FIELD DIAGNOSIS
DA- 232 (0+1)

Dr. K. V. Hari Prasad
Associate Professor
Dept. of Entomology
S. V. Agricultural College
Tirupati

IMPORTANCE OF FIELD DIAGNOSIS IN AGRICULTURE

Plants in particular crop plants requires around 17 major and minor nutrients for completing their life cycle. These nutrients are generally supplied through soil and water. Macro and micro nutrients are generally obtained as chemical fertilizers and organic manures. When these macro and micro nutrients are not supplied in required quantities plants exhibit deficiency symptoms. Under field conditions crop plants are also exposed to various problems such as plant disease producing pathogens, insects, nematodes, rodents, birds etc., which damage the crop at different stages of development.

For an Agricultural student it is very essential to differentiate these damages from that of nutrient deficiency symptoms. Nutrient deficiency symptoms generally will appear on many plants and the symptoms are almost identical. However if the symptoms differ from plant to plant or within the plant then it is more likely due to pathogens rather than nutrient deficiency.

Insect and non insect pests cause a particular type of damage to the plant parts often characteristic to particular pests. The pest mostly insect not present on the site of damage makes it difficult to know the casual organism. Sometimes , the symptoms of damage caused by insects may closely resemble to those resulted due to pathogens or due to nutritional disorders. So, practical experience makes familiar about the correct diagnosis on the basis of visual symptoms of damage to take appropriate control measures .

DIAGNOSIS BY LOCATING SIGNS ON/NEAR PLANTS

Diagnosis by locating signs: Black ants, *Componotus compressus* movement on plant parts Honey dew secretion on plant parts: Sooty mould development on plant parts: All the above indicate the presence of Homopteran insects Eg: Mealy bug *Planococcus lilacenus*, Aphid , *Aphis craccivora*, Whitefly, *Bemisia tabaci*

Excreta of Insects: Black spots are found due to drying of excreta on leaves by thrips Presence of excreta indicate usually the lepidopteran larvae

Scale covering: The stem , leaves etc are covered heavily by the scale covering

Exuviae of insects: Moulted skins of leafhoppers , aphids etc present usually on lower surface of leaves BPH moulted skins at base of plant and floating in water

Damaged symptoms

Depending on the type of insect mouth parts the damage differs and the expression of damage which is technically known as “Symptoms of damage” also varies. These symptoms along with symptoms produced by certain non insect pests such as mites, nematodes, snails, slugs, rodents etc., will be dealt in detail in the following chapters

INDEX

Lecture No: 1. Damage caused by insect pests having different types of mouthparts and the damage symptoms:

Insects utilize the plants to derive their nutrition or as a habitat. The plants sustain injury to satisfy the requirements of insects. Such injury to the plants by the insects is reflected as economic loss to the farmers.The nature of injury/damage to the plant is related to the feeding habits of the insect. The peculiarity of mouth parts and mechanism/type of feeding determine to a larger extent the pest management strategies including the type of pesticide to be used.

The nature and symptoms of damage caused by insects based on their feeding habits according to the modification of their mouthparts is furnished hereunder.

1. Biting and Chewing type:

They are adapted for biting and chewing of the plant material. They bite leaves, buds, bracts, slender twigs etc, chew the bitten portions and swallow them. Leaves may be eaten up completely leaving only a network of veins.

Eg: Grasshoppers, caterpillars, beetles. They can be controlled effectively with stomach poisons when taken in along with food.

Based on the nature of damage, chewing insects can be classified into different groups as mentioned below.

1. Stem borers:

Larvae enter in to the stem and feed on internal contents. As a result, damaged part is cut off from the main plant and affected part wilts, dries up and exhibits symptoms like dead heart during vegetative stage and white ear during reproductive stage in case of paddy due to larval feeding inside the stem and they can be easily pulled out and bunchy top in case of sugarcane (destruction of growing point results in the activation of side buds, just below the growing point and produces a bunch of side shoots called bunchy top).

Eg: Stem borers of paddy, millets, sugarcane and brinjal

2. **Shoot borers:**

Larvae attack tender shoots and bore inside during vegetative stage of crop growth and cause wilting, drooping of terminal plant parts which later dry up.

Eg: Shoot borers of brinjal, bhendi, cotton and castor

3. Defoliators/Skeletonizers:

Larvae feed on the leaves completely leaving only midrib/veins or scrape the chlorophyll content of leaves or cause numerous holes.

Eg: Castor semilooper, ash weevils, tobacco caterpillar, epilachna beetle on brinjal.

4. Leaf miners:

Larvae mine leaves/leaflets between the epidermal layers and feed on greenish matter, resulting in the appearance of translucent mines/white patches/zig-zag galleries

Eg: leaf miners of citrus, Cashew and Rice hispa.

5. Leaf Webbers:

Larvae webs leaves/leaflets by means of silken threads and feed on the chlorophyll content by remaining within the web. Often faecal pellets/frass are found within the web.

Eg: Leaf Webbers on gingelly, groundnut, sapota, mango and cashew shoot andblossom webber.

6. Leaf folders:

Larvae fold leaves from tip to base /longitudinally /margin to margin there by giving appearance of a fold/roll and scrape the chlorophyll content remaining within the fold.

Eg: rice leaf folder, Cotton leaf roller

7. Gall makers:

Larvae feeding inside the stem/tiller/leaf/flower bud stimulates excessive growth of cells at the affected portion and distorts normal growth. It results in malformation of plant parts, exhibiting gall formation and gives shelter for the pest.

Examples:

Sunhemp stem borer, Tobacco stem borer, Cotton stem weevil.

8. Pod/capsule borers/boll worms:

During the reproductive stage of the crop larvae enter in to the pods, capsules and feed on the seeds/lint exhibiting symptoms like webbed condition of pods /bolls or web few pods/capsules with frass and excreta or holes of different sizes and shapes/damaged tissues (chilli/lint on Cotton).

Examples:

Spotted pod borer: It enters into pod near the pedicle and feeds on the ripeningseeds by remaining inside the pod, at the entrance hole , a mass of dried excreta can be seen.

Capsule borers of castor and gingelly: Webbing of capsules and holes on pods plugged with excreta.

Tobacco caterpillar: Irregular holes on pods with excreta inside.

Gram caterpillar: Damaged pods with round holes.

Pink bollworm: Rosette flower and double seed.

9. Fruit borers:

Larvae enter into the tender fruits and feed on fresh matter/pulp and plug the larval burrow with excreta.

Eg: Fruit borer of brinjal/bhendi/tomato, mango stone weevil,Cashew apple and nut borer.

10. Bark borers:

Larvae remain in a small tunnel at the axils of branches, under the bark constructing galleries of frassy web on the stem and near bark/angles of branches and move about, conceal inside the silken gallery and feed on the bark by scraping.

Eg: Bark eating caterpillars of citrus, mango, guava, jack etc.

11. Tree borers:

Larvae bore deep into the tree trunk, make the tunnels in zig-zag manner and feed on inner tissues, arresting translocation of sap to top portions of tree, there by the tree exhibits symptoms like yellowing, withering of leaves, drying of twigs or complete drying of tree. Sometimes, gummy material oozes from the affected portion on the tree trunk.

Eg: Tree borers of mango, cashew, coconut red palm weevil etc

12. Root feeders:

Larvae feed on roots/root nodules resulting in stunted growth/poor tillering /dryingof plants in isolated patches.

Examples:

Rice root weevil: Grub feeds on epidermis of stem and later enters in to soil and feed on roots. Affected plant turns yellow and stunted. Tillering is poor.

White Grubs: Devour secondary roots leaving supporti ng root only. As a result leaves of affected plants turn pale, droop down and ultimately wither off. Cut endof affected stem of collapsed plant swells, a characteristic diagnostic symptom .Drying of plants in patches.

Banana Rhizome weevil: grubs tunnel through pseudo stem and rhizome making circular hole, which increase in size with the growth of grubs. Plants break down at tunneled portion/ plant bears few fruits and suckers.Circular holes with black rotten tissue of rhizome plugged with excreta.

Termites in:
Paddy - feed on roots, foliage, stem and fallen heads
Sorghum - feed on roots and stem resulting in wilting and death of plant
Groundnut- feed on main stem which is bored at or just below the ground level. Mature and developing pods are also penetrated and filled with mud.
Sugarcane- enter the sets through buds and cut ends and devour the inner portion, roots are also damaged. Sometimes earthen sheeting at the base of plant, mud filled galleries in shoots, drying of shoots.
Potato- tubers are damaged

Mango- construct mud galleries on tree trunk, if earthen sheet is removed, eaten bark of trees is observed. Young plants will die and dry up.
Coconut –construct mud galleries on trunk. Bark and stem are eaten below the mud galleries. Nursery and transplanted fields show wilting of central shoot and stunted growth.

13. Seed feeders (Stored grain pests):

Grubs/larvae and adults feed on stored seeds either internally /externally by webbing the food particles.

Eg: Rice weevil, red flour beetle, rice moth etc.,

I. The symptoms of damage caused by biting & chewing insects is furnished below.

a. Defoliation/Skeletonization/ Scraping of leaves:

Early larval instars of large number of Lepidopteron pests with gregarious behavior feed on leaves by scraping the chlorophyll content and gives papery/scorched appearance leaving membranous cuticular layer and stout veins. Such feeding leads to skeletonization .

Eg: Tobacco caterpillar, Bihar hairy caterpillar, Red hairy caterpillar

b. Uneven cuts on leaf margins:

Eg: Grasshoppers on various crops, larvae of mustard saw fly on cruciferous crops

c. Uneven scraping of leaf surface (lace like):

Eg: Grubs and adults of *Henosepilachna vigintioctopunctata* on cucurbits, solanaceous and leguminous crops.

d. Small white streaks parallel to midrib on rice leaves:

Eg: Adults of Rice Hispa

e. Tubular cases attached to leaf/ floating in water in rice fields:

Eg: Larvae of case worm

f. Shot holes on leaves:

Eg: Larvae of sorghum and sugarcane stem borers, Adults of flea beetle on blackgram/greengram ,*Phyllotrea sp on crucifers* , Larvae of *Anomis sabulifera* on jute,

g. Scraping and gnawing of base of stem:

Eg: *Plutella xylostella* on mustard and rape, *Spodoptera litura* on potato.

II. Piercing and Sucking Type

Planthoppers, leafhoppers, thrips, paddy gundhy bug, red cotton bug, sorghum ear head bug, aphids, mealy bugs, scales and whiteflies possess piercing and sucking type of mouth parts.

However, they cause different types of symptoms on different cropsbased on their site and extent of feeding. Both nymphs and adults suck sap from base of the plant /leaves /tender terminal plant parts and thereby affect the vigour and growth of plants. In case of severe infestation, sooty mould develops on plant parts covered with honey dew excreted by insects while feeding. Different insects exhibit different symptoms.

These insects cause hopperburn, discolouration, curling of leaves, necrosis on leaf margins and their eventual weakening and death of plant parts. They may also attack young twigs and other parts of the plant and cause them to dry up.

As these insects take their food from inside the plant, stomach poisons are not effective, unless insecticide is a systemic toxicant. Contact poisons are more effective.

a. Hopper burn:

Plant hoppers are known to cause hopper burn on Rice. Similarly **Leafhoppers** cause hopper burn on **dicotyledon** crops like cotton, okra, castor, brinjal, potato, beansetc.

Differences in feeding behavior between Plant and leafhoppers

Plant Hoppers	**Leaf hoppers**
Suck sap from phloem element of monocotyledons	Suck sap from mesophyll paranchymatic cells/phloem elements either from stems/from veins
The damage is mainly through mechanical plugging of sieve elements with salivary sheaths (true sheaths were formed)	No such true salivary sheaths. The damage is mainly through mechanical wounding of cells.
Confined only to stems	Change their feeding sites according to the situation

Hopper burn in Groundnut: Under severe infestation, the leaf tips become necrotic in a typical "V" shape, giving the crop a scorched appearance known as hopper burn. Eg: Groundnut jassids

Curling of leaf margins/with necrotic patches Starting from leaf margin – Cotton leaf hopper

Uniform yellowing of leaves from mid half -Paddy leaf hopper

Reduced vigour/sooty mold, squaer/bolldrop-White flies on cotton

Yellowing /reduced/stunted growth/sooty mould-Aphids

Shriveled/chaffy and discolored grains/sooty mould on grain - Sorghum ear head bug

Mottled appearance with yellow patches on infested leaves/sooty mould/undeveloped grains on infested ear heads -Sorghum aphids

Gradual wilting and drying of ragi plants in patches -Ragi root aphids

III. Rasping and Sucking / Lacerating and Sucking Type:

Thrips are characterized by this type of mouth parts. Due to the peculiarity of mouth parts and their mechanism of action in rasping the tissues, exudation of juice from inside the plant takes place and it is sucked by thrips. The damaged part of the plant exhibit a whitish mottled/silvery appearance. Such insects can be controlled both by stomach and contact poisons.

a. Groundnut:

Nymphs and Adults suck sap from the surface of the leaf lets. This results initially in white patches on the upper surface and necrotic patches on lower surface of the leaves. Contact and stomach Insecticides are generally used for manging these insects.

b. Onion:

Presence of pale white blotches on leaves, gradually change to brown spots followed by gradual drying of leaves from tip down wards. Growth of tubers decreases resulting in yield loss –Onion thrips

c. Chillies:

Infested leaves start curling upward, crumbling and drop down. Wilting and drying of plants under severe infestation

d. Blackgram:

Leaves curl up, crumble, become brittle and plant growth retards .Infested flower buds do not develop in to pods.

e. Rice:

Rolling of leaf terminals/yellow reddish and scorched leaf tips/rolling of entire length of all leaves.

IV. Sponging and sucking or Lapping and sucking Type:

Dipterans (Houseflies) possess above mentioned type of mouth parts. These are not pests of Agricultural importance.

V. Chewing and Lapping Type:

Hymenopterans (Honey bees) possess above mentioned type of mouth parts.
These are not pests of Agricultural importance.

VI. Siphoning/simple sucking Type:

Adult stages of moths and butterflies possess this type of mouth parts, while the caterpillars possess the biting and chewing type of mouth parts.

In larval stage they cause extensive damage. Stomach poisons can effectively control the larval stages. In general, adult stages of moths and butterflies are not harmful. However,

adults of certain moths can cause damage to certain fruits.

Fruit feeders: Adults suck juice from ripened fruits with the help of proboscis resulting in minute holes consequently resulting in rotting due to infections whereas larvae feed on the weeds belonging to the family Menispermaceae.

Eg: Adults of Citrus fruit sucking moths and Castor semilooper

VII. Degenerate type of mouth parts:

Maggots of Diptera possess above mentioned type of mouth parts

Gall formers:

Paddy Gall Midge: Maggot feeds on growing point which stimulates the leaf sheath to form a hollow pale green cylindrical tube similar to onion leaf/ silver shoot /gall. Affected tiller do not bear panicles. Infestation in early period of crop induces vigorous subsidiary tillering.

Gingelly gall fly: Maggots feed on the ovary which results in the malformation of pod without proper setting of seeds.

Mango inflorescence midge: Three species of midges damage the inflorescence

Mango leaf galls: Small raised wart like galls on tender leaves.

Chilli Midge*:* Unopened buds are affected. Flowers dry and drop . Pods are deformed.

Jasmine blossom midge: Selling at the base of buds. Stunting, finally drying of plant.

Shoot borers:
Larvae attack tender shoots and bore inside during vegetative stage of cropgrowth and cause wilting, drooping of terminal plant parts which later dry up.

Eg: Shoot fly of sorghum and black gram stem fly

Pod Borers:
Maggot feeds under the epidermis for some time then enters the seed and consumes only part of the seed. Affected seed gets discoloured due to bacterial and fungal infections and becomes unfit for consumption. No visual symptoms are present on pods initially, but only after adult emergence, a minute hole can be seen on pod.

Eg: Redgram Pod fly

Fruit feeders:
Larvae feed on fruits resulting in holes plugged with excreta/ forming necrotic patches /rotting.

Eg: Fruit flies on cucurbits, Mango fruit fly, Ber fruit fly

Rhizome borers:
Maggots mine into mid rib of leaves and enter in to rhizome through petioleresulting in rotting of rhizome and dead hearts.

Eg: Turmeric rhizome fly.

Lecture No: 2 Identification and Diagnosis of mite pests and symptoms of damage in different crops

Mites belong to the order Acarina of the class Arachnida. The phytophagous mites belong mainly to the families Tetranychidae, Eriophyidae, Tarsonemidae and Tenupalpidae.
Mouth parts of mites are adapted for biting, piercing and sucking.

Tetranychids penetrate the plant tissue with sharp stylets and remove the cell contents. The chloroplasts disappear and the small amount of remaining cellular material coagulates to form an amber coloured mass. In the palisade layer, only the penetrated cells are damaged and continued feeding leads to irregular spots; transpiration rate accelerates which finally leads to the drying and dropping of leaves. The mite infestation inhibits photosynthesis; and changes the composition of leaf pigments leading to a complex of symptoms like -yellowing, bronzing, distortion, curling, crinkling, defoliation of leaves, -retardation of growth, dropping of flowers, reduction in size, quality and quantity of produce.
Eriophids in general, cause no serious mechanical damage to plant tissue by their feeding. Salivary growth regulators, when injected in to plants cause discolouration and growth modifications like galls, erinea, blisters, rust, brooming, leaf edge rolling etc.

Tarsonemids penetrate thin –walled mycelial strands and highly succulent tissues but, incapable of penetrating thick walled lignified tissues. Occasionally toxins are injected which presumably cause alteration of normal tissue.

Plant mites damage the crop plants in a number of ways as given below.

1. They suck the cellular materials by means of their cheliceral stylets resulting in the formation of characteristic white blotches on the leaves and devitalization of plants. Eg: Rice leaf mite, Sugarcane leaf mite
2. The eriophid mites cause severe deformation in plant parts. Eg: *Aceria gossypii* produces outgrowths of excessive hairs on cotton leaves*Aceria mangiferae* crowded buds and also galls in mangoes *Phyllocoptruta oleivora* pinkish brown blotches on citrus fruits
3. A few mites are known to transmit viral diseases Eg: *Aceria tulipae* is a vector of wheat streak mosaic virus; *Aceria cajani* transmits pigeon pea sterility mosaic virus

Some important mites affecting crops

1. Rice leaf mite: *Oligonychus oryzae* Tetranychidae
Adult yellowish, Nymphs light yellowish, colonies found underneath fine silken webs Mites damage symptoms are interveinal necrosis, leaves become whitish between the veins, get shredded and veins remain greenish.

2. Rice panicle mite *Stenotarsonemus spiniki*, Tarsonemidae
Whitish mites, colonies are found between stem and leaf sheath and cause damageto leaves, glumes and floral parts. Symptoms of mite damage on leaves can be clearlyseen at tillering stage. Infested leaves exhibit elongated, dark and brownish-black necrotic streaks measuring 0.5 to 2.0 cm length. Infested plants show poorly exerted ear heads and necrotic leaf sheaths.

3. Jowar Mite: *Oligonychus indicus, Schizotetranychus andropogoni* Tetranychidae
Greyish green mite. Nymphs and adults are found in colonies on underside of leaves underneath the fine silken webs and suck sap from leaves. Red patches develop on leaves which increase in size and spread on entire leaf, leaveswither and dry up and stem dries up in severe cases.

4. Cotton leaf mite: *Tetranychus telarius* , *T.bimaculatus* Tetranychidae: Adults are oval shapedgreen/red/amber coloured with two spots on body.Feed on lower surface of leaves underneath a web. Close observation reveals pin point sized mites on lower surface of leaf.

Leaves curl up, hard, crisp and shed.

5. Wooly mite of cotton: *Aceria gossypii* Eriophyiidae

Mites are found on both surfaces of leaves. Growing shoots are attacked. Infested parts including leaves, buds and squares are covered in the outgrowths of dense white hairs. Heavily infested plants show crumpled leaves, distorted growth and lack of fruiting branches. Damage results in felt like outgrowths onleaf surface called "erinium" patches.

6. Red gram mite: *Aceria cajani* Eriophyiidae :

Both the nymphs and adults are found in colonies underneath tender leaves. The infestation causes yellowing of leaves, suppression of flowering and fruiting. This mite also transmits pigeon pea sterility mosaic virus. Diseased plants look bushy,pale green without flowers or pods, leaves are small with yellow and green patches.

7. Citrus rust mite: *Phyllocoptruta oleivora* Eriophyiidae :

Specific on citrus, It is a minute, yellowish, wedge shaped, worm like. Colonies are found both on leaves and fruits. Mites puncture the epidermal cells of leaves and tender fruits. Infestation results in rusty brown patches on leaves as well as fruits. Locally it is known as "Mangu"

8. Brinjal mite: *Tetranychus telarius* Tetranychidae

Colonies of mites are found feeding on lower surface of leaves by remaining underneath the web, resulting in yellow spots on dorsal surface of leaves, affectedleaves gradually curl, get wrinkled and crumpled. In heavy infestation even fruits are affected.

9. Chilli white mite: *Polyphagotarsonemus latus, Tarsonemus transulcens* Tarsonemidae

Mites are tiny, white and transparent and found mostly under the lower side ofleaves. Both nymphs and adults suck sap particularly from terminal /auxillary tender shoots and devitalize the plant. Infested leaves curl downwards along the margins, petioles of older leavesare elongated, younger leaves reduced in size and form a cluster at the tip of branch and affected leaves turn dark green and become brittle.

***Polyphagotarsonemus latus* on cotton:**

Both nymphs and adults infest the tender shoot and leaves on both sides and cause severe crinkling, downward cupping, brittleness of the leaves and gives a shiny appearance to the plant(without flower of boll formation)

10. Coconut mite: *Eriophes guerreronis* Eriophyiidae :

The mites inhabit the floral bracts and tender portions and immature nutscovered by perianth. They suck sap from meristematic tissues. -Initially the damage appears as white later brownish triangular patches at theseparation of the floral bracts and extends towards the free part of the nut. Ultimately longitudinal fissures appears on the nut. -Heavy shedding of the buttons results in the loss of yields. Reduction in size of nut, kernel content and poor quality of the nut.

Lecture No: 3 Insects (Thrips, Leafhoppers , Aphids, Mealybugs and Whitefliesin different crops) as vectors of Plant pathogens

Transmission of a plant virus from diseased to a healthy susceptible host by avector is the culmination of several sequential events/steps.

The first step is the acquisition of virus from the infested plant and the last step issuccessful inoculation of the healthy one. Between these two events, the virus has to be carried in infectious state and many factors determine completion of transmission cycle.

1. Acquisition is not affected even if the cell, from which virus-laden sap is ingested , is fatally injured.

2. Similarly, cells inoculated with virus have to survive necessarily long enough forthe virus to infect adjacent cells.

3. Further, a particular virus is transmitted by a single taxonomic group of vectorsthat too by a certain spp.

4. Different spp. of the same virus often differs in transmission efficiency.

5. Within the single species active and inactive races of the same vector specieswere also discovered.

Thus vector transmission of virus is not mere mechanical transfer but far more complex. Therefore there must be potential barriers to transmission and no set of characters are unknown to distinguish vector species from non-vectorones.

Classification of virus transmission by insects:

Based on retention of infectivity of the vector (Watson & Roberts,1939)	**Based on the route of virus transport (Kennedy et al 1962)**	**Latest categorization(Harris, 1977)**
1. Non-persistant **2.** Persistent **3.** Semi persistent	**1.** Stylet- borne **2.** Circulative	**1.** Non-circulative a. Non-persistent b. Semi- persistent **2.** Circulative (Persistent) a. Circulative non propagative b. Circulative propagataive

I. Non-circulative viruses

A. Non-persistent viruses

Transmission of non-persistent viruses (stylet borne **:** viruses adhere to tips of stylets,

immediately acquired during feeding and transmitted by vectors soon after acquisition) is virtually a monopoly of aphids. Non persistent viruses are readily sap transmissible due to their presence in relatively superficial tissues.

Examples of some aphid-borne non persistent viruses:

VIRUS	VECTOR
Alfalfa mosaic	*Acyrthosiphum pisum*
Bean common mosaic	*Aphis craccirora*
Papaya (mosaic) ring spot	*A . gossypii*
Soybean mosaic	*A . gossypii*
Lettuce mosaic	*Myzus persicae*
Potato virus Y	*Myzus persicae*
Turnip mosaic	*Myzus persicae*
Sugarcane mosaic	*Rhopalosiphum maidis*

Non-persistent transmission by hoppers is yet unknown. But Whitefly,

Bemisia tabaci is known to transmit non-persistently such as Cowpea mild mottle virus (CMMV) and Tomato pale chlorosis diseasevirus (TPCDV). But transmission properties are different from typical non persistent transmission by aphids.

B. Semi-persistent viruses:

These are sometimes regarded as non-persistent viruses with longertransmission thresholds and retention periods.

Being non-circulative, these are closer to non-persistent viruses as far as transmission properties are concerned, but have more vector specificitythan non-persistent ones.

Besides aphids, whiteflies and leafhoppers are known to transmit semi persistent viruses.

Examples of some semi persistent viruses & their vectors

VIRUS	VECTOR GROUP	VECTOR SPECIES
Citrus tristiza	Aphid	*Toxoptera citricidus*
Rice tungro	Leaf hopper	*Nephotettx virescens*
Cucumber yellows	Whitefly	*T. vaporarium*

II. Circulative (persistent) viruses: A circulative virus has to pass through at least two barriers within the insect body.

Firstly, the gut wall must be permeable for entry of the virus in to the haemocoel and translocation to the salivary glands by the haemolymph. The second barrier that the virus has to pass through is the salivary glands.

Leafhoppers and planthoppers transmit maximum number of circulative or persistent viruses. Besides hoppers, aphids and whiteflies also transmit numbers of circulative viruses.

Most of the hopper borne viruses seems to multiply in their vectors (**that is circulative**

propagation) and only a few can be clearly classified as circulative non propagative.

Persistent viruses seem to be concentrated mostly in the phloem and generally do not involve epidermal and mesophyll tissues. Such viruses are sap inoculable.

Examples of circulative (persistent) viruses and their vectors are given in the following table

virus	**Vector group**	**Vector species**
Banana bunchy top	aphid	*Pentalonia nigronervosa*
Groundnut rossette	aphid	*Aphis craccivora*
Rice dwarf	Leaf hopper	*Nephotettix cincticeps*
Beet curly top	Leaf hopper	*Circulifer tenellus*
Rice grassy stunt	plant hopper	*Nilaparvata lugens*
Maize streak	Plant hopper	*Cicadulina mibila*
Bhendi yellow vein mosaic	whitefly	*Bemisia tabaci*
Tomato yellow leaf curl	whitefly	*Bemisia tabaci*
Tomato spotted wilt	Thrips	*Thrips tabaci*
Beet leaf curl	Lace wing bug	*Piesma quadrata*
Wheat streak mosaic	mite	*Aceria tulipae*
Maize rough dwarf	Plant hopper	*Laodelphax striatellus*
Squash mosaic	beetle	*Diabrotica undecimpunctata*

Lecture no. 4 Damage caused by insects to plant parts like seed, seedlings, stem and leaves

The insect pests cause damage to the seeds and seedlings during the early stage of the growth period. Symptoms exhibited during the seedling stage on different crops are furnished here under.

A. Damages to seeds and seedlings

No.	Symptoms	Details	Insect group and crops	Examples
1	Dead hearts on seedling	**Maggots** of various diptera bore into young stem, usually killing the growing point and making the apical leaf turn brown and die; Seedlings before 4 weeks age of the sorghum crop areseverely damaged resulting in the formation of dead hearts which can be pulled out easily and emit foul smell.	Sorghum shootfly Agromyzidae : Diptera	*Atherigona soccata*
2	Seedling stem cut andplant lying onground	Tobacco cut worms Black cut worm (potato,Tobacco, cabbage)	Tobacco caterpillar Noctuidae	*Spodoptera sp Agrotis ipsilon*
3	a. Cotyledons of large seeds bored and eaten	Larvae bore into epicotyl and hypocotyl and prevent germination.	Bean seed fly	*Ophiomyia phaseoli*
	b. Stem bored, Seedling with swollen hollowed stem.	Larvae bore in the stem of various seedlings	Bean fly Agromyzidae	*Ophiomyia phaseoli*
4	Stem severed and plant removed		Several species of termites; leaf cutting ants and harvester ants	
5	Cotyledons or first leaves spitted and eaten	Adult flea beetles make a shot – hole effect on seedlings of cruciferae, cotton and othercrops, frequently stunting and killing the seedlings		

6	Seedling or young plant wilting and dying as a result of underground stem being eaten		Stem flies, cut worms	*Ophiomyia phaseoli*

B. Damage to stems

	Symptoms	**Details**	**Insect group and crops**	**Examples**
1	Cereals shoots with dead hearts	Severing of the growing part of the tiller in paddy or the stem in sorghum results in dead hearts which can be easily pulledout.	Paddy and sorghum stem borers	*Scirpophaga incertulas* *Chilo partellus*
2	Cereal stems made to galls and distorted	Gall midge or silver shoot or onion leaf in paddy with profuse tillering in the infested hills.	Paddy gallmidge	*Orseolia oryzae*
3	Cereal andgrass stem borers	a. Caterpillars of the family Pyralidae generally bore rice and grassstems, while the		
		b. larger caterpillars of the Noctuidae bore stalks ofMaize, sorghum; tunnels in sugarcane are usuallyvery short because the stem is solid and pith less	Sugarcaneearly shoot borer Pink stem borer or ragi borer	*Chilo infuscatellus* *Sesamia inferens*
4	Drooping of terminal shoots, leaves and death of plant	Caterpillars bore into petioles of leaves, tender shoots	Spotted pod boll worm/ Bhendi shoot borer	*Earias vitella*
			Brinjal shoot and fruit borer	*Leucinodes arbonalis*
5	Banana pseudo stem borer and death of plant	a. Larvae make extensive tunnel galleries in which they pupate and adults may also be found the central shoot gets killed resulting in premature withering and death of	Banana stem weevil	*Cosmopolites sordidus*

		plants. b. Larvae bore into the pseudo stem of turmeric resulting in yellowing anddrying of shoots	Turmeric shoot borer	*Conogethes punctiferalis*
6	Twigs galled	Made by feeding larvae ofgall midges (Diptera: Cecidomyidae. Some gall wasps, old galls have multiple holes; a few twig galls are madeby weevil larvae and some wooly aphids		
7	Twig – coveredbags hanging from twigs and thin branches	Bag worms usually feed on the leaves but pupate with the bag firmly attached to twigs by a silken thread		
8	Shoot and distal part of stem wilted and dying	The shoot may be boredby a caterpillar or a longicorn beetle larva ; some heteroptera feed onyoung shoots of woody shrubs and their toxic saliva enters the vascular system and kills the stem distally; shoots on trees are killed terminally in some regions by ovipositing cicadas and also some long horned grasshopper		
9	Tree trunk and branches bored, sometimes bark eaten externally	Mango, cashew tree borers and bark eating caterpillars		

C. Leaf damage

1. Internal damage or mining

Insects feed between the epidermal layers by scraping the chlorophyll content and cause mines in different shapes. Depending on the shape, the leaf mines canbe classified as mentioned below.

Example: Serpentine mine: *Liriomyza trifoli*
Rice hispa *Dicladispa armigera*
Citrus leaf miner *Phyllocnistis citrella*

2. External damage on leaf

Insects damage the leaves externally in different ways either by scraping,skeletonization and feeding and as mentioned below

- Free feeding: Insects feed on part of all of leaf or needle except largest leafveins which are often left uneaten e.g Many lepidopterous caterpillars

- Hole feeding: Insect feeds in small patches, rough all layers of a leaf creating many holes in a leaf. e.g Flea beetles in pulses

- Skelitonizing: Insect feeds on the soft material between the veins and leaves the veins as a "skeleton" of the leaf. e.g Early instars of tobacco caterpillars

- Window feeding: Insect feeds on only one surface of leaf that allows the lightto penetrate through the remaining leaf layer. e.g Early instar of many caterpillar.

3. Shelter feeding

Insects make a shelter on or within the leaves by webbing with silken threads and then feed on the foliage.Sometimes abnormal plant growth induced due to insect feeding may also serveas shelters.

The shelter may be in different ways.

- Web enclosed foliage: Many caterpillars web foliage together and live within this enclosure and feed on the enclosed foliage as Window feeders, Skelitonisers or free feeders. e.g Mango leaf webber

- Leaf tying or needle tying: Caterpillars tie two to six leaves or needles as the case may be together with silk and feed primarily as window feeders or Skelitonisers. e.g Casuarina bag worm

- Leaf folding or rolling: Caterpillars rolls an individual leaf, fastens it together with silk and feeds on it remaining within as a skelitonizer or window feeder. e.g Leaf folder in paddy

- Crinkled leaves: Leaves become cupped, crinkled or curled. e.g Mites, aphids, thrips, mealybugs.

- Leaf and petiole galls: Abnormal growth, if formed around the feeding siteforming galls.

Example: Erineum leaf gall, petiole gall, pongamia leafgall midge,

Insect signs of infestation

A. Silk shelters are made entirely from silk produced by caterpillars e.g Tentcaterpillar,

B. Larval cases are made out of silk, debris of frass e.g bag worm

C. Spittle masses or floating masses produced to enclose the nymphs e.g Spittle bug.

D. Scale and aphid coverings.

E. Honey dew and sooty mould: The liquid faeces of sap feeders containing sugaris called as honey dews on which black sooty mould fungus grows. e.g Scales, aphids, whiteflies.

F. Insect remains: Egg shells, exuviae, pupal cases, cocoons, frass and trails of silk.

Damage to leaves - Paddy

No.	Symptoms	Insect
1	Young terminal leaves drying in nursery	Rice thrips
2	Leaf roll longitudinally	Leaf roller Rice leaf roller
3	White parallel streaksalong long axis	Hispa or spiny beetles
4	White parallel streaks with cut leaf tip forming leaftube	Rice case worm
5	Graminaceous leaf cut laterally and roll longitudinally	Rice skipper
6	Longitudinal marginal blotching	Rice whorl maggot
7	Grazing like cutting ofseedlings	Rice swarming caterpillar or cut worm
8	Hopper burn	Rice BPH
9	Hanging leaf cases	Case worm or bag worm
10	Margin irregularly eaten	The commonest form of leaf damage by defoliating pests caused by grasshoppers, locusts.

Sorghum
1. Parallel or serial holes Sorghum stem borer
2. Bubble froth or spittle mass on leaf or leaf axil Spittle bugs on graminaceous plants - spittle bug

Cotton:
1. Leaf roll longitudinally Cotton leaf roller
2. Leaf edges curled under,with honey dew, sooty mould and ant movement - Aphids, Jassids, Mealy bugs,Scales, White flies, Psyllids
3. Irregular shaped holes - Many lepidopteran caterpillars andgrasshoppers, some polyphagous caterpillar

Pulses and oil seeds
1. Leaf folded and mined - Ground nut and red gram leaf miner
2. Complete defoliation - Hairy caterpillars(Castor), Sphyngids (gingelly)
3. Phyllody Gingelly

Vegetables
1. Lamina with ladder like windowing leaving veins intact - Epilachna beetle on Brinjal and Bitter gourd
2. Leaf skeletonised with papery appearance - Early instars of cut worm on cotton,castor, Cabbage diamond back moth
3. Many small shot holes Radish flea beetle
4. Little leaf of brinjal (Phytoplams) transmitted by leaf hopper

Spices and condiments
1. Leaves silvered and wilting - Onion thrips
2. Young terminal leavescurling upward along margin - Chillies thrips, Pepper marginal gall thrips

Fruits
1. Slit like small cut, sometimes T shaped splits - Grapevine flea beetle
2. Larger regular shaped holes Tortoise beetles,Sweet potato, Ber
3. Leaf lets rolled - Coconut skipper
4. Leaf mine broad withcentral black faecal pellets and leaf edge folded dorsally for Citrus leaf miner
5. Leaves webbed together - Mango shoot webber; Sapota leaf webber
6. Leaves fastened together to form nest - Red tree ant in Mango
7. Leaf cut laterally androlled across - Mango, sapota, leaf twistingweevil
8. Semi-circular leaf cut - Leaf cutting bee on guava
9. Round and elongated galls- gall midges (Diptera: Cecidomyidae), gall mites(Acarina: Eryophidae), gall wasps(Hymenoptera: Chalcidoidea,Cynipoidea, and Symphyta), and some Psyllidae Mango leaf galls (gall midges) Pongamia leaf gall
10.Minute yellow specks onleaf Banana tinged ,Coconut tinged
11. Bunchy top of banana – Viral disease transmitted by aphids
12. Frond with V shaped cut - Coconut rhinoceros beetle
13. Lamina pitted - Psyllidae in the group Triazinae cause ventral leaf pits at the sites where the nymphs sit and feed, young leaves sometimes may beconsiderably deformed

Lecture no 5: Damage caused by insects to plant parts like buds and flowers,roots and tubers by soil inhabiting insects

Damage to flowers and buds

No	Symptoms	Details
1	Flower petals and perianth destroyed	Adult blister beetles (Meloidae) chew petals of many plants, often common on Malvaceae; adult flower beetles Scarabaeidae) make small holes in petals, orange banded blister beetleBrown banded *Mylabris pustulata*
2	Flowers partially eaten	petals damage by adults on pulses *Mylabris pustulata*
3	Petals scarified	Flowers of leguminosae, compositae, etc.inhabited by adults and nymphs of thrips (Thripidae) which scarify the bases of the petals
4	Flowers inhabited by tiny black beetles, making feeding making scars at the base of the petal	Legume flowers inhabited by Apion weevils
5	Dropping of flowers/webbing of flowers and flower buds	Red gram pod borer, gram caterpillar, spotted pod borer
6	Presence of Webbing and galleries on inflorescence	Cashew blossom webber, Castor shoot and capsule borer
7	Presence of rosette flowers/Interlocular damage	Cotton pink boll worm
8	Anthers eaten	Pollen beetles
9	Maize tassels eaten	By grasshoppers or maize tassel beetle
10	Silk damaged	Maize ear worm
11	Flowers inhabited by tiny maggots	Gall midge larvae (Diptera: Cecidomyidae), usually causing flower drop and deformation
12	Flower budsbored	Moring bud worm Sappota bud worm Jasmine bud worm
13	Buds gnawed with large holes	Eaten by large caterpillars; sometimes bylong horned grasshoppers
14	Flower petalswith small holes	Cotton flower weevil

15	Squares damaged	Cotton spotted boll worm, Cotton spiny boll worm
16	Drying of inflorescence with large scalewithering and shedding	Mango hopper
17	Inflorescencewebbed	Mango flower webber
18	Blighted inflorescence	Cashew mirid bug

Damage to roots and tubers

1. Wilting and drying of plants in patches due tofeeding on roots and rootlets- Rice root weevil, Termites in sugarcane,Wheat, Ground nut

2. Wilting and drying of plants and presence oflarge number of ants at the base of ragi tillers - Ragi root aphid

3. Rhizome extensively bored/ Wilting of plants - Banana rhizome weevil

4. Tuber damaged - Potato white grubs

5. Vines drying and black scars and holes on tubers – Sweet potato weevil

Lecture no 6: Damage caused by insects to pods and fruits

The insect pests that cause damage to pods and fruits exhibit different symptoms like holes, dropping, distortion or abnormal growth, webbing, shriveling, oozing of brownish fluid, scars on surface and chaffy grains etc.

The different symptoms caused by insect pests on different crops are furnished here under.

Damage to fruits and pods

No.	Symptoms	Insect group and crop
1	Webbing	Mango flower webbers
2	Bored Fruits	Brinjal fruit borer, Tomato fruit borer, Chilli fruit borer Mango fruit borer
3	Boll damage	Cotton boll worms
4	Damaged buds andcapsules with round holes	American boll worm
5	Ear head with chaffygrains	Rice ear head bug Sorghum ear head bugStink bug
6	Ear head with chaffy grains and protruding pupal cases	Sorghum gall midge
7	Webbing of grains in the ear head	Sorghum web worm
8	Cob damaged	Maize ear worm
9	Pod bored	Pulse pod borers,Gram pod borers,Plume moth Spotted pod borer, Spiny pod borer
10	Pods shriveled with shriveled grains inside	Red gram pod bug
11	Necrotic spots on fruitsand pods	Mirid bugs on guava fruitand cocoa pod
12	Flower and young capsules with galls	Gingelly gall midge
13	Citrus fruits with necroticlesion, rotting and dropping of fruits	Citrus fruit sucking moth
14	Bore hole pomegranatefruits, feeds on pulp and seed	Anar butterfly
15	Maggots bore into fruitand feed on pulp resulting in brown patches	Guava fruit fly
16	Purple discoloration of fruits	San Jose scale

17	Premature dropping of tender fruits and oozingof brownish fluid from infested pods	Tea mosquito bug Citrus fruit sucking moth Coconut slug, Guava fruit borer
18	Larvae bores into berries and feeds onthem	Grape berry borer
19	Fruit and berry surfacecorky	Grapevine berry thrips, Banana fruit thrips, Cardamom thrips
20	Berries damaged	Pepper pollu beetle Coffee berry borer
21	T shaped marking on marble sized mango fruits	Mango nut weevil
22	Maggots feed on pulp resulting in rotting andfruit drop	Mango fruit fly, Ber fruit fly, Cucurbit fruit fly
23	Holes on stored cereal grains (Rice, Sorghum,maize, Wheat etc.)	Rice weevil Lesser grain borer
24	Cereal grains with exithole and flap door	Angoumois grain moth (Paddy, sorghum, maize)
25	Pin head sized holes on processed tobacco	Cigarette beetle
26	Pin head sized holes onspices	Drug store beetle (turmeric ,coriander, ginger)
27	Pulse seeds with circular holes and white eggs cemented on surface	Pulse beetle (All pulse grains)

Lecture: 7 Complex Symptoms of damage caused by insect/non- insect pests

1. Leaf folder vs. Rice Hispa

S. No.	Leaf folder	Rice hispa
1	Only the larval stage is damaging	Both the grubs and adultscause damage
2	Longitudinal folding of leaves. Sometimes joins the leaf tip to the basal part of the leaf blade . When the foldings are open faecal material can be seen	No folding. Grub mines theleaf blade near the tip it results in irregular translucent white patches
3	White long patches that are parallel to the midrib	Adult scrape the upper surface of leaf blade andcause small white streaksparallel to midrib
	In severe cases field gives burnt/scorched appearance from distance	
4	The insect can attack the crop at any stage of cropgrowth	Nurseries and young transplanted seedling areaffected more
5	The damage is more in flag leaf initiation and flowering stage	

2. Rice whorl maggot and yellow stem borer

S. No	Rice whorl maggot	Yellow stem borer
1	Maggots are the damaging stage	Caterpillars are thedamaging stage
2	No dead hearts	Damage leads to deadhearts at the seedling stage and white earheads at milky stage of the crop
3	A row of concentric holes can be seen inyoung emerging leaves	Irregular leaf scrapings are observed

3. Early shoot borer and internode borer in sugarcane

S. No	Early shoot borer	Internode borer
1	Damage causes dead hearts within 1-3 months old crop.	Damages the crop after 3 months of age

2	The dead hearts can beeasily pulled and gives offensive odour	No dead hearts can be seen but the internodes becomes constricted and shortand the affected tissues become red in colour
3	A number of bore holes can be seen at the base ofthe shoot just above the ground level	A number of bore holes can be seen at thenodal region
4	The damage also induces production of side tillers	No side tillers are produced

4. Dipteran galls/ psyllid galls

S. No	Dipteran galls	Psyllid galls
1	Gall midges and certain fruit flies cause swelling (galls) in the tissues of theplants they feed on.	Sucking of Psyllid nymphs forms disfiguring galls on the leaves of host plants
2	The brightly coloured gallfly larvae live in leaves and flowers, usually causing the formation of tissue swellings (galls).	As they feed, the nymphs secrete substances that stimulate abnormal plant growth, forming galls over the feeding nymphs.
3	No sooty mold development	Sooty mold development takes place

5. Rhizome fly and rhizome rot

S. No	**Rhizome fly**	**Rhizome rot**
1	Rhizome and roots are tunneled by the maggots	Initial disease symptoms appear onthe pseudostem and later spread tothe rhizome
2	The tunneling and feeding predisposes to attack of rhizome rot	Rhizomes rot, become soft, brightorange of the rhizome changes tobrown
3	The affected plants becomes chlorotic and dry subsequently	Infected plants show progressivedrying up of the leaves along themargins, later entire leaf dries up

6. Panicle mite vs Sheath rot

S. No	Panicle mite	Sheath rot

1	Panicle rice mites cause damage to plants by directly by feeding on leaftissue in the leaf sheath and developing grains at the milk stage	Generally occurs at booting stage
2	Affected glumes had brownish to black and shriveled ovaries	Initial symptoms are on flag leaf sheath as oblong or irregular greyish brown spot. Spots enlarge and develop grey center with brownmargins
3	Rice plants that had poorly exerted earheads and necrotic leaf sheaths	Depending on early or late infection, leads to non-emergence or partial emergence of panicle or rotting of panicle. Abundant whitishpowdery growth is formed inside the leaf sheath.

Lecture No: 8 Damage caused by non insect pests like nematodes, snails, birds, rodents, bats, wild boars and other mammals in important field crops

I. Nematodes:

Plant parasitic nematodes are obligate parasites and most of them feed onsubterranean plant parts. Nematodes feeding on plant tissues may cause either mechanical or biochemical injury which is ultimately responsible for manifestation of disease symptoms.Mechanical injury occurs as a result of continuous thrusting of stylets in to the cells of host plants. Biochemical injury occurs due to effect of the release of nematode salivary juices in to the plant cells. These juices include hydrolytic enzymes which dissolve cell walls oract as a digestive enzyme.

The symptoms of injury caused by plan parasitic nematodes are divided in to two categories.

A. Above Ground Symptoms:

1. Distorted and Abnormal Growth: Larvae of *Anguina tritici* feed on the growing pointof wheat seedlings without killing it .The affected plant show twisted and crinkled leaves.
2. Leaf Galls: Some species of Anguina produce galls on leaf surface Eg: *Anguina tumafaciens* produce galls on *Cynodon transvelensis*
3. Seed Galls: Eg: *Anguina tritici* on Wheat. The nematode larvae feed on floral primordia and seed galls become green and soft in initial stage and later turn to black – brown hard structure.
4. Stem Galls: These galls may be greenish or reddish in color. A number of species of *Anguina* form galls on *Cynodon transvelensis.*
5. Necrosis and discoloration of foliage and stem: The discoloration may range fromlight to dark shades and these symptoms are not very specific for Eg: *Aphelenchoides ritzemabosi* caused interveinal discoloration on chrysanthemum and straw berry.
6. Lesions and Spots: The foliar nematodes cause destruction of leaf parenchyma which may appear in the form of spots and lesions. The spots first appear on the lower side of leaf surface as small yellowish areas, which later turn to brown and finally black in color. These spots may coalesce together and the entire leaf is destroyed.
Eg: *Aphelenchoides ritzemabosi* on chrysanthemum.
7. Devitalised buds: The infection kills the buds or growing point and stops the further growth of affected tissues. Eg: *Aphelenchoides besseyi*

B. Below Ground Symptoms:

1. Root Galls and cysts: Galling of roots is the most characteristic symptom produced by root knot nematode (*Meloidogyne* sp.). The Presence of white or brown cyst projecting on root surface is a characteristic symptom Eg: *Heterodera avenae* on wheat
2. Root Proliferation : Infection by some species of nematodes result in decay of roots. But due to the injury, plants grow more roots in cluster especially behind the damaged portion. Eg: *Heterodera* sp and *Globodera* sp
3. Lesions and Necrosis: Lesions or superficial discoloration and injury due to killing ofcells over large area Eg: Pratylenchus sp , *Radopholus* ps , *Xipehinima* sp
4. Devitalised root Tips: Due to penetration of roots just behind the root tip results in stoppage of further growth and appearance of stubby roots Eg: *Trichodorus* and *Belonolaimus* spp

5. Root Rots: Secondary microorganisms enter through the injuries made by nematodes and cause extensive root tissue destruction. Eg: *Ditylenchus destructor*

Some Important plant parasitic nematodes causing damage to crops

1. White tip nematode of Rice /spring dwarf nematode: *Aphelenchoides besseyi*
Feed on foliage as ectoparasite. Larvae move to panicle and enter grainsLeaf tips turn yellow, brown and finally white, dry up and hang down. Tips of developing leaves become twisted and crinkledKernels distorted and in severe cases become chaffed.

2. Wheat Gall nematode: Ear cockle nematode: *Anguina tritici*
Feeds on tender foliage as ectoparasite. Enter young green grain and converts it in to a gall Grow and reproduce in the gall. Affected plant become stunted with wrinkled and twisted leaves. Infested grains ripen slowly, smaller in size with irregular contour. Grains converted in to galls, associated with a bacterium *Corynibacterium tritici* causingrotting of spikelet with yellow slime oozing (yellow slime disease)

3. Wheat cyst nematode: *Heterodera avenae*
Second stage larva enter root near tip and feeds on tissuesShallow root system Stunted plants with chlorotic leaves

4. Root knot nematode: *Meloidogyne incognita, M. javanica*
Second stage larva enter the rootsKnot like galls on roots. Stunted plant with chlorotic leaves

5. Citrus nematode: *Tylenchulus semipenetrans*
Females remain attached to roots with head region buried in tissues. Drying of apical leaves, buds, twigs down wards: this is known as Die Back. Trees showreduced vigour

6. Banana burrowing nematode: *Radopholus similis*
Endoparasite responsible for panama wilt of Banana. Nematode enter root at any point, feed on cell contents and migrate through root tissues. Roots are severed from plant
Reduced root system with few short stubs/ Affected plants get toppled

7. Rice root nematode: *Hirschmanniella oryzae*
Endoparasite on rice, bajra, cotton and sugarcane whenthey are grown on infested rice fields
Nematode enters the root a little behind the root tipNo visual symptoms above the ground are noticed.

8. Reniform nematode: *Rotylenchulus reniformis*
Infects Cotton, Bajra, Jowar, Castor, Chillies, Papaya, Bhendi, Tomato and BrinjalIt remains attached to the roots with its anterior end buried into the tissues of rootsDwarf and unhealthy plants

9. Root lesion nematode, meadow nematode: *Pratylenchus* sp
Infects Chillies, Coffee, Corn, Cotton, Rice, Pine apple, Rose and Wheat. Both young and adult nematodes enter the roots and feed on the cell contents
Their infection is associated with that of pathogenic fungi and bacteria which enter through the openings made by the nematode. As a cumulative result brown lesions in the roots develop. Affected fibrous roots dieleading to formation of tufts of adventitious roots.

10. Bulb and Stem nematode: *Ditylenchus dipsaci*
Infects Onion, garlic, potato, tobacco, oats, beans and lucerne more than 400 host species. Nematode enters the host through natural openings and cause rotting of tissues

11. Rice stem nematode: *Ditylenchus angustus*
It lives in the soil and when seedlings are planted, it becomes active climbs up onthe stem and attacks the growing point, stem, leaves and nodes. When young seedlingsare attacked, they die. In case of older plants they are severely stunted and leaves withered. When the panicle is attacked, the grains fail to develop and the ear head contains only shriveled grains The heads may be either twisted and deformed.

12. Lance Nematode: *Hoplolaimus* sp
It is a very common nematode in all types of soil. It is the most importantnematode of Sugarcane. The infected sugarcane plants show stunting of upper internodes, curling of new leaves and withered tip of old leaves, root system is reduced ,young lateral roots develop reddish brown lesions .

13. Spiral nematode: *Helicotylenchus* sp and *Rotylenchus* sp
Polyphagous and found associated with the roots of sugarcane , Banana, potato,Rice, maize, wheat, oilseeds and tea .

II. Snail damage

These terrestrial creatures do cause damage to crops particularly in vegetables, ornamentals and other crops grown under glasshouse conditions. Slugs and snails feed on the lower leaves of many plants especially in the areas between the veins. Immature slugs and snails damage plants by rasping away the surface tissue, while adults eat holes through the leaves, nip off tender shoots or cause complete destruction of seedlings. Damage to the leaves, along with wind, often causes leaves to shed or in the case of grass and corn, to split lengthwise.

During day time slugs and snails can often be found on the ground near the injured plants, hiding under decaying plant debris, stones, clods of soil, or logs.

Slugs and snails are legless creatures that glide along on a path of mucous . This mucous dries out and can be seen in the daytime as a shiny trail over leaves, fruit and soil. The detection of these "slime trails" may be the only way of determining their presence, as slugs and snails generally feed at night. They lay eggs in groups on the surface of plants or in the soil. It takes 3-5 months for the young ones top become adults.

Management

1. They generally infest moist places hence making the breeding ground dry can reduce the infestation.
2. Identifying their presence with the help of slime trails and hand collection and destroying them in salt or soap water solution.
3. Placing heaps of vegetable waste or debris or wet gunny bags where snails and slugs take shelter during hot day time where they can collected and killed.
4. Poison baiting within plates or lids placed in the soil and baited with Honey + yeast or sugar or joggery syrup attracts snails and slugs and thus can be collected and killed

5. These creatures are deterred by copper and hence placing copper sheets inside the greenhouse in areas of high infestation may reduce the attack.
6. Metaldehyde pellets available as 2 or 4 % G can be used @ 2kg/acre. When snails and slugs feed on the chemical they die of dehydration and paralysis.

III. Birds damage

A number of birds feed upon grains from earheads of field crops, fruits and vegetables. They actually consume very little quantity but often causes more damage than what they actually eat.
Major bird species affecting different crops are as follows

1. Crow *Corvus* spp. – Omnivorous , Damage wheat, cobs of maize, jowar, groundnut, ripe fruits of fig, mulberry and chillies.
2. The parrot *Psittacula cyanocephalus* – normally frugivorous, It attacks ripening cereal crops and food grains, cuts and feeds on maize, jowar, bajra, wheat, barley grains and fruits such as guava, fig, mango, pomegranate etc., (both semi ripened and ripened fruits are cut and eat leading to fruit drop).
3. The house sparrow – *Passer domesticus* mainly grainivorous, damages the ear heads of jowar, maize, bajra and soft and fleshy fruits such as mulberry and fig .It also feeds on green leafy vegetables.
4. The blue rock pigeon *Columba livia* mainly grainivorous eat food grains , maize, pulses and groundnut.
5. The yellow throated sparrow causes heavy damage to wheat and barley.
6. The Mynah *Acridotheres tristis* – it often damages food grains in fields ,fruits and vegetables.
7. The Rosy pastor *Sturnus roseus*- feeds on cereals and nectar of flame of forest.
8. The Baya or Weaver bird –*Ploceus philippinus* It is a pest of grain crops feed on Paddy grains.

- Crop damage occurs at various stages of crop production due to birds i.e. seeds may be removed after sowing, seedlings may be pulled out, grains in milky stage or at the ripening stage may be fed upon under uprooted conditions.
- The pigeons and crows inflict the damage at the germination and seedlingstages.
- The birds pick up the seed from the field after the post sowing irrigation and feed on the soaked seeds which were in the process of germination. They also pluck out on the developing young seedlings.
- At the flowering stage, the Rose ringed parakeets infest the male inflorescence of maize (Tassel) and feed on the anthers and pollen grains.
- At the tender maize cob stage, the parakeets damage the cobs with the silky style and green husk.
- At milky stage of the maize cob when they split and strip away the covering bracts thereby exposing the grain for easy feeding and further damage.
- In sunflower when the seeds are soft the parrots cause extensive damage by feeding on the seed thus reducing the yield.

Management

1. Habitat manipulation: trimming trees, removal of shrubs on borders reduces roosting place where birds perch/settle/sleep.

2. Netting: arrangement of traps and nets for catching the birds.
3. Scaring by
Beating empty drums
Mechanical bird scarers
Metallic ribbons
Pyrotechniques (art of making fire works)
Bioacoustics - making distress calls
Firing blanks with gun
Throwing missiles
Catapulting (to shoot from a hurl)
4. Destruction of eggs and nests
5. Use of non toxic and sticky material like " Lassa"
6. Use of repellents like cupric oxide, methiocarb.
7. Use of chemosterilants like mestranol, ornitrol, avitrol.
8. Use of stupefying substances, immobilizers, narcotizers (Alfachloralose 1 – 2 % in bait.)

IV. Rodent damage:

The popular field rats most widely distributed in the country and causing damage to crops are *Bandicota bengalensis* , *Rattus meltada* , *Tatera indica* and *Mus booduga.*

Damage caused by rodents in important crops

Paddy
Damage in the paddy crop can be observed from the bund by observing the patches inside the field which are nothing but stems that are cut by rats, causing severe yield loss. They also cause severe yield loss in the paddy crop by cutting the ear heads.

Sugarcane
In case of sugarcane, they damage canes at the bottom portion leading to loss of quality of the juice. Rodent damage in sugarcane is highest when there is heavy lodging.

Groundnut
Rodents cause damage to the fully grown groundnut crop by feeding on their roots and pods. The damage can be seen as sudden drying of plants in patches.

Vegetables
Damage to most of the vegetables is to compensate water loss during summer. In case of chilli crop, plants were cut and the ripen fruits are damaged.

Coconut and fruits

In case of fruits, they cut the unripe fruits, eat up a portion fruits and vegetables and causes heavy yield loss.
In case of coconut, these rodents harbour at the crown region and causes the damage by cutting the unripe fruits, gnawing the developing nuts and swallowing the material inside it. All these damage, causes severe pre mature nut fall.

Detection of rodent infestation

1. Visual sighting and typical noise.
2. Rat burrows.
3. Rat droppings and urine marks.
4. Feet or tail marks on dustry floors, greasy marks left by rats.
5. Gnawed articles (torn bags and spilled grains etc. or damaged doors andwindows).
6. Disappearance of bait.

Management

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 in the field to pose any threat to field crops

- 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 harborages.
- Encouraging natural enemies (snakes, birds *etc*.,)

Intervention:

- Setting of indegenous traps

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 %.
Pre baiting should be done 2 – 3 days before.
Baiting: Broken rice (local food) – 96 parts; Edible oil – 2 parts; Zinc phosphide – 2 parts @10 bait stations / ac
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.

Coconut rats

Management of coconut rats involve

- Nailing tin hat / tin sheets around trunk of grown up trees.
- Avoid close planting.

- Placing bromadiolone cake @ 2 pieces or 33 g per tree in crown at opposite directions.
- Inserting Aluminium phosphide tablets in holes made in bole.
- Use of traps, burrow smoking.

V. Bat damage

Bats are the only mammals that are capable of true flight. Bats are of two types microbats Or insect eating bats which produce ultrasound, with which they locate the host insects and megabats or fruit eating bats that do not produce any ultrasound but have clear vision and acute sense of smell with which they feed on fruits.

India is home to about a hundred species of bats, including 12 fruit bats, all of them consume fruits such as guava, grapes, mango etc., flowers and/or flower products. The grinding teeth of most species are large and flat to allow them to chew fruit.
The damage symptoms include large compressed pieces of skin and flesh under the trees which are known as 'spats'. These are nothing but piece of fruit that is cut and pressed between tongue and mouth parts and the juice has been extracted and the remaining skin has been spit out. Either the fruits are eaten completely or part of the fruit. If a part of the fruit is eaten we can see 'spats' under the tree and feeding teeth marks on the fruit. Bats can also dislodge the fruit while feeding on other fruits in which case we cannot see any markings.

VI. Wild boar damage *(Sus scrofa)*
Sugarcane
The damage in sugarcane is by tearing away the rind on the stalks which are near the ground. Once the rind is stripped off, boar consumes the soft, juicy part within. Wild boar damage can be easily differentiated from rodent damage by the prescence of largepieces of rind.

Groundnut
Wild boar root out groundnuts from underneath the plants, scrapping out a depression of 5-10 cm deep. Some plants would be uprooted and die whereas on some plants only the nuts would be removed but the plant will survive. Wild boars prefer groundnuts when they are soft, fresh-grown stage before the shells harden.

Maize
Wild boars start damaging the maize crop, when the kernels are in milky stage. Stems are knocked over with their bodies and the kernels are eaten from the cobs. If the cobs are soft, the whole cob can be consumed. Trampling of the field can be clearly seen in case of wild boar damage.

VII. Other Mammals:

Squirrels: *Funambulus pawarum* 3 striped squirrel common in South India*Funambulus pinnati* 5 striped squrirrel common in North India. They are diurnal feed on seeds and nuts. Peak activity is observed during morning and evening.
Porcupine: *Hystrix indica:*
Damage tuber crops potato, sweet potato , Turnip and carrot.

Jackal: *Canius aureus* (Jackal) Omnivorus feed on ripe sugarcane, maize, muskmelon

Vulpus vulpus (Fox) feed on melons, pods of gram

Elephant: Herbivorus, Feed on bamboo, Sugarcane fields

Monkeys: Brown faced monkey: *Macacca muletta* ; Black face monkey: *Presbytis entellus* Damages no of crops like lady's finger, raddish, chillies, bittergourd, colacasia are not preferred.Prefer maize cobs and fruits.