021).

7. Mustard sawfly, *Athelia lugens proxima* (Tenthredinidae: Hymenoptera)

Distribution: A polyphagous pest native to Southern Mexico and Central America (Sahu *et al.*, 2018).

Host range: Cabbage, mustard, radish, turnip and okra. Additionally seen to be consuming leaves of *Cocoloba* species (Chauhan & Shukla, 2014).

Biology and description of pest: As laid, eggs have a creamy white tint, but when they hatch, they change to a dark color with two black spots. At the leaf margin, eggs are placed singly in slits created by an ovipositor that resembles a saw. Six instars are passed by the fully black larva. On the forehead, hairs are clearly seen in the sixth instar. Ashy green is the hue of the final larval instars. Pupate in silky cocoon between leaves. At the prepupal stage, males have nine abdominal segments while females have seven, which aids in sex determination. Adults are small orange yellow in color with black markings on the body. In adult, head has sub triangular in shape with antennae which are of filiform and cylindrical shape. Wings are dark black in color. Ovipositional period ends within 6-8 days. Incubation priod completes within 5-6 days. Eggs hatches in 4-8 days. Adult longevity varies from 7-10 days. This pest takes around 27-32 days to complete their life cycle (Bhatt, 2000; Kumaranag *et al.*, 2014).

Nature of Damage: Have high potential to defoliate the crop at the seedling stage. The edges of the leaves are nibbled by the larva, which later bites a hole in them. After skeletonizing the leaves, the larvae later travel to the shoot, causing the plant to dry out. When adults lay eggs using their saw-like ovipositor, they cause damage (Sahu, *et al*., 2018).

Management:

- Neem-based products, such as **leaf powder applied at 7.5 kg per ha** and **neem oil** applied at **2%,** can help to lower population (Agrawal and Saroj, 2003).
- Use of plant extract such as ***Alpinia galangal***, ***Curcuma longa,* Aframomum melegueta** and ***Zingiber officinale*** (Chandel *et al.*, 2011).
- Treatment with the **Neem oil @ 2 per cent** found effective as it causes larvae death, pupal inhibition, inhibition of adult emergence, and larval repellent effects (Agarwal and Saroj, 2003).
- **Neem leaf powder** applied to the soil @ **75 kg per ha** results in a decrease in population and an increase in grain yield (Srivastva and Singh, 2003).

8. Cabbage flea beetle, *Phyllotreta cruciferae, P. chotanica, P.birmanica, P. oncera, P. downesi* (Chrysomellidae: Coleoptera)

Distribution: Widely distributed in Europe, Ernst USSR, North and South America, Australia, Japan and India (Eastman *et al.,* 2005).

Host range: Feed on cruciferous plants including mustard, raya, toria, taramina, radish, turnip, cabbage, cauliflower, and Knol khol. (Grubinger, 2005).

Biology and description of the pest: The 5mm long larvae are filthy white with a pale white head. The color of the adults ranges from shiny black to black. All species have extremely thick femora, which they use to leap like fleas. Depending on the temperature, the female lays 50–80 creamy white eggs in the soil near the host plants, which hatch in 12–15 days. Larvae go through three moults. Adult beetles that overwinter emerge in the final week of February or the first week of March. The pupal stage lasts for 8 to 14 days, while the larval stage lasts for 3 to 4 weeks. (Atwal and Dhaliwal, 2005).

Nature of Damage: Both the adult and grub stages of the insect are destructive. The adult feeds on the host plants cotyledons and leaves, leaving behind round holes. Attacks on the branches, flowers and even seed pods are possible. The new leaves become unfit for food, while the old, eaten-away leaves dry up. A decomposing odour emanates from the affected plants. Grubs are soil-dwelling creatures that eat plant roots. (Capinera, 2001).

Management:

- Early sowing of the crop should be done (Knodel *et al.,* 2008).
- **Chinese southern giant mustard (*Brassica juncea* var. *crispifolia*)** can be used as trap crop (Grubinger, 2005).
- Deep summer ploughing should be followed to kill the overwintering population of the pest (Andow *et al.,* 1986).
- **Row covers** made of polyester screen can act as a physical barrier which prevents adult from attacking vegetable crops and laying their eggs at the base of these plants (Capinera, 2001).

- Parasitoid wasp *i.e.,* ***Microctonus vittatae, M.*** (Hymenoptera: Braconidae) is reported to parasitize adults of *P. cruciferae* (Capinera 2001).
- **Entomopathogenic fungi** such as **Metarhizium anisopliae** and **Beauveria bassiana** infects adult of Cabbage flea beetles (Ortega-Ramos *et al.,* 2021).
- **Entomopathogenic nematodes,** particularly species of *Steinernema* have been found to be highly effective under field conditions (Hokkanen et al., 2006).
- Formulations derived from the bacteria ***Bacillus thuringiensis*** **(Bt) subspecies** ***tenebrionis*** are used widely as biopesticides (Pole, 2021).
- **FLiPPER,** a naturally occurring by-product of the manufacturing of olive oil, has a significant mortality rate just one day after treatment (Pole, 2021).
- **Azadirachtin** made from the neem tree and M-Pede (fatty acid product) found to be beneficial against the insect (Reddy *et al.,* 2014).

Conclusion:

Pests are the main factor causing yield losses in different crops, and they can be controlled by developing Integrated Pest Management strategies at different growth phases. For the identification of key pest growth stages and their sustainable management, biology and ecology are also helpful. DBM, leaf webber, cabbage aphid, semilooper, cabbage head borer, cabbage butterfly, mustard sawfly, and flea beetles are among the primary pests of crucifers that are generating considerable crop losses. The sustainable management by integrating different stratergies of pest control not only results in reduced losses but also provides solution to the problems such as insecticide resistance, resurgence and residual effect of insecticides. For all these concerns caused by chemical insecticides an eco-friendly management is adopted. The usage of biopesticides, comprise a wide range of microbial pesticides and biochemicals derived from microorganisms and other natural sources. The usage of such natural resources and eco-friendly insecticides will have a significant impact on farming and public health initiatives.

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INSECT PESTS OF CUCURBITACEOUS VEGETABLE CROPS AND THEIR ECOFRIENDLY MANAGEMENT

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Introduction:

Vegetables are an essential part of our daily life. It not only provides nutrition but also essential phytochemicals and essential amino acids needed by humans for disease healing. All parts of vegetable plants like leaves, stems, flowers, pods and roots are full of medicinal properties. Cucurbitaceous vegetable crops like cucumber, Long melon, water melon, muskmelon, pumpkin, snake gourd, bottle gourd and bitter gourds play an important role among the vegetable crops. Cucurbits are a family with a total of 90 genera and 750 species. Despite the use of this fruit all over the world, the knowledge of its medicinal properties is limited. Cucurbit species is an excellent plant with high medicinal properties and high nutritional value. The production of such special plant species is reduced due to various factors, among which the yield is greatly reduced by insect pests. Fruit flies (*Bactrocera spp*.), Semilooper (*Anadevidia peponis*), Spotted beetle (*Epilachna spp.*), Pumpkin beetle (*Raphidopalpa foveicollis* (Red beetle), *Aulacophora cincta* (Grey with black border) and *A. lewisii*, *A. intermedia* (Blue beetle)), Stem weevil (*Baris trichosanthis*), Pumpkin caterpillar (*Cryptographis indica*) and sucking pests like Aphids, bugs, plume moth, scales are the important pests on cucurbits.

Insect pests of cucurbitaceous vegetable crops

Major Pests	Minor Pests
1. Fruit flies (*Bactrocera cucurbitae, B. zonata, B. ciliatus*)	**6. Stem gall fly** (*Neolasioptera falcata*)
2. Pumpkin beetles (*Aulacophora foveicollis, A. cincta, A. intermedia*)	**7. Stem borer or clear winged Moth** (*Melittia eurytion*)
3. Leaf eating caterpillar (*Plusia (Anadevidia) peponis, A. signata A. orichalcea)*	**8. Stem boring beetle** (*Apomecyna saltator*)
4. Serpentine leaf miner (*Liriomyza trifolii*)	**9. Plume moth** (*Sphenarches caffer*)
5. Gherkin fruit borer or Gourd Semilooper (*Diaphania (Cryptographis) indica*)	**10. Stink bug** (*Aspongopus janus*)

	11. Spotted leaf beetle (*Epilachna vigintioctopunctata*)
	12. Blister beetle (*Mylabris pustulata*)
	13. Snake gourd stem weevil (*Baris trichosanthis*)

Major pests

1 Common Name : **Fruit flies**

Scientific Name : *Bactrocera cucurbitae* (Coquillet), *B. zonata*, *B. ciliates* (Two other allied species common in India are *Dacus ciliatis* and *Bactrocera dorsalis.*)

Family : Tephritidae

Order : Diptera

Distribution : India, Pakistan, Myanmar, Malaysia, China, Formosa, Japan, East Africa, Australia and Hawaiian Islands

Host Range	Damage Symptoms	Biology
● Melons, Gourds, Chow-Chow, tomato, chillies, guava, citrus, pear, fig, cauliflower, etc.	● Maggots cause damage by feeding on near-ripe fruits, riddling them and contaminating the pulp. ● Malformed fruits followed by oozing out of brown resin like fluid. ● It cause premature dropping. ● The damaged fruits decay by bacterial infection.	**Egg:** within 15 to 55 days, the Adult female can lays 58 to 95 eggs. Egg period will be 1 to 9 days. **Maggot**: Absence of leg and head, broader at one end and narrow pointed at another end. It will pupate within 3 to 21 days. **Pupa**: It pupates under soil and looks barrel shape and light brown in colour, It will hatch within 6 to 30 days. **Adult:** It has reddish brown with yellow markings on their thorax. Adult will emerge at morning and mating will occur at dusk. It completes many generation within a year.

Management:

- Infested portions like fruits and leaves should dump in deep pits.
- The fruit fly population is very low in high temperature with dry condition and it reach high population at rainy season, hence showing dates should be altered in endemic areas.
- Soil raking up or ploughing should follow to kill the pupae.
- Use trap crop of ribbed gourd

- Eucalyptus oil, citronella oil, vinegar (acetic acid), lactic acid and dextrose are act as attractants - to trap adult flies.
- The combination of malathion 50 EC (50ml) + Sugar (0.5kg) in 50 L of water per ha as poison bait. Spray at weekly interval as well as keep in earthen lids and place randomly at different parts of the field.
- We can use maize as a trap crop and the bait spray should be given on it.
- **Fruit fly trap:** Keep wet fishmeal (5g) in container with six holes (3 mm dia), above 2 cm from the bottom. Keep the cotton plug (treated with dichlorvos at 0.1 ml or a drop) inside the bag. Every week we should add diclorvos and once in 20 days the fishmeal should be renewed. recommended dose - 20 traps/ acre.
- Use methyl eugenol trap for monitoring and mass trapping.
- Pupal parasitoids like *Opius fletcheri, O. compensatus* and *O. insisus* , *Spalangia philippinensis* and *Pachycepoideus debrius*. *Dirhinus giffardi* and *D. lzonensis* are highly effective, hence we have to conserve properly.

2	Common Name : Pumpkin beetles Scientific Name : *Aulacophora foveicollis, A. cincta, A.intermedia* Family : Chrysomelidae Order : Coleoptera Distribution : Asia, Australia, southern Europe and Africa		
Host Range		**Damage Symptoms**	**Biology**
● Ash gourd , pumpkin, tinda, ghia tori, cucumber and melon.		● Grubs and adult beetles damage the crop. ● **Grubs** feed the root, underground stems of creepers and on fruits lying in contact with the soil. ● **The adults** feed on all parts of the plant which are above the ground. ● The early sown cucurbits are highly susceptible so resowing should be followed.	**Egg**: Adult female lays 300 yellow coloured eggs singly or 8 to 9 batches under moist soil, near base of the plant It will hatch within 6 to 15 days. **Grub**: Neonate grubs are dirty white but full matured grubs are creamy yellow in colour with 22 mm long. 13 to 25 days will be the grub period **Pupa**: It pupates in earthen chambers (thick walled) in the depth of 20 to 25cm under the soil. Pupal period - 7 to 17 days **Adult:** Adult beetles are 5 to 8 mm long with oblong shape and found concealed in groups. ***A. foveicollis:*** 6.8 mm long and red in colour

		A. cincta: grey with black in colour and the borders are having glistening yellow or red in colour. ***A. intermedia***: Blue colour adult. Adult period – 60 to 85 days. Total life cycle - 26 to 37 days and completes 5 generations per year.

Management

- To avoid pest incidence the early planting should be follow from October to November months.
- Soil raking up should be followed regularly to kill the eggs as well as grubs.
- Infested leaves and fruits should be destroyed manually.

3	Common Name : **Leaf eating caterpillar** Scientific Name : *Plusia (Anadevidia) peponis, A. signata A. orichalcea* Family : Noctuidae Order : Lepidoptera Distribution : All over the country	
Host Range	**Damage Symptoms**	**Biology**
● All cucurbitaceous crops	● The caterpillar cuts the edges of leaf lamina, folds it over the leaf and feeds from within leaf roll.	**Egg:** Female lays spherical sculptured greenish white eggs singly on the tender leaves. **Larva**: Larva is a greenish semi looper with black warts. It has humped abdominal segment measures 35-40 mm long. It has greenish body with white longitudinal lines surrounded by black tubercles with thin hairs. They are active in winter. **Pupa**: Inside the leaf fold they pupate as thin silken cocoon. Greenish pupae turns dark brown before emergence. **Adult:** Brownish moth has shiny brown fore wings. It take one month to complete its life cycle.

Management

- Manual Collection and destruction of caterpillars.
- Conserve and increase the population of larval parasitoids: *Apanteles plusia* and *A. taragamae*.

4 Common Name : Serpentine leaf miner
Scientific Name : *Liriomyza trifolii* (Burgess)
Family : Agromyzidae
Order : Diptera
Distribution : It is a native pests of Florida of southern US and Caribbean islands. Recently introduced into India (Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu)

Host Range	Damage Symptoms	Biology
● Vegetables, Ornamentals, fibre crops, Pulses, oilseeds, green manures, fodder, narcotics and weeds of 16 families and it's a serious pests on tomato, cotton, ridge gourd, brinjal, cucumber and potato	● Maggots mines into leaves and cause serpentine mines ● Drying and drooping of leaves will occur.	**Egg:** Female thrusts eggs into the epidermal layer of leaves. Egg period – 2 to 4 days. **Larva**: orange yellowish maggots with apodous head. Larval peiod – 7 to 10 days**.** **Pupa**: Pupates within mines. Pupal period – 5 to 7 days. **Adult:** Pale yellow in colour It take 21 days to complete a life cycle.

Management

- Collect and destroy mined leaves
- Spray NSKE 5%

5 Common Name : **Snake gourd semi looper / gherkin fruit borer**
Scientific Name : *Diaphania (Cryptographis) indica* (Saunders)
Family : Crambidae
Order : Lepidoptera
Distribution : Distributed all over India, Mayanmar, Sri Lanka, Fiji, Oriental and Australian regions, Netherlands, Samoa, Mauritius, Tonga Island, Indo-China, Japan and Sudan.

Host Range	Damage Symptoms	Biology
● Melon, gourds, cucumber, cucurbits and particularly	● Larvae webs leaves and feed the leaves, Ovaries and young developing fruits ● Affected flowers bears no fruits and infested	**Egg:** The adult female can lays 366 eggs on the lower surface of the leaves as single or in group. Incubation period is 3 to 6 days. **Larva**: Bright green elongated and has two thin longitudinal lines (white colour) on their dorsal side. Larval period – 9 to 14.

gerkhins and coccinia	fruits become unfit for consumption.	**Pupa**: Pupation occurs within the flowers as cocoon. Pupal period – 5 to 13 days **Adult:** Transparent white winged adult has broad and dark brown patches on its marginal portion and female has anal tuft of hairs (orange colour). Adult period – 3 to 7 days. **Total life cycle –** 23 to 33 days

Management

- Early instar larva should be destroyed manually.
- Encourage the larval parasitoid (*Apanteles spp*.) activity.

Miner pests

6	Common Name	:	Stem gall fly
	Scientific Name	:	*Neolasioptera falcate*
	Family	:	Cecidomyiidae
	Order	:	Diptera

- The young one feeds within distal stems of bitter, ribbed and smooth gourds
- It makes elongated galls between nodes.
- In heavy infestation stunting of plants will occur.

Management:

- Manual removal and destruction of shoots should be followed early infestation stage.

7	Common Name	:	Stem borer /clear winged moth
	Scientific Name	:	*Melittia eurytion*
	Family	:	Aegeriidae
	Order	:	Lepidoptera

- Snake gourd widely affected by this pest and occurrence will be all over India.
- It's a clear winged adult moth and the hind legs have fan like tufts hairs.
- Larva produce galls by making bore holes in the stems.
- We can examine the frass outside the bore holes.
- Stunted growth of the plant as well as reduced foliage production will occur.
- Pupation occurs inside the soil as earthen cocoon and pupal period completes within 20 to 24 days.

Management:

- Damaged plant parts with larvae should be destructed manually.
- Conserve and improve the activity of *Apanteles* spp.

8	Common Name	:	Stem boring grey beetle
	Scientific Name	:	*Apomecyna saltator*
	Family	:	Cerambycidae
	Order	:	Coleoptera

- *Coccinea* vines severely infested by this pest and it lead to death of the plants.
- The longicorn beetle female is a white spotted greyish- brown coloured one and the male is smaller than female with black in colour .
- On internodes below the bark the female lays eggs singly.
- Grubs bore the stems and make tunnel inside.
- Adults infesting the soft portions of the stem.
- Adult female lays 38 to 52 eggs; egg period will be 5 to 7 days.
- Larva has 6 instars and completes within 31to 35 days.
- Pupal period 7 to 9 days.
- One life cycle – 80 to 98 days. Adult period – 37 to 43 days.

9	Common Name	:	Plume moth
	Scientific Name	:	*Sphenarches caffer*
	Family	:	Pterophoridae
	Order	:	Lepidoptera

- This is a common pest of bottle-gourd in South India.
- Adult is a tiny plume moth.
- Eggs are laid singly on buds and leaves.
- Both larva and pupa have spines on the body.
- Larva feeds on the foliage.
- Collect and destroy larvae and pupae in their early stages.

10	Common Name	:	Stink bug
	Scientific Name	:	*Aspongopus janus*
	Family	:	Pentatomidae
	Order	:	Hemiptera

- Red and black coloured bug occurs on leaves and tender shoots by clinging in large numbers.
- Buggy odour emitted by the nymph and adult bugs
- It infests the tender parts of the plant and makes retarded growth.
- Manual collection and destruction of nymph and adult along the branch or twigs

11	Common Name	:	Spotted leaf beetle
	Scientific Name	:	*Epilachna vigintioctopunctata*
	Family	:	Coccinellidae
	Order	:	Coleoptera

- **Damage symptoms:** Grubs and adult scrape the leaves and cause damage mainly on bitter gourd and also attack water melon, pumkin and melons.
- **Egg:** egg period – 2 to 4 days: Cigar shaped, laid in clusters on lower leaf surface, yellow; 120-460 eggs/female.
- **Grub:** grub period- 10 to 35 days. Yellowish bearing six rows of longitudinal spines.
- **Pupa:** It has spines on posterior end cum devoid of spines on posterior end and yellow in colour. Pupation occurs on the leaves or stem and the pupal period will be 5 to 6 days.
- **Adult**: *E. dodecastigma* (6 spots per elytra with copper colour), *E. demurille* (6 black spots with yellow border on each elytra and looks dull light copper colour). *E. vigintioctopunctata* (14 spots on each elytra and dark red in colour).
- It completes their life cycle within 20 to 50 days and make seven generations per year.

Management

- Beetles, grubs and pupae should be collect and destroyed manually.
- We can kill the beetles, grubs and pupae with kerosenated water.

12	Common Name	:	Flower feeder
	Scientific Name	:	*Mylabris pustulata*
	Family	:	Meloidae
	Order	:	Coleoptera

- The adult beetles infest the all parts of the flowers (pollens, petals and flower buds) and it leads to affect the fruit setting.
- Collection and destruction of adult beetles in the early morning and destroy manually.

13	Common Name	:	Snake gourd stem weevil
	Scientific Name	:	*Baris trichosanthis*
	Family	:	Curculionidae
	Order	:	Coleoptera

- The weevils make infestation by feeding the leaves.
- It lays the eggs in nodes, the incubation period being 5-6 days.
- The grubs bore into the stem or the petiole for about 3 weeks and cause withering of leaves.
- They pupate in the bore hole itself and pupal period is 7 days.

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INSECT PESTS OF MANGO AND THEIR ECO-FRIENDLY MANAGEMENT

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Introduction:

Mango (*Mangifera indica* Linn.) is a popular fruit all over the world and is referred to as the "King of Fruits." It is the most profitable fruit that can be cultivated in tropical and subtropical climates (Abdullah and Shamsulaman, 2008). It is infested by insect pests as well as non-insect pests (Chavan *et al*., 2009). It is one of the extensively cultivated fruit crops in tropical regions. India stands first among mango growing countries of the world both in area and production and shares 55% of the world's mango production (National Horticultural Board 2021). Wide range of soil and climatic adaptability of mango makes it a suitable fruit crop all over India. Mango is prone to a variety of pests, including insects, pathogens, mites and vertebrates. Insect pests, on the other hand, frequently pose a serious threat to profitable cultivation. The hoppers, fruit flies, fruit borer, nut weevil etc. are considered economically important pests to mango. Climate change not only influences the mango production but also directly and indirectly has an impact on the insect pests associated with mango. Pests that were once considered minor have become major, such as thrips, and vice versa. Farmers in India are relying solely on pesticides which lead to pest resistance, environmental pollution and harmful residues in soil, water and food. Even though organic farming has gained credence in recent years, use of chemical pesticides remains the main acceptable solution for pest management. This chapter discusses mango insect pests and mites, their biology, damage potential and eco-friendly management strategies to mitigate the negative impact of chemicals.

Major pests of mango

1. Mango hopper (Hemiptera: Cicadellidae)

Mango hopper is a major pest of mango and it widespread in India. Over 18 species have been reported as pest around world. Totally, 15 species have been reported from Asia. Among them, only 3-4 species are serious pest of mango, *viz. Idioscopus niverosparsus* (Leth), *I. clypealis* (Leth), *I. nagpurensis* (Pruthi) and *Amritodus atkinsoni* (Leth) (Soomro 1987; Waite 2002). The eggs are deposited by females in panicles or midribs of tender leaves. The young leaves, blossoms and shoots are the parts of plant preferred by adults and nymphs to feed. During feeding, leafhoppers excrete honeydew, upon which sooty mould develops. This interferes with photosynthesis, adversely reducing plant development and productivity. Affected inflorescences turn brown and droopy.

I. niverosparsus newly emerged nymph remains immobile before moving into feeding spot. The tip of stylet is wider in male than in female. Nymph resembles adult except the rudimentary wing pads and the pads emerge in third instar and by the fourth and final instar (Dwarka *et al*., 2022). The adult's scutellum has three spots and its light brown wings have a noticeable white band running across. It is slightly smaller than the other adults. The smallest one is *I. clypealis* with two spots on scutellum and dark spots on anterior margin of vertex which are absent in males and measuring 3.5-4mm in female and 3-3.5 mm in male (Bashir *et al*., 2020). *A. atkinsoni* is the largest and has two spots on scutellum and is light brown in colour measuring in length of 3.4 – 3.7 mm males and 3.-3.9 mm females (86) (Bashir *et al*., 2020). It includes 7stages viz., egg, nymphal (5 instar) and adult stages required 4-7, 8-13 and the total life cycle is completed in 15–19 days (82). Although the number of generations varies depending on location, the insect mostly has two to three generations per year. The insect goes overwinters as adult. The population reaches upto peak at March- April and abiotic factors such maximum and minimum temperature and relative humidity responsible for population fluctuation (Tandon *et al*., 1983). Hoppers hibernate between the cracks and cervices of tree bark and clinging sound can be heard at peak period of significant infestation. The orchard spacing also plays a role for breeding of hopper. Closer spacing and dense varieties response for high population (Reddy and Dinesh, 2005).

Large number of nymphs and adults suck sap from same inflorescence causing the flower buds and blooms to wither and shed, resulting in heavy loss during fruit setting. Premature fruit drop and fruit setting was reported by Bindra *et al*. (1971). Both nymph and adult excrete honey dew which leads to development of scooty mould (Plate 4) on leaves and inflorescence (burnt appearance) which affect the photosynthetic efficiency CABI, (2003). In severe infestations, the leaves and fruits appear to be dripping with honey dew. Shady and damp places are more favourable for hoppers during summer.

Plate 1:
I. niverosparsus

Plate 2:
I. clypealis

Plate 3:
A. atkinsoni

Plate 4:
Hopper infestation

Management

- Avoid dense planting and proper pruning to regulate the number of flushes in a year.
- Five sprays of *Metarrhizium anisopliae* (oil formulation @ 0.5 ml/l) or five sprays of *Verticillium lecanii* (Commercial product @ 5 gm/l.) (Munj *et al*., 2020) instead of

synthetic insecticides which help to conserve the natural enemies of predators like coccinellids (e.g. *Coccinella septempunctata*, *C. transversalis* and *Menochilus sexmaculatus*) and spider.

- Spray botanical pesticides like azadirachtin 1% at 3 ml/l, if hopper population is low (4/panicle), neem oil and pungam oil at 1% at 10ml/l (Chaudhari *et al*., 2017).
- Significant variations in hopper incidence were found between genotypes, reflecting the extent of host plant resistance. (Devi Thangam *et al*., 2013).

2. Thrips (Thysanopter: Thirpidae)

The genus Thrips includes more than 295 species worldwide (Thrips Wiki, 2017), including 44 species that were reported from India (Rachana and Varatharajan, 2017). Several species in this genus are significant pests that damage crops either directly by feeding and laying eggs or indirectly by spreading tospoviruses (Marullo and Mound, 2002) and a few are of economic importance i.e., pollinators and predators. The generation may be completed in 20 days at 30C. It includes (6 stages) like egg, larval (2 instar), pre-pupal, pupal and adult stages. Eggs are deposited in leaf tissue. The average egg laid by a female is 50, though they can lay up to 200. The larva resembles adult except in the criteria of wing development and body size. Larvae typically feed in groups and prefer older leaves, especially those with midrib and veins. Pre-pupal and pupal stages are inactive. Adults are pale yellow or whitish in colour with numerous dark setae on the body. A dark line runs along the back of the body as a result of the wing junction. The pale fringed wings are thin. Adult longevity is 10–30 days for females and 7–20 days for males. From India, the species reported on mango are *Aeolothrips collaris* (Priesner), *Anaphothrips sudanensis* (Trybom), *Caliothrips indicus* (Bagnall), *Rhipiphorothrip scruentatus* (Hood), *Neoheegeria mangiferae* (Priesner), *Haplothrips ganglbaueri* (Schmutz), *Selenothrips rubrocinctus* (Giard), *Ramaswamiahiella subnudula* (Karny), *Frankliniella schultzai* (Karny) and *Scirtothrips dorsalis* (Hood). Of these, the first four species feed on the leaves and last five infest the inflorescences. For first time *Frankliniella schultzai and Thrips sunudula* Karny was reported on mango inflorescence in India (Krsihnamoorthy and Visalakshi, 2012). *Thrips palmi* Karny infesting mango flowers in India, caused scab-like feeding scars with delayed fruit growth (Reddy *et al*., 2018). Thrips colonize the leaves, inflorescence, fruits, new flush and they suck the sap by lacerating the tissues (Plate 5 & 6) (Pena *et al.*, 2002). The population rise to peak during hot dry weather and when the infestation is severe, the leaf tips curl and turn brown in colour (Aliakbarpour and Chesalmah, 2010).

Plate 5: Thrips damage on leaves

Plate 6: Fruit infestation

Management

- Infestation should be monitored by placing sticky traps at regular intervals.
- Three weekly sprays of *M. anisopliae* (IIHR oil formulation @ 0.5 ml/l) from panicle initiation stage and one spray each at pea and lemon sized stages (Munj *et al*., 2020)
- *M. ansiopliae* at a concentration of 1×109 spores/ml with adjuvant (sunflower and Triton-X) (Visalakshy and Krishnamoorthy, 2016)
- Spraying of neem soap at 10 g/l or neem-based pesticides prevents establishment of thrips. Conservation of natural enemies, viz. predatory thrips, predatory mites, anthocorid bugs or minute pirate bugs (*Orius* spp.), ground beetles, lacewings, hoverflies and spiders.

3. Mango leaf/shoot webber (Lepidoptera: Pyralidae)

Two important species of leaf webber are reported in India viz., *Orthaga euadrusalis* Walker and *O. exvinacea* Hampson. In recent years, *O. euadrusalis* has emerged as a significant barrier to mango production in Uttar Pradesh, Bihar, and other regions of Northern India (Srivastava *et al*., 1997). In Uttar Pradesh, it was initially noted as a significant pest of mango (Tandon and Srivastava, 1980). Mango pest *O. exvinacea* has been identified in West Bengal (Jha and paul, 2020). It was formerly thought to be a minor pest, but is now considered a major problem and it is also reported as occasional pest of mango in South India. The most active period of leaf webber is from August to December and its distribution is affected by maximum and minimum temperature. Kasar *et al*, (2017) reported that the webs within tree were more in western and southern side compared to the northern and eastern side.

Adult moths are medium sized. Females are dark coloured and they lay their eggs on leaves. The eggs are a drab greenish colour and eventually hatch in 4–7 days. Larvae of the first instar feed on the chlorophyll in the leaves and from the second instar onward, they begin to web the leaves and consume the entire leaf, leaving the midrib and veins. The dorsally striped, brownish blue caterpillar is between 2.5 and 3 cm long and has whitish striations. The larval period ranges from 15 to 33 days with five developmental instars. When disturbed, the caterpillars jerkily tumble to the ground. The caterpillar scraps the chlorophyll of tender leaves surface gregariously. Young larvae form a web of two to three leaves and devour them by cutting

the leaves from the margins to the midrib, leaving the vein network behind. (Plate 7). They pupate inside the web, however the caterpillars of the last generation in December and January secrete a thread that allows them to hang and fall to the earth where they pupate in the soil. They spin a cocoon, which adheres to the soil. The webbed leaves and dried apical branches of the afflicted trees make them noticeable. Most of the time, such an attack inhibits fruit setting and flowers blooming. Trees that are severely infested have a burned appearance and completely prevent flowering (Vergese, 1998). Between 16 and 18 days, the pupal stage develops. The adult emerges from the pupating hibernating larvae at the end of April and it completes five generations in a year. (Beria *et al*. 2008).

Plate 7: Leaf webber infestation

Management

- The infestation of the pest has the potential to cause production loss of 25-100%, if not managed (shrestha *et al*., 2022).
- Along with pupa and larva, the web nest can be scraped off and burnt.
- Biological methods by conserving the predators like *Hormius, Pediobius bruchicida, Brachymeria lasus*, *Oecama* sp., etc. pathogens like *Serratia marcescens* and *Beauveria bassiana*, etc. which reduces the chemical usages (Shrestha *et al*., 2022).
- Two or three times spraying of *Beauveria bassiana* during the period of highest humidity can also check the pest population (Srivastava & Tandon, 1980).
- Planting resistant variety like Amrapali and pruning to remove the old and infested branches is the legal method which regulates the mobility of plant parts (Singh *et al*., 2006).
- Botanicals like nemactine 0.4 % or nimbicidine 0.2 % sprayed to reduce the incidence (Singh, 1999).

4. Mealybug (Hemiptera: Pseudococcidae)

Out of 20 species of mealybug, three species, viz. *Drosicha stebbingi* (Green), *Drosicha mangiferae* (Green), and *Rastrococcus iceryoides* (Green) were reported in India. The insect (Margarodid: *D. mangiferae*) typically produces single generation in a year. After mating, females enter the soil in June and die after laying upto 400-500eggs, at a depth of down to 15 cm. During mid-December, eggs continue to hatch until January. The nymphs emerge from the

soil and move to tender shoots, where they settle. The duration of first instar varies from 45 to 71 days, second instar 18 to 38 days and third instar for female 15 to 26 days. The late instar nymphs and adult females are flat, oval and waxy white. The life cycle was finished in May or June and total period around 77–135 days for female and 67–119 days for male (Yadav *et al*., 2004). According to Prasad and Singh (1976), the degree of attack varies, depending on year and locality in India, mostly on soil and surrounding environment. Development is favoured by dry conditions during hatching and moderate rainfall (55–60 mm) during oviposition. Adults begin to form in April. Males quickly pass away after mating. The females go into the ground in May to lay their eggs and the eggs don't hatch until the end of December.

The inflorescence, succulent leaf, lower surface of the leaf midrib, petiole, apex of the plant, leaf, etc. are the main plant parts where infection occurs (Plate 8) (Ali, 2011). Both nymph and female adult adhere and remain stationary to the panicle to start feeding and it continues throughout the development. Panicles that are affected shrivel and dry out. Sooty mould covers the infected plants. Mealybug infestation on panicles causes fruits to drop off too soon and shrink in size (Singh and Mukherjee 1989). A clear sign of infestation is the presence of white cottony cushioned nymphs and adults (Mani, 2016).

Plate 8: Mealybug infestation on leaves, stalk and fruits

Management

- Orchard ploughing in month of November–December.
- Weeds removal like *Clerodendrum infortunatum*, an alternate host plant of the giant mealy bugs.
- Field release of *C. montrouzieri* at 50/plant results significant reduction in the number of mealybug-infested mango fruits (Mani *et al*., 1995).
- Glue traps around trunk at a height of 1 foot from the ground and changed once after 10 days (Kour *et al*., 2022).
- Transplanting of 5-6 lemon grass seedlings around the tree trunks in the first week of December (Kour *et al*., 2022).

- Conserving natural enemies, viz. the parasitoids *Anagyrus* sp. nr. *dactylopii* (How.), *Anagyrus* sp., *Coccophagus* sp. *C. sexvittatus* Hayat (pseudococci group), *Allotropa* sp, and predators *Leucopis* sp., *C. perspicax, S. epeus* (Narasimham and Chacko, 1988).
- Predatory ants *Camponotus* sp., *Myrmicaria brunnea* Saunders and *Oecophylla smaragdina* (F.) were also known to attack *R. iceroides*. Upto 42% parasitism was observed in nature (Tandon and Lal, 1978). The parasitoid, *Anagyrus pseudococci* Gir., and the predator, *Cacoxenus perspicax* (Knab.) are known to be of greater importance.

5. Midges (Diptera: Cecidomyiidae)

Mango midges are the serious pest all over the world. Totally 16 species of gall midges attack mango in Asia. Out of them, four to five species damage the inflorescence and contribute to heavy loss in fruit yield (Peña 2002). Mango midges, viz. *Procystiophora mangiferae, Dasineura amaramanjarae, Erosomyia mangiferae, Erosomyia indica* and *Procontarinia matteiana* are distributed throughout mango orchard in India. Gall midges have a general life pattern with four separate stages in their life cycle: the egg, larva, pupa and adult.

5.1 *Procystiophora mangiferae* (Felt)

P. mangiferae (Felt) is one of the blossom gall midge species feeding on mango. The larval sternal spatula is a typical structure which helps in identification of such midge (Grover, 1984) and strongly sclerotized blade like ovipositor is present at the end of abdomen. Mating takes place as nuptial flight and female searches the suitable bud for egg-laying. Usually one to two, rarely three eggs are laid by a female in one sitting. Eggs are laid in the fold between sepals and petals and on hatching the larvae enter blossom. After hatching, the first instars migrate to suitable places and begin to feed actively. The larva passes to attain second and third instars which shows a crown of sternal spatula but, the sternal spatula is fully formed at fouth instars and sclerotized being brown in colour. Pupa spins a cocoon of silken fibres and pupates inside the bud. *P. mangiferae* is a minute orange coloured midge in which the male is smaller than the female. The sepals of heavily infested buds wither, while the petals turn yellowish-red and project out. The projecting petals constitute a good character for the identification of the infected bud. The infected buds fail to open and drop ultimately. Sometime the larvae also drop on the soil for pupation (Tripathi *et al*., 2020).

5.2 *Dasineura amaramanjarae*

The adult female lays 40-50 eggs near the stamens, in 8 -10 minutes' interval. Egg laying fluctuates depending upon the temperature and humidity (Prasad and Grover, 1976). After hatching, the larvae start feeding, destroy the flower buds and also make a small tunnel in branches. The afflicted buds have crimson petals and the flower buds become black, dried up, and dropped off. Several larvae can be noticed in a single flower but only one larva can be found per gall. They attack panicles which become dry and fall due to slight pressure of wind,

thus the loss of flower and fruits. After full feeding, mature larvae leave the inflorescences and enter the soil for pupation (Grover, 1985). Out of four larval instars', second and third instars cause most of the damages. In the case of severe infestation, the reduction in yield can reach 60% to 100% due to fall of hallowed fruits in the soil (Prasad, 1966a). In natural condition, the life cycle is completed in 16 - 19 days (Memon *et al*., 2020).

5.3 *Erosomyia mangiferae*

The pest is active only during the flowering season and spends the other period as pupae in the soil. During flowering, females lay eggs on flower buds (immature blossoms) and scarcely on tender inflorescence axis. After hatching, the maggots start feeding on flower buds and make small tunnels in branches (Plate 10). Due to secondary infection by *Colletotrichum gloeosporioides* [Glomerella cingulata], infested buds get black, dry and drop off. The damage grows severe when adult larvae exited on branches and fruit set was entirely impeded. Larvae penetrate the soil to pupate when they have completed the feeding. The pest produced 3-4 overlapping generations during flowering (January-April) and each generation lasts approximately 20 days. The maximum population density was observed in the middle of February in Minab (Pezhman and Askari, 2004).

5.4 *Erosomyia indica* Grover & Prasad

The immature panicles are infested by the midge by oviposition during the bud burst stage and the first instar maggots bore into the flower buds, expanding panicle and small fruits. Infested panicles have a distinctive right-angled bend with a dirty exit hole through which maggots of the final instar emerge to pupate in soil. The infected inflorescence becomes stunted and malformed and fails to open. The second generation infests very young fruits, which eventually drop before the marble stage (Chowdhary, 2015).

5.5 *Procontarinia matteiana*

P. matteiana was reported as an economic pest during 1980s in Indian Gujarat, as it damaged 25.80 to 47.70% leaves of 3 varieties (Alphonso, Kesar and Rajapuri) of mango in 17 places (Jhala *et al*., 1987). This pest can cause serious damage in the absence of natural enemies. The adult females lay their eggs on the ventral surfaces of leaves; on hatching, the maggots bore into the leaf tissue and feed within it, resulting in the formation of small, raised, wartlike galls on the leaves (Plate 9). At the beginning of gall development it is light green with increased size and gradually becomes hard and concave at oviposition site. The affected leaves are badly deformed and drop prematurely. It completes its life cycle in 40 to 45 days. The abdomen of males is brown and light green in females (Rehman *et al*., 2013).

Plate 9: Damage on leaves

Plate 10: Inflorescence damage

Management

- Deep plough the orchard in November to expose pupae and diapausing larvae to sun's heat and natural enemies.
- Spray of NSKE 10% on mango tree canopy plus racking (hoeing) of soil under the mango tree canopy (Rehman *et al*., 2014).
- Conservation of parasitoids *Eupelmus* sp., *Platygaster* sp. and *Systasis* sp. were associated with *Dasineura* sp., and *Tetrastychus* sp. was associated with *E. indica.* An external parasitoid, the pteromalid *Pirene* sp., was found attacking *Procystiphora mangiferae* (Felt). Predators of the cecidomyiids include *Formica* sp., *Oecophila* sp. and *Camponotus* sp. (Grover, 1986).
- To conserve the parasitoid such *Chrysonotomyia pulcherrima* (Kerrich), *Synopeas mangiferae Austin,* and *Inostemma oculare* Austin (Jhala, 2015).

6. Scale insect (Hemiptera: Coccidae)

The mango scales, though a minor pest earlier, are gaining much attention in recent years infecting the leaves and fruits in mango. Four species of scale insects which include *Aulacaspis tubercularis, Aonidiella aurantii, Aspidiotus destructor* and *Ceroplastis rubens* and were associated in mango ecosystem. Among them, *Aulacaspis tubercularis,* and *Aspidiotus destructor* are major problems especially in late planting orchards. The scales are present throughout the year with overlapping generations and reproduce parthenogenically. The males have wings, whilst the adult females don't. The female spends sedentary existence, sucking the cell sap from the plant parts. The adult female lays tiny eggs in a pouch. Larvae crawl to the plants' delicate areas after hatching, where they quickly attach themselves. When the larva periodically moults, it loses its natural shape and transforms into a tiny, footless mass that is covered in scale. At this stage, it is challenging to distinguish between male and female larva, but after one to two moults, the male larvae eventually manifest as winged forms. They mate with females and pass away quickly. For the entirety of their lives, the females remain stationary in one location. They grow by feeding on the sap, losing their feet, feelers, etc., and deposit a waxy coating called a puparium over their bodies (Rawat and Jakhmola, 1970). Both nymphs and adult scales suck the sap of the leaves and other tender parts that reduce plant vigour. Infected

leaves turn light green or yellow before dying. During severe infestation, both the leaves and branches are killed. Honeydew secretion promotes the growth of sooty mould on mango leaves and other vulnerable areas of the plant. Flower spikes and fruits may also be infested (Plate 11). Both species not only affect the quantity but also quality of the mango fruit by causing blemishes on the fruits affecting the commercial value of the fruit and also their export potential (Kumari *et al*., 2014). Severe infestation tends to adversely affect the growth and fruit bearing capacity of the tree.

Plate 11: Scale symptom on leaf, stem and fruit

Management

- Pruning removal of old dry branches, offshoots, and infested parts (Terefe *et al*., 2014).
- Use of planting material that is free from scales to minimize the scale population.
- To conserve the natural enemies: *Aphytis pseudococci*, *Encarsia* sp., *Promascidia unfascitiventris*, Habrolepis diaspidi as parasitoids and *Cryptolaemus montrouzieri, Chilocorus nigritus Cybocephalus micans, Scymnus syriacus* as predator (Mani *et al*., 1995)

7. Shoot Gall Psylla (Hemiptera: Psyllidae)

Mango shoot gall psylla, *Apsylla cistellata* is regarded as one of the most notorious pest affecting the mango production (Gundappa *et al*., 2018). The scale lays egg from mid February. Each female lays averagely 141-150 eggs on either side of the mid rib of a single leaf. Freshly laid eggs look like rectangular block with rounded corners and are almost transparent. There are six nymphal instars. The nymph is minute with a pair of setaceous antennae, 2 pair of distinct wing pads and 3 pair of legs. Freshly hatched nymph is small and yellowish but changes in size and colour over the time. The body colours of both sexes are similar but differ in size and shape of the abdomen (Monobrullah and singh, 1998). The pest becomes active in August and between August and September, the nymphs hatch from their eggs and crawl to nearby buds to scavenge cell sap which secretes a chemical (probably phenyl amino acids). Feeding causes the buds to grow into hard, conical, green galls, which are typically visible between September and October. Affected terminal shoots, green conical galls develop in the leaf axis as a result of adult insects

laying eggs or nymphs feeding on them. There is no flowering or fruit setting as a response of the development of the green galls (Chowdhary, 2015).

Management

- Removal of eggs bearing leaves from shoot resulted in 95.57 per cent decreases over control (Kumar *et al*., 2007).
- Prune the shoots at 15 cm height of tree which bear galls during September (Samui and Jha, 2009).
- Collect and destroy the galls with nymphs.

8. Mites (Acari: Tetranychidae and Eriophyidae)

Due to the indiscriminate use of insecticides against sucking pests and mites, the sporadic pests of mango have the potential to become severe pests. They colonize on leaves, buds and fruits. Among mites species, the bud mite, *Eriophyes mangiferae* (Sayed) and spider mite, *Oligonychus mangiferus* Rahman and Sapras commonly occur in India. The bud mite, *E. mangiferae* (Sayed) is a major pest in Delhi, Uttar Pradesh and Punjab (Singh and Mukherjee 1989). The infestation begins in April and intensifies until it reaches its climax in June. Spider mite feeds on the upper surface of mango foliage. The leaves and sensitive stem showed bronzing symptom as a results of both nymphs and adults feeding. On closer inspection, leaf webbing from mite colonies is visible. A witches' broom effect results from the mango bud mite damage without presence of *Fusarium* association, which causes the abundance of shoots at terminal (hypertrophy). When *Fusarium* association happens, the trees develop floral and foliar galls (Ochoa *et al*., 1994) and the interaction of bud mite with the fungus results in rapid necrosis of hypertrophy, producing multiple budding and subsequent gall formation where flowers and leaves would normally occur. Besides these mites, the broad mite, *Polyphagotarsonemus lotus* (Banks) of family Tarsonemidae, is displayed occasionally infest the nursery seedlings, causing stunting and crinkling of new leaves and rolling of leaf margins.

Management

Conserve the predacious mite such *Typhlodromops swirskii* (Phytiseiidae) which is found associated with bud mite in mango.

9. Mango stem borer (Coleoptera: Cerambycidae)

Five species of *Batocera* namely *B. rufomacuata* de Geer, *B. roylie* Hope, *B. rubus* Linnaus, *B. titana* Thompson and *B. numitor* Newmen have been reported infesting mango trees. Among them, *B. rufomaculata* is posing an increasingly serious threat to mango plantations all over the nation. The pest has one generation in a year. Adults are sturdy, dark brown beetles with males measuring 50–55 mm and females 55–60 mm. With the onset of the monsoon, adults emerge and begin mating. Between June and August, the female beetle lays the eggs singly on the main trunk of elder mango trees. A beetle can lay up to 200 eggs, which hatch

in seven to thirteen days. The eggs are shiny white, oval in shape. The developed grubs are robust, yellowish ivory and have well-defined segmentation. Pupation lasts 20–25 days and occurs in the tunnel. Adult longevity is 60–100days, with a total life cycle of 170–190 days (Venkata *et al*., 2018). According to reports, the infestation varies from one to eight percent depending on how well the orchards are maintained. Affected trees gradually lose their strength, show drying of their branches and in severe cases, even die. The harmful stage is the grubs burrow and feed through the bark, creating tunnels and inserts an egg under the bark. After hatching from the egg, the neonate larva initially feed under the bark. Young larvae begin feeding in the phloem tissue then migrate into the heartwood to pupate. The small larvae damage was difficult to be observed, but presence of hole, dripping sap, and frass at entry point can be observed on the bark when they grew up (Plate 12). If the damage is severe, the branches begin to turn yellow, which is followed by the drying of the terminal shoots and branches, which eventually ends in the death of the entire tree (Aromna *et al*., 2007). Varietal preference of borer is evident with *Alphonso*, *Langra* and *Jehangir* being the most susceptible (25–50% damage) and *Himayuddin* and *Banganapalli* the least susceptible ones (Palaniswamy *et al*., 1979; Reddy *et al*. 2015). Rootstock and spacing of orchard are other factors supposed to influence the borer infestation levels (Reddy *et al*., 2015).


Plate 12: Damage symptom on mango bark

Management

- Sanitation of orchard farm, extracting grubs through hooked wires from holes and kill them or by injecting dilute kerosene oil, petrol etc. and covering holes with wet clay soaked water (Baradevanal *et al*., 2021).
- Heavily damaged stems and branches must be pruned and chopped off (Nagar *et al*., 2014).
- The orchard should be tilled three times during June, July and August at 15cm depth in soil (Mohyuddin *et al*., 1993).
- Capturing of freshly emerged adult beetles by using the stem wrapping with nylon mesh during May–August (Reddy *et al*., 2014).

10. Fruit Flies (Dipter: Tephritidae)

Fruit flies are major pests of mangoes in most parts of the world and cause heavy economic losses (Veeresh, 1989; Verghese *et al*., 2011). They have attained the status of quarantine insect pest worldwide. Around the world, various Tephritidae species are associated with mango. All *Dacus* species that attack mango have recently been placed in the genus *Bactrocera*. Several species of *Bactocera* distributed throughout Indian subcontinent, among them six to seven species are found infesting mango fruits in India. They include *Bactrocera dorsalis* (Hendel), *B. Caryeae* (Kapoor), *B. correcta* (Bezzi) and *B. Zonata* (Bezzi). Of them, *B. dorsalis*, commonly called the Oriental fruit fly, was earlier considered to be the most important and dominant species complex.

The adult female fly lays 4 to 5 eggs in batches under the skin of fruits with a needle-like ovipositor at the tip of abdomen. The fly drives bacteria from the epidermis into the flesh during puncturing of fruit result as fruit decay and forms a substrate for larval feed (Fletcher, 1987). Egg hatches within 1 to 2 days to produce larva that feeds on the fruits flesh, causing more decay, exhibiting bad odour and in some cases, premature fruit fall (Plate 12). The larvae grows in size by moulting twice, defining three larval stages (instars). The larva develops in the fruit for approximately 6 to 9 days. When completely developed, the larval emerges from the fruit, falls to the ground, burrows into the soil or organic matter for a short distance and its skin thickens and hardens to create a puparium, inside which the larvae turns into an adult. (Daniel *et al.*, 2009). Shortly after adult females emerge, they search for a protein meal to mature eggs.

Plate 12: Fruit flies infestation

Management

- Collect infested fallen fruits and dispose them in pits by burrying.
- Deep ploughing during November–December exposes pupae to hot sun and predators.
- Combination of male annihilation technique (MAT) (using methyl eugenol as a lure) and sanitation reduces the infestation (Verghese *et al*., 2006).
- Use of methyl eugenol bottle traps at 6/acre throughout fruiting period to attracts male flies.

- **Postharvest disinfestations of fruits:** Immerse mango fruits in hot water at 48 °C ± 1 °C for 60 min within 24 h after harvest. This resulys 100% mortality of eggs in the fruit without affecting the quality. For export to Europe or Japan, vapour heat treatment and to the USA, gamma irradiation (400 Gy) are mandatory.

11. Mango nut/stone weevil (Coleoptera: Curculionidae)

The mango stone or nut weevil (MSW) *Sternochetus mangiferae* (Fabricius) is a monophagous pest of mango. It has an univoltine life cycle, and in India, the majority of that time is spent as an adult dozing off from May/June to February/March. The adults are start feeding and mating when their fruits reach "pea size" (about 0.5–1 cm in diameter). When mango fruits are at "lime size," oviposition begins (2–4 cm diameter). The adult female lay a single egg in boat-shaped depression (shallow cut) of the fruit rind, and spreads a transparent liquid secretion over the egg (Pradhan, 1969). This secretion may have been derived as exudates from wounds made by the female in the nearby epicarp. Oviposition sites can be noticed on the rind as dark brown patches as this liquid dries to form a resin. (Uma Maheswari and Purusotham, 1999). The larva hatches from egg after 5–7 days (Shukla and Tandon, 1985) and bores through the flesh to reach the seed coat, leaving a visible track as a streak of water area leading to the seed. At the time of fruit development, the site of oviposition and burrows are disappears. The larva initially mines the seed coat in a zigzag pattern before moving into the seed, where it develops through five larval instars and a pupal stage in 35–54 days. (De and Pande, 1988). Adults break through the seed, pulp and rind to emerge (Plate 13), then gather in tiny groups in the cracks and crevices of mango stems, branches, leaf litter, clods, etc. until the following flowering season.

The direct loss from MSW varies between 5% and 80% depending on the variety of mango (Verghese, 2000). A MSW infestation may also encourage the early fall of maturing fruit, which would result in indirect losses. Despite the fact that mangoes generate numerous fruits on a panicle, the majority of them naturally drop off before they reach pea size (Singh, 1978). Once the fruits are attain “marble size” (1–2 cm diameter) the risk of further fruit fall is of serious concern to the farmer, especially if the number of fruits per panicle is low and this stage of fruit is vulnerable to MSW. It is supposed that the trees as a defence strategy may shed infested fruits; it is not clear, however, whether fruit fall is directly stimulated by the injuries of oviposition and subsequent larval establishment. Follett (2002) noted that MSW infestation can rises fruit fall in mango during early fruit development but so far no study in India has conclusively determined whether MSW causes fruit drop.

Plate 13: Weevil damage in fruit

Management

- Field sanitation, *i.e.*, the removal of all fallen fruits and seeds, is very labour-intensive and demands complete removal and disposal of fallen fruits from affected orchards.
- To disturb the resting weevils, use a strong broom to clean the stem and branch joints.
- Mango weevil has few natural enemies. Parasitoids are unknown, probably because of the concealed nature of most of the weevil's life stages. Adults may be susceptible to predation by ants, rodents, lizards and birds (Hansen, 1993).

12. Fruit borer (Lepidoptera: Pyralidae)

The rise of minor pests to significant status and the development of pest resistance have made it difficult to control mango fruit pests, solely through the indiscriminate use of synthetic pesticides. *Deanolis* (=*Noorda*) *albizonalis*, Hampson believed to be a minor pest, has recently developed a significant status in Andhra Pradesh and Karnataka. (Zaheruddeen and Sujatha, 1993). Butani (1979) described *Deanolis albizonalis* Hampson as a important pest in Orissa, India. The pest is subjected to quarantine in Australia. The main host of this fruit borer is *Mangifera indica L.*, although it also has wild hosts including *Cyperus rotundus* (*coco grass*) and *Mangifera odorata.*

It causes 10-52% damage of fruits from pin head stage to full maturity and it is likely to spread in the new areas. The insect complete the five larval instars in 11-13 days. The durations of the incubation, pre-pupal and pupal phases were, respectively, 2-3 days, 4.5–6 days, and 9–11 days. Only during the fruiting season, two to three overlapping generations can be discovered; for the rest of the year, they survive as pre-pupae hidden inside the tree's cracks and fissures. Pupation is seen in the mango plant's dried branches and cracks in the bark. Single larva itself destroyed the one to three mango fruits. On the other side, it is also possible to find many larvae in a single mango seed. The average adult's lifespan is displayed to be 5–6 days for females and 1–2.5 days for males. The first generation larvae attack the fruits between the second and third weeks of March, with the peak infection occurring during the first week of April and the population declining further. The next peak infection is noted around the second week of May, followed by a decline. Full-grown larvae have white body with red intersegmental bands, a dark brown head and a mandible that was highly sclerotized. Adults' wing is ashy wood colour

combined with a bluish pink metallic sheen, and the middle of the forewing has two black spots. The presence of brush-like dark brown hairs ventrally on the mesotibia and tarsus distinguishes males from females. The fruit borer consumes both the flesh and seed of mango but mostly preferred the seed (Plate 14) and the damaged fruit become not fit for human consumption (Sahoo and Jha, 2006).

Plate 14: Fruit infestation

Management

- Affected and fallen fruits are collected and destructed to minimize the damage.
- During offseason, availability of mango fruit stood out as limiting factor that influences the size of insect population.
- Clean cultivation as weed plants serves as alternate hosts.
- Two species of egg parasitoids and one species of larval predator were observed to attack the immature stages of the borer, *viz*. *Trichoqramma chilonis*, *T. chilotraeae* and a vespid wasp, *Rhychium attrisimum* (Golez, 1989).
- Larval parasitoids, viz, *Angitia trochanterata*, *Apanteles* sp., and *Bracon brevicornis*, have been displayed as effective.

Minor Pests:

The reddish brown aphid *Toxoptera odinae* suck the sap from leaves, petiole and fruits and cause the shedding of flowers in case of severe infestation. The nymph and adult suck the sap of tender leaves of mango by the leafhopper *Amrasca splendens* Ghauri. Blossom feeder and webber, *Eublemma* sp. damage the inflorescence by webbing and feeding. The leaves are fed vigorously during night time by white grub beetle, *Holotrichia consanguinea* Blanchard and *Anomala* sp. Slug caterpillar, *Latoia lepida* Cramer damage the leaves by vigour feeding. The cutting and feeding on leaves is characteristics of leaf cutting weevil *Deporaus marginatus* Pascal. The commonly noticed leaf miner on mango is *Acrocercops syngramma* Meyrick and skeletonization of leaves by Leaf-mining Weevil, *Rhynchaenus mangiferae* Marshall. Bark-eating caterpillar such *Indarbela quadrinotata* Walker and *I. tetraonis* Moore directly feeds on bark and make holes on stem. The caterpillar of *Euproctis fraterna* (Moore) and *Somena scintillans* Wlk. Feed on flowers. The fruits are damaged by sucking of Fruit-sucking moths, *Eudocima maternal* (Linn.) and *E. fullonica* (Clerck). Termite *Odontotermes* spp. affects branches and stem by constructing mounds. No direct damage but nuisance to workers is caused

by Red ant, *Oecophylla smaragdina* Fabricius and also act as biocontrol agent against sucking pests. Castor capsule borer, *Conogethes punctiferalis* (Guenee) larvae also bore the fruits.

Conclusion:

The differential varieties and commercial cultivation of mango in orchard makes significant change in pest community structure over year. Over usage of synthetic chemicals leading to spurt in sucking pest has also taken toll of natural enemies. Climate change drives the crop phenology which directly impacts pest population dynamics and damage and also influences the minor pest to become major. Mango production must satisfy worldwide standards, which call for residue-free products. As a result, excellent agricultural practises must be strengthened, and research in this area is essential. Host plant resistance and semiochemicals are underused components of integrated pest management that must be addressed as soon as possible. The conservation of orchard ecosystems is a successful strategy because they sustain a diverse fauna of indigenous natural enemies.

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MAJOR INSECT PESTS OF TEMPERATE FRUITS AND THEIR ECO-FRIENDLY MANAGEMENT

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Introduction:

Temperate fruit trees are members of the Rosaceae family whose species include pomes like apple, quince, and pear and stone fruits like apricot, plum, peach, and cherry. They are well suited to temperate climates. These fruits provide a major contribution to human nutrition since they are rich in phytonutrients, dietary fibres, and antioxidants and regular eating of these fruits may lower the risk of cancer and cardiovascular illnesses. These fruit crops are highly prized and have more economic value. This chapter is discussing various insect pests of temperate fruit plant and their eco-friendly management.

List of major insect pests of temperate fruits

1.	San Jose scale	*Quadraspidiotus perniciosus*	Diaspididae	Hemiptera
2.	Apple woolly aphid	*Eriosoma lanigerum*	Pemphigidae	Hemiptera
3.	Apple stem borer	*Apriona cinerea*	Lamiidae	Coleoptera
4.	Apple root borer	*Dorysthenes hugelii*	Cerambycidae	Coleoptera
5.	Peach stem borer	*Sphenoptera lafertei*	Buprestidae	Coleoptera
6.	Tent caterpillar	*Malacosoma indica*	Lasiocampidae	Lepidoptera
7.	Apple leaf folder	*Archips termias*	Tortricidae	Lepidoptera
8.	Indian gypsy moth	*Lymantria obfuscata*	Lymantriidae	Lepidoptera
9.	Almond weevil	*Myllocerus lactivirens*	Curculionidae	Coleoptera
10.	Peach fruit fly	*Bactrocera zonata*	Tephritidae	Diptera

1. San Jose Scale, *Quadraspidiotus perniciosus* Comstock

Host range: Apple, plum, pear, peach, raspberry, and blackberry currant.

Morphology and biology

First instar	After first moult	Adults
Crawlers: They insert their stylet into the plant tissue and start to feed by sucking the cell sap and secreting a white waxy material (white cap stage); eventually, the waxy covering turns black (black cap stage).	Shape: Male-Elliptical Female-Circular	Male- Yellow-winged insects Female-Yellow-lemon colour without wings. Hidden by Grey coloured scales. 200 to 400 nymphs may be born to each female, they start to emerge from under the edge of the scale covering.

Nature of damage and symptoms

Nymph and adult female scales suck the sap from leaves, twigs, branches, and fruits. Purplish-red halos on young bark and leaf tissues followed by the formation of sooty mould. Infestation on fruits causes purple discolouration making them unfit for marketing. Shoot infestation causes loss of vigour and the mortality of trees.

Management

- Infested plant pruning and burning
- The parasitoids, *Encarsia perniciosi* (nymphal and adult), *Aphytis aonidiae* and *Aphytis vandenboschi* are well-known for eliminating the apple San Jose scale.

2. Woolly Aphid, *Eriosoma lanigerum* Hausmann

Host range

Apple, peach, pear, almond and crab-apple

Morphology and biology

Nymphs	Adults
Four nymphal instars. First instar - crawlers (mobile). Subsequent instars (sessile).	Little purple aphids (1-2 mm) in length. The nymphs begin secreting waxy filament within 24 hours, which causes them to become woolly so they got their name woolly aphids. Sessile. Reproduce in asexual, parthenogenetic, and sexual ways after mating. 13 generations/year.

Nature of damage and symptoms

The adults suck the cell sap from the twigs, barks and roots. Swellings or knots form on the roots, interfering with normal plant processes. The affected twigs shrivel and the young nursery plants may decease rapidly. The plants that have been affected exhibit pale green leaves and stems and branches covered in cottony dots which are white in colour. Infestation leads to

sooty mould formation on leaves & fruits and later formation of galls on roots thus weakening the plant growth.

Management

- Pruning and burning of infested plant parts.
- Use resistant rootstocks like Golden Delicious, and Morton Stocks.
- Woolly aphids can be managed by the release of nymphal parasitoid, *Aphelinus mali*.
- Syrphids- *Heringia calacarata* and *Eupeodes americanus* can target superficial woolly apple aphid root colonies, which generalist species are unable to do.
- Coccinellids- *Coccinella transversoguttata, Hippodamia convergens* and *Parapriasus australasiae* and chrysopid- *Chrysopa nigriconi* are known to suppress the population of aphids.
- European Earwig, *Forficula Auricularia* L. (Dermaptera: Forficulidae) is another localized, omnivorous predator feeding Woolly apple aphids.
- Fungal Pathogen *Verticillium lecanii* is the known fungal pathogen of *E. lanigerum*.

3. Apple Stem Borer, *Apriona cinerea* Cheverlot

Host range

Apple, peach, fig, drumstick, mulberry and trees belong to the family Salicaceae

Morphology and biology

Egg	Larva	Pupa	Adult
Creamy white in colour. Elongated oval in shape, rounded at both ends, the front end is broader than the rear end, with hexagonal sculpturing on the surface of the egg.	Creamy white legless grub, Elongate and cylindrical in shape. The head is chestnut brown in colour. Abdomen with small chestnut brown asperities. Undergoes hibernation in winter. Resumes activity in summer.	Exarate type	Ashy grey beetle with black under the surface. The base of the elytra black tubercles. Vertex of the head with longitudinal impressed line.

Total life cycle duration - two years.

Nature of damage and symptoms

Branches having a small circular hole with a mass of excreta are seen because of the grubs feeding, chewed-up wood particles protrude out with bark gnawed and leaves are defoliated, shoots with circuitous galleries, trunk hollowed out and the infested trees remain stunted. Adults also feed bark and cut more than they eat.

Management

- The removal of alternative/other hosts.
- Manual picking and killing of adults.

- Injection of *Beauvaria bassiana* into larval holes.
- Parasitic nematodes, *Steinernema pravassos* and *Heterorhabditis* spp. are effective
- Destruction of infested plants and plant parts.
- Clone G-48 (*Populus deltoides*) in India is relatively tolerant to stem borer.
- Natural enemies like *Neoplectana*, *Alaus* sp., *Aprostocetus fukutai*, *Beauveriana bassiana* and *Dastarcus helophoroides* are known to suppress the pest.
- Location of live holes and injection of petrol and sealing them with mud to kill the pest.

4. Apple Root Borer, *Dorysthenes hugelii* Redtenbacher

Host range: Apple, apricot, cherry, pear, peach, and walnut.

Morphology and biology

Egg	Larva	Pupa	Adult
Ovoid shape and yellow-white in colour Laid below the soil surface. Egg period: 30-40 days	Creamy-white with a black head. Grub period: up to 3.5 years	Pupate in soil.	The adults are chestnut brown in colour with darker head and thorax than the elytra. They begin mating immediately after emerging (after a monsoon shower), and the males die after mating. Females survive for 10-12 days before laying eggs to reproduce.

Nature of damage and symptom

The grubs feed on the roots of trees. Grubs may burrow into the roots or girdle them. The branches wilt and the leaves become small. Young trees die right away, while older trees weaken and gradually topple over due to the effect of high winds.

Management

- Avoid growing apple orchards in dry sandy soils.
- Remove the grubs from the afflicted trees and eliminate them.
- Inter-culturing in the soil beneath the trees assists in the grub's killing.
- During winter, prune and burn any affected shoots and branches.

5. Peach Stem Borer, *Sphenoptera lafertei* Thompson

Host range

Trees of Peaches, almonds, apricots, cherries, loquat, pears, and plums

Morphology and biology

Egg	Larva	Pupa	Adult
Spherical white eggs laid singly on the trunk and primary branches of the tree. Duration - 20 days.	Smoky dark to black colour, club-shaped (1.8-2.4 mm) long. It is also known as the flat headed borer. Undergoes hibernation in winter.	Exarate type	The mature beetle is 1-1.3 cm long and blackish golden in colour.

The pest completes three generations in a year.

Nature of damage and symptoms

The grubs after emergence feed under the bark, making minute irregular galleries causing the loosening and splitting of barks. It also bores deep into the branches of trees. Gum beads oozing can be seen. Adults feed on the leaves of the plants, which turn pale and The attacked branches wither and yield no fruit. The damaged tree ultimately dies.

Management

- Larvae may be found feeding the bark underneath tree wrap that has been left after winter. So, avoid leaving trees wrapped after winter.
- If the injury is restricted within the bark, it can be cut back to healthy tissue and larvae can be removed.
- Trees and shrubs should be well-watered and mulched, as stressed plants are more prone to injury.

6. Tent Caterpillar, *Malacosoma indicum* Walker

Host range

Apple, pear, apricot, walnut, cherry and plum

Morphology and biology

Egg	Larva	Pupa	Adult
Eggs occur in masses (100 to 350 eggs) Covered with Spumaline - a dark brown, foamy material. Passes 9 months per year in the egg stage. Active in the remaining 3 months	Live gregariously Each larva spins a silken nest at a suitable place on the tree. The caterpillars rest in the nests throughout the day and feed on the leaves at night. A fully grown larva is 40-45 mm long. Hairy with fine white colour setae and a black body. A shoeprint-shaped or whitish keyhole marking is present on the dorsal body. Larval duration: 39-68 days	Pupation takes place within a light yellow, loosely woven silken cocoon. Pupal duration: 8 - 22 days.	Male moth - light red colour Female moth - light brown colour.

Total life cycle duration - one year

Nature of damage and symptoms

The midrib and other tougher veins are only left after the caterpillars devoured the leaf. Extreme infestations may result in complete defoliation of the plant, after complete defoliation caterpillars may start feeding on the twigs' soft bark. When there is a major infestation, 40–50 % of the apple trees in an orchard may lose their leaves, resulting in a meagre crop.

Management

- Pruning and destroying all branches carrying egg masses before larva emergence is a preventative and least harmful strategy.
- This should be done in the winter after most leaves were dropped and the egg masses are visible. Tree trunks may be coated with stickers just before or after caterpillar emergence to catch roaming caterpillars and prevent them from climbing and descending trees, limiting their travels and lowering their population.
- Caterpillars and pupae should be brushed off, squashed, or smashed. By cleaning the tents with a pole and some rags soaked in kerosene, the caterpillars could be destroyed. The ideal results are produced when the procedure is carried out from 12 to 3 p.m. on sunny days. Put kerosene water in an open container beneath the tree so that any falling larvae can be easily destroyed.
- Parasitoids like tachinid flies can be used.

7. Apple Leaf Folder, *Archips termias* Meyrick

Host range

Apple, *Acacia nilotica*, citrus, rosa, *Coffea liberica*, *Malus pumila, Malus sylvestris* and *Prunus persica*.

Morphology and biology

Egg	Larva	Pupa	Adult
Dorsoventrally flattened and laid in clusters of 35-180 on the upper surface of the leaf or on the depressed fruit surface. Egg duration - 1-2 weeks	The pest hibernates as a larva for about seven to eight months. Larval duration 3-5 weeks	Pupal duration - 1-3 weeks	Adults are small buff-coloured tortricid moths.

Nature of damage and symptoms

It feeds on foliage by folding young leaves with silken threads. It also damages the fruit in the field as well as in storage by the way of scrapping the skin and causing up to 41 per cent loss in storage.

Management

- *Bacillus thuringiensis* is effective against small caterpillars.
- Avoid late-maturing varieties.

8. Indian Gypsy Moth, *Lymantria obfuscata* Walker

Host range

Apricots, apple, walnut trees and forest trees like willows (*Salix babylonica*), *S. sataz* and poplar (*Populus* spp).

Morphology and biology

Egg	Larva	Pupa	Adult
Eggs laid in batches of 200-400 below the bark and covered with yellowish-brown hairs. Round, shiny, and light greyish brown in color.	The caterpillars are 4-5 cm long. Clothed with tufts of hair. The larval duration is 66-100 days.	They pupate in soil among the debris. The pupal duration is 9-21 days.	The male and female moths survive for 4-10 days and 11-31 days respectively. The female moths - dark grey in colour and their wings are atrophied.

It is a univoltine pest.

Nature of damage and symptoms

Gregarious caterpillars feed voraciously at night time. Defoliating the host trees completely fails fruit formation.

Management

- Egg parasitoids like *Anastatuis kashmiriensis*, *Telenomus* sp, larval parasitoids like *Cotesia melanoscela*, *Glyptapantelos indiensis*, *G. flevicoxis*, tachinid (*Pales* sp), pupal parasitoids like *Brachymeria intermedia*, *B. lasus* (pupal) etc.
- Attractant plants like carrot, sunflower, buckwheat, alfalfa, corn, and shrubs can be planted to attract minute pirate bugs and lacewing.
- Nectar-rich plants with small flowers like mustard, sunflower, buckwheat, and cowpea can be planted to serve as the source of food for the adult parasitoids.

9. Almond Weevil, *Myllocerus lactivirens* Marshal

Host range

Almond, pear, apple, apricot, ber, citrus, falsa, loquat, mango, peach, plum and pomegranate.

Morphology and biology

Egg	Larva	Pupa	Adult
Oval shape, creamy-yellow colour, smooth surface and transparent. Egg duration - 4-5 days	Grubs are creamy white in colour. 4 mm length. Stout body without legs. Have short setae which aid in locomotion. Grubs eat the roots of their hosts by tunnelling up to 20-30 cm deep into the soil. The grub period - 10 months	Pupation takes place on the soil surface in the upper 2.5 cm. Pupal period - 4-5 days. Pupal diapause in winter	The weevils are small and pale metallic green colour.

Nature of damage and symptoms

The weevils congregate on the ventral surface, gnaw irregular holes, and progressively feed the whole leaf laminae, leaving just the mid-ribs. The fragile leaves are consumed first, followed by the skeletonization of the older leaves.

Management

- Cultural practices like pruning off the damaged shoots and branches of the trees may help to reduce damage.
- Adults can be collected when they drop on a sheet placed on the ground by shaking the trees. Also, damage can be minimized by collecting the damaged blossoms from the ground.
- Parasitoids like *Scambus pomorum* (Hymenoptera: Ichneumonidae), *Bracon disdiscoidens* and *Syrrhizus delusorius* (Hymenoptera: Braconidae) are known to be effective.

10. Peach Fruit Fly, *Bactrocera zonata* (Saunders)

Host range

Peach, fig, apple, guava, ber, pear, citrus and pear.

Morphology and biology

Egg	Larva	Pupa	Adult
White, cylindrical eggs underneath the skin. A resinous secretion is found in the place of oviposition. Egg duration: 2-4 days.	The maggots feed on the fruit pulp by making galleries for 4-16 days. The maggots are dirty white in colour, acephalous and apodous. 1 cm in length.	Pupation takes place in the soil at 2.5-7.6 cm depth. Pupal duration – 1 week	Each female fly lay 137 eggs in a lifetime. The adult is small and resembles the size of a housefly. Reddish brown in colour with yellow cross bands on the abdomen. Wings - clear, with a little brown mark on each tip.

Of all fruit flies, this species is most severe in many fruits, but now the mango fruit fly is replacing it. The mango fruit fly is also replacing the Mediterranean fruit fly in the Hawaii islands and other places.

Nature of damage and symptoms

Attacked fruits are malformed, misshaped, undersized and rot. The damaged fruits become unmarketable. The damaging stage is maggots and the infestation can be seen as dark punctures, oozing of fluid from fruits, and rotting and dropping of fruits.

Management

- Use of early maturing varieties
- Racking the orchard to expose the pupa of the fly.
- Harvest the ripening fruits and remove any mature fruit from the tree.
- Remove the fallen fruits regularly and bury them at 60 cm deep.
- Fix methyl eugenol-based Punjab Agricultural University fruit fly traps at the rate of 40 traps per ha.

Lists of other pests of minor importance

Cottony cushion scale	*Icerya purchasi*	Margarodidae	Hemiptera
Apple codling moth	*Cydia pomonella*	Tortricidae	Lepidoptera
Apple borer	*Nephopteryx eugraphella*	Phycitidae	Lepidoptera

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INSECT PESTS OF ORNAMENTAL PLANTS AND THEIR ECO-FRIENDLY MANAGEMENT

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Abstract:

Ornamental crop grown commercially in India. Science ornamentals plants come from different parts of plants, belonging to a number of families, the pests that have adopted themselves to feeding on these ornamentals plants are also of different types. Insect pests attack these plants at seedling, growth and seed development stage. The incidences of several pest like, rose aphid, thrips, chrysanthemum aphid, serpentine leaf miner, jasmine bud worm, jasmine leaf worm, cotton aphid, white grub etc. The main objective of this chapter will be about the identification, life history nature of damage and ecofriendly management of different pests attacking on ornamentals crop.

Keywords: Ornamental, pests, damage, ecofriendly management and identification.

1. Rose aphid

S.N.: *Macrosipgum rosariformis* Das,

Order: Hemiptera

Family: Aphididae

Distribution: This aphid has been recorded in Punjab, Delhi, Karnataka, Andhra Pradesh and the Nilgiri hills.

Identification: The non winged *M. rosariformis* has an elongated body size 2.5-2.6mm, large red eyes, black cotnucles.

Life history:

Nymphal stage development is completed in 11 to 14 days of the non- winged forms and 14 to 19 days of the winged forms, the growth being the quickest in first week of March . In northern India, the insect seems in the middle of November. The population rises progressively and is the highest in March, decreasing early in April as the season warm up the winged forms are current throughout the period from November to April, but there is rise in their number from December onwards, getting the peak in March, when about 90 per cent of the adult stage become winged. The aphid reproduces most rapidly in late summer but cannot withstand the summer heat. Therefore, it's population declines.

Damage:

Jaskiewicz (1997) who observed that the strong invasion by these aphid, caused in high deformation of flowers stems and leaves of rose plants. Derek (2017) in Australia described that *M. rosae* is a serious insect pest on this crop and it is duplicating, parthenogenticcally and viviparous whole year round. It nurses mostly on the mature leaf and evolving flower-buds of roses**.** The rose aphid sucks cell sap from the twigs tender leaves and buds. It is mainly injurious to tender buds, ensuing in the disfigurement and withering of flowers. Each aphid makes strictly punctures, producing wounds, which leaf their mark as the flower opens. The black fungus also grow on the honeydew emitted by theses insects, giving an ugly look to the plant and aphids are very essential economically because of transferring plant viruses and their related diseases (Black man and Eastop.2000).

Management:

- Spray 500ml of malathion 50 EC or methyl demeton 25 EC in 500 lit. of water per hectare.
- The application may be continual at the repetition of the insect pest.

2. Rose sawfly

S.N.: *Arge fumipennis*

Order: Hymenoptera

Family: Argidae

Host: rose

Identification: Newly emerged larvae are green in colour with black head and thoracic legs. Adults on appearance are dull in colour which soon changed into magnificent black orange in colour. Males are lightly smaller in size as compare to females.

Damage: Damage is produced by larvae feed voraciously on the leaf and cause complete defoliation. In female insect makes an ovipositional slit on the stem and side divisions with the help of saw like ovipositor.

Life cycle: The pest seems during first week of July with the onset of monsoon and relics active through out the rainy season. Newly developed larvae feed on leaf in clusters larval development is finished in around 15 days 5 larval instars. Pupate takes place in debris in safe silicon cocoons. Papul period is lasts for 1 to 2 days.

Management:

Application of malathion (0.05%) or carbaryl (0.1%) and reappearance the spray next 10 days if essential.

3. Thrips

S.N.: *Thrips flavus*

Order; Thysanoptera

Family: Thripidae

Identification: These are very small, slender insects. Adults are brown and nymphs stage are reddish in color.

Nature of damage: Their attack coincides with the look of new flush. Both nymphs and adults stages scrap the surface and suck the oozing cell sap from apical buds, leaf tender shoots and flowers. Tip of the leaf get mottled and crumbled. Brown scars plus burnt margins happen on petals of infected flowers. Sternly attacked flowers remain unopened or else half unwrapped and finally dries away.

Management:

- For monitoring of thrips, blue sticky cards must be placed 1 to 2" overhead the crop canopy
  at the rate of 2 each 1000 ft^2.
- Application of oxy- demeton methyl 0.025 % at 10 days break is effective.

4**. Armoured scale,**

S. N. *Aonidiella aurantii*

Nature of damage:

This pest sucks the cell sap since the tender shoots. Infested plants loose vitality develops weak and bear less and insignificant sized flowers. In case of severe damage, the twigs get dehydrated and harming of plant takes place. All plant parts may also scum to severe outbreak. Attack is more separate during spring season.

Identification:

Female insect is reddish brown in colour through hard waxy scale layer on the body also are without legs too having useless antennae. Scales are generally originated on the tender shoots part.

Management:

- Prune and remove the damaged leaves and twigs.
- Scrap the scale also destroy the equivalent by reproduction the infested stems through swab of cotton drenched in methylated sprit.
- Application with chlorpyriphos 0.04 per cent otherwise dimethoate (0.03%).

5. Chrysanthemum aphid:

S.N.: *Macrosiphoniella sanborni*

Family: Aphididae:

Order: Hemiptera

These pests, *Macrosiphoniella sanborni* is a wide spread pest on cultivated area of chrysanthemum throughout the world. It is a holocyclic type through East Asian early point (Heie, 1995). It feeds mostly on young leaf and evolving flower buds besides could developed

very abundant on them. In case of high damage, the aphid reasons significant damage which outcomes in deformation and disruption of flower growth and it too act as vector to Virus B and Vein mottle (Blackman and Eastop, 1984).

Host: Mainly Chrysanthemum

Nature of damage:

Nymphs and adults stage by suck the cell sap from growing shoots and apical leaves of the plant. Feeding results in the reduce of vigour, stunted, yellowing of leaves, premature leaf fall. Flowers dry up hastily aphids emit honey dew on which smoky mould grows and delays the photosynthesis. This pest is also accountable for transmitting viral disease

Identification: Nymphs stage are greenish black in colour where as adults stage are chocolate brown in colour which feed in clusters. Adult be able to be winged or wingless in form.

Life cycle: Alates look like with the environment fluctuations (like day length, temperature), when aphid developed over swarming or the vegetation begins to decline and they need migration. Duplicate is both type parthenogenetic vivipary along with sexual.

Management

- Application of dimethoate (0.03%) or oxy- demeton methyl (0.025%) as soon as the occurrence is observed.
- Repeat the spray later 10 days if mandatory. Parasitoids like *Aphidius sp* and predators such as syrphids, coccinellids and chrysopid are also active against these aphids in the nature.
- When these natural enemies are active, application of insecticides should be evaded.

6. Serpentine leaf miner

S.N.: *Liriomyza trifolii*

Order: Diptera

Family: Agromyzidae

Distribution: broad-based.

Hosts: Polyphagous in nature.

Nature of damage: The adult females also cause damage by creating feeding punctures. The seedlings and young plants will lead to total destruction. The fungi and bacteria can invade the feeding punctures. Price and Harbaugh (1981) ascertained a growth of microbe leaf spot disease, possibly *Pseudomonas cichorii* (Swing), in chrysanthemum damaged by *L. trifolii*, that serious in the environments of the mined leaf remarkably. Maggot suckle on the pole mesophyll tissue in among the 2 epidermis of the leaf. Infested leaves give clear papery presence in the mined part, decrease the photosynthesis. The attack appears throughout April and is more noticeable from June forward.

Identification: Recently laid eggs are white in colour and translucent and chance opaque as the growth advances. The maggot are orange yellow in colour without legs Pupae are orange yellow in color originally which turns dark brown on development. The adult stage are tiny grayish black flies through plum red eyes plus the females are bigger as compare to males.

Life cycle: Maggots development is in 10 to 14 days and three larval instars. Pupal period is 8 to 10 days. Oviposition, Pre-oviposition and post-oviposition phases differs from 1-3, 8-15 and 1-3 days, correspondingly. Male life spam is 8 to 12 days Female durability is 13-17 days and each female can lay 22t o 186 eggs

Management

- Natural enemies also destroy this pest and Parasitoids are more for the duration of July-August month.
- If occurrence is more, application of triazophos (0.15%) monitored by another bunch of deltamethrin 0.0028% at 10 days intermissions.

7. Gladiolus thrips

S.N.: *Taeniothrips simplex*

Order: Thysanoptera

Family: Thripidae

Identification: The nymphs are light yellow. Adults are black in colour. Wings have hairs which are prescribed like the parts of the spine.

Damage:

Both the nymphs and adults stage are damaging and suck the oozing sap and tissue. Affected plant parts grow silvery streaks which later on turn brown in colour. Infested leaves get deformed and finally dries up. If mature plants are attacked, there is a decrease in flower production besides quality. Thrips also occurrence corms under storage infested corms developed sticky, shrivel and harvest weak plants when planted.

Life cycle:

Adults stage emerge in early spring besides begin to feed on leaf and spikes. Later about three weeks they disclosure placing eggs in the tissue of leaves. On hatching young ones flinch feeding on the leaf and spikes. Nymphs developed full fed in around two weeks. Pupation take place in soil. Papal passé is 4 about one week.

Management:

- Field sanitation, Monitoring with Blue‟ sticky cards. Application of oxy- demeton methyl 0.025% or dimethoate 0.03% at ten day interval.
- Soil usage of phorote 10G @ 1.00 kg a.i./ ha and Drenching with chlorpyriphos 0.04% or deltamethrin 0.0028% to exterminate the pupae stage.

8. Jasmine leaf webworm

S.N.: *Nausibie geometralis* Guenee)

Order: lepidoptera

Family: pyraustidae

Distribution: This pest is usually disseminated in West Africa, India, Myanmar, Java, Taiwan, Sri Lanka, Pakistan, China, and Australia.

Identification: The webber are brown color with hyaline patches on the wings venation. Webber abdomen is purplish brown in colour which is inters with later at patches of light shades in per segments. The young larvae are light yellow colour however they produce the become darker.

Life history:

This pest is peak in during the rainy season. The moths are seen resting on the lower surface of leaf on the periphery of the plants, thus evading the inner shaded portions. The female lays 15 to 20 eggs singly on the leaf lamina the eggs are greenish yellow colour which hatch in 3 to 4days. The caterpillar become full grown in 12 to 15 days after passing through 5 instars. The larvae spin widespread webbings in the cool portion of the plant nearby the leaf on which they nurse and pupate take place within that area and pre pupal stage lasts 6 to 7 days besides the life cycle is finished in 22 to 24 days during July- August.

Damage:

This pest is a defoliator, testified as a serious pest in India (Gajera *et. al*,). The caterpillars web the leaf and nibble to make holes in the leaves which are quite often condensed to mere veins. The severely condemned bush existent **'burnt appearance'** since the damaged besides dried leaf remain entrapped in the web**.** The caterpillar skeletonizes the leaves by eating away the parenchyma. As effect of the gregarious attack of the caterpillar, the energy of the plant is compact which tells upon its further growth and the production of bud, which are so significant for receiving a good profitable Jasmine flower.

Management:

- Spray 500ml of dimethoate 30 EC in 500 liters of water/ hectare.

9. Jasmine budworm

S.N.: *Hendecasis duplifascialis* Hampson

Order: lepidoptera

Family: pyraustidae

The most devastating pest of jasmine is bud worm, *H. duplifascialis*. The budworm, *H. duplifascialis,* was first described by Hampson in West Africa, Ceylon, India and David (1958) noted in Delhi and south India. Lanfang *et al*., (2007) described that the budworm of this crop, was widely scattered in all jasmine engraining parts in Yuanjiang, with jasmine as the only cloud

species. It happened from April to October, through the ovipositional peaks in August and September.

Identification: The moth stage is pale white. The larvae is yellowish green in colour with a separate black head and prothoracic shield.

Life history:

The recently laid eggs are around Creamy besides glued to the flower buds. The eggs hatch in 2.6 to 3.5 days and the caterpillar passes through 5 instars. The total larval period varies from 11.5 to 17 days provisional of the Jasmine species. The pupal stage is 6.5 to 9.0 days and the life cycle is finished within 21 to 29 days.

Damage:

Kalshoven (1950) identified that the budworm, *H. duplifascialis* larvae bore into the emerging buds and nurse on the inner petals of the fastened bud in the early stages, appear through a round hole finished on the corolla tube for burrowing into other buds in the same shoot .The eaten flower turns violet and finally dries out. single caterpillar may damage upto six flower buds. During heavy damage the adjacent buds sideways, the inflorescence is webbed composed by silken thread.

Management: Application of 500 ml of dimethoate 30 EC and 200 ml of cypermethrin 25 EC in 500 lit. of water per hectare.

10. Lily moth

S.N.: ***Plytela gloriosae*** **Fabricius**

Order: lepidoptera

Family: noctuidae

Distribution: This moth stage is a sporadic and particular pest of this plant in India and Shri Lanka.

Identification: This moth has mosaic forms of yellow, red and black colour on fore wings, through a row of black yellow colour dots on the apical margins and hind wings are black. The full-grown larva size 3.9 to 4.2 cm and retains black, red and white colour mosaic designs on the body.

Life history:

The adult stage emerges from the overwintering pupae after the first dense shower in July. The female insect lay round, yellowish colour eggs on the apical part of the under surface of leaf clusters of 14 to 42. The caterpillar emerges from eggs after 3 to 6 days and they nurse on leaf for 16-20 days. When full fed, they pupation take place in the soil in an earthen cocoon and the adults emerge within 15 to 20 days. The insect has 2 generations within a year and the pupae of 2 generation hibernate.

Damage: The larvae stage feed on green matter of leaf which may affect in whole defoliation of the Lily.

Management: Application of 500 ml of malathion 50 EC or endosuy 35 EC in 500 lit of water per ha.

11. **Sunflower lacewing bug**

S.N.: ***Cadnilos retirius*** **Distant**

Oder: Hemiptera

Family: Tingidae

Identification: This bug is a minute insect size about 4 mm through transparent, shiny, reticulated wings and black colour body.

Life history:

The pest appears through July and remains active up to September. The adult female insect bugs lay eggs mostly on the upper outward of the host plants. The Eggs are injected slantingly into plant tissue leaf the opercula uncovered, which seem like white or brown colour dots. The eggs hatch in 5 to 7 days and the mature nymphs stage moult 5 times through nymphal period of 2 to 3 weeks and then they become adults.

Damage:

Both the stages nymphs and adults cause injury to many garden plants/ crops like Daisy, chrysanthemum, marigold, sunflower, gaillardia, vernonia, launea etc. They suck plant cell sap and the ingested leaf turn yellowish brown and ultimately dry up.

Management: spray 500ml of malathion 50ECin 500 lit. of water per hectar.

12. Hollyhock tingid bug

S.N.: *Urentius euonymus* Fabricius

Order: Hemiptera

Family: Tingidae

Identification: The bugs are accepted by their compactly reticulate body besides wings and size about 5 to 6 mm in measurement. The nymphal stage are spiny in presence.

Life history: The hollyhock tingid bug appears on hollyhock plants from match to June month. The adult female insect lays eggs on upper surface of leaf. The development period of the eggs in 8 to 10 days. There are 5 nymphal instars is completed within 15-27 days. Full developmental cycle is finished on a sole leaf. The insect overwinters in egg stage.

Damage:

The tingid bug damaged the garden hollyhock, althaea roses, *Abutilon indicum*, *Chrozophora rottleri and Sida cordifolia.* Both nymphs and adults stage suck plant cell sap from the undersurface of leaves. The damaged Leaf become pale yellow and turn brown in color. Finally they shrink and dry up.

Management:

- Application of 500 ml of dimethoate 30 EC in 500 lit of water per ha.

13. Banded blister beetle

S.N.*: Mylabris phalerata* Pallas

Order: Coleoptera

Family: Meloidae

This noticeable large beetle has 6 alternating, bright orange colour and black bands, beside the general dark contextual of the body. The adult beetle insect attack the flowers of *H. Rosa sinensis* and *Ruellia indica* then other plants from July to September months, and devour them entirely. In August month, the population develops high and they seem to be more noticeable than flowers.

Management:

- Hand pick and destroy the beetles population.
- Application of 500 ml of endosulfan 35 EC or 1.25 kg carbaryl 50WP in 625litres of water per ha.

14. Cotton aphid

S.N.: *Aphid gossypii* Glover

Order: Hemiptera

Family: Aphididae

Distribution: The cotton aphid is world wide in distribution.

Identification: The adult are small, greenish brown and soft bodied insects found in colonies on the tender parts of the plants and under surface of the leaves.

Life history: The adults exist in both winged and wingless forms. The alate as well as apterous females reproduce parthenogenetically besides Viviparously. Female insect may spring birth 8 to 20 nymphs. The nymphs moult 4 times to developed adults in 7 to 10 days.

Host plant:

Both adults and nymphs stage suck plant cell sap of numerous ornamental trees like *cassia glauca, Hibiscus rosa* sinensis, *tecoma capensis* and Rosa from September to April monts in northern india. The extreme population is detected in *H. Rosa sinensis* during March April.

Damage:

Severe damaged outcomes in curling of leaf, undersized growth and gradual drying in addition death of new plants. Black sooty mould grows on the honeydew of the insect which falls on the leaf.

Management:

- These insecticides can be used in 250 lit. of water per gac. 750 ml of formothion 25 EC or oxydemeton methyl 25 EC, 625 ml of dimethoate 30 EC, 100 ml imidacloprid.

15. Dusky cotton bug

S.N.: *Oxycarenus hyalinipennis* Costa,

Order: Hemiptera

Family: lygaeidae

The nymphs and adults of this pest species are commonly found feeding on *H. Rosa sinensis*, Dambeya natalensis, *D. Spectabilis*, *malvasiscus arboreus*, *j. Multiflorum*, *Bauhinia acuminata* and *plumeria acuminata* throughout the year except during winter months. The host plant *H. Rosa- sinensis* is most preferred by this bug. The maximum population of the insect is found from match to may. The flower buds of Hibiscus plants become pale as a result of its feeding and fall down without opening. The adults usually feed on the terminal portions they hide in the clusters of dry ley and flowers during December - January.

Life history:

The cigar designed eggs are put in the summer on host plant. Initially they are whitish spinning pale and lastly becoming light pink before hatch. The eggs are generally laid in singly and small clusters of 3 to 18 each. The egg stage lasts 5 to 10 days and nymph, in emerge pass through 7 stage completing the development in 31 to 40 days. Life cycle lasts 36 to 50 days and generation are finished in a year.

Management: spray against leafhopper should be done only at economic threshold levy of 1- 2 nymphs/ leaf or when second grade damage symptoms appear in 50 per cent of the vegetation. Any one of the subsequent insecticides can be apply in 300 litres of water per hectar and 750 ml of formothion 25 EC or oxydemeton methyl 25 EC 625 ml of dimethoate 30 EC.

16. Citrus psylla

S.N.: *Daiphorina citri* Kuwayana,

Order: Hemiptera

Family: Aphalaridae

Distribution: the citrus psylla is distributed throughout the orient and has been reported from India, china, taiwan, japan, shri lanka, the east indies and new Guinea.

Identification: The adult is small 3mm in length and rests on the leaf surface with closed wings, the tail end of the body being turned upwards. The nymphs are flat, louse like and orange yellow.

Life history:

The female adults lay on an average 500 almond shaped orange colour and pursued eggs on tender leaf and shoots of plants. The eggs are laid either singly or in groups of two or three and are arranged in straight line, there being as many as 50 eggs in one place. The eggs hatch are in 10-20 days in winter and 4-6 days in summer. On emerging, the light yellow nymphs have a tendency to stick close to the egg shell. There are five nymphal stages development is completed in 10-15 days in summer and 34-36 days in winter. There overlapping generations in year,

Host plant: The citrus psylla is a severe pest of *murraya paniculata* from april to july. It also feeds on *plumeria acuminata*, *dombeya spectabilis* and *duranta plumieri*.

Damage:

Both the nymphs and adults stage suck the cell sap in millions with the support of their sharp, piercing mouthpart. The vigor of the plants deteriorates and the young leaf and twigs stop rising further the leaf buds, flower buds, leaf may wilt and dies. This insect is also responsible for spreading the greening virus.

Management:

Tetrastichus radiatus is an important parasitoid of nymph and is distributed in all the ornamental plants spray 1.70 lit. of dimethoate 30EC OR 1.25 lit. of malathion 50EC or 500m, of fenitrthion 50EC in 1250 lit. of water per ha during rainy season.

17. White grubs

S.N.: *Holotrichia consanguinea* Blanchard

Family: Scarabaeidae,

Order: Coleoptera

Distribution: Cosmopolitan.

Host range: Polyphagous in nature, damage almost the vegetable crops, oilseeds pulses, cereals, tobacco, millets, potato, groundnut , sorghum, maize, groundnut, soybean, groundnut, ornamental trees, etc

Identification: Newly laid eggs are creamy white colour which chances dirty white before hatching. Full grown caterpillar of Brahmina coriacea are 35 to 38 mm in length **"C**" shaped. Adults stage are of different colours.

Damage:

Both the grubs and adults stage are damaging. Grubs stage feed on underground plant portion of various crop. Older second and 3rd instar grubs are more infesting. Due to covered feeding white grubs usually remain ignored and at harvest a great number of tubers are originate infested/ damaged. Occasionally up to 80 per cent of the yield may be lost. These grubs are also originate to nurse on the roots of horticultural/ forest plant sales outlet and some ornamental trees. White grubs are severe pests of lawn grass too Adult stage nurse on the foliage of numerous trees

Life cycle

Hatching period is 7 to 12 days. There are 3 larval instars. The period of particular instars is around 20, 30 and 75 day. Whole larval period is about 125 days. Pupal period kinds from 12 to 20 days. Adult longevity ranges between 15 and 145 days. There are one generation in a year. Beetles occur during monsoon season. Lay eggs in soil and pupate in cells through April – May months.

Management:

Gather grubs stages from soil while plugging the field besides kill them. Eliminate weeds from bunds also fields. Apply only well decomposed FYM. Collect/trap adult stage during May-June month at night and kill them application of host plants with chlorpyriphos 0.04% and quinalphos 0.1% instantly after first monsoon shower. Application of phorate10 G 25-30Kg/ ha or carbofuran 3G 80-100Kg/ha near plant base at the time of earthing up or soaking of ridges with chlorpyriphos 20 EC @2.5 L/ha is active against these pests. Inundating can be frequent after 20-25 days.

18. Ground nut aphid

S.N.: *Aphis craccivora*

Order: Hemiptera

Family: Aphididae

Hosts: rose, Ground nut, Bougainvillea spp plant and numerous other plants of economic status.

Identification: Adults are black or brown in colour with inconstant size.

Damage: Both the nymphs and adults stage suck the cell sap since tender plant portions. Downward cupping of leaf and early fall of flowers.

Life history:

The offsprings of winged system may be wingless. Duplicate is parthenogenetic and viviparous. The female can produce 8 to 30 young in life span of 10 to 12 days. Nymphs pass through 4 moults and developed adult in 5 to 8 days. Apterous form females insect start generating brood in 24 hours of reaching the stage. Insect breeds throughout the year. Both the alatae as well as apterae forms are existent.

Management:

- The pest can be managed by apply the crop with oxy- demeton methyl 0.025 % or phosphamidon 0.03% or malathion 0.05% as soon as the attack is observed.
- Natural enemies like syrphids, coccinellids, chrysopids, etc. similarly take care of these aphids Sidestep apply of pesticides when these natural enemies are energetic.

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MAJOR INSECT PESTS OF SPICES AND THEIR MANAGEMENT

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Abstract:

The production of spices in India was 4.07 million tonnes. Scince spices come from different parts of plants, belonging to a number of families, the pests that have adopted themselves to feeding on these aromatic plants are also of different types. Apart from the sphere pests of the spice plant life, a number of pests of stored grain merchandise also harm spices in garage. Insect pests attack these plants at seedling, growth and seed development stage.the incidences of several pest like banana aphid, leaf eating caterpillar, stem borer, rizome weevil, pollu beetle, chilli thrips, coriander aphid, rizome fly etc. on spices crops an increasing trend. The climate change will also affect the pests distribution and statud as well as the pest management practices. the main objective of this chapter will be about the identification, nature of damage, life cycle and management of different pests attcking on spices crop.

Keywords: Spices, damage, management and identification.

Large Cardamom: Here are 23 insect pests originate connected with large cardamom, however they all are not causing the financial harm to the plant. The various insect pests that attack huge cardamom, leaf caterpillar (*Artona chorista* Jordon), Shootfly, (*Merochlorops dimorphus* Cherian) stem borer (*Glyphipterix spp*.) and White grub (*Holotrichia sp*.) are considered as main pests. Aphids are responsible for transmitting viral diseases *viz*., foorkey and chirke (Vijayan *et al.* 2018).

1. Banana aphid

Scientific name: *Pentalonia nigronrvosa* Coquerel

Order : Hemiptera

Family : Aphididae

Distribution: This aphid is pantropic in spreading and is of mainly incidence in southern parts of India, Sri Lanka and Astralia.

Identification: The insect pest is dark brown pyriform size 1.34 mm in lenth and with 6 segmented antennae which are elongated than the body. The winged form colour is dark brown, extended and pyriform. They are longer than the wingless form but with minus body width.

Life history: In this insect reproduction due to parthenogenetically. The durability of adult insect differs from 8 to 26 days with in normal of 14 days. A single female may produce as many as 4

off springs in one day. The development is finished through 3-4 moults taking 13 and 15 days individually from November till January. There are 21-24 life cycle in a year.

Host plants: Banana and cardamom.

Damage: The aphids suck cell sap from the leaf sheath and pseudo stem. These insect pest causes little direct loss but is of considerable impact being vector of amomum mosaic, foorky disease of large cardamom and cardamom mosaic.

Management: Application of 875 ml of dimethoate 30EC in 250 lit. of water per hectare at an interval of fifteen days.

2. Leaf eating caterpillar

The leaf eating caterpillar (*Artona chorista* Jordon) is the only major pest presently causing economic loss in all over the region.

Seasonal occurrence: The pest present sporadically in widespread form every year in all the cardamom rising orchard of North East area and Darjeeling region of West Bengal. Generally the incidence of the pest is observed from June to July and October to March in the orchard.

Nature and extent of damage: The leaf caterpillar is monophagous and is highly host specific. The caterpillar are expansive in nature and feed on lower layer of the leaves, leaving clear epidermis and veins. Ultimately defoliation of the plant by the pest affects the yield. There are 2 life cycle per year in the field, first generation from May to August and second generation from September to April.

Management:

i) The caterpillar are expressive in nature and feed beneath the cardamom leaves; the infested leaves can easily be recognized from expanse and these may be collected along with caterpillar and destroyed in June-July and October-December.

ii) There are some natural enemies which kill the caterpillar and pupae of leaf caterpillars. These natural enemies decrease the pest population considerably in the field. Pentatomid bug and syrphid fly maggots are documented as predators on these insect. Two dipteran, *Bactromyra sp*. and *Nedina sp*. and 2 hymenopteran (*Venturia sp*. and *Nesochorus sp*.) parasitoids are observed as natural enemies of leaf caterpillars.

3. Stem borer

Scientific name: *Glyphepterix sp*.

Order : Lepidoptera

Family : Glyphiperidae

Stem borer is also associated to large cardamom in all the cardamom growing area.

Occurrence: Stem borer occurrence is noticed throughout the year. But in four periods, December-January, March-April, May-June and September- October their profusion is more.

Nature of damage

The caterpillars feed on the central portion of the shoot. The central leaf of the plant gets dried up and this symptom is known as **dead heart**. Infestation of this pest is also indicated by the presence of entry holes plugged with excreta.

Management:

- Damaged young shoots should be removed at ground level and destroyed.
- Application of NSKE also reduces the pest problem.

4. Cardamom thirps

Scientific name: *Sciothirps cardamom*

Order : Thysanoptera:

Family : Thripidae

Distribution: These insect is the damaging pest of cardamom in South India and was first discovered in 1993 in a cardamom state at valparai on Annamalai hills.

Identification: The adult is greyish- brown and size 1.25 to 1.50 mm in length.

Life cycle: The female lays eggs 5-71 at random on all the feeding ranges of the plant. The young nymphs arise from the eggs in 9 to 12 days. The first two nymphal instars are vigorous and produce by feeding on the plant sap. Life cycle is finished in 25- 30 days.

Host plant. Cardamom

Damage: The thrips cause infestation by sucking cell sap and nourishes on tender blossoms also bunch pods of cardamom. The cause damage on the flower stalk consequences in shedding of flowers.

Management: Sprays 875 ml of Dimethoate 30 EC or 1 lit. of Quinalphos 25 EC in 250 litres of water per hectares.

5. Rhizome weevil

Scientific name: *Prodictes haematicus* Chevrolat,

Order : coleopteran,

Family : curculionidae

Distribution: The rizome weevil is found widely distributed in various parts of south india.

Identification: The adult stage is a brown weevil assessing 1.2 cm in length, with three dark lines on pronotum.

Life history: The weevil mature in great records in April, soon after an early shower of the rainy season and eggs are laid in hollows made on rhizomes. The mature grubs emerged of the eggs in 8 to 10 days and bore into the rhizome, creating tunnel. The caterpillars feed inside the rhizome and become full feed in 3 weeks. These are pupate within the feeding channels for another three weeks. On appearance the adult weevils insect live for 7 to 8 months. Here only one generation completed in a year.

Host plant preferences: cardamom

Nature of Damage: The stark tunnelling and nursing by larvae inside the rhizome results in the kill of entire clumps of the plants.

Management

- Destroy affected plants if the larvae population is more with in the soil, drenching the immoral of the clamp with 1.25 lit. of Malathion 50 EC and 1.300 kg of carbaryl 50 WP in 625 lit. of water per hectare.

6. **Cardamom hairy caterpillar**

Scientific name: *Eupterote cardamom* Ranga Ayyar

Order : Lepidoptera,

Family : Bombycidae

Distribution. It is sporadic insect pest of cardamom plant in South India.

Identification: The adults stage are large moth, coheres in dye, with post medial line on the wings they size 7-8 cm in wing expanse. The caterpillar are hairy, dark grey in dye with pale brown head posture conical tufts of hairs on dorsal side of the body part. When full grown the caterpillar size 9 cm in length.

Life history: The moth appear with the beginning of the South West monsoon rains in June and July month. The female moth laid 400 to 500 yellowish and dome formed eggs in flat crowds on the under surface of leaf. Each egg mass contains around 50 to 160 eggs. The hatching period of eggs ensues in 15 to 17 days. The caterpillars documentations through ten instars in 140 to 151 days. It pupates take place within the soil in a silken cocoon at a wisdom of 5 to 8 cm for 7 to 8 months. The adult stage lives for about twenty days. Here only one generation completed in year.

Damage: The caterpillars feed on leaf of the gloom trees up to the 6^{th} or 7^{th} stage instar and then bead down on the cardamom plants rising underneath, with the help of silken threads. They start feed on the leaf insatiably also defoliate the cardamom plants producing heavy decline in the yield.

Management.

- Application of 500 ml of malathion 50 EC or 500 gm of carbaryl 50WPin 250 lit of water per ha.

7. Cardamom white fly

Scientific name: *Kanakarajiella cardamomi*,

Order : Hemipteran,

Family : Aleyrodidae

This white fly was first reported infesting cardamom in 1975. The nymphs and adults suck the sap from leaves and cause chlorotic patches. Heavy infestation causes development of black sooty mould on the honeydew excreted by the nymphs. The adult whitefly inserts the eggs

into tissue by a pedicle. There are four nymphal instars, the last being the pupal stage. Life cycle completed in 2 to 3 weeks depending on weather.

Management

- Spray application of ethion or acephate or neem oil has been found to be effective for control of this pest.

8. Grapevine thrips

S.N: *Rhipiphorothrips cruentatus* Hood,

Order: Thysanoptera,

Family: Heliothripidae

Distribution. This is the most destructive pest in India.

Identification: The adults are minute, being 1.4 mm long, blackish brown, with yellowish wings. The nymphs stage are yellowish brown in colour just obvious to the unaided eye as minute fast moving streaks on the bottom of leaf and in the centre of numerous flowers.

Life cycle: The adult stage laid eggs on the under surface of leaf by making minor slits in the plant tissues, insertion one egg in one slit. The female insect on usually, lay fifty eggs which are dull white, bean shaped. The eggs hatch in 3 to 8 days and nymphs appear yellowish brown. They feeds the underside of leaf. They are full feed in 9 to 20 days and throughout the season of energetic breeding. The pupation take place in leaves. The female insect can breed with otherwise without fertilization, the fertilized eggs hatch into females insect also unfertilized eggs hatch addicted to males insect. These insect hibernates as a pupa within the soil from December to march and throughout the dynamic period, several generations are finished in a year.

Host plant: Besides, cardamom, this pest also feeds on rose, jamun, and aak etc.

Damage: Infested Plants suffer because of continuous feeding by great number of insects pest. The damaned leaf take a whitish hue obtain a withered look, and then trun brown. The leaf finally curl up also drop off the plant. Such creepers either do not endure fruit or the fruit descents off hastily.

Management

- Remove grasses from orchard field and prune infested leaf.
- Application of 0.500 lit. of malathion 50 EC in 500 lit. of water.

Black paper

1. **Pollu beetle**:

Pollu beetles belong to Chrysomelidae families and the most destructive insect pest of pepper in India (Devasahayam *et al*. 1988) and feed on tender shoots, leaf of black pepper in the lower improvement (Devasahayam and Koya, 1994). The grub bores the young spikes. The necrotic patches are developed infested spikes and the berries become gloomy. The plants in

shades area of crop plantations are commonly infested by this type of insect pest (Ravindran 2000a).

S.N.: *Longitarsus nigripennis* Motschulsky

Order: coleopteran

Family: chrysomelidae

Distribution: This beetle is a particular pest of black pepper in India happening frequently in the plantations.

Identification: The adult stage is a slight shining, blue and yellow flea beetle with stout hind legs. The full grown larvae is yellowish with a black head besides its size 5 mm in length

Life cycle: The females mark shallow fleabags on the berries and lay 1 to 2 eggs in holes. The female insect, on an average, lay round 100 eggs and hatch in 5 to 8 days the young larvae bore into the berry and suckle for 20 to 32 days. Then they drop to the ground and pupate in an earthen cell in the soil at 5 to 7.6 cm depth. Adults stage appear in 6-7 days after pupation. The life cycle is completed in 39 to 50 days. The insect finishes 4 overlapping generations in per year.

Host plants: Black paper

Damage: The larvae cause infestation by boring into the berries and ingestion of contents totally in about ten days. Grubs destroys at least 3 to 4 berries throughout the larval period. The infested berries seem dark in colour, are muted inside and crumble when pushed. The larvae may also eat into the spike also cause the entire distal region to dry up. The beetle feed voraciously on tender leaf and make dumps in them.

Management:

- Cultivating the soil at the base of climbers at fixed intervals can decrease the population noticeably.
- Application 1.5 lit of dimethoate 30 EC in 500 lit of water per ha in last July and again in early October month.

2. Leaf gall thrips

Leaf gall thrips are more serious pest in younger vine and nursery plants (Devasahayam and Koya, 1994). They feed on leaf and infested leaves become thick, malformed and crinkled (Ravindran *et al.* 2000). Leaf gall thrips are observed completely infesting black pepper plants (23.2-28.4%) in southwestern part of Ethiopia (Daba *et al.* 2017). Apart from leaf gall, the pest infestation caused in reduction in size and malformation of infested leaves. Banerjee *et al.* (1981) also reported that the leaf thrips were the most severe pest of pepper in South Wynad area of Kerala.

Scientific name: *Liothrips karyi*

Order : Thysanoptera

Family : Phleothripidae

Identification and life cycle of the pest

Eggs are laid in single within the marginal leaf folds or on the leaf surface. egg period 6-8 days nymphs whitish and sluggish. Nymphal period 9-13 days. Pupal period 2-3 days. Adults black colour with deeply fringed wings and longevity is 7 to 9 days.

Damage:

Damage due to this insect is more severe at higher altitude mainly in newer climbers and also in the nurseries. The nourishing of thrips on tender leaf causes the leaf margins tocurl down and inwards causing in the creation of marginal leaf galls. The damaged foliage become thick, malformed and wrinkled. Life stages of the insect pest can be appreciated within the gall. In severe cases of damage the growth of young climbers is affected

Management

- Parasitoids, *Pseudoscymcus sp Aphytis sp,and Chilocorus circumdatus* etc.
- Predators: *Androthrips flavipes, Rhodesiella sp*, predatory mite, hoverflies, thrips, mirida etc.
- Application of dimethoate 20EC and quinalphos 25 EC 1 lit per ha. Sprig on the appearance of flushes during June- July.

3. Top shoot borer

S.N. Cydia hemidoxa

Family: Eucosmidae:

Order: Lepidoptera

Damage: The larvae damage terminal shoots by boring into them desiccating of terminal portions of the vines.

Identification: Adults are yellow coloured and the incidence is more during August to December, when tender shoots are presented Pest takes around a month to complete its life cycle.

Management

- Application of vines with dimethoate or phosphamidon at 0.05% is effective
- Parasitoids like *Euderus sp*. (Eulophidae), *Apanteles sp.* (Braconidae), and *Goniozus sp.*
- (Bethylidae) have been observed to attack the caterpillars in nature.

Turmeric

1. Skpper butterfly

Scientific name: *Udaspes folus* Cramer

Order : Lepidoptera

Family : Hesperidae

This butterfly is a common pest of turmeric. The moth is brownish black butterfly with 8 white spots on fore wings and one large patch on hind wing. The full grown caterpillar is dark green

and size 3.6 cm in dimension. A female insects lays around 50 eggs on foliage which hatch in 3 to 4 days. The caterpillar undergoes 5 instars during 12 to 21 days besides pupates in leaf fold for 6 to 7 days. The caterpillar which pupates in December appears only in march month and the insect is abundant during August to October month. The infestation is caused by the larvae stage which fold the leaf and feed on them.

Management

- The pest can be kept further down check by amassing the adult stage with the help on net and destroying them.
- In case of heavy infestation application of 1.5 lit. of quinalphos 25 EC in 500 lit. of water per hectare.

2. Castor capsule borer

S.N.: *Dichocrocis punctiferalis* Guenee

Order: Lepidoptera

Family: Pyralidae

Distribution: This borer is distributed throught india as uttar Pradesh, bihar, Orissa, maharashtre, Gujrat, Karnataka and tamil nadu

Identification: The moth are orange yellow with black markings on both the wings. The full grown caterpillar measures 25-30 mm in length, is reddish brown with black boltches all over the body and a pale stripe on the lateral side.

Life cycle: The moths lay eggs on leaves and other soft parts of the plant. The eggs hatch in about a week. The larvae pass through 4-5 instars and are full fed in 2-3 weeks pupation takes place inside the seed or sometimes in the frass that collects after feeding the pupal stage lasts about one week. The total life cycle is completed in 4-5 weeks and 3 generations in a year.

Host plant: It is polyphagous insect pest of crops.

Damage: The attack by this borer is recognized from a distance by the webbed in turmic. The yield is reduced considerably since the damage rizome

Management

- It is advisable that the infested rizome may be collected and destroyed.
- Application 2.5 kg of Carbaryl 50 WP in 625 lit. of water per hectare and repeat at 15 days intervals.

Ginger

Ginger is a main rhizomatous spice, medicine, cash as well as industrial crop only. Rhizome fly is a most damaging insect pest of ginger. The maggots of the rhizome flies were found to be associated with the rhizome rot due to which decaying and rotting of the rhizomes. The rhizome rot is more common during rainy season. Hence, the commonly reported herein to find out the effective controlling of ginger rhizome fly and associated rhizome rot.

1. Rhizome fly

S.N: *Mimegralla coerruleifrons* Mocquart

Order: Diptera

Family: Micropisidae.

Rhizome fly is becoming a serious menace to the cultivation of ginger crops in recent years in Maharashtra.

Identification: Adults flies are large in shape with slender body and long legs. The body is black in colour, transparent wings with ashy spots. Eggs: Are small, white, cigar shaped, tapering at either side. Larva: Creamy white in colour, apodous and measures 9.5 mm. in length and 1.95 mm in breadth.

Host Plants: Turmeric and ginger.

Nature of damage: The maggots feed on the rhizome as a result of which yellowing of plants and rotting of rhizomes takes place.

Life History: Flies are noticed in fields during Aug.-Sept.

Eggs Lay singly or in cluster of 6 to 10 at the base of the vegetation under surface the lumps of soil, in fissures and on surface of soil. Incubation periods 2 to 5 days. Larva: Larval periods: 13 to 18 days. Pupa: Maggots pupate in rotten rhizomes. Pupal periods is 10 to 15 days and life cycle is finished in 4 weeks.

Management:

1. Application with 0.05% fenitrothion or Chloropyrifos.
2. Soil application of phorate 10G @ 20 kg/ha or carbaryl 10 D 20 kg /ha.
3. Preventive measures is devastation of stray plants in off season, choice of vigorous rhizomes for planting.
4. Removal plus destruction of rotten rhizomes along with maggots from the field next harvest of crop will assistance to check the refinement of the pest.

2. Scale insect

S.N: *Aspidiotus hartii* Cockerell

Order: Hemiptera

Family: Diaspidiae

This is a minor spherical hard scale insect which damage the rhizome in great numbers. A female insect lays around 180 eggs below the scale which hatch inside a day. The nympal stage takes around 30 days for its growth. The male scale forms a pupa formerly emergence as the winged adult stage the insect increases in great numbers on stockpiled ginger rhizomes which analyst. Rhizomes in the field condition are also criticised by the scale and the damaged plants look pale and dry.

Management:

- Application of 750 ml of malathion 50ECor 500 ml of dimethoate 30ECin 500 lit. of water per ha.

Coriander

The important pests of coriander are whitefly and coriander aphid

1. Cotton whitefly

S.N.: *Bemisia tabaci* Gennadius

Order: Hemipteran

Family: Aleyrodidae

Distribution: This pest is distributed throughout the northen and western regions of the indian sub continent and is a very serious pest of coriander particularly in the dry areas.

Identification: In the winged stage they are 1-1.5mm long and their yellowish bodies are slightly dusted with a white waxy powder. They have two pairs of pure white wings and have prominent long hind wings.

Life cycle: The females lay stalked eggs singly on the bottom of the leaf, and lay 119 eggs per female insect. The eggs hatch in 3 to 5 days during summer, 5 to 33 days in winter. The nymphs stage suck cell sap and grow into 3 stages to from the pupae within 9 to 14 days in summer and in 17 to 81 days in winter and 2 to 8 days the pupae change into whiteflies. Total life cycle is finished in 14 to 122 days and 11 generations are finished in a year.

Host plants: This insect pest also nurses on several plants such cabbage, cauliflower, potato brinjal, okra and coriander.

Damage: The infestation is caused by both the nymphs and the adults by sucking the sap from the leaves. Insects exude honey dew which attracts sooty mould there fore in severe damage the plants not only become weak but the mould interferes with the normal photosynthesis resulting in poor growth and yield of coriander.

Management

Any one of following insecticides can be used in 250 lit. of water per ha. 750 ml of formothion 25 EC Or oxydemeton methyl 25 EC 625ml of dimethoate 30EC, 100ml of imidacloprid 200SL.

2. Coriander aphid: Coriander aphid (*Hyadaphis coriandri*) is probably native place to Central Asia. It is known as a main pest of coriander.

S.N.: *Hyadaphis coriandri* Das,

Order: Hemiptera,

Family: Aphididae

Identification: These insect are yellowish green in color and look like they have been scattered in greyish wax. They size 1.3 to 2.1mm in length. There are three to 4 nymphal instars. The first

instars are off white in color which becomes light green in the second instars and third instars are green in color. The siphunculi (cornicles) are short, pale, and slightly swollen with a length that is twice as long as wide. The siphunculi /cornicle is a hole on the dorsal lateral of an insect where pheromones are emitted.

Life cycle: A single female laid around 40 to 50 young ones and they take 8 to 12 days to mature. The life cycle is finished in 14 to 21 days during summer and 6 weeks in winter.

Damage: To leaves and stems Make the plant unmarketable Damage to flowers Lowers the seed yield Causes deformed seeds to form Makes the seeds unmarketable. It has been observed that the umbels (flowers) of heavily damaged plants drop and no capsule formation takes place. In less damaged plants, the seeds are deformed, affecting the quality and quantity of the produce. In India, yield losses of up to 64 per cent have been recorded.

Host plant: Cumin fennel, carrot, coriander.

Management:

- Removal of aphid damaged twings at 15 day intervals starting with the first appearance of the pest has been found effective if cheap labour is available.
- Application of insecticides oxydemeton methyl, dimethoate 30 EC, quinalphos 25EC, malathion 50EC, chlorpyriphos 20 EC. Etc.

Cinnamon

The cinnamon crop is infested by a total number of insect pests, but individual cinnamon butterfly is careful to be the most damaging pest.

1. Cinnamon butterfly

S.N.: *Chilasia clytia* Linnaeus

Order; lepidopters,

Family: papilionidae

Distribution

Cinnamon butterfly is commonly scattered in the cinnamon areas of Shri Lanka and South India.

Identification

Freshly hatched larvae are black in colour by white patches colour which later undergo various change in colour pattern.

Life history: The butterfly lays eggs individually on the both side surface of young leaf petioles and even tender shoots part of the plant. Eggs are lesser round and pale yellow in dye. The caterpillar hatch out in 3 to 5 days. The caterpillar moults 5 times to whole its growth in 12-18 days and the pupation takes abode in rough silken padding on the stem arranged by the caterpillar. The pupal stage period is completed in 11 to 13 days the adults stage live for 3-5 days besides total life cycle is completed in 24 to 36 days.

Host plants: The insect has been described to feed on a numeral of wild species of cinnamon besides other forest plants.

Damage: After hatching the 1st instar larva starts feeding on the lamina of newly appeared leaves and later instars insatiably on the tender leaves leaving individual the mid rib with slice of veins.

Management

- The pest population can be kept below check by gathering the butterflies with the support of net destroying them.
- In case of unadorned infestation application 1.5 lit. of Quinalphos 25 EC in 500 lit of water per hectare.

Chillies

1. **Chilli thrip**

   S.N.: *Scirtothrips dorsalis* Hood

   Order; Thysanoptera

   Family:Thripidae

Distribution:

It is a polyphagous pest having a wide range of host plants such as tea, grapevine, castor, cotton, *Prosopis juliflora*, etc. It is distributed all over India. It is abundant on sacred lotus in Thailand (Mound and Palmer 1981), and on chilli peppers in India (Ramakrishna Ayyar 1932, Ramakrishna Ayyar and Subbiah 1935).

Nature of damage: Eggs are laid on or just under leaf tissues. According to Sanap and Nawale (1987), adult and nymphs of S. dorsalis suck the cell sap of leaves, causing rolling of the leaf upward and leaf size reduction. For example, a chief infestation of *S. dorsalis* in pepper plants changes the presence of the plant to is called "**chilli leaf curl**." Yield loss due to thrips attack may range from 25 to 50 %.

Life history:

Eggs are minute and dirty white in colour. Nymphs and adults stages are also tiny, slender, fragile, and yellowish-straw in colour; adults have deeply fringed wings that are equally grey in colour. Reproduction is both sexual and parthenogenetic. In case of sexual reproduction, oviposition period lasts for around a month during which a female lays on an average 100 eggs @ 2 - 4 eggs per day. A single life-cycle is completed in 2 -2½ weeks. As many as 25 overlapping generations are completed per year. The thrips Franklinothrips vespiformis (Crawford) and Erythrothrips asiaticus R. &. M. are predaceous on the insect.

Management strategies:

- Application of 0.03% dimethoate or phosalone or monocrotophos or 0.2% carbaryl.

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INSECT PESTS OF STORED PRODUCT AND THEIR ECO-FRIENDLY MANAGEMENT

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Abstract:

Since different insect life stages damage the quality of food grains and other food products and cause financial harm, infestation of stored grains is a very serious issue. Food grains are being contaminated by a significant number of stored grain insect pests in farmer shops and public warehouses as a result of uncontrolled environmental conditions and inadequate warehousing technologies. Nowadays, employing eco-friendly management techniques is imperative to protect the environment from the harmful impacts of toxic chemicals used in pest control.

Keywords: Stored, damage, insect, management

Introduction:

One of the main issues in the modern world is the security and safety of the food supply. Food grains must be preserved and stored safely in order to be delivered to consumers on time. For their use in home or commercial settings, various food commodities such as harvested legumes and grains, processed plant and animal food products, and semi-perishables require safe storage. Almost all of the storage is dedicated to domestic or commercial grain storage (Said and Pradhan, 2014). Currently, a variety of facilities, from modest metal bins to substantial grain elevators and silos, assure the secure storage of grains. During the protracted storage period, agricultural commodities are typically vulnerable to contamination and damage from biotic and abiotic agents. Insects, mites, rats, birds, and microbes are among the biotic agents that significantly reduce storage.

Several bug species seriously harm goods that are stored, accounting for 10% to 20% of all storage losses (Esther *et al.*, 2014). Insects causing losses of stored goods of agricultural and animal origin are mentioned as including more than 600 species of beetles, 70 species of moths, and 355 species of mites (Rajendran and Sriranjini, 2008). There are significant quantitative and qualitative losses in the stored commodities as a result of this large pest arena. Because of the favourable microclimate at the storage location, insect pests that cause harm to storage products frequently arrive from the field. They are then kept around during different processing and storage channels (Hagstrum and Phillips, 2017). Numerous insect pests start their damage during the crop's ripening stage and continue during the storage process (Sallam, 1999).

However, old bags, storage buildings, old containers, cross-over infestations, harvesters, and other machinery are the main causes of infestations in storage (Perez-Mendoza *et al*., 2004). (Sinclair and White, 1980). By correctly harvesting and drying grains to a safe storage moisture content, which will be provided by grain storage agencies, the initial infection can be reduced. Insects from one place to another are transported and spread during storage operations mostly through the supply of grain. Due to the fact that many insects have powerful wings, they are occasionally also dispersed through active flight (Ridley *et al.,* 2011).

Chemical pesticides are the most popular and efficient method of controlling insect pests. Because of the indiscriminate use of chemical pesticides, insects will inevitably become resistant, leading to the reappearance of lesser pests that pose a high risk to human health and the environment.

The most concerning situation created by these dangerous pesticides is the contamination of the air, water, and soil leading to health risks and the emergence of new diseases among people (Carson, 2007), as well as negative effects on human life, wild life, and other flora and fauna. The need to find environmentally friendly, safer, and efficient methods of pest control in storage conditions has become more pressing as the public becomes more aware of the negative effects of pesticides on human health, air, water, and soil resources, as well as the development of resistance and resurgence among insect-pests.

In this chapter, we are discussing eco-friendly management of storage insect-pests.

Classification:

The most popular classification of storage insects as "principal pests" and "secondary pests" is based on their eating behaviour. The main feeders are those that can harm whole, undamaged grains. Their lifecycle involves the whole grain since their young dig into the grain's kernel and feed there, occasionally causing a "hidden" infestation. These can seriously harm the property, and if ignored until they have established a population, they are difficult to control.

The key to minimising their impact is routine monitoring. Because they settle on grains that have previously been harmed by primary pests or other types of damages, secondary feeders are frequently referred to as "**bran bugs**." They typically eat broken kernels, trash, or higher moisture weed seeds to live. These insects' larval stages were discovered outside the grains and often cannot start an infestation of whole grains.

However, once established, these often contribute to spoiling, albeit not to the same extent as primary insects. Given that their life phases were mobile in the commodities region, their damage is simple to identify. A few of the external pests feed on mould and fungi. Via their presence and metabolic wastes, they contaminate the grains, causing moisture to be produced (through faeces and condensed heat), which promotes the growth of mould (Magan *et al*., 2003). As a result, the growth of mould shows the degree of grain rotting. The foreign grain beetle, rusty grain beetle, hairy fungus beetle, and psocids are examples of common mould feeders.

Origin of pest insects in stored grain:

It is unknown where the stored grain pests came from. They undoubtedly inhabited the fields, with some of them breeding in seed supplies that eluded birds and other animals, some consuming the dried or decomposing carcasses of plants or animals, and still others boring into plant roots, tubers, and stems.

Insects that were unintentionally brought in with these stockpiles were able to easily survive thanks to the practise of storing seeds, roots, herbs, and dried meats for nourishment that man adopted in the beginning.

These stores provided ideal breeding circumstances, eliminating the need for these insects to travel great distances in search of food. It is true that some pests of stored grain have entirely lost their ability to fly, whether or whether this is due to their cushy lifestyle and lack of necessity for flying.

The rice weevil (*Sitophilus oryzae* L.), which is closely related, is still a potent flyer, whereas the granary weevil (*Sitophilus granarius* L.) has lost all except the traces of its wings. There is evidence that many of the creatures that affect grain storage today were common in the past.

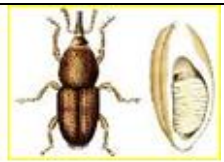
Losses from storage:

In addition to the direct loss of kernels, insects can also result in accumulations of frass, exuviae, webbing, and dead insects. Grain that contains excessive amounts of this insect waste may not be fit for human consumption. Changes in the storage environment brought on by insects may create warm, damp "hotspots" where storage fungi can grow and cause additional losses.

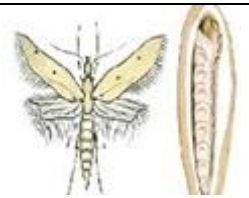
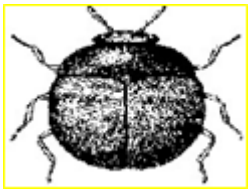
Between 5 and 10% of stored goods losses worldwide are attributed to insect damage. The net value of losses in storage in the USA has been estimated at about US$200 million yearly, with heavier losses occurring in the tropics potentially reaching 30%. (Weaver and Petroff, 2004).

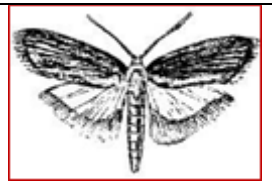
The post-harvest stages of production can be made 30% more productive with the use of efficient technology, and advances in storage techniques will yield the greatest benefits. The pulse beetle (*Callosobruchus chinensis* L.) assault causes significant quality and quantitative losses in chickpea seeds in underdeveloped nations (Alam, 1971; Abrol, 1999). During postharvest handling and storage, over 8.5% of total annual yield is wasted (Agrawal *et al*., 1988).

Table 1. List of important primary and secondary pests of stored grains. Source: Rajasri *et al.* (2015)

Rice, maize and other cereals in storage Stored cereals and Other stored foodstuffs Cowpea, soybean and other pulses Stored leaf and cigarettes of tobacco Cocoa beans, groundnut, peas and beans, many stored grains and flours Dried herbs and spices	Rice weevil *Sitophilus oryzae*(L) Lesser grain borer R*hyizopertha dominica* (F.) *Callosobruchus chinensis* (L.) *C.maculatus*(F.) Cigarette beetle (Tobacco beetle) *Lasioderma serricorne* Drug store beetle: *Stegobium paniceum.*	The grain is hollowed out as the larva develops inside it, where it dwells and feeds. The entire grain of rice, the preferred host, is typically destroyed by the time the adult emerges. Both larvae and adults consume the grains in a random, typically external, manner. The adults have a very lengthy lifespan. Both of them are major pests that can more easily attack paddy rice than Sitophilus. The pea or bean is pierced by the larvae. The source of infestations is typically farms, however mature beetles can fly up to a half mile. Following harvest, the infected pods are brought into the farm storehouse for further processing. Although the larvae can attack unharmed cereal grains and pulse seeds, they frequently choose to feed on the seed's germ. Larvae and adults puncture the packs of packed cigarettes. Grubs eat through dried herbs and spices, creating tiny, cylindrical galleries. Adults rarely, if ever, eat. The final three segments in Stegobium combine to form a large, loosely segmented club. In contrast to Lasioderma, the elytra exhibit longitudinal striae or grooves.	    

External feeders

Hosts	Insect	Damage	Illustration
Paddy, maize and wheat, both in the field and in grain stores- Sorghum and other stored grains, and dried fruits Cereals and groundnut (main). pulses, spices and various cereal and pulse cakes (alternative).	Angoumois grain moth *Sitotroga cereallla* Khapra beetle *Trogoderma granarium*	A little window in the grain can serve as a sign that the grain is infested with adult larvae or pupae. When the adult first emerges, it squeezes through this tiny window and leaves the "trap door" hinged to the grain, which is typical of this pest. The larvae typically hollow out the grains of stored pulses and cereal grains. In the hot, humid tropics, development moves swiftly, and very huge populations may develop quickly. The pest is somewhat polyphagous and can remain in facultative diapause for up to a year without food.	 
Maize, wheat and other stored grains (main). Many types of stored foodstuffs (alternative). Flour, animal feed and other ground material	Red flour beetle *Tribolium castaneum* (Herbst) Confused flour beetle: *Tribolium confusum*	Adults showing up on the grain's surface indicate an infestation; previously broken or holed grains as well as grain harmed by other bugs show substantial damage. Larvae and adults both cause harm. Without a microscope or magnifying glass, it is challenging to identify the adult from the red flour beetle. Flour, animal feed, and other ground materials are consumed by larvae and adults. The confused flour beetle is more prevalent in flour mills than anywhere else, and unlike the red flour beetle, the adults of this species do not fly.	 

Stored grains (main). Other plant and animal stored products (alternative)	Saw-toothed grain beetle *Oryzaephilus surinamensis* (L.),	Oryzaephilus beetles are general feeders that typically attack stored goods secondarily, after more noxious primary pests like grain weevils and pyralid moths. Their actual diet comprises of discarded plant and animal parts. 0. mercator is more frequently discovered on oil-seed products than 0. surinamensis.	
	Indian meal moth *Plodia interpunctella*	Oryzaephilus beetles are general feeders that often attack items that have been stored as secondary pests, after more dangerous primary pests like grain weevils and pyralid moths. Their true diet consists of leftover animal and plant components. On oil-seed products, 0. mercator is more frequently found than 0. surinamensis.	
	Tropical warehouse Moth (= Almond moth; *Ephestia cautella*	Greyish in colour, the mature moth has sporadic patterns on its wings. Its length is roughly 13 mm. The wings are folded along the belly when the bird is at rest. Adult moths only live for a little over two weeks. Bag surfaces and grain both have webbing, and there are cocoons between nearby surfaces.	
Rice, jowar, other millets, whole cereals, cereal products, dals, processed products of cereals, pulses, oilseeds, nuts, dry fruits and milled spices.	Rice moth: *Corcyra cephalonica (Staint)*	Damage is exclusively the fault of the larva. Food grains are contaminated with frass, moults, and dense webbing by it. Kernels from entire grains are bonded into lumps that weigh up to 2 kg. Darker stores tend to have more of it. Infestation in bulk grains often only affects the upper 45 cm.	

Various forms of storage loss brought on by insects:

Quantitative loss:

The weight of the stored grains decreases as a result of direct insect feeding. For instance, during its development, a rice weevil will consume 14 mg of a 20 mg rice kernel. Not only is there a weight loss, but there is also a commercial loss of whole grain. A female weevil has the biological capacity to generate 1,500,000 offspring through three generations each year, which will eat 1,500,000 rice kernels (amounting to 30 kg of rice). In three generations, a gravid *Sitotroga cerealella* female may entirely consume 50 g of rice.

Qualitative loss:

A range of qualitative changes, including chemical alterations in grain composition, are brought about by direct insect feeding on cereal grains. Additionally, grains that have been contaminated by body parts and skin from moults are more prone to the transmission of harmful germs.

Seed viability loss:

In paddy, it has been discovered that insect feeding results in a 3.6-41% reduction of seed viability (unmilled rice).

Eco-friendly management of storage insect-pests:

Preventive measures:

- The majority of the damage can be avoided by drying the grains to a moisture content of 10 to 14%, depending on the type of grain. Drying can be done in the sun or with any modern dryer.
- After the grains have been harvested, specific precautions must be taken to prevent the initial infection or inoculum of storage pests before the grains are moved to storage. Below is a list of some of the preventative strategies. Sanitation of the storage area is necessary, and this entails clearing away any dirt, trash, foreign objects, insects, and infested grains in order to prevent an initial infestation.
- Grain handling should be done correctly, and the storage facility shouldn't be harmed. To prevent mechanical damage or to stay away from walls, proper stacking dimensions and wooden dunnage should be maintained. A proper spacing should be kept in between each layer.
- By exposing the grains to sunlight for a shorter amount of time, the first infestation that is seen in the field can occasionally be controlled.
- Making use of upgraded storage facilities. Under warehouses in India, grains are stored in a variety of ways, from small metal bins to bulk storage in gunny sacks. Future applications of the emerging hermetic storage idea are possible. Jute bags are frequently used, and it is also advised to combine them with polythene liner.
- Newer lots must be stored separately from older stocks and should be kept apart from them.

- The Pusa bin, PAU bin, TNAU bin, and other modified bins that have been created by various institutions for Indian circumstances can be used.
- Another crucial procedure to be followed before storage and a layer of insecticide spray can be advised right after storage is the de-infestation of bulk and bag storage structures using pesticides. Since the use of dichlorvos in warehouses was prohibited, the possibilities for disinfectants and surface sprays at this time are deltamethrin and malathion.

Curative measures:

The following non-chemical techniques can be used to manage insect pest infestations in stored grains.

a. Physical control:

Temperature, mechanical methods, moisture and relative humidity control, structural methods (such as grain silos, packing), irradiation, and sanitation are all examples of physical control procedures (Fields and Muir, 1995).

The red flour beetle (*Tribolium castaneum* Herbst) has a highly developed chemosensory system (Barrer, 1983) and can distinguish changes in its immediate surroundings, including temperature (Saxena *et al.,* 1992; Dowdy, 1999), humidity (Evans, 1983), carbon dioxide levels (Soderstrom *et al*., 1992), and even different hues (Ramos *et al*., 1983; Viswanathan *et al*., 1996; Khan *et al*., 1998).

Sheribha *et al*. (2010) evaluated the viability of utilising coloured lighting systems to manage *T. castaneum* on stored goods. They discovered that *T. castaneum* adults do not favour red light. Thus, *T. castaneum* insects may be controlled without the use of chemical pesticides if storage facilities were illuminated in the colour red.

Legal methods:

Laws can be implemented to prohibit the entry of insects that are not native to a region, such as the Destructive Insects and Pests Act 1914 in India.

Exclusion:

As the introduction of pests means preventing losses in both time and goods, prevention is a key component of every successful pest-management programme. If goods like grains, cereals, flour, and other packed commodities are carefully inspected, entry of insects into storage facilities can be effectively prevented.

It is important to check storage materials for live insects, insect eggs, and insect frass. Any contaminated material needs to be destroyed or disinfested right away. Use of screens on windows and doors will stop insects from entering. Fill any gaps or rodent tunnels where insects might enter. By employing sodium-based lighting instead of mercury-based lighting, it is also feasible to reduce the area's appeal to insects.

Environmental modifications:

Storage pests can be controlled with heat and cold treatments since heat can kill some pests and cold can stop their growth. It has been claimed that a temperature of 15 ℃ stops storage bugs from feeding, while a temperature of 4 ℃ gradually kills them.

Cold treatment:

Nearly all insect pests die at temperatures below 4°C, especially their larval stages. At the freezing point, death happens quickly. *Trogoderma species*, *Ephestia species*, and *Plodia interpunctella* are cold-tolerant species, in contrast to *T. castaneum* and *Oryzaephilus mercator*, which are extremely sensitive to the cold. The insects are often exposed to temperatures between 10 and 20 ℃ for a few days before being exposed to a lethal cold temperature in most field uses of a low temperature to reduce insect pests.

Heat treatment:

The majority of insect pests that attack stored grains pass away in 10–20 minutes at 50–60°C. Development is halted by exposure to temperatures just 5 C above the species' ideal. Most bug pests are eliminated within 2 hours of exposure to 50°C. To ensure a consistent grain temperature throughout the storage structure, grain heating is done utilising a hot-air stored grains 399 fluidized bed, infrared radiation, high-frequency dielectric, and microwave heating.

Irradiation:

Grain disinfestation techniques have also included the use of ionising radiation, such as gamma rays (emitted by cobalt-60 and cesium-137), x rays, or electric beams (Hallman, 2013). The molecular effects of these radiations have the potential to alter DNA's structure.

Insects with DNA damage experience sterility, death, mutations, and deformities. Although the radiations are easily operated by irradiators and successfully penetrate objects, they come at a higher initial cost and with a larger dose that could be harmful to people's health (Hasan and Khan, 1998). According to sources, at least 33 countries allow some stored products to be irradiated; however, only 14 countries allow it for all kept products (Hallman, 2013).

After exposing *C. chinensis* adults to gamma radiation at doses of 0, 200, 300, 400, 500, and 600 Gy, Chiluwal *et al*. (2019) discovered a decline in female fecundity, hatchability, and adult fertility. The effectiveness of gamma-irradiation combined with food-grade diatomaceous earth (DE) against *S. granarius*, *T. castaneum*, and *R. dominica* was investigated by Sileem *et al*. in 2019. The combination of 100 Gy gamma-radiation exposure and DE @ 1 g/kg was found to be significantly associated with complete mortality among their treatments.

Fast Neutron Irradiation (FNI) at 0, 64, 128, 192, and 256 Gy was evaluated against P. interpunctella by Hassan et al. in 2019. The 256 Gy dose was found to be the standard lethal dose and effective in stopping the development of all immature stages. A thorough understanding of gamma and x-ray use for irradiation, integration with other compatible procedures, and safer

handling of these radiations are required to be explored for field-scale and may be employed as an efficient alternative to currently practising methods.

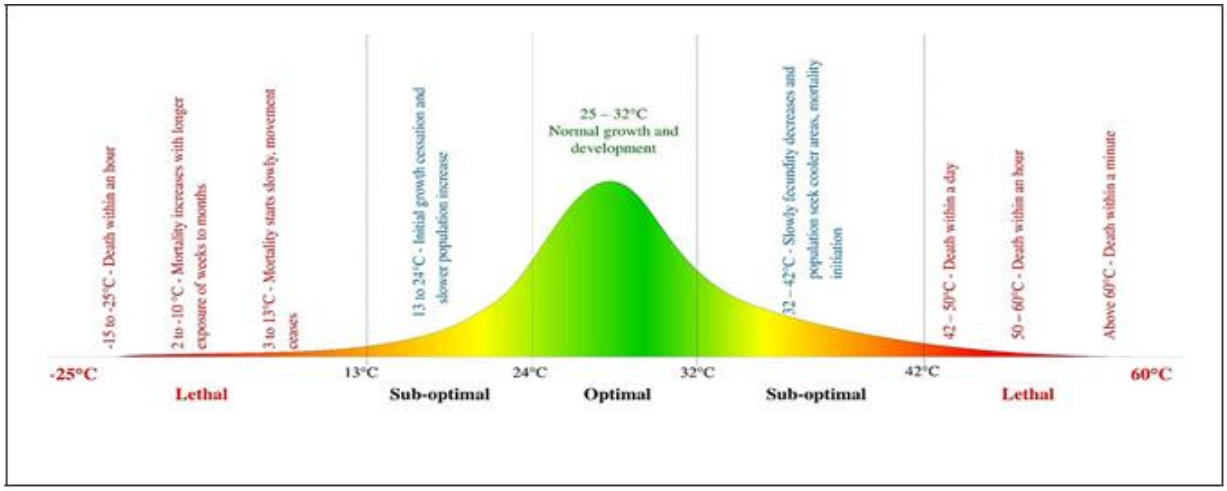


Figure 1: Illustrates how temperature affects the growth and development of insects

Desiccants:

Some desiccants such as earth, silica gel and non-silica and diatomaceous earth can be combined with stored grains to provide protection against insect damage. The desiccants are removed from the grain or stored foods before processing by a cleaning operation that also removes debris. The rate for bulk grain is 100–300 g/t, depending on the insect species and the grain moisture content. The rate for surface treatment is 0.3 mg/g to the top 45.7 cm of the grain mass. Alternative dusting preparations include ash, laterite dust, clay dust or very fi ne sand. The quantities commonly applied vary considerably and can reach up to 50% by volume.

Sorting:

Food grains with bug infestations, mould, mechanical damage, or any other subpar qualities need to be removed and processed as away. By doing this, you can keep the nutritious grains clean and the produce's general quality high.

Divide the harvest:

Always divide produce intended for storage into two portions: one for immediate daily needs and the other for long-term preservation. In most cases, insects do not result in losses for three to four months. Food grains meant for immediate consumption do not need to be treated, however those meant for long-term storage do need to be treated properly.

Lime treatment:

One of the most significant and affordable dusts for food grains preserved in their husks is quicklime. Insects are dehydrated by lime dust, which also clogs their respiratory openings.

Storage structures:

Farmers and governments frequently store food grains in order to use them later. The grains are typically kept at homes or in sizable storage facilities. However, it is common practise

in many regions of the world to store grains in various sorts of buildings (Manandhar *et al*., 2018). They are created as tribal knowledge and used to create artificial buildings as time goes on.

The buildings can be categorised as either (a) above-ground and underground structures or (b) conventional and modern structures (Hui *et al*., 2002). Men used to dig pits and store grain close to where they lived in the past. However, they frequently suffered damage from rats or microbiological decomposition. They eventually started storing in wooden elevators, above-ground mud bins, bamboo baskets, and so forth. Many writers have previously published thorough listings of various storage architectures (Deka *et al*., 2006; Ashok *et al*., 2018), however few of these are out-of-date and barely apparent now. The development and adoption of metal bins, automated storage facilities, enormous warehouses, lofty elevators, silos, and other upgraded buildings are seen as a result of the evolution of human knowledge and skills.

On the other hand, these buildings sparked the creation of complex microclimates and storage conditions. In due course, insects also adapt to these networks and disperse to numerous regions. Hermetic and low-pressure storage structures are widely used nowadays.

Hermetic storage:

Hermetic seals are a result of the idea of putting a barrier between the commodity and the grain. The concept of de-oxygenation inside the storage structure is used in airtight storage to lower aerobic conditions because many conventional structures are internally oxygenated. Because of the increased carbon dioxide (CO_2) due to the decrease in oxygen (O_2) concentration, the insects' metabolic processes are significantly impacted, ultimately resulting in death.

A developing area of engineering study in relation to agriculture is the storage of grains in hermetic seal containers (Kumar *et al*., 2017). It is useful to manage pests during storage by using an airtight or gas-tight closure because it raises grain temperature, causes desiccation, and prevents immigration by confining the volatiles inside (Finkelman *et al*., 2002). The gas-tight situation, however, was equally harmful to grains that were being stored. Controlled aeration, adjusting the gas proportion, or adding an insect-proof barrier, however, provide additional benefits and success with hermetic storage structures in contemporary management techniques (Navarro *et al.*, 2004). There are a number of academic works on designing and creating different configurationally modified hermetic storages (Baributsa and Njoroge, 2020).

They are more expensive when made of metals than bags. Even so, they are praised for having contemporary storage facilities. Improved subterranean storage facilities for grains, pulses, and oilseeds were continued in use in Asian and African locations because lower O2 concentrations report desired insect mortality (Somavat *et al.*, 2017). The most popular types of hermetic buildings include metal, cement, and plastic silos, metal drums, hermetic cocoons that may hold a small amount of material up to tonnes, hermetic bags, and other polymer bags and

containers. There are many capacities and sizes for these hermetic buildings (Baributsa and Cristine, 2020).

Figure 2: Storage structures for pest management

b. Biological control:

1. Semio-chemicals:

The hunt for food, sex partners, and egg-laying sites, as well as defensive actions to guard against unfavourable environmental circumstances and natural adversaries, account for a large portion of the activity of insect pests of stored products. Chemical cues produced by the insects themselves or by other organisms, such as the plants they feed on, can alter their behaviour. Pheromones and allelochemicals fall within this category. For some insects, such as flour beetles and lepidopteran insects, insect traps are available.

Semiochemicals are chemical signals created by one insect or organism that cause the receiving insect or organism to exhibit certain behavioural or physiological reactions. Pheromones, which are intra-specific chemical signals, and "allelochemicals," which are inter-specific chemical signals, are two categories into which they are frequently divided (Abd El-Ghany, 2019). Pheromones are mostly used in stored-product protection. These aid insects in

their quests for food, mates, egg-laying sites, defence, and other activities (Cox and Collins, 2002). Semiochemicals were found in over 40 species of stored-product insects (Phillips and Throne, 2010).

They are mostly utilised as attracticides, repellents, feeding and oviposition deterrents, mass trapping lures, and formulations to disrupt mating behaviour in pest management. There are two primary categories of pheromones: aggregation (both sex) and sex (unisex). Insects that eat stored grains, including Pyralid (Phycitinae), Anobiidae, Bruchidae, and Dermestidae, have been used as examples of sex pheromones.

Similarly, Bostrichidae, Curculionidae, Cucujidae, Silvanidae, and Tenebrionidae aggregation pheromones (Phillips and Throne, 2010). Different trap designs were created, and their effectiveness at dispensing artificial lures to draw stored-grain insects was assessed (Sambaraju and Phillips, 2008). Although the pheromone components are species-specific, there has also been some observed cross-attraction (Cox, 2004).

2. Botanicals:

It has long been customary to utilise plant derivatives to safeguard stored goods. Because of their active constituents, botanicals have been used to manage insects in a variety of ways, including as repellents, antifeedants, toxicants, chemosterilants, and growth regulators.

The volatiles (essential oils) derived from plants are the main emphasis as the green chemistry of insecticides has evolved (Rajendran and Sriranjini, 2008). Due to their affordability and safety for humans, the usage of botanicals is becoming more and more popular worldwide. Plant oils acted mostly through neurotoxicity, including neuromodulation and the suppression of the enzyme acetylcholine esterase.

There is evidence that several plant families, including the meliaceae, myrtaceae, apiaceae, lamiaceae, lauraceae, poaceae, pinaceae, and others, contain volatile secondary metabolites or terpenoids that are insecticidal (Talukder, 2006). Studies on the effectiveness of plant products against stored grain pests have been done in the past, and there are a lot of evaluations available for essential oils (Mossa, 2016; Singh and Kaur, 2018). In contrast to eggs, adult insects were typically found to be more sensitive.More than 75 plant items were examined by Rajendran and Sriranjini (2008) for their ability to act as fumigants against stored pests.

It was discovered that *T. castaneum, R. dominica, S. oryzae, and S. zeamais* were the main targets of testing for the fumigant toxicity of plant essential oils. Little research has been done on moth pests like *C. cephalonica* and *S. cerealella* (Mangang *et al*., 2020). Even though numerous plants' extracted oils have been investigated for their ability to repel pests from storage, only few of them were able to formulate and register for use in the commercial sector. As a result, just 1% of the global insecticide market is made up of botanicals (Campolo *et al.,* 2018). These plant compounds may function as chemical fumigation alternatives in light of

human health issues. Studies on the toxicity, screening, effectiveness, sorption, formulation, and fumigation of botanicals, particularly essential oils, are receiving more attention these days.

3. Biopesticides:

Biological control is a potential method or approach for protecting stored grain without endangering the environment (Matthias, 2010). Biopesticides in this study mostly represent pathogenic biological agents, such as fungi, bacteria, viruses, protozoa, and others.

In a scientific setting, a variety of insect diseases were tested against stored-grain insects (Batta and Kavallieratos, 2018; Kumar *et al*., 2019). Furthermore, none of them were considered to be widely utilised due to their host specificity and restricted environmental adaptations. Synergists, particularly diatomaceous earth, were tested in combination to increase their potency and wide range of adaptability.

Among the entomopathogenic fungi that are commercially accessible are *Beauveria bassiana*, *Metarhizium anisopliae*, and *Bacillus thuringiensis* (Bt), which was primarily studied against stored-grain pests, particularly beetles (Batta, 2016). Bt was tried long ago for the stored grain moths, but the commercial application is constrained by the larger dose, the separation of the carrier after treatment, the large facilities for mass culturing, the region-specific strains, and other factors (Arthurs and Dara, 2019).

According to Shapiro-Ilan *et al.* (2007), *Bacillus thurengiensis* var. kurstaki (Btk) is efficient against pests that attack stored grains, particularly *P. interpunctella* and other moths (Lord *et al.*, 2007). According to Malaikozhundan and Vinodhini (2018), the Bt (4 108 cells/mL) was extremely effective against *C. maculatus* in a lab setting (100% mortality). Even though entomopathogens exhibited a population decrease in comparison to conventional insecticides, the efficacy was slower. In storage settings, the use of entomopathogens, primarily fungi, was thought to be promising. In their 2017 study, Rumbos and Athanassiou highlighted the use of entomopathogenic fungi in the control of stored pests. The effectiveness of other diseases, such as viruses and protozoans, against stored-grain insect pests has also been studied.

Protozoans, specifically *Nosema whitei* (Milner, 1973) and *Nosema plodiae* (Kellen and Lindegren, 1974), have long been known to infest many insects, including flour beetles and phycitine moths. Similar to this, viruses (mostly baculoviruses) have also received significant attention in studies of lepidopetan pests including *P. interpunctella* and *E. cautella* (Vail *et al*., 1991).

For the successful application of promising biopesticides, more study in this area is needed addressing the isolation of local strains, screening, and formulation of efficient strains, as well as the combination of several strains with various host ranges.

4. Natural enemies:

The management of stored pests by natural enemies (predators and parasitoids) has been researched for a century. However, the majority of them were concentrated on topics like genetics, toxicity, biology of natural enemies, population and evolutionary ecology, and others. The first known widespread discharge of a parasitoid occurred between 1942 and 1945 in cocoa warehouses in Bahia, Brazil, which were infested with *Cadra cautella*, according to Flinn and Scholler (2012).

Several authors periodically reviewed the use of insect parasitoids and predators against stored-product insect pests (Matthias, 2010; Flinn and Scholler, 2012). Biological control emerges as one of the most essential and durable elements of the integrated pest management strategy. The focus on biocontrol was also being increased by issues with insecticide residues in storage and stored grains, an approach to organic farming, food safety, and other factors (Flinn and Scholler, 2012). The field environment and the stored grain ecosystem cannot be compared, and the storage parameters have a substantial impact on the activity of natural enemies (Hagstrum and Subramanyam, 2009). The prerequisite for biocontrol is understanding the biology and behaviour of entomophagous insects that prey on pests of stored grains.

The simultaneous adaptation of these organisms to various environments in cooperation with the hosts is one of the promising fields of study. Cassi (2017) looked at 137 references connected to biological control in the food or storage industry, and found that parasitoids, entomopathogens, and predators made up 51, 21, and 18% of them. The two main predators were mites (56%) and heteropterans (24%). Pteromalids and braconids made up the majority of parasitoids, accounting for 70%, followed by bethylids, ichneumonids, and trichogrammatids (24%), chalcidids, and eulopids (3%). You can find a comprehensive list of reported and efficient natural enemies of stored-product insects elsewhere (van Lenteren *et al*., 2018).

Although one of the most efficient methods is biological control, food safety must be addressed carefully, and historically sociological problems were associated with the presence of insects (biocontrol agents) (Flinn and Scholler, 2012; Belda and Riudavets, 2013; van Lenteren *et al*., 2018). In the past, there were very few applications of predators and parasitoids that were both affordable and field-level inundative. Lab studies make up a large portion of the studies. On a commercial scale, the integration of biological control techniques with other pest management techniques is progressing slowly.

5.Entomopathogenic nematodes (EPNs):

Entomopathogenic nematodes are used to control insects, which is a novel strategy in pest management as nematode science develops (Arthurs *et al*., 2004). In addition to being investigated and found to be efficient against stored-grain insects, two significant genera,

Steinernema and *Heterhorhabditis*, demonstrated effectiveness against pests of field crops (Rumbos and Athanassiou, 2017).

6. Molecular interventions:

A unique method of controlling insects is to interfere with an organism's natural gene expression. RNA interference (RNAi) and Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) were the two molecular tools used (Perkin *et al*., 2016).

For these investigations, the rust-red flour bug, *T. castaneum*, was used as a model insect, and the majority of the information accessible in the published articles was primarily for this insect (Gilles et al., 2015). *T. castaneum* was chosen as the host because to its simpler laboratory growth and robust RNAi response throughout all embryonic stages.

Normally, CRISPR deactivates Cas9 (DNA binder) and RNAi operates at dsRNA to prevent further gene activation (Qi *et al.,* 2014). Only after thorough research are these methods capable of managing stored-grain pests. A necessary first step and a topic of concern is the identification of particular genes in insects infesting grains that have been kept.

When compared to other related approaches, such as gene editing and gene modification, these revolutionary technologies seem futuristic.

Usage of Nanotechnology in storage pest management:

Scientific domains both fundamental and practical, such as protecting stored grains, are increasingly conducting nanotechnology studies. Novel features of the nanoparticles, such as modifications in electrical conductivity, surface chemistry, and reactivity, have increased their significance (Zayed, 2018). According to Stadler *et al*. (2010), a number of metallic oxides, including zinc, silver, aluminium, silica, and others, were typically prepared as nanoparticles.

However, due to its antibacterial, antifungal, UV filtering, greater catalytic, and photochemical activity, zinc oxide nanoparticles were frequently employed (Meruvu *et al*., 2011). In a study against *C. maculatu*s, Malaikozhundan *et al*. (2017) developed Bt-coated zinc oxide nanoparticles (Bt-ZnO NPs) and observed that they reduced fecundity and hatchability (LC50 - 10.71 g/mL) and lengthened larval, pupal, and total development period (@25 g/mL). The entomotoxicity of surface-functionalized silica nanoparticle (SNP) against *S. oryzae* was studied by Debnath *et al*. (2011), and they discovered that it was extremely effective, causing more than 90% mortality.

Nickel-oxide nanoparticles (NiO NPs) were examined by Rahman et al. (2020) against C. maculatus that had infested black gramme and they discovered lower fecundity and an extended developing time at concentrations of 5, 10, 20, and 40 ppm NiO NPs, respectively. For their considerable impact on adult insect mortality, fecundity, hatchability, and biology, efficacy tests of nanoparticles were also carried out against *T. castaneum, S. oryzae, R. dominica*, and *C. maculatus* in a laboratory setting (El-Saadony *et al*., 2020). To employ this unique strategy in

stored product protection, thorough and field-level studies of nanoparticle applications are needed.

Future aspects:

Eco-friendly insect-pest control calls for the manipulation of local natural resources for the preservation and enhancement of natural enemies, which can be accomplished by successfully involving farmers in training and adoption of such practises on a broad scale. Government actions are occasionally needed for large-scale inoculative and inundative releases of diverse bio-agents.

Conclusion:

Since it is anticipated that many nations all over the world experience significant losses as a result of attacks by stored-product insects as well as from poor storage conditions, it is past time to consider the seriousness of the problem of storage losses.It is necessary to use a systems approach as opposed to a piecemeal one. To reduce postharvest losses at the farm level, where over 70% of grains are kept and used for food, feed, and seed, the current postharvest system needs to be improved.It is urgent to implement eco-friendly management solutions for the control of storage pests due to the negative impacts of utilising chemical insecticides, and by using these strategies we are able to protect the environment from these poisonous chemicals.

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NON-INSECT PESTS AND THEIR ECO-FRIENDLY MANAGEMENT

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Introduction:

In agriculture there is a class of animals known as non-insect pests which includes mammals, birds, nematodes, molluscs and mites. The losses in crop production due to insect pests and non-insect pest are around 30 per cent. Non-insect pests are estimated to cost our crops range of Rs. 810 crores per year, with rodents alone causing a loss of Rs. 360 crores. Non-insect pests of crops include phytophagous mites, rodents, birds, and nematodes, as well as crabs, millipedes, snails, and some non-rodent mammals, in roughly descending order of their importance.Among m any mammalian pests, including jackals, bats, elephants, bears, bison, neelgai, monkeys, hares, black buck, deer, and wild boar, fall under the wildlife conservation group and are thus protected under the Wildlife Protection Act of 1972. One must always select effective eco-friendly pest management strategies rather than just relying on chemical control which often are deterrent to environment and wildlife.

1. Rodents

Rodents are vertebrate pests which belong to class Mammalia and have an external covering of hairs. Its order Rodentia includes a large number of animals ranging in size from the smallest mice to as large as porcupine, squirrel and beaver etc. Rats not only feed on grains but also contaminate 20 times more than what they consume with their droppings, urine and hair. They daily consume food equal to about 10% of their body weight, damage about 20 times the amount they actually consume, by their gnawing activity and by polluting the food grains.It has been estimated that there are about 2500 million rats in India. They inflict, on an average, about 5-10 per cent loss in food production alone. Of the 84 species of rodents in India. Some of the important rodent species found in field and storage are discussed in this section.

Field rodents

Common Name	Scientific Name	Habit and Habitat	Distinctive character	Distribution
Indian mole rat / lesser bandicoot	*Bandicota bengalensis*	Lives in cultivated plains in gardens, good burrower; most important as per destruction is concerned	Grey, black or blackish grey, much bigger than Louse rat, weighs 900-1400g, head+body length 15-23cm, tail length 12- 18 cm	Common in moist alluvial tracts

Soft furred field rat / grass rat	*Rattus (Millardia) meltada*	Lives in cultivated fields, forests and rocks, prevalent in black cotton soil; burrowing type	Pale brownish on the back,grey, greyish white underside, palest one found in desert zones, West and dense soft furred and large rounded ears, head+ body length 12-15cm, tail length 12-15cm	Peninsular India, Punjab, Uttar Pradesh, south India
Short tailed bandicoot rat	*Nesokia indica*	Inhabits in cultivated fields but occurs under natural vegetation near crop fields	Bigger, robust built than *B. bengalensis*	Delhi, Punjab, Haryana, Rajasthan, Uttar Pradesh
Indian gerbil rat / antelope rat	*Tatera indica*	Found in cultivated lands, under bushes, hedges, in open plains,burrowing type, fast runner, nocturnal	Reddish brown to fawn or greyish fawn, tail with a tuft of hairs at end, hind feet very long to help in taking long leaps, head+ body length 15-18cm, tail 10-13cm	Widely distributed
Indian field mouse	*Mus booduga*	Common in field bund, compounds & gardens: occasionally in houses	Pale sandy in deserts, widely brown or dark greyish brown in humid, white bellied, head+ body length 5-8cm, tail length 5-7cm	Worldwide distributed in irrigated fields
Brown spiny mouse	*Mus platythrix*	Burrowing type. small pebbles are found near mouth of burrow	Whole body covered with spines, hack spines thicker and coarse than those of lower parts	Widely distributed
Coconut rat/ Common rat	*Rattus rattuswroughtoni*	Lives and breeds inside nests specially constructed in the crowns of palms.	It is reddish or yellowish brown with a pure white belly	Widely distributed
Indian long tailed tree mouse	*Vandeleuria oleracea*	Lives on trees and shrubs	Chestnut red coat above, white bellied; beautiful soft furred with very long tail, head+ body 5-9cm, tail length 7-12cm	All over India

Rodents in stores

Common Name	**Scientific Name**	**Habit and Habitat**	**Distinctive character**	**Distribution**
House mouse	*Mus musculus*	Lives indoors, outdoors, gardens and fields near villages/towns, climber, burrower	Brownish gray& lighter outdoors, gardens shades, tail longer than & fields near body, snout pointed, villages/towns, droppings small, scattered, climber, burrower thin & spindle shaped, weighs 15- 16g, head + body size 5-8cm, tail length 10-13cm	Worldwide
House rat / common rat	*Rattus rattusrufuscens*	Lives inside the building, not a burrowing type, good climber, rare in sewers.	Gray, black, brown or fawn on the dorsal side, may have white belly, tail is longer than the head and body, snout pointed, droppings scattered always in banana shaped, average adult weighs 250 grams. Size: Head & body 12-15 cm. Tail: 20-30 cm	Found everywhere, mainly in port areas.
Larger Bandicoot /Bandicoot rat	*Bandicota indica*	Lives in gardens, near garbage binsand human dwellings. found on the roadside.they get run over by cars and die on the road.	Dark gray-brown upper parts with a profusion of long, black hairs. Sides are gray with a few long, black hairs. Short, light gray fur occurs on the ventral surfaces. It has a dark and naked, scaly tail, and dark feet with light-coloured claws.The young are much lighter in colour.	Widely distributed
Brown rat /Norway rat / sewer rat	*Rattus norvegicus*	Lives indoors and sewers, can burrow and climb.	Brown, darkest on the back, white or whitish or light brown on the belly, tail is shorter than the body, snout blunt, droppings in groups generally ellipsoidal or spindle shaped, average adult weighs 320 gm. Size: head + body 17-20 cm. Tail: 12-18 cm.	Widely distributed

Management of rodents

Field rodents

Three basic components of IPM as in any other pest are

1. Prevention 2. Observation 3. Intervention

Prevention: Food and habitat manipulation is the key in preventing rodents

- Summer ploughing
- Keep the field bunds free from weeds
- Trimming the field bunds and reducing the number of bunds as far as possible.
- Selecting uniform maturing varieties
- Uniform planting, avoiding staggered sowings / plantings
- Monitoring rodent population build up particularly after floods / natural calamities.
- Avoiding hay stacks near field to eliminate harbourages.
- Encouraging natural enemies (snakes, birds etc.,)

Observation: ·

- Identifying species can be made by visual observation of species or their burrowing pattern.
- Assessment of rodent population by burrow count is handy because single adult whether male or female, inhabits a burrow.
- ETL 2% tiller damage (Rice) 15 % affected hills

Intervention: ·

- Setting of indigenoustraps: Bow traps @ 20 – 25 / ha
- Smoking burrows with burrow fumigator (originally designed at APRII, Maruteru, AP)
- Baiting on a community approach over a large area. Rats are colour blind and can not vomit. This character is exploited in baiting.

1. Acute poison: Zinc phosphide 2 %. ii. Pre baiting should be done 2 – 3 days before. iii. Baiting: Broken rice (local food) – 96 parts, Edible oil – 2 parts, Zinc phosphide – 2 parts iv. 10 bait stations / ac v. Followed by baiting, fumigation with aluminium phosphide after enumeration of burrows @ 2 pellets (1.2 g) / burrow. * Zinc phosphide burrowing can be done only once during the season.

2. Single dose Anticoagulants i. Bromadiolone 0.25 CB at same ratio. ii. Bait can be used at any number of times at 10 – 15 days interval during crop season.

3. Sustained baiting with Bromadiolone bait throughout crop period at bait stations, each provided with 15 – 20 g of freshly prepared bait.

Management of rodents

In stores· Killing by sticks

· Using traps: Snap neck trap, Live catch trap or Wonder trap

· Encouraging predators like cats, dogs, owls and hawks.

· Use of chronic anti coagulants

Rodafarin 'C' (solid bait) Rodafarin 'C' – one part 2. Sugar – one part 3. Vegetable oil – one part 4. Crushed grain /corn meal – 17 parts

Rodafarin 'S' (liquid bait)

- Rodafarin 'S' – one part 2. Water – 19 parts 3. Effective in stores as there is lack of water in stores
- Death of rats is observed after 2.5 day of continuous feeding.
- Bromadiolone (ROBAN, MOOSH MOOSH): Single dose anticoagulant new generation rodenticide. Bromadialone 0.005% RB (Ready Bait). One piece should be kept at hiding place / runways etc.,
- Coumatetralyl (RACUMIN): new group of anticoagulants is available as loose bait or tracking powder

2. Birds

Birds belong to the class Aves, with featherscovered all over their body and have a unique characteristic of forelimbs modified as wings. Mouth is continued to form a beak and are homoethermous and grainivorous. They cause consider amount of damage to the maturing grains and fruits in agricultural crops and also about 0.85% losses are caused bythem in storage. The damage done in fields and stores is appreciable in both quantitativelyand qualitatively. Average consumption by birds ranges from 8 to 25 gm per day. Some of them are responsible for spreading diseases. They also create nuisance and unhygienic conditions in warehouses.In India only 25 of about 12000 species of birds found to inflict damage to crops and fields. Peacocks can damage cauliflower or cabbage nurseries 90-95 per cent, if not properly protected. Some of the important birds of agricultural importance are described here below.

Common name	**Scientific name**	**Damaged plant parts**
Common pigeon, Blue rock – pigeon	*Columba livia*	Grainivorous, eat food grains in grain mandies, godowns
House Sparrow	*Passer domesticus*	Principally omnivorous and grainivorous; lives or enters house and warehouses, eat grains in open / bag storage
House Crow	*Corvus splendens*	Omnivorous feeding on kitchen waste to dead animals and hence considered as the best scavenger.
Rose ringed parakeet	*Psittaculakrameri*	Normally frugivorous, attacks ripening cereal crops and foodgrains in open storage

Common mynah	*Acridotheres tristis*	Damages food grains in fields and mandies but seldom enters ware-houses
Baya/Weever bird	*Ploceusphilippinus*	Pest of paddy grains
Spotted Munia	*Lonchurapunctuata*	Feed on ripening paddy grains, other grass seed.
Parrot	*Psittaculacyanocephalus*	Guava, pearl millet, sorghum. maize, mango, fig
Yellow throated sparrow	*Gymnorhisxanthocollis*	Wheat, barley
Peacock*	*Pavocristatus*	Tender seedlings like cabbage, cauliflower. ornamentals
Blackdrongo or King crow	*Dicrurusadsimilis*	It feeds on insects, and is common in open agricultural areas and light forest in its range.

* Protected under Act due to its status as National Bird and not as endangered

Management

- Bird damage can be prevented by scaring them away using mechanical bird scarers, beating empty drums, pyrotechniques (art of making fireworks) and bioacoustics (making distress calls) setup in orchards/fields.
- Use of metalized reflective ribbons /plastic garbage bags of various colours to repel them.
- Installation of carbide gun, scare- crow etc. on strategic places. About one kg calcium carbide is required for eight hours to repel birds from 2-3 acres.
- Application of Pestgo, a highly viscous gel at roosting to create stickyness.
- Use of catapults, tin drums; crackers and other indigenous tactics.
- Baiting with misorol (4-amino pyridine), a behavioural repellent. It has to be applied with preferred food for particular bird species e.g. guava for parrots while meat for vultures.
- Fencing and netting especially for peacocks, keeping in find their small flight range as well as existence of an object suited for the sortie.
- Playing of distress calls prevents brown-eared bulbuls-damaging fruits in orchards.
- Destruction of eggs and nests
- Use of non toxic and sticky material like " Lassa"
- Growing bird resistant varieties like - Ganga 3 in maize andRed sorghum
- Use of repellents like cupric oxide, methiocarb.

- Use of chemosterilants like mestranol, ornitrol, avitrol.
- Fumigation of holes
- Use of stupefying substances, immobilizers, narcotizers (Alfachloralose 1 – 2 % in bait).

3. Nematodes

Nematodes are minute worm – like animals without true body cavity and with unsegmented, bilaterally symmetrical and externally cuticularized body. Nematodes are popularly known as round worms. They are found in the soil, in all types of aquatic environment and in animals and plants as parasites and otherwise. Nematodes belong to the phylum Nematoda.

Figure 1: Different species of plant parasitic nematodes

Plant parasitic nematodes or phytoparasitic nematodes constitute one of the important groups of organisms which live in soil around plant roots. They are often microscopic, long and slender eel worm, confined usually to the top soil of 20-25 cm. Plant parasitic nematodes cause extensive damage to cultivated plants, resulting in heavy losses. The damage may be caused directly, or indirectly when the phyto parasitic nematodes transmit plant viruses or allow other pathogens to enterthe plant through damaged areas created by these nematodes. All the plant parasitic nematodes possess a sharp, pointed, protrusible buccal stylet to puncture plant cells. The parasitic nematodes suck the cell sap from the punctured cells and injects saliva into plant cell while feeding which is toxic to plants and causes many symptoms in the plants.In plants,

they are either endoparasites or ectoparasites. Economically important plant parasitic nematodes, their damages and management are explained in this section.

White tip nematode of rice/ spring dwarf nematode: *Aphelenchoides besseyi*

It is widely distributed in Tamil Nadu. Remain alive as pre adult, beneath the hull of paddy seed for two years. When seed are sown, immature forms become active and move up the plant along a thin film of moisture and feed on foliage as ectoparasites. Adults lay eggs on foliage. Larvae move to panicle when it is formed and enter grains.

The symptoms are

- Leaf tips (2-5 cm) turn yellow, brown and finally turn white, dry up and hang down.
- Tips of developing leaves become twisted and crinkled.
- Kernels distorted and in severe cases it become chaffy.

Management:

- Treatment of paddy seeds with hot water at 52 – 55^{o}C for 15 minutes.
- Seed treatment with N – 244 @ 3 ml a.i. for every litre gives 100 % control

Wheat gall nematode/ ear cockle nematode: *Anguina tritici*

It is a major pest in all wheat-growing regions around the world. When sown under favourable moisture conditions, second instar larvae inside seed galls become activated and emerge from the seed. The larva climbs the plant through a thin layer of moisture. As an ectoparasite, it feeds on tender foliage. It enters young green grain and converts it into a gall, where it grows and reproduces. Each female inside the gall lays hundreds of eggs, and the larvae that hatch remain in the seed and can survive in dry seeds for years. When those seeds are planted, the cycle repeats again.

The following symptoms can be seen.

- Affected plant stunted with wrinkled and twisted leaves.
- Infested grains ripen slowly, smaller in size with irregular contour.
- Whole or part of the grain converted into galls, cockles or pepper galls

Nematode infestation is associated with “Tundu disease” or “yellow slime” disease caused by a bacterium, Corynebacterium tritici causing rotting of spikelet with oozing of yellow slime (yellow slime disease). This results in twisting of leaves, distortion of ear heads, rotting of spikelets with profuse oozing of yellow slimy liquid.

Management

Seeds for sowing should be immersed in salt solution by dissolving 10 kg of common salt in 60 litres of water. The floating seeds should be rejected (or) Seeds pre soaked in water about 2 h and after rejecting seeds that float, (light and chaffy seeds) the remaining seeds are kept in hot water at 50^{o} C for 2 h. Seeds treated by either of the above methods should be shade dried by spreading on floor in a thin layer

-Resistant variety is Kanred (USA).

Root knot nematode: *Meloidogyne* spp.

M. incognita and *M. javanica* infest all vegetables, other crops like cotton, sugarcane, chillies, wheat, barley, tea. *M. incognita* infests brinjal, chillies, tomato and bhendi while *M. arenaria* infests chillies and tomato. Infections with this nematode result in the invasion of pathogens such as *Fusarium* and *Rhizoctonia*. Female lays 200-500 eggs in a gelatinous sac surrounding the female's posterior tip. The egg mass can be seen protruding from the galled roots. The second stage larva is long, slender, and cylindrical. Female larva swells up after entering the roots at each moult. The adult female is flask-shaped and spherical. Males are slender. As a result of feeding by nematode, infested roots show: -

Knot-like galls on roots.

Stunted plants with chlorotic leaves.

Management

- Fallowing field in summer after 2 or 3 deep ploughings and drying
- Keeping the field in flooded condition for a few days, wherever possible.
- Ploughing nursery area and spreading paddy husk uniformly @ 20 kg/m2 (about 15 cm thickness), burning it and ploughing back facilitates productionof nematode free seedlings.
- Crop rotation with mustard · Application of chopped leaves of pongamia and crotalaria reduces disease severity.
- Preplant soil fumigation with DD mixture.
- Nursery treatment with carbofuran 3G @ 65 g/m2 and in main field carbofuran 3G @ 4 kg a.i./ha is effective.
- Resistant varieties in tomato are Nematox,Nemared, SL 120,Ronita, NTR – 1 and Pelican

Citrus nematode: *Tylenchulus semipenetrans*

It infests many citrus species and related genera throughout all citrus growing areas. Females are swollen, sac-like, and remain attached to their roots, with the head region buried in tissues. Drying of apical leaves, buds, and twigs downward- known as die back- is the result of damage. Trees show reduced vigour and a gradual decrease in yield.

Management

- Selection of planting material from nematode free nurseries.
- Application of neem or castor cake @ 15 kg / tree
- Application of carbofuran 3G @ 50 g / tree and watering.
- Avoiding brinjal, tomato and tobacco as intercrops in citrus gardens which are nematode prone.
- Preplant soil fumigation with DD mixture and using clean nursey stocks.

- In infested orchards, soil drenching with DBCP (Dibromo chloro propane) is found to be effective.

4. Mites

Mites are very small members of the class Arachnida, sometimes microscopic, arthropods with an oval or elongated body.The body plan has two regions, a cephalothorax (with no separate head) or prosoma, and an opisthosoma or abdomen. Segmentation has almost entirely been lost and the prosoma and opisthosoma are fused, only the positioning of the limbs indicating the location of the segments. The legs are 3 pairs in larvae and nymph while adult has four pairs of legs, although some have only two or three pairs.Most mites have four pairs of legs, each with six segments, which may be modified for swimming or other purposes. The mouthparts, called chelecerae, are adapted for piercing, sucking and lacerating. Respiration is taken care by trachea but in absence of tracheal respiration, cutaneousrespiration plays role. The phytophagous mites belongs mainly to the families Tetranychidae and Eriophyidae.

Important species of mites

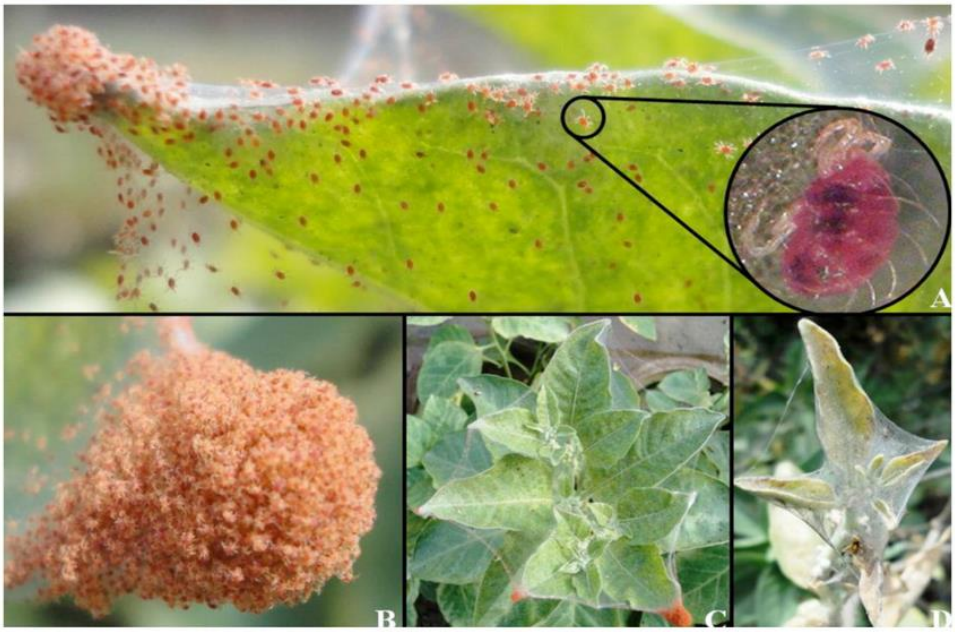

Figure 2: Attack of phytophagous mites on crop plants

1. Mites infesting crops

Common name	Scientific name	Family
Two spotted spider mite	*Tetranychus urticae*	Tetranychidae
Cucurbitaceous mite	*Tetranychus cucurbitae*	Tetranychidae
Mango mite	*Aceria mangiferae*	Eriophyidae
Sorghum mite	*Oligonychus indicus*	Tetranychidae
Cotton mite	*Tetranychus macfarlanei*	Tetranychidae
Cotton leaf mite	*Tetranychus telarius, T. bimaculatus,*	Tetranychidae

Wooly mite of cotton	*Aceria gossypii*	Eriophyidae
Rice leaf mite	*Oligonychu soryzae*	Tetranychidae
Rice panicle mite	*Steneotarsonemus spiniki*	Tarsonemidae
Sugarcane mite	*Schizotetranychus andropogoni*	Tetranychidae
Chilli mites/broad mite/yellow mite	*Polyphagotarsonemus latus,*	Tarsonemidae
Cocunut mite	*Aceria guerreonis* *(Eriophyes guerreonis)*	Tetranychidae
Jasmine eriophyid mite	*Aceria jasmini*	Eriophyidae
Mites on vegetable	*Tetranychus telarius, T. bimaculatus*	Tetranychidae
Brown wheat mite	*Petrobia latens*	Tetranychidae
Citrus green/leaf mite	*Eutetranychus banksi*	Tetranychidae
Citrus rust mite	*Phyllocoptruta oleivora*	Eriophyidae
Red gram mite	*Aceria cajani*	Eriophyidae
Tea mites Red spider mite: Purple mite: Pink mite: Scarlet mite:	 *Oligonychu scoffeae* *Calacarus carinatus* *Acaphyllatheae* *Brevipalpus australis*	 Tetranychidae Eriophyidae Eriophyidae Tenuipalpidae

2. Mites infesting storage grains

Common name	Scientific name	Family
Grain Mite	*Acarus siro*Linnaeus	Acaridae
Mold Mite	*Tyrophagus putrescentiae*	Acaridae

3. Mites of Medical and public health importance

Common name	Scientific name	Family
Cheese Mite	*Tyrolichus casei*	Acaridae
House Dust Mite	*Dermatophagoides spp.*	Pyroglyphidae

4. Mites infesting veterinary animals

Common name	Scientific name	Family
Chicken Mite	*Dermanyssus gallinae*	Dermanyssidae
Mange mite (In dogs)	*Demodex canis*	Demodecidae
Itch or Scabies Mite	*Sarcoptesscabiei hominis*	Sarcoptidae
Straw Itch Mite	*Pyemotestritici*	Pyemotidae

5. Mites infesting beneficial insects

Common name	Scientific name	Family
Honey bees mite	*Varroa spp.*	Varroidae
Honey bee tracheal mite	*Acarapis woodi*	Tarsonemidae

6.Mites in Biological control

Common name	Scientific name	Family
Predatory mite	*Phytoseiulus persimilis*	*Phytoseiidae*

Spider mites: *Tetranychus urticae* Koch, the two-spotted spider mite. They are most common plant pests. Injury symptoms include flecking, discoloration (bronzing), and scorching of leaves, which can result in leaf loss and plant death. Many spider mites produce webbing, especially when they are in large numbers. This webbing protects the mites and their eggs from natural enemies and environmental changes. Spider mites thrive in dry conditions, which is why they are so prevalent in the country's arid regions. They feed more in dry conditions because the lower humidity allows them to expel excess water. At the same time, most of their natural enemies prefer moister environments and are stressed by aridity. Furthermore, plants that are stressed by drought can change their chemistry, making them more nutritious to spider mites. Irrigation and moisture management can be important cultural controls for spider mites.

Management

Cultural

- Avoiding monoculture
- Intercropping with non - host crops
- Destroying mite damaged parts in case of Erinium patches and malformations
- Adopting clean cultivation

Biological

Predatory mites – *Amblyseius longispinosus ,A. cucumerus*

Coccinellids: · *Brumussuturalis*, *Scymnusgracilis*, *Stethouruspauperculus*

Thrips: *Scolothrips indicus*

Lygaeids: *Geocoris sp.*

Chemicals: Chemicals which kill ticks and mites are called Acaricides

Specific acaricides- Dicofol (KELTHANE), Tetradifon (TIDEON), Aryl alkyl sulphide (ARAMITE),Barium polysulphide (SOLBAR)

Insecticides with acaricidal properties - Phosphamidon, Dimethoate, Methyl demeton, Formothion, Phosalone, Monocrotophos, Ethion, Phorate granules, Disulfoton granules

5. Snails and Slugs- The members of this group are soft-bodied belong to the order Stylommatophora and class Gastropoda of the phylum Mollusca. They are the animals without backbone, having asymmetrical, unsegmented and spirally coiled body. Slugs, unlike snails, have

only a rudimentary shell that is often enclosed in a visceral hump. The snails are large in size, bisexual and nocturnal in habits.In India, 1500 species of land snails occur but the number of species of slugs is limited.

Some common species of snails

i. Common garden snail: *Helix* spp
ii. Green house snail: *Opeasgracilis*
iii. Giant African snail: *Achatina fulica*

• African giant snail damage mainly plantation crops *viz.*, coffee, rubber and arecanut

Damage symptoms: Snails emerge from their hiding places during the rainy season and destroy many vegetables, ornamentals, plantation, and fruit crops. During the day, they hide beneath fallen leaves and stones; they also climb on papaya, banana, and a variety of other plants, remaining clinged to the lower and protected surface of the leaves. Another species is the golden snail, which can be devastating to newly planted rice, particularly in Indonesia, and causes re-planting.

Slugs: *Limax* spp.

Damage symptoms: Slugs are nocturnal, but active feeding can be seen during the day, especially in the morning when the weather is cloudy or rainy. They cut and devour tender plant parts such as flowers, leaves etc, from the margins. During the rainy season, their nuisance value is evident, particularly in lawns during morning walks.

Management

During off season the hiding places of the snail can be searched and the snails collected and destroyed.

During the rainy season, moist gunny sacks or leaves can be heaped near the cropped area's fence, and the snails that collect under these can be gathered and killed the next morning. Hermit crabs, which kill, eat, and occupy the snail's shell, keep it in check. *Orthomorpha sp*., a predator millipede, inactivates and consumes the snail.The two exotic predatory snails *Euglandina rosea* (Ferussac) and *Gonaxis quadrilateralis* Preston can be introduced for biological control of this snail.

The commonly used Molluscide is Metaldehyde, available in market as Snail Kill.

6. Crabs

Rice field crab: *Paratelphus ahydrodromus* (Herbst) (Decapoda, Crustacea): The body is oval, with the abdomen tucked beneath the thoracic region. It lives in holes drilled into the sides of field bunds, irrigation channels, and fields. About 3,00,700 crabs are usually seen over a hectare of an attacked field. They are mostly active after dusk and at night.

Damage symptoms: Young seedlings in nurseries and newly transplanted ones in the main field are damaged, usually within a fortnight of planting. The seedlings are cut into small pieces at

ground level and carried to the feeding holes. The outer sheaths of older plants are cut open and the tender inner portions consumed. Bits of leaves and stems can be seen floating in water in an attacked field. In Tamil Nadu, severe damage to the Samba crop is observed in September-October.

Management

Spraying methyl parathion 50 EC at 1 l/ha over a thin sheet of water in the field and draining three days after application has given about 80% control.

Granular application of phorate 10 G at 2 kg/ha in between rice field and bund is effective.

7. Millipedes

Tapioca millipede: *Harpurostreptus sp.* (Harpagophoridae: Diplopoda): It measures 8.7 cm in length and is brownish black in colour. Adults and juveniles have been observed feeding on tender buds and roots of newly planted tapioca setts, causing stunting and, in some cases, plant death. They also devour the roots of chillies. Baiting with 10 parts of carbaryl mixed with 2 parts of jaggery and 18 parts of rice bran or drenching the soil to a depth of about 5 to 8 cm with chlorpyrifos 0.02% emulsion are useful in controlling the pest. In Maharashtra, another millipede, *Lulus sp*., has been reported to cause significant damage to jowar.

Conclusion:

Non-insect pests are an important pest in agriculture ecosystems, causing significant losses comparable to insect pests. As a result, prompt intervention and management are required; additionally, some animals protected under the Wildlife Protection Act of 1972 must be managed by developing and implementing eco-friendly, chemical-free management strategies.

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INVASIVE INSECT PESTS OF INDIA AND THEIR MANAGEMENT

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Abstract:

Invasion of alien insect species is second greatest threat to biodiversity after habitat loss, these insect species are non-native or exotic species that colonize outside their natural adapted habitat and have high dispersal potential. Apple wooly aphid (*Eriosoma lanigerum*), Cottony cushion scale (*Icerya purchasi*), Subabul psyllid (*Heteropsylla cubana*), Coffee berry borer (*Hypothenemus hampei*), Serpentine leaf miner (*Liriomyza trifoli*), Coconut mite (*Aceria guerrerinis*) are few examples. Alien invasive insect species can affect through simple trophic interactions such has herbivory, predation and parasitism to eradicating the native insect species and thereby affecting the valuable agricultural ecosystem on which we depend. The classical biological control plays key role in supressing the invasive insect species, this can be done with international cooperation through exchange of information on invasive pests and their natural enemies. The interdisciplinary coordinated work among researchers helps in identifying and assessing their ecological problems.

Keywords: Invasion, Alien insect, Biodiversity loss, Natural Enemies

Introduction:

India is one of the fastest growing economies in the world, which contributes $330 billion (2014) as export, and which trades with as many as 190 countries in the world. Furthermore, India occupies 7th position with respect to total area (3.2Million square kilometres), this excessive trade and wide area has made India an opportunistic target for the introduction of invasive alien species (Singh *et al.*, 2020).

Alien species are non-native or exotic organisms that colonize outside the native area, when alien species outrage and dominates the native species its designated as Invasive Alien Species (IAS) (Raghhubanshi *et al*., 2005), According to the International Union for Conservation of Nature (IUCN) an invasive alien species is an alien species which becomes established in natural or semi-natural ecosystems or habitats, is an agent of change, and threatens native biological diversity. Invasive Alien Species can be regarded as biological poisons which will deteriorate the native biodiversity, from the history, Invasive alien species such as Sugarcane Wooly Aphd, Papaya Mealybug, Eucalyptus Gall Wasp, Rugose Spiralling Whitefly, Fall armyworm and Casava mealybug were managed under the three module of biological control (Shylehsa *et al.,* 2010; Selvaraj *et al.,* 2012; Ballal, 2022) *viz,* conservation,

augmentation, and classical biological control. Classical biological control involves importation of coevolved natural enemy from the homeland of invasive alien species. Augmentation involves mass multiplication and release of natural enemies, to the places where the pest is outreached. Conservation involves the habitat manipulation to build the natural enemy population in pest concentric zone (Ballal, 2022**)**, though for managing invasive insects, biological control plays crucial. Still, when insect population outreached to bring pest population down, chemical control is obligatory, and by manipulating little cultivation tactics the management will be easier. Hence, this publication aims to elucidate different options available for successful management of Invasive alien insects.

Woolly Apple Aphid, *Eriosoma lanigerum* (Hausmann), (Hemiptera: Aphididae):

Woolly apple aphid, highly pestiferous insect feeds mainly on Malus plant species (Walker *et al.,* 1988), it is one of the most important invasive apple pestsin the world, having spread from eastern north America to entire apple growing region of the planet (Upama Adhikari, 2022).

Biology and nature of damage:

Wooly apple aphids are light purple color aphids, have 3 different life stages, viz., Egg, Nymph (4 instars) and Adult. Woolly apple aphids reproduce by asexual, sexual and parthenogenetic way (Sherwant *et al.,* 2016**),** the type of reproduction varies with the season. During the month of march female reproduce parthenogenetically and produce 30-116 nymphs which later became alate or apterous adults, alate adults migrate to new place and start new colony where as apterous adults became sedentary and feed and reproduce throughout the year, whereas alate one present only from July to October (Sherwant *et al.,* 2016). The nymphal stage, has four instars, which requires 11 days in summer and 93 days in the winter (Rahman and Khan, 1941). First instar nymphs are called crawlers, which are highly mobile and most active, and they go in search of the host plant, once they find suitable place then they undergo further moulting and become sessile (Asante *et al.,* 1991). Further, nymphs begin secreting waxy filaments, which makes them to become woolly, these woolly waxy filaments protect the colonies while also give them characteristic woolly look (Shaw and Walker 1996). Initially aphids feed on the roots, once the colony is established in the roots, aphids tend to move up and down the trunk of an apple tree (Sushma *et al.,* 1995). Feeding of aphids in the arboreal part can result in early defoliation, stem breaking, and finally results in the formation of rosettes. (Brown *et al.,* 1991). Aphids also invade into the calyces, in course of development aphids produces honey dew which leads into formation of sooty mold, as a result of all these activities, fruiting ability of plants got harmed leads into loss of monetary gains. In a single year, aphids complete up-to 13 generations (Sherwant *et al.,* 2016).

Management of Apple Woolly Aphid.

- **Biological control:** Altogether there are 73 species of predatory insects belonging to the Coleoptera, Diptera, Neuroptera, Dermaptera, and Hemiptera. Areknown to feed on Apple woolly aphid (Upamaadhikari, 2022). Predators from Coccinellid family plays a crucial role, by accounting 48% of all predatory insects. Main biological control agents are *Aphelinus mali* (Hymenoptera: Aphelinidae); European earwig, *Forficula auricularia* (Dermaptera: Forficulidae); Lady beetle, *Parapriasus australasiae* (Coleoptera: Coccinellidae); Syrphid, *Heringiacalcarataii;* Fungal pathogen; *Vericillium lecanii*. Out of all listed biocontrol agents, *Aphelinus mali* (Hymenoptera: Aphelinidae**)** was found to be prime parasitoid, solely contributing more than 50% parasitisation, necessitating no further management methods. However, in Western Europe using of only *Aphelinus mali* is inadequate (Monteiro and Souza, 2004).
- **Mechanical control:** Restricting the mobility of crawlers migrating out of the soil into aerial plant can save the apple plants, this can be aided by using sticky bands. Two sticky insect-exclusion bands were stapled securely around the trunk of each tree can successively restrict the movement of crawlers. Further, there is need to control the edaphic aphid colony, because this colony is primary inoculum for arboreal part. Mulches and row coverings, can have indirect effect on edaphic pest populations, due to mulching natural enemy assemblage will be easier, and mulching can vary the soil temperature in a such a way where the aphids cannot multiply (Vincent *et al*., 2003).
- **Resistant Variety:** Edaphic aphid population is primary inoculum, and these subtarean aphid populations are resistant to predation and difficult to control with pesticides. These subterrain aphids can be controlled via resistant root stocks viz., Northern Spy, Robusta %, and Aotea (Sandanayaka *et al.,* 2003).
- **Cultural control:** Aphids used to feed on phloem sap, and nutrional quality of phloem is mostly determined by the amount of soluble amino acids it provides (Rousselin *et al.*, 2017). Further, amino acid pool can be influenced by the availability of water (, with the mild water restriction which have mere effect on photosynthesis but it can alter the soluble amino acid, which will directly affect the phloem depending woolly apple aphid population.
- **Chemical control:** The systemic insecticides and non-insecticides known to control the subterrain and aerial aphid population respectively, during late 1990's systemic insecticides such as pirimicarb and vamidothion are known to control subterrain population where as non-systemic insecticide chlorphyrifos, are used to supress the aerial colonies (Thwaite *et al.,* 1995). Further, Imidacloprid is also labelled to have good root systemic action insecticide, which gave excellent control of woolly aphid in trees upto 7years old. Other pesticides claimed to have

effect towards woolly apple aphids are Diazinon, Malathion etc. (Bradley *et al.,* 1997; Khan *et al.,* 2015).

***Paracoccus marginatus* Williams and Granara de Willink (Hemiptera: Pseudococcidae)**


Source: Tanwar *et al.*, 2010

Papaya mealybug (PM), *Paracoccus marginatus* is a small sap sucking insect native to Mexico (Miller *et al.,* 1999), has wide host range known to feed over 60 plant species including economically important tropical fruits, vegetables and ornamentals (Meyrdirk and Kauffman 2001; Meyer-dirk *et al.,* 2004). The papaya mealybug came into lime light when it causes havoc on agricultural and horticultural crops in Coimbatore during 2008, subsequently two years later papaya mealybug assumed major pest status, after attacking 1500 hectares of mulberry crop in Tripura, Tamil Nadu, leading to enormous financial losses to mulberry crop growers across the district (Muniappan *et al.,* 2008; Muniappa 2009). It has now spread widely over papaya growing areas of India (Mani *et al.,* 2012). Losses estimated up-to 60 per cent depending upon the crop (Selvaraj, 2012).

Nature of Damage: The mealybugs, initially colonize under surface of the papaya leaves along with the veins and later mealybugs will cover all over the fruits and making them unfit for marketing, the loss estimated in the range of 60-80%. Due to excessive growing and phytotoxic chemicals released by bugs during sap sucking it leads killing of younger plants, in addition, mealybugs known to produce excessive honey dew to attract ants, subsequently due to honey dew secretion by the mealybugs heavy sooty mould develops on the fruit and plant which make them unfit for marketing (Shylesha *et al.,* 2011; Selvaraj, 2012).

Management of Papaya Mealybug, *Paracoccus marignatus*

Biological Control: Papaya mealybug successfully controlled by imporataion three species of encyrtid parasitoids *Acerophagus papayae, Psuedleptomastix Mexicana* and *Angryrus loecki* from Puerto Rico where these parasitoids are known to supress the papaya mealybug. The credit of successful control of invasive papaya mealybug in India goes to NBAII where they took help from United States Department of Agriculture – Animal and Plant Health Inspection Services (USDA-APHIS), imported the above parasitoids and released in the mealybug infested fields,

after six months of release, mealybug population drastically decreased (Shylesha *et al.,* 2010; CR ballal, 2022).

Chemical control: Ants serves as carriers of mealubugs. So, have to locate the ant colonies and destroy them by drenching the chloropyriphos 20 EC @ 0.0ml/liter. To kill mealybugs, profenophos 50EC (2 ml/litre), chlorpyriphos 20 EC (2 ml/litre), buprofezin 25 EC (2 ml/litre), thiamethoxam 25 WG (0.6g/litre) are recommended (Tanwar *et al.*, 2010).

Cultural and Mechanical

- Regular monitoring and diagnosing early presence of the mealybug
- Pruning of infested branches
- Clean cultivation, removal and burning of crop residues
- Removal of alternate host or weeds such as *Hibiscusm Parthenium* nearby main crop field
- Avoiding the movement of planting materials from infested field
- Avoiding flood irrigation
- Sanitization of farm equipment's
- Application of sticky bands on arms of main stem to restrict the movement of crawlers. (Tanwar *et al.,* 2010)

Rugose spiralling whitefly, *Aleurodicus rugioperculatus* martin (Hemiptera: Aleyrodidae)

Rugose spiralling whitefly (RSW), *Aleurodicus rugioperculatus* Martin is an invasive pest, native to the Central America and known to feed on 120 host plants. In India, the first occurrence of RSW was reported during 2016 on coconut in Coimbatore district of Tamil Nadu, subsequently RSW spreads into coconut growing areas, and known to feed on 45 host plants. Nymphs and adults of RSW suck the sap aggressively on leaf sap, results in premature drying and leaf drop, during course of development also produces honey dew and wax which further leads to development of Sooty mould, which will mainly affect the economic returns of coconut farmers (Pradhan *et al.,* 2020; Elango *et al.,* 2022; Pradhan *et al.*, 2022).

Characteristic T shaped exit hole on the dorsal surface of the pupae to come outside, after emergence mate with opposite sex and deposit eggs on under surface of the coconut leaf, in addition, eggs will be laid in characteristic spiral manner, have incubation period of 6.9±0.88 days, and adult longevity varies from 22.7±3.48 days. There are four nymphal instars, first instar nymphs are highly active and mobile known as crawlers have function legs and antennae, once the crawlers find suitable niche, they will become sedentary and start sucking the plant juices from phloem tissues, in addition, also secrete wax, where the entire body will cover with copious quantity of waxy materials which subsequently restrict the entry of pesticides and gives pseudo immunity (Franscis *et al.*, 2016; Rao *et al.,* 2018; Elango K. 2019).

Management of Rugose Spiralling Whitefly

Biological control: Invasive RSW was known to parasitize by various parasitoids, where maximum percent of parasitisation was recorded from *Encarsia guadeloupae* (which was fortuitously got introduced from Lakshadweep during 1990's), conservation and augmentation of *E. guadeloupae* successfully reduced the RSW population (Elango, 2019; Saranya *et al.,* 2021; Ballal, 2022). Though *Encarsia guadeloupae* inhibit the development of RSW but there is a need for repeated mass multiplication and release of parasitoids, this cumbersomeness can be managed by using the entomopathogenic fungus *Isaria fumororosea.* The entomopathogen *Isaria fumororosea*used in green house and open field condition as mycoinsecticide to control whitefly. However, natural epizootics of this fungus was observed in Andhra Pradesh, further it's also known from several researches that fungus can be safely integrated with other predators and parasitoids (Pradhan *et al.,* 2020; Sumalatha *et al.,* 2020; Sandeep *et al.,* 2022).

Chemical control: Chemical spraying should be done when the population exceeds ETL, generally systemic insecticides should be applied by drenching/burying pellets/soil application/ trunk injection, to get quick knockdown effect contact insecticides can be applied to the foliage that will instantly kill the whiteflies (Mannion, 2010), Suggested chemicals are Dinotefuran 20 SG, thiamethoxam 25 WG, and Azadirachtin 10000 ppm found excellent for controlling RSW in field (Pradhan *et al.*, 2020).

Cultural and Mechanical Control:

- Removing the infested leaves
- Proper spacing according to recommendation
- Avoiding overuse of fertilizers
- Installation yellow sticky traps (@15/acre)

Fall armyworm, *Spodoptera frugiperda* (JE Smith, 1797) (Noctuidae: Lepidoptera)

The Fall armyworm (FAW), *Spodoptera frugiperda*(JE Smith, 1797) (Lepidoptera: Noctuidae) is a highly pestiferous, ravaging and polyphagous insect, which feeds approximately on 350 plant species, having high affinity towards plants belong to the family poaceae (Sharanabasappa *et al.,* 2018), where fall armyworm feeds on key food crops (e.g., maize, sorghum, rice, soybean) and fibre crops (e.g., cotton) leads to serious economic damage (Montezano *et al.,* 2018; Overton *et al.,* 2021) FAW native to tropical and subtropical areas of the America,it is also a strong seasonal migrator, transacting between North and South America (Rwomushana, 2019). Since its first observation in africa during 2016, had invaded many countries worldwide, including Southern Asia, and parts of Oceania, Southern Australia (EPPO 2020).

Biology and Nature of Damage: Under favourable environmental condition, the egg hatching (≈30°C) takes place in just two days (du Plessis *et al.,* 2020), generally larvae go through six

instars (Leiderman & Sauer 1953; Campos 1970; Escalante 1974; Ali *et al.*, 1990; Murúa *et al.*, 2004). However, number of instars vary from 5 to 10, depending on the suitable host plants, temperature and adverse conditions (Esperk *et al.*, 2007; Montezano *et al.*, 2019). Total larval duration varies from as short as 10 days at 32°C to as long as 30 days (<20°C) (Pitre & Hogg 1983; du Plessis *et al.*, 2020). Pupal duration varies from eight to nine days at optimal temperature, under unfavourable temperature it can extend even up-to 30 days. Altogether total life cycle is completed in about 30days under favourable environmental conditions ((28°C; 65% RH) and can extend up-to 90 days during lower temperature days. (Gergs and Baden, 2021). Fall armyworm lacks the diapause, however, its chill susceptible and therefore cannot survive during extreme lower temperature (du Plessis *et al.*, 2020). Fall armyworm used to lay batch wise eggs, once neonates hatch from the eggs used to feed gregariously leads to formation papery windows on leaf, after initial feeding the early instar larvae disperse via mechanism called ballooning. After dispersal each larvae occupies each plant, then started feeding from inside the whorls and cause extensive damage to leaf sheath by causing large holes accompanied by the large excreta, leads to loss of foliage, In addition, larvae also attack the cobs in later crop stage (Lungbill, 1928; Sparks, 1979; Shylesha *et al.*, 2018).

Larvae of Fall armyworm (Source: Firake *et al.*, 2019)

Management of FAW

Biological Control: For to manage invasive insect, biological control plays a key role. According to Akutse *et al.* (2019) Strains of *Metarhizium anisopliae* found to cause 87% egg mortality and *Beauveria bassiana* known to cause 100% mortality to the adult moths. Egg-larval parasitoid, *Chelonus insularis*is one of the major biological control agents used to parasitize the eggs of FAW, *Chelonu sinsularis*was found more competitive then *Trichogramma* and *Telonomus* wasps (Meagher *et al.*, 2016). In addition to *Chelonu sinsularis*, the larval parasitoid *Campoletis flavicincta* extensively used to supress larval population of FAW. Furthermore, Predatory earwig, *Doruluteipes* known to feed as many as 10-21 caterpillars per day (Reis *et al.*, 1988; Cruiz *et al.*, 2002; Matos-neto *et al.*, 2004). In addition, Sf MNPV combined with Spinosad will restrict the fall armyworm by 90% (Mendez *et al.*, 2002).

Cultural and Mechanical control: Cultural measures includes deep ploughing which will expose the FAW pupae to predators, intercropping of maize with pulse crops of concerned

region, erection of bird perches (10/acre), and timely sowing avoiding staggered sowings Destruction of egg masses by handpicking and immersing them in oil water/kerosene, application of surf powder/dry sand into the mid whorl to destroy the niche of caterpillar, using of pheromone traps to mass trap the male adults populations (@15/acre) (Firake *et al.,* 2019).

Push-Pull Technology: This technology involves the behavioural manipulation of insect pests as well as their natural enemies via the integration of stimuli that will repel the pest from protected crop (push), subsequently the trap crop sown on border will attract the repelled pest population (pull) (Cook *et al.,* 2007). Push pull pest management method in maize crop involves, intercropping with desmodium known to repel the FAW population, whereas planting of Brachiaria cv Mulato II attract FAW away from maize crop (Khan *et al.,* 2008; Kumela *et al*., 2019), by following Push-Pull strategy Mildega and his co-workers reduced FAW damage about 86.7% and increased maize yield up-to 2.7 times compared to monocropping maize (Midega *et al.,* 2018).

Chemical control: Initial spraying of NSKE 5%/ Azadiractin 1500 ppm to inhibit hatching of eggs, further to manage FAW larvae, its recommended to spray spineotoram 11.7% SC or Thiamethoxam 12.6%+Lambda cyhalothrin 9.5%. However, for late age caterpillar poison baiting is recommended with mixture of 10 kg rice bran + 2kg jaggery with 2-3 litres of water (Firake *et al.,* 2019).

Management of Sugarcane Wooly Aphid, *Ceratovacuna lanigera*

Biological Control:

- Conservation and augmentation of natural preadators viz, *Diapha aphidivora , Ishchiodon scutellaris, Episyrphusbaleatus, Chrysopa sp., Schymnus sp., Cheilomenes sexmaculata, Coccinella septempunctata, Synnonycha grandis*, *Brumus sp.* and *Dideopsisaegrota*
- Introduction of *Encarsia flavoscutellum*

Cultural control

- Planting of healthy canes
- Planting of Sugarcane sets in paired row
- Avoiding excessive usage of Nitrogenous fertilizers
- Proper rapping of canes all along the rows
- Destruction of infested tops

Chemical control

- Sets treatment with chlorpyripos 20 EC solution
- Application of Phorate granules 10 G @ 5kg/ac or spray with acephate 75 SP
- Recommended chemicals are Dimethoate 30 EC 1.7ml/lit, Oxydemeton methyl 25 EC 1.3 ml/lit

Table1: List of Invasive Insects to India

Sr. No.	Common Name	Scientific Name	Year of Introduction
1	Wooly apple aphid	*Eriosoma lanigerum*	1889
2	San Jose Scale	*Quadras pidiotus pernicious* (Comstock)	1911
3	Diamond back moth	*Plutella xylostella* (Linn.)	1914
4	Lantana Bug	*Orhezia insignis* Browne	1915
5	Cottony cushiony scale	*Icerya purchasi* Maskell	1921
6	Potato tuber moth	*Phthorimaea operculella* (Zeller)	1937
7	Pine woolly aphid	*Pineus pini* (Macquart)	1970
8	Subabul psyllid	*Heteropsylla cubana*Crawford	1988
9	Serpentine leaf miner	*Liriomyza trifoli*(Burgess)	1990
10	Coffee berry borer	*Hypothenemus hampei* (Ferrrari)	1990
11	Spiraling whitefly	*Aleurodicus disperses* Russell	1993
12	Coconut eriophid mite	*Aceria gurreonis*Keifer	1997
13	Silver leaf whitefly	*Bemisia argentifolii* Bellows	1999
14	Sapota seed borer	*Trymaltis margarias*	2001
15	Papaya mealy bug	*Paracoccus marginatus* Wiliams and Granara de Willink	2005
16	Erythrina gall wasp	*Qudrastichs erythrinae* Kim	2005
	Lotus lily midge	*Stenochironomus nelumbus*	2005
17	Blue gum chalcid	*Leptocybeinvasa* Fisher and La Salle	2006
18	Cotton mealy bug	*Phenococcus solenopsis*Tinsley	2006
19	Madeira mealy bug	*Phenococcus madeirensis*	2012
20	South American tomato leaf miner	*Tuta absoluta* Meyrick	2014
21	Western flower thrips	*Frankliniella occidentalis*	2016
22	Coconut rugose whitefly	*Aleurodicus rugioperculatus*	2017
23	Brown peach aphid	*Pterochloroides persicae*	2018
24	Fall armyworm	*Spodoptera frugiperda* (J.E. Smith)	2018
25	Bondar's Nesting whitefly	*Paralerodes bondari*	2019
26	Nesting whitefly	*Paralerodes mini Laccarino*	2019
27	Palm infesting whitefly	*Aleurotrachetus atratus*Hempel	2019
28	Casava Mealy bug	*Phenococcus manihoti*	2021
29	Thrips	*Thrips parvispinus*(Karny)	2022

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INSECT PESTS OF MEDICAL IMPORTANCE AND THEIR MANAGEMENT

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Background:

Arthropods are visible to us in various ways throughout our daily lives. Some people view them as beautiful flyers, singers, pollinators, sources of food and natural indicators while others view them as pests, annoyances, allergens and pathogen vectors. Arthropods have a role in the spread of parasitic and pathogenic illnesses that harm both plants and animals. The eradication or control of vector insect populations remains a key component of many of these illnesses' effective control efforts. In this article, we'll talk about insects from the perspective of vital animals in medicine. Some insects are the cause of health problems in both humans and animals, either directly or indirectly. Therefore, the fields of veterinary medicine and medical entomology take centre stage. When it comes to public health, veterinary entomology is crucial since many animal diseases have the ability to "jump species" and endanger human health. Bovine encephalitis is one such disease, and insects have the potential to transmit it (Bouzalas *et al*., 2014). Arthropod concerns include ruining food and other materials due to their feeding habits, causing annoyance and perhaps being implicated in the transmission of infectious organisms because to their widespread occurrence in domestic situations. Others prey on household furnishings and building framework, making them unsafe or unsound. In addition, a huge variety of arthropods make vertebrates sick. Intoxication can be caused directly by bites, stings, or defence secretions or indirectly by hypersensitivity (allergy). The ongoing conflict between man and insects is brought about by the simultaneous needs of certain insect species and human beings. The insects feed on if they desire them. They draw blood from our domestic animals' veins. We won't be able to completely keep them out of our homes if they decide to make us their home. In truth, we are powerless to defend ourselves against their annoyance and pestilence. Thus, the conflict between people and insects has persisted, and if humans are to survive, they must first subdue the insects.

Introduction:

A subfield of entomology called medical entomology studies how arthropods affect human health and that of vertebrate animals. In other words, it is the branch of research that deals specifically with the vectors that have an impact on both human and animal health. Many vectorborne diseases, including dengue, malaria, diarrhoea, leishmaniasis, and many more, have spread as a result of incorrect and ineffective management of insect vectors. Insect vectors, such as mosquitoes, houseflies, sandflies, cockroaches, tsetse fly, blowflies, human louse, black flies,

horse flies, stable flies, fleas, bedbugs, triatomid bugs, urticating lepidoptera, and many others, spread many infectious illnesses that pose a hazard to public health. The majority of diseases in tropical nations are presumably transmitted by insects. More than one million people die each year from hematophagous insects, which are the primary carriers of numerous diseases like the Zika virus, dengue, malaria, and yellow fever (Van der Goes and Carlson, 2006; Draupeau *et at.*, 2009). Knowing the behaviours of the insect vectors and how they spread disease is crucial. Without some understanding of entomology, and more specifically, medical entomology, it is challenging to apply insect control strategies. In light of this, this course focuses on the study of arthropods (particularly insects) that are significant for public health. Even the average person is aware of the dangers that insects pose to human health, in addition to zoologists and medical professionals. The issue is particularly serious when unexpected disease outbreaks, which insects are directly responsible for, occur.

Health effects caused by insects

Arthropods have a variety of effects on human health and comfort. The least dangerous of these is probably the widespread fear of insects (entomophobia). These situations can be greatly improved by having a thorough understanding of the appearance of hazardous, useful, and harmless arthropods. Arthropods have been linked to the following negative impacts on health:

Arthropods prey on people, domestic animals, and wild animals.

- They nip at you and draw blood.
- They inject toxins into both humans and animals and spread contagious germs
- They infest both people and animals with dipteran larva, a condition known as myiasis.
- Irritate and annoy both humans and animals.
- They envenomize people through their bite, sting, spines, or secretions. Swelling, pain, redness, rash, fever, allergic reactions, blood poisoning, and even death are possible side effects of envenomation.
- Arthropods parasitize people, animals, and plants. Examples include louse, ticks, and aphids on animals and plants, respectively.
- Accidentally injure sensory organs when they enter the mouth, nose, ears, or eyes.
- They elicit allergic and asthmatic reactions because to their smell, secretions, and bits of dead bodies.
- Crop adulteration, caused by arthropods' excretions of fecula, dead bodies, eggshells, urine, or germs, is another impact.
- Entomophobia (fear of insects) is caused by arthropods, which can result in anxiety disorders, hysteria, hallucinations, etc.

Insect as a transmission agent

Mechanical disease transmission: Arthropods physically transport disease agents from one host to another by means of their body components (example wings, hairs, feces, etc). No changes to the organism's number, form, or developmental stages occur during the transmission of this sort of sickness; instead, the disease is only deposited in the host's body, food, or beverage.

Biological disease transmission: Before infecting the host, the agent may cause changes in the arthropod's morphology or number of developmental stages (Sarwar, 2015). This comprises propagative, cyclodevelopmental, and cyclopropagative transmissions as well as hereditary (transovarian) and transital transmissions.

Trans ovarian/ Trans-stadial transmission: It is a form of disease transmission in which the pathogen-carrying adult insects and/or other arthropods transmit the disease-causing agent to the immature stage (often the egg). The contaminated egg becomes infectious or is capable of spreading the disease to humans and other animals once it has reached the end of its embryonic stage. Arthropods that display hereditary disease transmission include sand flies.

- Propagative: Only more pathogens are present and the developmental stage is constant in a propagative kind of disease transmission. Typical examples of the propagative type of disease spread are the plague and typhus.
- Cyclo-developmental: In this type of disease transmission, only the disease pathogen's developmental stage (or form) is altered (from small to giant, immature to matured stage, etc.), but the pathogenic organisms themselves do not vary in quantity. Example Filariasis
- Cyclo-propagative disease transmission combines propagative and cyclo-developmental disease transmission, in which the disease pathogen undergoes changes in both its quantity and its developmental form (stage).

Insect pest of medical importance

Numerous insects and other arthropods have an impact on human health. Members of the orders Diptera, Hemiptera, Thysanoptera, Phthiraptera, and Siphonaptera are among these arthropods. They have the ability to infect humans with disease, bite, sting, and/or parasitize them.

1. House fly

Scientific name: *Musca domestica*

Family: Muscidae; Order: Diptera

Distribution: Worldwide

House flies come in roughly 60 different species. The housefly is a significant pest of cattle, poultry, and urban areas. It spreads a wide range of microorganisms, including viruses, bacteria, and protozoans (Malik *et al.*, 2007). The most significant breeding grounds for houseflies, a repository of pathogens, can be found in open sewers, cesspools, and cesspits that

have accumulated piles of animal waste, trash, sewage sludge, and solid organic waste. Microorganisms that adhere to a fly's outer surfaces may only last a few hours, but those that are consumed with food may remain in the fly's crop or gut for several days. When these flies come into contact with people or food, transmission occurs. These infections are spread by contact with their body surface, excrement, extra saliva from the mouth, and mouthparts (Kobayashi *et al.*, 1999).

On their feet and mouthparts, house flies can carry the pathogens that cause cholera (*Vibrio comma*), typhoid fever (*Eberthella typhosa*), and dysentery (*Shigella dysenteriae*). House flies can also transmit rickettsiae of Q fever (*Coxiella burnetii*), viruses of polio, coxsackie, and infectious hepatitis, bacteria like cholera (*Vibrio cholerae*), anthrax, *Campylobacter, Shigella, Salmonella, Escherichia coli*, *Staphylococcus aureus,* and yaws' spirochaetes (House flies are also capable of carrying the eggs of a number of helminths, including *Taenia, Ancylostoma, Dipylidium, Diphyllobothrium, Enterobius, Trichuris* and *Ascaris*. Eye-worms (*Thelazia* species) are relatively uncommon eye diseases that are biologically spread by *Musca* species. Excreta from flies have also been shown to contain pathogenic fungi, such as *Microsporum canis*, which causes 'tinea capitis' in humans. In addition to these illnesses, houseflies can spread anthrax, salmonellosis, tuberculosis, and several types of ophthalmia. They spread the eggs of some parasitic worms, such as roundworms, and carry over 100 diseases (Sarwar, 2015).

Management

Covering doors and entrances with plastic screening with a mesh size of 3–4 strands per centimetre will stop flies from entering buildings (2-3 openings per centimetre). Environmental sanitation standards provide for eliminating their breeding grounds, such as timely rubbish disposal and covering dustbins. House fly population control can be achieved physically with tools like fly swatters, sticky tapes, light traps, and grids that conduct electricity. Fly development was entirely prevented when azadirachtin was administered at a rate of 0.03 mg/kg of body weight per day or when ground neem seeds were supplied at a rate of 10 mg seed/kg of body weight. *Entomophora muscae*, *Metarhizium anisopliae* and *Beauveria bassiana* are common entomopathogenic fungi used for various fly control formulations. *B. thuringiensis kurstaki* H3a3b3c was shown to be extremely harmful for house fly larvae, as evidenced by the 50–80% mortality rate it caused (Malik *et al.*, 2007). Effective predators of house fly larvae include the flies *Hydrotaea aenescens* and *Ophyra capensis* (Betke *et al.*, 1989). Insect development inhibitors like diflubenzuron and cyromazine as well as larvicides such emulsions of fenchlorphos, coumaphos, fenitrothion, or fenthion in breeding areas will lower the population of house flies. For use inside, adulticides like permethrin, cypermethrin, and deltamethrin can be applied or sprayed in aerosol form at a rate of 1% naled, 2% primiphos-methyl, 0.1 to 0.5% fenchlorphos, and 0.1% pyrethroids.

2. Mosquito

Scientific name: *Aedes aegypti* (yellow fever mosquito), *Aedes albopictus* (Asian tiger mosquito), *Aedes vexans* (inland floodwater mosquito), *Anopheles freeborni* (malaria mosquito), *C. quinquefasciatus* (southern house mosquito), *Culex tarsalis* (western encephalitis mosquito), *Psorophora columbiae* (dark ricefield mosquito)

Family: Culicidae; Order: Diptera

Distribution: They have worldwide distribution. The only areas where they have not been reported are Antartica and a few islands.

There are about 3000 mosquito species in the globe, and more than 100 of them spread diseases to people (Murugan *et al.,* 2015). Every mosquito is considered a pesky biting insect. One of the most significant insect pests that negatively impacts human and domestic animal health and welfare on a global scale are mosquitoes. Female mosquitoes must consume blood in order to produce eggs, and they bite you hurt as they do so. They have the ability to spread a variety of disease-causing pathogens to people and other animals when feeding. Important vectors include the genera *Anopheles, Culex, Aedes, Psorophora, Haemagogus* and *Sabethes*. The *Anopheles* species spreads arboviruses, human filarial parasites *Brugia malayi* and *B. timori* (Partono *et al.,* 1973), as well as malaria, filariasis or elephantiasis (*Wuchereria hancrofti*) and other diseases. Some *Culex* species spread *W. bancrofti* as well as a number of arboviruses, or viruses carried by arthropods. Some *Mansonia* species transmit *B. malayi,* occasionally *W. bancrofti* and a few arboviruses, and certain *Aedes* species transmit yellow fever, dengue, encephalitis, microcephaly, and many other arboviruses. In a few restricted regions, they are also vectors of *W. bancrofti* and *B. malayi*. Certain infections are linked to the vectoring of particular mosquito species. Malaria and dengue are the two most serious infectious diseases spread by mosquitoes; each year, dengue affects over 390 million people (Bhatt *et al.,* 2013). In places where disease is endemic, mosquitoes cause significant economic burden and act as vectors for a wide range of human and veterinary infections and parasites. They can cause significant morbidity and mortality (Pavela, 2015).

Management:

The three major methods for limiting their population growth are: (1) using pesticides to eradicate adult mosquito species; (2) reducing adult populations by interfering with fertility and oviposition; or (3) killing mosquito larvae (Pavela, 2015). Mosquito nets with 9 to 10 meshes offer protection from mosquitoes that bite at night. Reducing storage space, restricting mosquito oviposition entry points in septic tanks, soak-away pits, draining mosquito breeding grounds, etc. can reduce their population. A trap named "ovillanta," created by researchers from Canada and Mexico, uses old tyres with lures to draw mosquitoes. The larvivorous fish *Gambusia affinis*, also known as the top minnow or mosquito fish, which has two subspecies, the South African

guppy *Poecilia reticulata* and the western mosquito fish *G. affinis affinis*, has been observed to effectively consume mosquito larvae. The later one may also withstand organic pollutants. It is also observed that the container breeding mosquitos are predated by the predaceous larvae of *Toxorhynchites* sp. Natural mosquito pathogens observed are *Culicinomyces clavosporus* and *Tolypocladium cylindrosporum* (Russell *et al*., 1979; Soares *et al.*, 1979). Few entomopathogens belong to the class Oomycotes. The most significant of these is *Lagenidium giganteum,* a mosquito-borne disease (Glenn & Chapman, 1978). In the aquatic environment, *Leptolegnia* sp. is a facultative parasite of mosquitoes, chironomids, and various other Diptera (Seymour, 1976). It has been known to be extremely pathogenic for *Culex, Aedes, Anopheles, Culiseta, Psorophora*, and *Uranotaenia* early instar larvae (Sweeney, 1981). These infect mosquito larvae by adhering to and penetrating the cuticle, or occasionally by entering through the mouth (Mclnnis, 1975). Mosquitoes are found to be killed by Coelomomyces species which has thick-walled, resistant sporangia, which are a member of the *Coelomyces* genus. Some of the naturally pathogenic mosquito species are *Culicinomyces clavosporus* and *Tolypocladium cylindrosporum* (Russell *et al.,* 1979; Soares *et al.,* 1979). Mosquito larvae are adversely affected by fungus-derived secondary metabolites of *Aspergillus* sp, *Fusarium sporotrichoides, Penicillium verrucosum, Aspergillus terreus, Fusarium oxysporum, Lagenidium giganteum* and *Chrysosporium*.

The importance of EOs suited for use as active components in botanical larvicides has increased in recent years (Pavoni *et al.,* 2019). *Romanomermis culicivorax*, a parasitic worm, is a promising biocontrol agent. Additionally helpful is the bacteria *Bacillus thuringiensis israelensis* (Bti). *Anopheles stephensi, Aedes aegypti* and *Culex quinquefasciatus* three species of vector mosquitoes, have all been shown to be susceptible to *P. fluorescens'* showing deadly effects on their larvae and pupae. Oils suffocate or poison mosquito larvae in order to kill them. Insect repellents including ethylhexanediol, cyclohexamethylene carbamide, and diethyltoulamide (DEET), as well as electrically powered vapourisers with insecticides like DEET or dimethylphthalate (DIMP), are advised for use to defend against mosquito bites. In genetic control, releasing healthy, sterile male mosquitoes mass-produced in laboratories into the wild allows them to mate with females in competition with naturally fertile males, leading to a significant number of infertile inseminations. Such females will lay infertile eggs that will not hatch, reducing or eliminating the vector as a result. The other genetic control techniques involves translocation, cytoplasmic incompatibility, insertion of deadly genes or genes that render mosquitoes incapable of serving as a vector and meiotic drive that results in the creation of an more number of males.

3. Sandflies

Scientific name: *Phlebotomus* spp, *Culicoides milnei, C. inornatipennis, C. grahamii, C. furens, Mansonella perstans*

Family: Ceratopogonidae; Order: Diptera

Distribution: worldwide.

About 30 species of sandflies from the genus *Phlebotomus* have been identified as major disease vectors (Desjeux 2004). Leishmaniasis is linked to a group of illnesses that have a wide range of clinical and epidemiological characteristics (common name Kala-azar). 88 nations have an endemic form of the vector-borne illness leishmaniasis (Desjeux 1996). It may manifest as cutaneous or visceral leishmaniasis. In addition to Leishmaniasis, *Phlebotomus* spp. also transmit numerous bacteria and viruses that result in a variety of disease outbreaks in people. These include Bartonellosis (Carrion disease) (Birtles, 2001), the phlebovirus, which contains nine viral species (Sandfly fever Naples, Salehabad, Rift valley fever, Uukuniemi, Bujaru, Candiru, Chilibre, Frijoles, Punta Toro), Toscana virus, Sicilian virus, vesiculovirus, Naples virus, sandfly fever, Chandipura encephalitis and orbivirus stomatitis (Depaquit *et al.,* 2010; Reddy, 2013; Maroli *et al.,* 2013). When female sandflies consume a blood meal, virus transmission to people and animals takes place. The sandfly serves as the main reservoir host for the viruses, allowing them to multiply and spread from thm to vertebrate hosts (Alkan *et al.,* 2013).

Management:

The population can be effectively controlled by residual treatment of the walls of residential buildings and/or animal shelters, fogging, or ULV treatments of malathion in the breeding locations (forests and habitat regions close to residential areas). The bacteria *Bacillus thuringiensis* var. *israelensis* can infect sandfly larvae. The use of ITNs (Insecticides treated nets) may be the most long-lasting method of reducing intradomiciliary transmission of Leishmania because they act as "baited traps" in which sandflies attracted by exhaled CO_2 and host odour die after landing on treated surfaces. ITNs do not emit repellent vapour (Elnaem *et al.,* 1999). Neem oil applied topically at a concentration of 2% provided 7–10 hours of 86–97% control. (Dhiman & Sharma, 1994). DEPA (N,N-diethylphenyl acetamide) is a commercially marketed insect repellent. applications for pyrethroids is recommented and the two compounds most frequently used are cypermethrin (125 mg a.i./m2) and deltamethrin (25 mg/m2).

4. Tsetse fly

Scientific name: *Glossina fuscipes, G. morsitans, G. pallidipes, G. swynnertoni, G. tachinoides* and *G. palpalis*

Family: Glossinidae, Trypanosomatidae; Order: Diptera

Distribution: worldwide

Due to their significance in the transmission of the African trypanosomes *Trypanosoma brucei gambiense* and *T. brucei rhodesiense,* which cause Gambian sleeping sickness and Rhodesian sleeping sickness, respectively, the *Glossina* sp. have significant medical and economic significance. The vectors, *G. morsitans, G. swynnertoni,* and *G. pallidipes,* prefer domestic livestock, particularly bovids, to humans. The disease ia a zoonosis.

Management:

The population control is brought about by the use of insecticides alone (using various deployment techniques as aerial spraying or ground spraying), in combination with baits or traps, or both (Allsopp and Hursey, 2004). Tsetse flies can be drawn into a trap by placing blue or black traps with attractants like cow urine. Tsetse flies are controlled by insecticidal control, which involves spraying residual chemicals on the ground and dispersing insecticides over large areas from aircraft (Allsopp, 2001). Successful attempts at disease eradication utilising the "sterile insect method" (SIT) have led to the total eradication of illness from farming communities.

5. Blowflies

Scientific name: *Cordylobia anthropophaga, Chrysomyia albiceps, C. chloropyga, C. putoria, C. rufifacies, C. bezziana, Cochliomyia macellaria, C. horninivorax, Lucilia sericata, L. cuprina*

Family: Calliphoridae; Order: Diptera

Distribution: worldwide

Fly eggs are laid at the wound regions and genital orifices when they are attracted to unhygienic discharges. The egg will hatch and cause myiasis in the injured area. Myiasis is an infestation of live people and vertebrate animals by dipterous larvae that pupate after feeding on the hosts' living tissue or liquid bodily fluids (Erzinclioglu 1987). Both mandatory and facultative myiasis are possible. Almost any area of the body develops boil-like swellings that are painful, inflamed, even hard, and ooze serous fluids. Normally, 1 or 2 larvae infest a patient, however up to 60 larvae have been found in several lesions on the same patient.

Management:

Effective management practices include cleaning wounded or unhygienic areas, spraying them with organophosphate or carbamate every 7 to 10 days, and spraying the surrounding walls and fences every two weeks. Reducing the accumulation of potential breeding sites for blow flies, such as household garbage, trash cans, trash dumps, dustbins, waste from slaughterhouses, and waste from meat packing industries, are other examples. Larvae can be removed by irrigating affected areas with 5 to 15% ethanol or choroform. In order to expose the firmly embedded larvae, surgery might be required.

6. Black flies

Scientific name: *Simulium damnosum, S. amazonicum, S. achraceum, S. metallicum, S. exiguum*

Family: Simulidae; Order: Diptera

Distribution: worldwide

There are around 2200 species of black flies (family: Simuliidae) distributed among 24 genera worldwide. (Adler and Crosskey, 2018). Among them, only four genera viz. *Simulium*, *Prosimulium*, *Austrosimulium* and *Cnephia* bite humans. (Adler et al. 2019).

They spread serious illnesses such as bovine onchocerciasis, mansonellosis, avian leucocytozoonosis, river blindness, and a number of arboviruses, which cause severe human suffering and economic harm. (Adler and McCreadie 1997; Adler et al. 2010). Black flies' biting and annoyance issues have had negative effects on most outdoor activities. Bite marks on the legs can make it difficult to move and bites around the eyes can cause swelling that impairs vision. In regions like the northeastern United States, a general syndrome that is also known as black fly fever is prevalent. Black flies have also been linked to mechanical transmission of the bacterial cause of tularemia, the Eastern and Venezuelan equine encephalitis viruses, the endemic pemphigus foliaceus or fogo selvage, the thrombocytopenic purpura disorder that causes a low platelet count, and the nodding syndrome, which causes epileptic seizures in children. By leaving behind numerous itchy skin sores, black flies in the Marquesas Islands have been linked to the indirect transfer of the Hepatitis B virus. (Chanteau *et al.*, 1993).

Management:

The use of head nets with fine mesh reduces fly attack. Using the entomopathogenic bacterium *Bacillus thuringiensis* var. *israelensis* (Bti, serotype H14), black flies are predominantly controlled worldwide (Gray *et al.*, 1999). Commonly seen parasites include mermithid nematodes, microsporidia, the chytrid fungus *Coelomycidium simulii*, and many viruses including iridescent virus and cytoplasmic polyhedrosis virus. Humans generally employ natural and manmade repellents for personal protection. The insect repellents that include the active component N, N-diethyl-meta-toluamide (DEET) are the most effective. Typically, DDT or permethrin compounds were used to fog the air and the ground. The use of pesticides and repellents is the mainstay of current management strategies for black flies in the adult stage.

7. Cockroaches

Scientific name: *Periplaneta americana* (American cockroach), *Blatella germanica* (German cockroach), *Blatta orientalis* (Oriental cockroach). *P. australasiae* (Australian cockroach), and *Supella longipalpa* (brown-banded cockroach).

Family: Blattidae; Order: Blattodea

Distribution: Worldwide

There are roughly 4000 kinds of cockroaches, and 30 of those are connected to homes. These loathsome insects are significant food contaminants. Microorganisms such harmful bacteria, viruses, fungi, protozoa, and helminthes are transmitted by cockroaches. They are

mechanical transmitters of infections and spread microorganisms due to their unhygienic living habits, which include regurgitating and excreting their partially digested meals over human food if it is left out uncovered. Pathogens that they carry could persist on the cuticle, in the digestive tract, and on the faces of the insects, making them potential chronic carriers. They are carriers of pathogenic organisms such as poliomyelitis-causing viruses, protozoans causing amebiasis, *Giardia lamblia*, *Pentatrichomonas hominis* and *Shigella dysenteriae,* as well as bacteria like the bubonic plague (*Yersenia pestis*), gastric infections (*Escherichia coli*), abscesses (*Staphylococcus aureus*), *Klebsiella pneumonia* (Naeem *et al.,* 2014). The acanthocephalid *Moniliformis moniliformis*, which is widespread in rodents, can also infect cats, dogs, and very infrequently humans, is known to infect cockroaches as intermediate hosts. Cockroaches also carry nematodes such *Gonglyonema pulchrum*, a common parasite of herbivores and sporadically of humans and *Enterobius vermicularis*, a common human pinworm or threadworm. They have been reported to carry the parasite *Toxoplasma gondii*, which they may pass on to cats and possibly humans by consuming cat faeces. However, it can be challenging to evaluate their role as vectors because many of the illnesses that cockroaches carry can be spread in a variety of other ways. By ingesting cockroach-contaminated food or inhaling their dry faecal pellets, many people get allergy reactions.

Management:

The contamination can be decreased by not leaving food or soiled kitchen utensils out overnight in the kitchen and nearby places. In order to flush out and kill cockroaches, insecticidal spraying or dusting of synthetic pyrethroids like permethrin, cypermethrin, and deltamethrin used as sprays or more efficiently as aerosols in the hiding places of cockroaches is helpful. Insecticidal activity from a combination of a pyrethroid and an organophosphate or carbamate pesticide lasts for a long time. It lasts months to paint the walls and other surfaces with varnishes or paint that contains residual insecticides like 1% cypermethrin, 0.5% alphacypermethrin, or 2% diazinon. Pesticide with 1 or 2% organophosphate or carbamate is used as cockroach bait. Another helpful device is a pheromone trap with an attractant. The contact pesticide and stomach toxin known as borax (borax) is still safe to use (Cochran, 1982; Schal and Hamilton, 1990; Ambrose, 2007).

8. Flea

Scientific name: *Pulex irritans* (Human flea), *Xenopsylla cheopis* (rat flea), *Ctenocephalides canis* (dog flea), *Tunga penetrans* (jigger flea), *Echidnophaga gallinacea* (sticktight flea) (Azad, 1990 and Ambrose, 2007).

Family: Pulicidae; Order: Siphonaptera

Distribution: Worldwide, Despite having a global distribution, several genera only occur in certain regions. For instance, the *Xenopsylla* species, which are thought to be plague vectors, are restricted to the tropics and warmer parts of temperate countries.

Even though there are over 2500 species of fleas (Siphonaptera) in 239 genera, only a small number of them are significant human pests. The remaining 6% parasitize birds whereas 94% of species bite mammals. Human blood is sucked by fleas, which helps diseases spread among people. They are all transient, blood-sucking ectoparasites, primarily of mammals, but some will also feed on birds. A very small percentage will attack people. Beyond irritating, fleas are important to human health because they can spread illness. Fleas spread endemic or murine typhus as well as the plague (bubonic type). Several species of tape worm can infect humans after using the flea as an intermediate host, but this is uncommon. Cat fleas can spread bacteria that cause bartonella, murine typhus, tapeworm infections, and other diseases from animals to people. Oriental/tropical rat fleas, or *Xenopsylla cheopis*, are rodent parasites and the main carriers of murine typhus and the plague. Despite its common name, the human flea (and the closely related, more widespread species *P. simulans*) can attack and infest many different mammals and birds. It can also switch between any of these hosts. On bitten by flea, the skin will develop red, swollen, inflamed welts, along with irritation and edoema. Individual reactions differ, and more sensitive people may experience more severe reactions. Rat fleas and other fleas are the carriers of endemic typhus and the plague (*Yersinia pestis*). Certain cestodes, including *Dipylidium caninum*, *Hymenolepis nana*, and *H. diminuta*, are intermediate hosts of fleas, including the dog flea, rat flea, and *X. cheopis*. The fleas may also transmit the disease tularemia (*Pasteurella tularensis*), which is caused when the chigoe or jigger flea burrows into a person's feet (Gratz and Brown, 1983; Azad, 1990; Ambrose, 2007).

Management:

Fenthion can be formulated as a "spot solutions" and applied on a particular area of the skin. The skin absorbs insecticide and it reaches the blood and the blood feeding fleas ingest the insecticide and protect the animals for about a month. Since, most of the fleas are found a way from the host it is essential to treat dwellings of hosts with insecticidal powder or sprays with 0.5% HCH, 2% malathion, 0.5%, diazinon and 2% dichlorvos (DDVP) to kill adults and larvae of fleas. The nontoxic growth regulators e.g. methoprene that interferes with the development of integument of flea are found useful. They are formulated as tablets or syrups and administered to cats and dogs orally. Insecticidal aerosols or fogs and insecticidal bombs are also used. To control urban outbreaks of plague or murine typhus not only the fleas but also the rodents must be managed. Additionally, insecticidal sprays, fogs, and bombs are employed. Not only the fleas, but also the rodents, need to be managed if urban plague or murine typhus outbreaks are to be stopped. Anticoagulants like warfarin and femarin, as well as fast-acting "one dose" rodenticides

like zinc phosphide, sodium fluroacetate, or strychnine, as well as more recent fast-acting anticoagulants like bromadiolone and chlorophacinone, can all be used to kill rodents. Rodenticides must be used first, followed by the application of insecticides. If not, fleas will continue to bite humans and other creatures, killing them and possibly leading to a greater spread of disease. Personal flea prevention may be provided by insecticidal repellents such dimethylophthalate (DIMP), diethyltoulamide (DEET), or benzylbenzoate, as well as certain citrus oils like Oil of Citronella (Brown and Hebert, 1997).

9. Bed bug

Scientific name: *Cimex lectularius* (common bed bug), *C. hemipterus* (tropical bed bug), *Leptocimex boueti*

Family: Cimicidae; Order: Hemiptera

Distribution: *Cimex lectularius* is widely distributed in tropical and non-tropical countries whereas *C. hemipterus* is predominant in tropical countries and *Leptocimex boueti* found in West Africa.

Except for the eggs, bed bugs eat exclusively on blood. Their primary hosts are people, though they may also eat birds and domesticated animals as food. They penetrate the skin of the host with their proboscis, which resembles a needle, and extract blood (Delaunay *et al.*, 2011). Even though they are not thought of as vectors, bed bugs can spread the hepatitis B virus through their bites on humans. They have reportedly been linked to iron deficiency in babies in India. Numerous health issues, such as skin rashes, psychological consequences, and allergy reactions, can be brought on by bed bugs. The medical term for bed bug bites is "cimicosis," which can present with varying degrees of severity, ranging from no symptoms to small, indistinct red macular lesions that are less than 5 mm in diameter (Goddard and de Shazo R, 2009), which may later progress into large circular or ovoid wheals (Criado and Criado, 2011), which are typically described as papular urticaria and can be as big as 2 to 6 cm in diameter. Heavy infestations can lead to anaemia in children and the elderly, and repeated bites typically result in more severe reactions. Scratching insect bites might result in secondary illnesses. Although bed bugs can carry a variety of infections on and inside of them, under typical living circumstances, they have not been shown to be effective pathogen vectors.

Management:

The pest must be positively identified, the site must be examined to establish which areas need to be treated, non-chemical control methods must be used, insecticides must be applied, the effectiveness of the treatment programme must be assessed, and risk management protocols must be followed. Cleaning and drying items eliminates bed bugs. Furniture can be painted or varnished to lower the risk of bed bugs. Utilizing a vacuum cleaner or a canister steamer can be beneficial. Bed bug traps, especially those of the "pit-fall" variety, have been utilised in research

programmes for population monitoring for a long time. Another tool, the ClimbUp Insect Interceptor, serves as a bed bug deterrent and a monitoring tool (Wang et al., 2009Spraying emulsions of DDT 5%, HCH 0.5%, malathion 1 to 2%, diazinon 0.5%, dichlorvos (DDVP) 0.5%, carbaryl (Sevin) 1%, or propoxur (Baygon) 1% on bedding, clothing, and walls prevents infestation. Bed bugs are killed with the addition of 0.1 to 0.2% pyrethrins or synthetic pyrethroids, such as deltamethrin, permethrin, cypermethrin, or bioresmethrin, to sprays. The most popular silicate product in the world is diatomaceous earth dust, which is also available in aerosol and dust forms (DED). (St. Aubin F. 1991)

10. Kissing bug

Scientific name: *Triatoma infestans, T. dimidiata, T. brasiliensis, T. sordida, Triatoma rubida, T. protracta, T. gerstaeckeri, Rhodnius prolixus, Trypanosoma cruzi* and *Panstrongylus megistus*.

Family: Reduvidae; Order: Hemiptera

Distribution: Worldwide

There are 118 species and 14 genera of the haematophagous reduviids, sometimes known as kissing bugs or cone-nose bugs, which are members of the subfamily Triatominae. *Triatoma* and *Rhodnius* are two genera that are frequently found in other genera. The majority of the assassin bug species that are naturally infected with Chagas' illness belong to the genus *Triatoma*. However, the illness can spread to people by rubbing the protozoan organism in *Triatoma* faeces through the skin by scratching. The bugs are not efficient vectors since they do not directly inject the disease into the blood of their hosts during a bite. In most cases, they suck blood from the exposed areas of sleeping people at night without waking the host. Although almost harmless, their bite can occasionally be uncomfortable and have long-lasting repercussions. Triatomines frequently faeces during or right after eating, and this behaviour is crucial in the spread of the Chagas disease.

This order's subgroups could act as human and animal vectors (e.g. chagas disease or trypanosomiasis is transmitted by the bite of kissing bug through armadillos). In addition to biting individuals and causing them to lose blood, triatomines also spread *T. cruzi,* the parasite that causes Chagas disease or South American trypanosomiasis. (Panzera *et al.,* 2004) The parasite grows entirely in the bug's gut after being consumed with bloodmeal from the host. People become infected with the parasite when they come into touch with the excreta in abrasions, bug bite areas, or mucous membranes. (Pérez-Molina and Molina, 2018). For instance, when an insect bite causes localised discomfort and the person scratches, the infection is made easier. The only way the insect transmits is by its faeces, not through a bite. (Klotz *et al.,* 2014).Chagas disease is a zoonotic disease. Some animals catch an infection by eating the bugs or eating sick animals in addition to through the faeces.

Management:

The best way to get rid of bugs is to patch up gaps and crevices in the walls with plaster and replace mud-walled, thatched-roof homes with ones constructed of bricks or cement blocks, corrugated metal roofs, or concrete roofs. Once in two years, spraying of synthetic pyrethroids deltamethrin or lambdacyhalothrin (Icon) @ 0.25 to 0.5 g/m² and permethrin or cypermethrin @ 1 to 2 g/m² is effective in control. For homes that can be painted inside with slow-release emulsion paints containing insecticides like malathion are suitable. They are effective for more than two years. Insecticide-laced smoke bombs like dichlorvos (DDVP) or fenitrothion can also be useful for cleaning out homes of pests. Aerosol canisters, pyrethrin coils that must be burned to produce vapour, pyrethrin pastilles that must be heated on a special heating mat to produce insecticidal vapour, poison bait, and microencapsulation are some of the specific pyrethroid formulations utilised for public use in Argentina (Zerba,E, 1988).

11. Lice

Scientific name: *Pthirus pubis* (pubic or crab louse), *Pediculus humanus humanus* (body louse), *Pediculus humanus capitis* (head louse).

Family: Pediculidae; Order: Psocodea

Distribution: Cosmopolitan in distribution but common in temperate countries.

Among more than 3000 species of lice, only two species prefer humans as their host viz. *Pediculus humanus* and *Phthirus pubis*. Under *P. humanus* there are two morphotypes, *P. humanus* morphotype *capitis* (head lice) and *P. humanus* morphotype *corporis* (body lice) (Badiaga and Brouqui et al., 2012). They are ectoparasites that feed multiple times a day only on human blood.

Louse-borne typhus (*Rickettsiae prowazeki*), trench fever *Bartonella quintana*) and louse-borne relapsing fever (*Borrelia recurrentis*) are vectored by body lice (Ko and Elston 2004). Both humans and louses can contract louse-borne typhus. People are thought to hold the disease's reservoirs. For many years, asymptomatic carriers are still contagious for body lice. Many years after the initial attack, a person may experience recrudescences called Brill-sickness, Zinsser's which can transmit epidemic typhus. The term "pediculosis" for lice infestations is considered a contagious disease. Continuous body lice infestation causes the vagaband's disease, also known as morbus errorum or rough and pigmented skin. Because they feed frequently, lice pump saliva into their hosts' bodies, causing itching. The other toxic effects result in fatigue, irritation, or a downbeat attitude, and the host feels miserable. Feces can cause symptoms similar to hay fever when inhaled. There are no diseases that the pubic louse spreads. However, a phthiriasis infestation, also known as "crabs," can be extremely uncomfortable and occasionally embarrassing. Every day, they consume many bloodmeals. They can't go more than four days without a human host or bloodmeal. Although head lice are capable of spreading rickettsiae and

spirochaetes in lab settings, there is no proof that they are the actual disease-transmitting body lice in nature. The bacteria that causes impetigo can be spread by the head louse by bloodmeal and undamaged faeces.

Management:

Delousing is the best method for preventing infections brought on by louses. Regular garment and underwear changes, as well as boiling infected linens, are effective delousing techniques. Effective control is provided by shaving pubic hairs or using insecticidal lotions made for head louse. Applying the lotion to all hairy regions below the neck is advised. Applying a tiny amount of petroleum jelly twice day for ten days can be used to cure an infestation in the eyelashes; this will kill both nymphs and adults. Regular combing, soapy water washings, and warm water baths could cut down on the number of nymphs and adults. The nits that are firmly adhered to the hairs can be removed only by shaving the head or using a steel or plastic comb with fine, tightly spaced teeth. It is also effective to use physostigmine opthalmic ointment, 0.75 percent.

Shampoo with 0.7% pirimiphos-methyl and lotion products with 0.3% malathion or 0.5% pirimiphos-methyl were said to be 100% successful in community testing (Rupes *et al*., 1995). The tightly adhered eggs to the hairs cannot be removed by any insecticide, but they can be with a louse comb. Effective treatments include the use of DDT 10% dust, HCH 1%, malathion 1%, temephos (Abate) 2%, carbaryl (Sevin) 5%, propoxur (Baygon) 1%, or pyrethrum 0.2% mixed with an inert carrier, such as talc blasted at 30 g/person. Additionally, it has been claimed that cotrimoxazole is effective for treating head lice (Shashindran *et al.,* 1978). It is important to find a pesticide with a very low toxicity to mammals.

Conclusion:

Socio-economic sustainability is especially relevant to developing nations. The price of the control method, people's willingness to pay for the control method, and the method's accessibility are three crucial factors. In developing nations, the question of willingness to pay for a specific control approach is becoming more significant and is not always related to the cost. The global livestock industry will continue to suffer greatly economically as a result of diseases spread by flies and mosquitoes. The development of chemical resistance, problems with residues in humans and the environment and their unfavourable impacts are the main challenges linked with this. While emerging technologies like genetic engineering and the creation of vaccinations against pest insects in certain situations and diseases they spread in others in others hold out some hope for the future, these are not sufficiently developed to allow for widespread implementation. For the foreseeable future, we must preserve what we have and make use of it along with all of the IPM tenets, specifically targeted and strategic animal treatments, environmental control of breeding grounds, disease management, interference with reproduction

(SIT), alterations to vectorial capacity, and resistant breeds. The creation of effective vaccines against illnesses and their insect vectors, as well as the genetic manipulation of insects, must be the focus of research. Governments, particularly those in developing countries, must also create efficient policies that guarantee a sustainable market and service delivery.

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(ISBN: 978-93-88901-25-3)

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ISBN 978-93-88901-25-3

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