

EXPERIMENT NO. 1

PRACTICAL METHODS OF DIAGNOSIS AND DETECTION OF VARIOUS INSECT PESTS

1.1 Damage caused by insect pests having different types of mouth parts 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.

- **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 and blossom 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 (Bell shaped rolling of leaf).

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: caterpillar causes gall like swelling on stem and profuse branching occurs at affected portion of stem.

Tobacco stem borer: caterpillar mines into the leaf axil and then in to stem, bored stems become hollow, swollen and forms a gall.

Cotton stem weevil: Grub tunnels round the stem feeding on the soft tissue and this results in the formation of gall like swelling at the site of injury.

Amaranthus stem weevil: *Hypolixus truncatulus* twisting and swelling of branches and stems.

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 ripening seeds 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, casuarina, 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 /drying of 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 supporting root only. As a result leaves of affected plants turn pale, droop down and ultimately wither off. Cut end of 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.

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 give papery/scorched appearance leaving membranous cuticular layer and stout veins. Such feeding leads to skeletonization .

e.g. 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.

• 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 crops based 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 hopper burn, 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 viz *Nilaparvata lugens* and *Sogatella furcifera* of Delphacidae are known to cause hopper burn on Rice, a monocotyledon crop.

Leafhoppers belonging to the genus *Empoasca* of Cicadellidae are known to cause hopper burn on dicotyledon crops like cotton, okra, castor, brinjal, potato, beans etc.

The general symptoms of hopper burn caused by planthoppers and leaf hoppers is furnished here under.

Plant hoppers:- Yellowing of older leaf blades, progressive yellowing of all the plant parts, plants turn brown and die in patches. Suck sap from phloem element of monocotyledons. The damage is mainly through mechanical plugging of sieve elements with salivary sheaths (true sheaths were formed). Confined only to stems

Leaf hoppers:- Wilting of leaf tips in very young plants, chlorosis /necrosis on leaf margins, complete drying of leaves & wilting, premature leaf drop, stunted growth of plants. Suck sap from mesophyll paranchymatic cells/phloem elements either from stems/from veins. No such true salivary sheaths. The damage is mainly through mechanical wounding of cells. Change their feeding sites according to the situation.

Hopper burn in Groundnut:

Whitening of veins is the first symptom due to feeding from lower surface of leaflets, chlorotic (yellow) patches then appear especially at the tips of leaflets, probably caused by a reaction between jassids salivary secretion and plant sap. 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

b) Curling of leaf margins/with necrotic patches

Starting from leaf margin

-Cotton leaf hopper

c) Uniform yellowing of leaves from mid half

-Paddy leaf hopper

d) Reduced vigour/sooty mold, squaer/bolldrop

-White flies on cotton

e) Yellowing /reduced/stunted growth/sooty mould

-Aphids

f) Shriveled/chaffy and discolored grains/sooty

mould on grain

-Sorghum ear head bug/rice gundhi bug

g) Mottled appearance with yellow patches on infested leaves/sooty mould/undeveloped grains on infested ear heads

-Sorghum aphids

i) Gradual wilting and drying of ragi plants in patches

-Ragi root aphids

• 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. It consists of distortions of the young leaflets and patchy areas of necrotic tissue that puncture and split as leaf lets grow. Injury is normally seen in seedlings. In severe infestation, particularly in winter crop (November sown in South India), leaf distortion causes stunted plants. The effect of such damage on yields is not precisely known, but is not serious.

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.

- **Sponging and sucking or Lapping and sucking Type:**

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

- **Chewing and Lapping Type:**

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

- **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 semi-looper

- **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

Procytiphora mangiferae: The maggots feed on stalks of stamens, anthers, and ovary.

Dasineura amaramanjarae: The maggots feed inside the buds and they fail to open and drop down.

Erosomyia indica: The maggots attack the inflorescence stalk, flower buds and small developing fruits. The inflorescence becomes stunted and malformed and the buds do not open.

Mango leaf galls: *Procontarinia matteriana* Small raised wart like galls on tender leaves. Affected leaves deformed and drop prematurely.

Chilli Midge: *Asphondylia capsici*

Unopened buds are affected. Flowers dry and drop. Pods are deformed.

Coccinia gall fly: *Neolasioptera cephalandrae*

Elongated galls/swelling of distal stems in between the nodes. If cut open, gall shows maggots presence.

Jasmine blossom midge: *Contarinia maculipennis*

Swelling at the base of buds. Stunting, finally drying of plant.

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 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 petiole resulting in rotting of rhizome and dead hearts.

Eg: Turmeric rhizome fly.

EXPERIMENT NO. 2

METHODS OF INSECT PESTS, ASSESSMENT OF CROP YIELD LOSSES, CALCULATIONS BASED ON ECONOMICS OF IPM

2.1 Population assessment

Using fixed plot survey or roving survey population assessment is done either by visual observation or sampling.

Fixed plot survey: The plot is fixed in an area and the counts are made periodically at weekly intervals from seedling to maturity phase.

Roving Survey: Data on insect population and damage will be gathered from randomly selected plots in an area.

When the number of insect present on an area is relatively less, counting is done by visual observation. If the insect population is high and the population assessment is labourious, representative samples are taken which is known as sampling. The other methods used in insect population assessment are

- Net sweeping for hoppers, dragonfly, damselfly, grasshoppers etc
- Wet palm sweeping for rice thrips in nursery
- Sudden tapping and trapping with polythene bags for earhead pests of sorghum and cucumber.
- Light trapping for phototrophic insects
- Pheromone trapping for species specific insects
- Sticky traps for whitefly, aphids and hoppers
- Bait traps like fish meal trap for sorghum shoot fly and methyl eugenol for tephritid fruit flies.
- Assessment after knocking down of insects using chemicals.
- Use of Berleas funnel for soil and storage mites.
- Extraction of subterranean pests like grubs, earwigs etc from soil.

After assessing the insect population, decision regarding the types of control measures to be followed is done based on the Economic Threshold Level (ETL) and Economic Injury Level (EIL) of the pest. The beginning point of EIL is known as Gain Threshold.

$$\text{Gain Threshold} = \frac{\text{Management cost (Rs./acre)}}{\text{Market Value (Rs./kg)}}$$

EIL is also known as Action Thresholds Levels: The EIL concept is flexible and may vary from area to area, crop to crop depending upon the specific agronomic practices. The EIL decreases as the value of the crop increases.

Economic Injury Level (EIL) or Action Threshold Level

Definition: The lowest population density that will cause economic damage

$$EIL = C/VID$$

EIL= Number of injury equivalents per production unit (insect/ha)

C= Cost of management activity per unit of production (Rs./ha)

V= Market value per unit of product (Rs./tonnes)

I= Crop injury per pest density

D= Damage per unit injury (tone reduction/ ha)

If some loss become unavoidable, the relationship become

$$EIL = C/VIDK$$

Where K = Proportionate reduction of injury (if the proportionate reduction of injury is 60 per cent, the K value is taken as 0.6)

Economic Threshold Level

Definition: Population density at which control measures should be determined to prevent an increasing pest population from reaching the EIL or

Refers to number of insects per unit area when management action should be taken to prevent the pest from reaching EIL.

ETL is experimentally designed as follows

- Measure the yield of crop for a range of pest densities, including zero (control plot) under controlled experiments
- Measure the yield and total crop revenues in the same type of experiments for each management practices to be analysed.
- Compute total crop revenue for each management at each pest density (Yield × Price per unit of output)
- Compute net revenue (subtract cost of each management action from crop revenue at each pest density)
- The pest density where the net revenues under controlled and uncontrolled conditions are equal is the Economic Threshold Level.

Or

The pest density where Marginal crop revenue is equal to the management action cost is also ETL. (An hypothetical example is given in the table)

$$\text{Marginal crop revenue} = \text{Crop revenue from taking action} - \text{Crop revenue from not taking action}$$

It is clear that crop value and management cost are the two important factors deciding the EIL and ETL. In the given example if the price of fruit goes down to Rs. 1 per kg the management cost also should reduce by same proportion i.e. 10.40-5.20 to maintain the same ETL. In the given case if the management cost remains at the same level of Rs. 10.40, then the ETL will come down.

Table No. 2 Influence of crop value and management cost on ETL for a moringa plant affected by moringa fruit fly *Gitona distigma*

Pest density (% affected fruits)	Yield/Plant (Kg)	Management cost @ Rs. 10.40 / plant	@ Rs. 2/kg of fruit	
			Revenue	Net Revenue
0	40.00	It is uniform for all plants.	80.00	69.60
1	39.60		79.20	68.80
2	39.20		78.40	68.00
3	38.80		77.60	67.20
4	38.40		76.80	66.40
5	38.00		76.00	65.60
6	37.60		75.20	64.80
7	37.20		74.40	64.00
8	36.80		73.60	63.20
9	36.40		72.80	62.40
10	36.00		72.00	61.60
11	35.60		71.20	60.80
12	35.20		70.40	60.00
13	34.80		69.60	59.20
14	34.40		68.80	58.40
15	34.00		68.00	57.60
16	33.60		67.20	56.80
17	33.20		66.40	56.00
18	32.80		65.60	55.20
19	32.40		64.80	54.40
Uncontrolled	32.00	0	64.00	64.00

7 per cent affected fruits gives a net revenue of Rs. 64 which is equal to net revenue from uncontrolled condition.

Marginal crop revenue at 7 per cent of affected fruits

$$\begin{aligned}
 &= \text{Crop revenue from taking action} - \text{Crop revenue from not taking action} \\
 &= 74.40 - 64.00 \\
 &= \text{Rs. } 10.40
 \end{aligned}$$

So the marginal crop revenue at 7 per cent of affected fruits is Rs. 10.40 which is equal to the management cost.

Therefore ETL is 7 per cent affected fruits per plant.

2.2 Assessment of Insect Population and Damage

Objective

- To know the extent of pest load and their damage
- To workout economic injury level and economic threshold level
- To estimate yield loss
- To decide the timing of control measures in order to avoid indiscriminate use of insecticides

Rice

Sucking Insect

Thrips: Feeding results in longitudinal curling and yellowing with pointed leaftips mostly in the nursery. Leaves may dry in due course. Pass wet palm or table tennis bat over the seedling in five places and count the number of thrips (ETL 25/5 passes or 10 per cent of affected seedlings).

Green leafhopper (GLH): Feeding on leaves results in yellowing. It is the vector for rice tungro virus disease (RTV). Count the number of insects per seedling in the nursery (ETL : 50/100 seedling) or number per hill in the field (ETL: 5/hill at vegetative stage, 10/hill at reproductive stage, 2/hill in RTV endemic area). Sweep net can also be used for sampling (ETL: 60/25 sweeping).

Brown plant hopper (BPH): feeding on stem just above water level results in hopper burn. Count the total number of insects in 10 hills selected random in one square meter area (ETL: 1/tiller or 2/tiller if predatory spider is present).

Earhead bug: Black spot at feeding point on the grain and individual chaffy grains. Insects emit stinky odour. Count the number of bugs in 100 earheads selected at random (ETL: 5 at flowering stage or 16 bugs at milky stage/ 100 panicles).

Chewing insects

Rice stem borer: Assessment is based on eggs and larval damage. Presence of yellowish brown egg mass near the leaf tip and presence of dead heart at vegetative stage or white ear at reproductive stage.

Eggs in the nursery: Number of egg masses/m² (ETL: 2)

Larval Damage: count the total tillers and affected tillers in a unit area and arrive at a percentage.

$$\text{Per cent Dead Heart} = \frac{\text{Number of Dead Hearts}}{\text{Total number of tillers}} \times 100 \text{ (ETL: 10\%)}$$

$$\text{Per cent White ears} = \frac{\text{Number of White ears}}{\text{Total Productive of tillers}} \times 100 \text{ (ETL: 2\%)}$$

Gall midge: Assessment is based on damage on damage, silver shoot or onion shoot

$$\text{Per cent White ears} = \frac{\text{Number of Silver Shoot}}{\text{Total number of tillers}} \times 100 \text{ (ETL: 10\%)}$$

Leaf Folders: Assessment is based on damage, folded and scrapped leaves in 10 randomly selected plants.

$$\text{Per cent White ears} = \frac{\text{Number of Damaged leaves}}{\text{Total number of leaves}} \times 100)$$

(**ETL:** 10 % at vegetative stage or 5 % at flowering stage)

Whorl maggot: Assessment is based on damage, marginal blotching and yellow patches on the leaves in 10 randomly selected plants.

$$\text{Per cent White ears} = \frac{\text{Number of Damaged leaves}}{\text{Total number of leaves}} \times 100 \text{ (ETL: 25\%)}$$

Cotton

Sucking insects

Leafhoppers: Leafhoppers causes marginal yellowing, downward cupping of leaves and hopper burn. Count the number of hoppers in first two terminal leaves on 25 plants in the early stage and express as number of hoppers per leaf (ETL 1/leaf).

Aphid: De-sapping by aphid colonies results in curling and crinkling of leaves. Honey dew secreted by aphids attracts ants and invites sooty mould. Count the number of infested plants in 100 randomly selected plants and arrive at a percentage (ETL 20%).

Thrips: Thrips causes leaf crinkling, ragged margin and silvery white spots on the under surface. Count the number of insects on the top unopened leaves on 25 plants and express as number of thrips per leaf (ETL: 5/leaf).

Whitefly: Sedentary oval shaped nymphs and pupae and small white moth like adult insect desap the leaves resulting in yellowing, honey dew secretion and sooty mould infection. Count the number of nymphs and pupae on three leaves one at bottom, one at middle and at the top during vegetative and maturity phase (ETL: 5/leaf)

Mite: Small reddish mites within silken web desap the leaves particularly on matured ones causing yellowing and leaf droppings. As the mites are numerous in number, population per unit area is recorded. Small card with one square cm cut in the center is placed on the under surface of leaf and number of mites is recorded (ETL: 10/cm²)

Chewing insects:

Stem weevil: Assessment is based on damaged galls on the collar region of stem.

$$\text{Per cent Stem weevil damage} = \frac{\text{Number of infested Plants}}{\text{Total number of plants}} \times 100 \text{ (ETL: 10\%)}$$

Bollworms:

Spotted bollworm: Symptoms are wilting of shoots, presence of bore hole at base of the boll plugged with excreta.

American bollworm: Bollworm infestation in the square results in flaring and shedding. Circular clear bore hole is seen in the developing boll.

Pink bollworm: Symptoms include rosette flower, no holes at the entry point (boll tip), bore hole disappears as the boll matures. Bore hole in locule, discoloured lint and empty seeds. Damage is expressed as per cent affected bolls.

Tobacco cutworm: assessment is based on number of egg masses in 100 m area by walking criss cross at 20m in 5 places in the field. (ETL: 8/100 m row)

Vegetables

Shoot and Fruit borer: At vegetative stage, attack the shoot resulting drying and dropping of shoots. Count the total number of shoots damaged and arrive at a percentage.

Number basis: Count the infested as well as healthy fruits and arrive at a percentage.

Weight Basis: Weigh the damaged and healthy fruits and work out the percentage at harvest.

Ash weevil: Adults feed on leaves resulting notching of the edges of the leaves, while the grubs feed on roots causing wilting. Count the total number of leaves, the number of leaves showing notching symptom and arrive at a percentage. Count the total number of plants, the number of dried plants and arrive at a percentage.

Defoliators

Method I: Select 10 plants per plot at random, count the total number and number of leaves affected and arrive at a percentage.

Method II: Divide each leaf into 4 quarters, count affected quarters and work out the damage.

$$\text{Per cent damage} = \frac{\text{Number of Damaged quarters}}{\text{Total number of leaves} \times 4} \times 100$$

Method III: Tracing the margin of whole leaf and affected portion on a graph sheet to measure the area and work out per cent area of damage.

Method IV: Introduce the infested leaf into the leaf area meter and compare it with healthy leaf and difference will give the area damaged by the insect.

Bhendi

Fruit Borer: Count the total number and number of fruits damaged in a plot and arrive at a percentage.

Leafhopper:

Based on number of insects in three fully opened leaves, expressing as numbers per leaf.

Grading the damage visually by observing the leaves in sample plants.

Grade I: Free from hopper burn

Grade II: Crinkling and curling of a few leaves mostly in upper portion of the plant and yellowing.

Grade III: Crinkling and curling of leaves all over the plant and stunted growth.

$$\text{Mean grade index} = \frac{G_1N_1 + G_2N_2 + G_3N_3 + G_4N_4}{N}$$

Where G1, G2, G3 AND G4 are grades

N1, N2, N3 and N4 are number of plants in each grade

N is total number of plants sampled

EXPERIMENT NO. 3

IDENTIFICATION OF BIOCONTROL AGENTS, DIFFERENT PREDATORS AND NATURAL ENEMIES

3.1 Green lace wing: *Chrysoperla carnea* (Neuroptera, Chrysopidae)

Larvae are important predators of insect pests viz., aphids, mealy bugs, eggs and smaller larvae of various insects of agricultural importance and mites. Each larva has potential to feed on average 12 aphids/day or about 120 aphids during the entire developmental period.



Fig 3.1: Green lace wing: *Chrysoperla carnea*

3.2 Ladybird beetle: *Cryptolaemus montouzieri*: (Coccinellidae: Coleoptera)

The adults and larvae of these insects eat scale insects, especially mealybugs. Females lay their eggs among the egg sack of mealybugs. Larvae feed on mealybug eggs, young crawlers and their honeydew. They become adults in 24 days, after three larval stages and a pupal stage. The life span lasts two months.



Fig 3.2: Ladybird beetle: *Cryptolaemus montouzieri*

3.3 Ladybird beetle: *Cheilomenes sexmaculata* (Coccinellidae: Coleoptera)

Cheilomenes sexmaculata is a very important, polyphagous predator of aphids and other soft bodied insects. It has been recorded in most crop ecosystems, particularly where aphids are serious pests. It has been produced in the laboratory and used for the suppression of *A. craccivora* on groundnut.



Fig 3.3: Ladybird beetle: *Cheilomenes sexmaculata*

3.4 Egg parasitoid: *Trichogramma* Sp. (Hymenoptera, Trichogrammatidae)

Trichogramma sp are of common occurrence and distributed throughout the world. They parasitise eggs of Lepidopteran mainly but are also reported from Coleoptera, Neuroptera and Diptera. In India it is commercially available for the pest suppression of sugarcane, cotton, sorghum, maize and paddy borers.

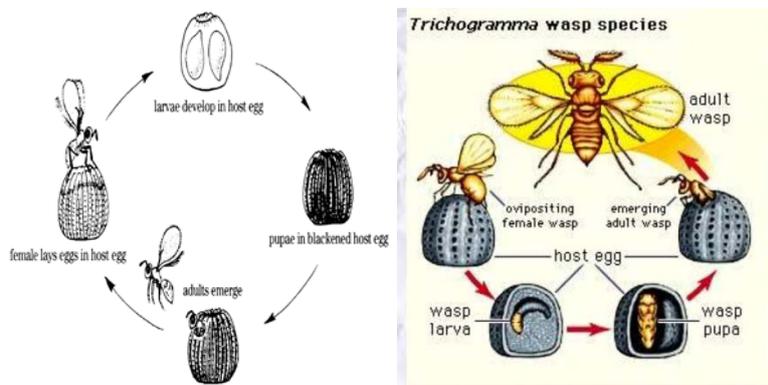


Fig 3.4: Egg parasitoid: *Trichogramma* Sp.

3.5 Larval parasitoid: *Bracon hebetor* (Braconidae: Hymenoptera)

It is a well known external, gregarious larval parasitoid of several of the lepidopterans.

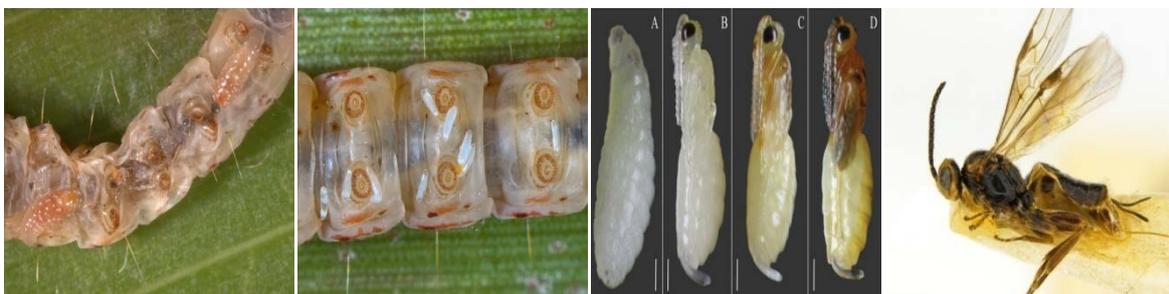


Fig 3.5: Larval parasitoid: *Bracon hebetor*

3.6 Pupal parasitoid: *Tetrastichus israeli* (Eulophidae: Hymenoptera)

The pupal parasitoid was observed to parasitise the pupae of *Opisina arenosella* and an average 90 adult parasitoids emerged from a single pupa under natural conditions. It can be mass reared on fresh pupae of *S. litura*, *H. armigera*, *Plusia* sp., or *Ergolis* sp.



Fig 3.6: Pupal parasitoid: *Tetrastichus israeli*

EXPERIMENT NO. 4

MASS MULTIPLICATION OF TRICHOGRAMMA AND NPV

4.1 *Trichogramma*

Trichogramma sp. are of common occurrence and distributed throughout the world. They parasitise eggs of Lepidopteran mainly but are also reported from Coleoptera, Neuroptera and Diptera. In India it is commercially available for the pest suppression of sugarcane, cotton, sorghum, maize and paddy borers

a) Biology:

- Incubation period : 24-36 days
- Larval period : 2-3 days
- Pupal period : 3-4 days
- Adult longevity
 - Male : 5-7 days
 - Female : 5-20 days
- Fecundity : 35-300 eggs

b) Equipment and facilities required:

Refrigerator, B.O.D. incubators, eggs of *Corcyra cephalonica* (rice meal moth), glass tubes, sieve (40 mesh size), paper cards, UV lamp, table lamp etc.,

c) Rearing:

In India, *Trichogramma* sp are reared on the eggs of rice meal moth. Freshly collected eggs of *Corcyra* are cleaned of the scales, mites and other foreign matter associated with these and are glued on the Trichocard with uniformly thin layer using 2 per cent gum Arabic in distilled water (W/V). The sprinkling of the eggs is done either with camel hair brush or a fine sieve which does not allow more than one or two eggs to pass through its hole at a time. Thus 18000-72000 (1 ml) frozen host eggs are glued on a trichocard (15x7.5 cm). If the eggs were not frozen the trichocard should be exposed to UV lamp for about 10 minutes. The card is further divided through punching into 6 strips each of 7.5x2.5 cm size which can be easily pressed and separated. A strip containing glued eggs on it was inserted into a glass tube (10x2.5 cm) having newly emerged adults. The adult parasitoids are provided with honey streaks (50% honey dissolved in water) drawn on inner side of the tube and secured tightly with muslin cloth and rubber bands. The card is changed after 24 hrs and replaced with fresh card. Thus continuity of change over is maintained for 3 to 4 days or till female survive and remain productive. The host eggs oviposited by female turns black after 3 days of parasitization. The parasitoid completes its life cycle in 7-9 days at $27 \pm 2^{\circ}\text{C}$ and $75 \pm 5\%$ RH.

Precautions:

1. If host eggs are not frozen/treated with UV rays to kill the embryo, the moth's larvae may hatch out from the unparasitised eggs. These larvae should be brushed out gently since they eat away the unparasitised eggs.
2. Avoid super parasitism either by exposing host eggs upto 8 hrs or providing 6 eggs for one parasitoid.
3. Maintain pure species of different species of Trichogrammatids through proper handling and regular examination.
4. Do not offer frozen eggs to *T. japonicum* as it does not develop well on such eggs.

5. Do not rear *T. brasiliensis* at the temperature exceeding 26⁰C where undesired male formation is more.
6. Do not cold store parasitized eggs at 5-10⁰C for more than 15-20 days as beyond this storage biological attributes of the parasitoids are affected.
7. Use healthy eggs of host for healthy parasitoid.
8. Do not put excess gum while sprinkling the host eggs.
9. Do not rely on super parasitized parasitoids as they are normally weak and unfit for the production of healthy progeny.

4.2 NPV

Among viruses of the group baculoviridae, nuclear polyhedrosis viruses are utilized for the successful suppression of various insect pests of many agricultural and horticultural crops.

Nuclear polyhedrosis viruses of *Helicoverpa armigera* and *Spdoptera litura* are highly specific to their respective live hosts for multiplication. So production of viruses for use as insecticides needs mass production of their hosts as a first step. Basic steps in the production of nuclear polyhedrosis viruses of any insect are

1. Mass culturing and maintenance of host insects
2. Host inoculation with viruses
3. Harvesting of viruses
4. Purification
5. Storage

Host insects can be reared either on their natural host plants (foliage, pod, fruit etc) or on artificial diet. Since natural host plants cannot be found throughout the year, maintenance of host insects on artificial diet has the advantages of rearing under sterile conditions, avoiding contamination, saving space, time and labour. Thus the use of artificial diet for mass production of host insects is economical and easy.

Mass culturing of host insects can be started either from field collected adults using light traps or from field collected larvae reared to adult stage in the laboratory. Production starts with the availability of males and females of the host insects that are allowed in a oviposition jar having 10% honey and water soaked cotton wads placed separately inside in lids as adults food and its top covered with muslin cloth pinned with few muslin cloth strips hanging inside the jar.

Eggs laid on cloth are collected daily and surface sterilized by soaking in 0.15% sodium hypochlorite for 5-10 minutes. Eggs settling at the bottom of the container are collected and incubated in petri dishes.

Rearing of newly hatched *H. armigera* larvae is done by transferring individually (since the larvae are cannibalistic) into rearing vials containing artificial diet. In case of *S. litura*, since the eggs are laid in masses and larval stages are not cannibalistic, first two instars can be reared in groups or castor leaves.

Table No. 4.1 Preparation of artificial diet

<u>Ingredients</u>	<u>Quantity</u>
Kabuli gram flour	105.00 g
Sorbic acid	1.00 g
Methyl para hydroxyl benzoate	2.00 g
Yeast tablets	10 g
Agar-agar	12.75 g
Formalin (10%)	2.00 ml
Vitamin E	2 capsules
Multivitaplex	2 capsules
Ascorbic acid	3.25 g
Streptomycin sulfate	0.25 g
Water	780.00 ml

Gram flour yeast tablets, methyl Parahydroxy benzoate and Sorbic acid are added to half the quantity of water in a blender and mixed for 2-3 minutes. Simultaneously agar-agar is boiled with remaining quantity of water and cooled down to 70°C. Hot agar liquid is added to the blender and mixed with other ingredients. Finally Multivitaplex, Vitamin E, Ascorbic acid and formalin are added and blended for about 2 minutes.

Hot liquid diet is dispensed into rearing vials/tubes and allowed for solidification at room temperature for about 20 minutes. Tubes/vials are arranged in plastic/aluminum trays. Single larvae should be introduced in each vial on the diet surface and closed with cotton plug. The trays can then be stacked on racks. While 20% of the larval population can be allowed to pupate for continuous maintenance of host insect culture, the rest can be used for virus production.

Mass production of viruses:

Infestation of 8 to 9 day old larvae is done by inoculating the surface of the diet poured in plastic cups (as against in vials/tubes used for healthy host insect culture), with a virus dose of 1.1×10^4 Polyhedral inclusion bodies per larva. Larvae are placed individually on virus contaminated diet in cups and capped. The containers are arranged in plastic trays and stacked on racks.

Observations on larval mortality is made daily and the moribund/dead larvae with viral symptoms (cuticle of the larvae becomes fragile and ruptures easily when touched; body colour changes to blue or bluish purple) are harvested and placed in conical flask.

The diseased/dead larvae are macerated in a mixture using sterile distilled water. The contents are allowed as such in conical flasks for several days at room temperature, during which time the polyhedra settle down as a white layer. Alternatively, macerated contents can be sieved through a double layer of muslin cloth and the filtrate is standardized for the PIB/ml using a haemocytometer for field use. 250 larval equivalents (LE)/Ha; One LE = 6×10^9 PIB

EXPERIMENT NO. 5

IDENTIFICATION AND NATURE OF DAMAGE OF IMPORTANT INSECT PESTS AND THEIR MANAGEMENT

Table 5.1 Identification of major insect pests of different crops and their damage symptoms

Insect particulars	Marks of identification	Nature and symptoms of damage
Rice		
PADDY STEM BORER: <i>Scirpophaga incertulas</i> (Walker), Pyralidae: Lepidoptera	Moth: Female yellowish brown, male pale yellow with pointed head. A prominent black spot present on each of the fore wings of the female, absent in male. Tuft of anal hairs present in female. Caterpillar: Yellowish white with a dark brown head and prothoracic shield.	Newly hatched larva moves on the leaf blade for 1-2 hours and later reaches the leaf sheath and bores into the stem near the nodal region at ground level. Larval feeding inside the stem results in the formation of dead heart or white ear during vegetative and reproductive stages respectively and they can be easily pulled out.
GALL MIDGE: <i>Orseolia oryzae</i> (Wood Mason) Mnai, Cecidomyiidae: Diptera	Adult: A dipteran fly with long slender legs. Female is bright red while male is darker in colour. Caterpillar: Pale red, apodous, tapering anteriorly.	Newly hatched maggot moves down to the shoot apex and feeds on the growing point. It results in the stimulation of leaf sheath to form a hollow pale green cylindrical tube similar to onion leaf. It is known as gall/onion leaf/silver shoot. Affected tillers do not bear panicles. Infestation in early growth period of crop induces vigorous subsidiary tillering.
BROWN PLANTHOPPER: <i>Nilaparvata lugens</i> (Stal), Delphacidae: Hemiptera	Adult: • Brown to brownish black. Nymph: • Pale white with brownish tinge.	Both nymphs and adults suck sap from the base of plant. Excessive sap drain from the plant results in yellowing of leaves initially and in course of time whole plant dries. Drying of plants occur in isolated patches and gradually in a circular pattern, exhibiting hopper burn symptom.

		Severe infestation results in development of sooty mould.
SORGHUM, MAIZE AND OTHER MILLETS		
<p>SORGHUM SHOOT FLY: <i>Atherigona soccata</i> Rondani, Muscidae: Diptera</p>	<p>Adult: Dark grey in colour and looks like a small housefly. Abdominal segments of male and female bear 6 and 4 dark spots respectively, arranged in two rows. Maggot: Pale yellow, apodous and tapering at one end.</p>	<p>Newly hatched maggot migrates to the upper surface of leaf, moves along the margin towards leaf sheath. On entering between the leaf sheath and axis, it nibbles the tissues and makes an horizontal cut. Young seedling dries and exhibits the dead heart symptoms.</p>
<p>SORGHUM STEM BORER: <i>Chilo partellus</i> Swinhoe, Pyralidae: Lepidoptera</p>	<p>Adult: Straw coloured with pale yellow grey forewings with black specks along caudal margin. In males, hind wings are pale straw coloured and in females, hyaline. Caterpillar: Dirty white with brown head having many dark spots on the body.</p>	<p>Initially, larvae feed on leaves causing shot holes. Later, larvae bore into the stem and cause dead heart as such young plants can be easily pulled out. They do not emit foul smell.</p>
<p>SORGHUM MIDGE: <i>Stenodiplosis sorghicola</i> (=<i>Contarinia sorghicola</i> Coquillet), Cecidomyiidae: Diptera</p>	<p>Adult: Slender and abdomen bright red. Wings when folded extend just beyond the tip of the abdomen. Maggot: Newly hatched maggot creamy white, later turn to orange red.</p>	<p>Maggots suck the contents of the developing ovaries which result in the production of chaffy florets/ grains.</p>
<p>SORGHUM EARHEAD BUG: <i>Calocoris angustatus</i> Leth Miridae: Hemiptera</p>	<p>Adult: Yellowish green and long legged. Nymph: First instar nymphs tiny with a mixture of yellow and orange red colour.</p>	<p>Both nymphs and adults suck sap from the developing grains. Grains become shriveled and discoloured.</p>
SORGHUM APHIDS:	Adult:	Both nymphs and adults suck

<p><i>Rhopalosiphum maidis</i> Fitch, Aphididae: Hemiptera</p>	<p>Black/ green with dark green legs, winged or wingless. Nymph: Yellowish.</p>	<p>sap from leaves and ear heads. Infested leaves exhibit mottled appearance with yellow patches. Grains do not develop in the affected ear heads. Sooty mould develops on infested parts due to the excretion of honey dew.</p>
<p>MITES: <i>Oligonychus indicus</i> Hirst, Tetranychidae: Acrina.</p>	<p>Adult: Grayish green, minute in size. Larva: Spherical and light amber coloured larva later becomes greenish and elongate.</p>	<p>Mites spin delicate webs on the lower surface of leaves and live inside the web. Nymphs and female adults suck sap from leaves. Infested leaves show characteristic red spots which enlarge and coalesce making the whole leaf reddish. Leaves and stem dry up in case of severe infestation</p>
SUGARCANE		
<p>EARLY SHOOT BORER: <i>Chilo infuscatellus</i> Snell, Pyralidae: Lepidoptera</p>	<p>Adult: Small grayish brown/ straw coloured with labial palpi projected forwards. A row of white dots present along the outer margin of fore wings. Caterpillar: White with five violet stripes dorsally and dorso-ventrally on its body and with a dark brown head.</p>	<p>Larvae at first feed on leaf epidermis and then enter the stem by making a hole just above ground level. It results in destruction of both growing point and central whorl forming a characteristic dead heart. Dead heart associated with foul smell.</p>
<p>TOP SHOOT BORER: <i>Scirpophaga nivella</i> Fabricius, Pyralidae: Lepidoptera</p>	<p>Adult: Creamy white, slightly bigger than early shoot borer. A tuft of crimson (deep red) coloured hairs present at the tip of abdomen of female and a black spot on forewings of male. Caterpillar: Pale white in colour.</p>	<p>Pest attack confines mainly to the top portion of the shoot. Caterpillar first tunnels into the midrib of leaves, and forms red markings. Later, it tunnels towards the central core of leaves and enters the shoot. As a result, number of small holes (shot holes) can be seen subsequently on central leaves. It feeds on growing point resulting in drying up of the central whorl of uncurled</p>

		<p>leaves, which forms dead heart.</p> <p>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.</p> <p>Note the low humidity is unfavorable for this pest.</p>
<p>INTERNODE BORER: <i>Chilo sachariphagus</i> indicus (Kapur), Pyralidae: Lepidoptera.</p>	<p>Adult: Small and straw coloured, forewings have a marginal dark line and hind wings are uniformly white.</p> <p>Caterpillar: White with brown head and dark spots on body.</p>	<p>Caterpillar bores at the nodal region and enters the stem.</p> <p>It's feeding makes the tissue red and the hole is plugged with excreta.</p> <p>Note that low temperature and high humidity are favorable.</p>
<p>MEALY BUG: <i>Saccharicoccus sacchari</i> G., Pseudococcidae: Hemiptera</p>	<p>Adult: Small pinkish oval insect attached to lower nodes, under the leaf sheaths and covered by a white waxy powder, females are sac like with clearly segmented body. Males are winged, but rare.</p>	<p>Both nymphs and adults suck sap from the canes near the leaf sheath.</p> <p>While feeding they excrete honey dew on affected portions.</p> <p>It helps in the development of sooty mould. As a result, internodes turn black.</p> <p>Due to heavy draining of sap, plants loose vigour and become stunted in growth.</p>
<p>SUGARCANE SCALE: <i>Melanaspis glomerata</i> (Green), Diaspididae: Hemiptera.</p>	<p>Adult: Grayish black, irregularly oval and slightly convex in shape.</p> <p>Females are flat and pyriform in shape while males are winged and small in size, but rare.</p> <p>Crawler: Tiny and light yellowish.</p>	<p>Infestation starts with the formation of internodes and gradually forms a thick encrustation on the stem.</p> <p>Both nymphs (crawlers) and adult females suck juice and cause shriveling and stunting of canes.</p> <p>Infested leaves exhibit mottled appearance with yellow patches.</p> <p>Sooty mould develops on infested parts due to the honey dew.</p>
PULSE		
<p>LENTIL POD BORER: <i>Etiella zinckenella</i> Treitsehcke,</p>	<p>Adult: Grey, delicate, forewings have dark</p>	<p>Newly hatched larvae feed on floral parts and later bore into pods and feed on seeds.</p>

<p>Pyralidae: Lepidoptera</p>	<p>marginal lines and a pale club shaped marking at 1/3 of the base of the wings. Caterpillar: Newly hatched ones greenish while the full grown caterpillars have purple tinge with 5 dots on prothorax.</p>	
<p>RED GRAM PODFLY: <i>Melanagromyza obtusa</i> (Malloch), Agromyzidae: Diptera.</p>	<p>Adult: A small metallic, black fly with strong legs and ovate abdomen. Wings clear veined and brownish yellow at the base. Maggot: Creamy white in colour.</p>	<p>Maggot feeds under the epidermis for some time, then enters the seed and consumes only part of a seed. Only one seed is sufficient for maggot to complete development. 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.</p>
<p>RED GRAM PLUME MOTH: <i>Exelastis atomosa</i> Wlsm, Pterophoridae: Lepidoptera.</p>	<p>Adult: Slender, grey with long narrow wings. Fore wings divided into two parts while hind wings cut into three parts and are provided with fringe like hairs. Caterpillar: Greenish brown with short hairs on the body.</p>	<p>Caterpillar first scrapes the surface of pods, enters into the pod by cutting a small hole and feeds on seeds. Seed is completely eaten away by the caterpillars, unlike pod fly. It feeds on flower buds and causes severe shedding of buds, flowers and pods.</p>
<p>SPOTTED POD BORER: <i>Maruca vitrata</i> Geyer, Pyralidae: Lepidoptera.</p>	<p>Adult: Bears white markings across the dark brown forewings and a dark border on the white hind wings. Caterpillar: Greenish with a brown head and short dark hairs and black spots</p>	<p>Caterpillar webs flower buds and feeds on them. It enters into pod also near the pedicel and feeds on the ripening seeds, by remaining inside the pod. At the entrance hole, a mass of dried excreta can be seen.</p>

	on the body.	
GRAM CATERPILLAR: <i>Helicoverpa armigera</i> (Hubner), Noctuidae: Lepidoptera.	Adult: A stout medium sized moth with dark/ grey/ brown forewings having a dark cross band near the outer margin and dark spots near costal margins. Caterpillar: Greenish with dark broken lines towards the lateral sides of the body. Body segmentation is distinct, covered with fine hairs.	Caterpillar feeds on leaves, flower buds and pods. Bracts of damaged flower buds spread out and curl downwards. While feeding, caterpillar inserts it's head inside the pod leaving rest of the body outside. Damaged pods with round holes.
TOBACCO CATERPILLAR: <i>Spodoptera litura</i> Fabricius, Noctuidae: Lepidoptera.	Adult: Medium sized moth with stout body. Forewings pale grey to dark brown in colour with wavy white markings and hind wings white with smoky margins. Caterpillar: Velvety black with yellowish green dorsal stripes and lateral white bands. A dark ring like structure is seen on anterior and posterior region in early stages.	During early instar, caterpillars scrape chlorophyll content of leaf lamina giving it a papery white appearance. During later instars, skeletonize the leaves leaving only veins and petioles. During flowering stage of crop, fed on the internal contents of pods and cause irregular holes.
STEM FLY: <i>Ophiomyia phaseoli</i> Spencer, Agromyzidae: Diptera.	Adult: Small black fly. Maggot: Tiny and apodous.	Maggots enter the tender stem through leaf petiole and feed on tissues. Affected plants wilt and gradually dry up leaving many gaps in the field. Infestation occurs only up to 30-35 days after sowing.
GROUNDNUT		
LEAF MINER: <i>Proaerema modicella</i> Deventer, Gelechiidae:	Adult: Small with dark brown wings and small distinct white spot on	Newly hatched larvae mine into tender leaflets between epidermal layers and feed. After about 8 days live as a

Lepidoptera.	fore wings. Caterpillar: Cylindrical, tapering posteriorly, brownish/light green in colour with dark head and prothorax.	miner, larvae bites its way out and webs together number of leaflets and feeds on the tissues, making a silk chamber for itself. Infestation results in skeletonization of leaflets. The infested field exhibit burnt appearance.
WHITE GRUB: <i>Holotrichia consanguinea</i> Fabricius, Scarabaeidae: Coleoptera.	Adult: A medium sized beetle with light yellowish/brownish elytra. Grub: White with a brown head.	Grubs devour secondary feeder roots, leaving the supporting root only. Leaves of affected plants turn pale, droop down and ultimately wither off. Cut end of the affected stem of collapsed plant swells, a characteristic diagnostic symptom. Drying of plants in patches
RED HAIRY CATERPILLAR: <i>Amsacta albistriga</i> Walker, <i>A. moorei</i> Butler, Arctiidae: Lepidoptera	Adult: Medium sized. In <i>A. albistriga</i> , forewings white with brownish spots all over and yellowish streak along the (costal) anterior margin; yellow band present on the head. In <i>A. moorei</i> , the anterior marginal streak of forewings and band on head is red in colour. Caterpillar: Both species are reddish brown with black bands on either end and bear long reddish brown hairs arising on warts all over the body.	During early stages, caterpillars feed in groups on the lower side of leaflets. As they grow, they feed voraciously on leaves, leaving behind the petiole and midrib on the main stem. They can be seen moving from one end of the field to other.
GROUNDNUT APHID: <i>Aphis craccivora</i> Koch, Aphididae: Hemiptera.	Adult: An oblong, soft bodied and dark brown insect. In alate form, wings are thin, transparent	Both nymphs and adults suck sap by remaining on lower surface of leaves and reduce vitality of the plant. In case of severe attack, leaves

	and held like a roof over the body. Nymph: Pale green initially, but later turn dark.	curl down, fade gradually and finally dry up. Black sooty mould develops on honey dew excreted by the aphids, which falls on leaves. It also transmits groundnut rosette/ stunt virus disease.
LEAFHOPPER: <i>Empoasca kerri</i> Cicadellidae: Hemiptera		Both nymphs and adults suck sap from central surface of leaves, also inject toxin causing whitening of veins and chlorotic patches at tips of leaflets in a typical 'V' – shape. There will be hopperburn in severe cases.
BRINJAL		
EPILACHNA BEETLE: <i>Henosepilachna vigintioctopunctata</i> Fabricius, Coccinellidae: Coleoptera.	Adult: An yellow hemispherical beetle with 12-28 black spots on elytra. Head partly concealed by pronotum. Grub: Body yellowish broad anteriorly and narrow posteriorly and covered with spiny structures all over.	Both grubs and adults scrape the leaves in characteristic manner and feed (ladder like scrapings). They confine their feeding activity mostly to the lower side of leaves.
SHOOT AND FRUIT BORER: <i>Leucinodes orbonalis</i> Guenee, Pyralidae: Lepidoptera.	Adult: White moth with pink brown markings on wings and blackish brown head and thorax. Caterpillar: Pinkish with sparingly disturbed hairs arising on warts all over the body.	If infestation occurs during vegetative phase, caterpillars enter into the petiole, midribs and young shoots. As a result, the infested shoot wilts and droops. During fruiting stage, caterpillars enter into fruits make holes and feed inside. Initially, the entry hole is so small that it is not visible. Later, fruits bear large circular holes plugged with excreta.
BRINJAL STEM BORER: <i>Euzophera perticella</i> Rag. Pyralidae: Lepidoptera.	Adult: Medium sized with grayish brown forewings having transverse lines in the middle and white hind wings.	Caterpillar enters into stem near the axil of leaf/ branch at ground level of the plant. Excreta can be seen coming out of the entry hole. An infested plant wilts and dries up.

	Caterpillar: Creamy white in colour.	
MEALY BUG: <i>Centroccoccus insolitus</i> Pseudococcidae: Hemiptera.	Adult: Brownish/ pinkish and oval in shape. Body covered with white waxy filamentous material.	Colonies of nymphs and adults suck sap from lower side of leaves, tender shoots and fruit stalks. Infestation results in yellowing and drying of plants. Infested leaves look as if white washed.
BRINJAL MITE: <i>Tetranychus telarius</i> L., Tetranychidae: Acarina.		Feed on lower surface of leaves by remaining underneath a web in case of red spider mites. Infested leaves curl down become hard and crisp and ultimately shed.
CRUCIFERS		
DIAMOND BACK MOTH: <i>Plutella xylostella</i> Linnaeus, Plutellidae: Lepidoptera.	Adult: Small grayish brown with narrow forewings having pale white marking at anal region which form a diamond like patch, when folded. Caterpillar: Small greenish with short hairs on body which tapers towards both the ends.	Caterpillars feed on the lower side of leaves and bite holes on leaves. Affected leaves present a withered appearance. In severe case, leaves are skeletonized.
CABBAGE BORER: <i>Helulla undalis</i> Fabricius, Pyralidae: Lepidoptera.	Adult: Small pale brown with grey wavy lines and central elliptical marking on forewings. Caterpillar: Brownish with a black head and four longitudinal lines on the body.	Caterpillars web the leaves and bore into stem, stalk or leaf veins. They bore into the cabbage head also and make it unfit for consumption.
CABBAGE LEAF WEBBER: <i>Crocidolomia pavonana</i> Zeller, Pyralidae: Lepidoptera	Adult: Small with light brownish forewings. Caterpillar: Bears red head with brown longitudinal stripes and rows of	Caterpillars web the foliage and skeletonize the leaves. Feed on flower heads in case of cabbage and cauliflower. Also feeds on flowers and pods in case of mustard.

	tubercles on the body.	
PUMPKIN BEETLE: <i>Raphidopalpa foveicollis</i> Lucas, <i>Aulacophora cincta</i> Fabricius, <i>A. intermedia</i> Jacob, Galerucidae: Coleoptera	Adult: <i>R. foveicollis</i> adults with reddish brown elytra. <i>A. cincta</i> adults have grey elytra with black border. <i>A. intermedia</i> adults have blue black elytra. Caterpillar: Creamy white with dark oval shield at back.	Adult beetles bite holes on the cotyledon leaves and flowers. Grubs damage the plants by boring into the roots, underground stems and sometimes fruits touching the soil.
SNAKE GOURD SEMILOOPER: <i>Anadevidia peponis</i> Fabricius, Noctuidae: Lepidoptera	Adult: Dark brown with shiny brown forewings. Caterpillar: Greenish with white longitudinal lines and black tubercles with thin hairs arising on them. Last abdominal segment is humped.	Caterpillars defoliate the plants.
SERPENTINE LEAF MINER: <i>Liriomyza trifoli</i> (Burgess), Agromyzidae: Diptera	Adult: Small black flies. Maggot: Leg less, orange yellow.	The maggot soon after emergence mines into the leaf and feed on the mesophyll tissues, resulting in characteristic serpentine white line ending in the shape of snakehood. Infested leaves sun scorch and drop. 50-90% leaves amaged in severe cases.
MANGO		
MANGO LEAFHOPPE R: <i>Amritodus atkinsoni</i> (Lethierry), <i>Idioscopus clypealis</i> (Lethierry), <i>I. niveosparsus</i> (Lethierry), Cicadellidae: Hemiptera	<i>A. atkinsoni</i> : largest light brown with two spots on scutellum. <i>I. clypealis</i> : smallest, light brown with spots on scutellum and a dark spot on vertex. <i>I. niveosparsus</i> : medium sized, with three spots on scutellum and prominent white band across its light brown	Both nymphs and adults suck sap from leaves, tender shoots and inflorescence. Flower buds, flower etc., first become flaccid then wither and die, leading to reduction in fruit set. They produce sticky honey dew which encourages the development of sooty mould and which in turn hinders the photosynthetic activity.

	wings.	
MANGO TREE BORER: <i>Batocera rufomaculata</i> Degger, Cerambycidae: Coleoptera	Adult: Brownish grey with two pink spots and a pair of lateral spines on thorax. Grub: White, fleshy with dark brown head and strong jaws.	Grubs tunnel through the stem, eating away the nutrition- translocation system and ultimately kill the tree. Depending on the intensity of attack, the affected trees show the symptoms like withering of leaves and twigs and drying of entire tree. A white/ yellowish exudates dripping down of the stem indicate the occurrence of stem borer, during its early stage of attack.
MANGO STONE WEEVIL: <i>Sternochetus mangiferae</i> Fabricius, Curculionidae: Coleoptera.	Adult: A stout, grayish brown weevil. Grub: White, thick, fleshy and legless.	Grub soon after hatching, burrows into the mesocarp flesh of tender fruit and reaches the region where the endocarp seed coat is still very soft. Once, the grub crosses this barrier of seed coat, it reaches seed endosperm to complete its life cycle. In the mean time, the fruit develops and heals up the larval tunnel, so that no external symptom is visible. Adult, which emerges from seeds, also feeds on seed. This hastens the maturity of infested fruit.
MANGO LEAF WEBBER: <i>Orthaga exvinacea</i> Wlk., Noctuidae: Lepidoptera	Adult: Medium sized, dark brown stout moth. Caterpillar: Slender pale green grows about 35 mm long.	Caterpillar webs terminal leaves and feed by scraping inside. Leaves are skeletonised. Flower stalks do not emerge properly.
CASHEW		
CASHEW TREE BORER: <i>Placaederus ferrugineus</i> Linnaeus, Cerambycidae: Coleoptera	Adult: Medium sized, dark brown longicorn beetle. Grub: Creamy white, robust and fleshy.	Newly hatched grubs feed on the subepidermal and soft wood tissues below the bark. Gradually, they bore into the stem and root. Bore holes are plugged with chewed fibre and excreta. Gummy, resinous material

		oozes from the attacked portion. In the later stages, grubs feed on the inner tissues by forming irregular tunnels. When vascular tissues get damaged, ascent of sap gets disrupted, leaves turn yellow and twigs and branches dry leading to the death of tree.
CASHEW SHOOT AND BLOSSOM WEBBER: <i>Lamida monocusalis</i> Walker, Pyralidae: Lepidoptera	Adult: Medium sized dark brown moth. Caterpillar: Newly hatched pale white caterpillar turns to reddish brown, when full grown and bears lateral longitudinal bands and pinkish dorsal lines.	Caterpillar webs the leaves and feeds. It webs the inflorescence also, at the time of blossoming. Apples and nuts are also damaged. They feed by scraping the upper green layer of apples and nuts when they are tender. It results in cracking of tissues and retardation in nut development.
CASHEW LEAF MINER: <i>Acrocercops syngramma</i> Gracillaridae: Lepidoptera	Adult: Minute moth silvery grey in colour. Caterpillar: Yellowish and turns reddish brown.	Caterpillars mine into leaves and roll the fresh leaves. The thin epidermal layers of tender leaf swell up in the mined areas and appear as whitish blistered patches. In older leaves, big holes are formed due to drying and crumbling of mined areas.
BANANA		
BANANA RHIZOME WEEVIL: <i>Cosmopolites sordidus</i> , Curculionidae: Coleoptera.	Adult: Medium, dark brown, ridged, drawn out mouthparts. ½” long elytra do not cover the abdomen completely. Caterpillar: Dwarf, stout with red head and powerful mandibles.	Grubs tunnel through pseudostem and rhizome making circular hole, which increase in size with the growth of grubs. Tunnels up to 2-3’ in stem with 6-10 grubs/stem. Plants break down at tunneled portion. Less number of fruits and suckers. Circular holes with black rotten tissue of rhizome, plugged with excreta.
COCONUT		
COCONUT BLACK HEADED CATERPILLAR	Adult: Medium in sized with	Caterpillar constructs a silken gallery on the lower side of

<p>AR: <i>Opisina arenosella</i> Meyr., Cryptophasidae: Lepidoptera</p>	<p>pale grayish wings. Few black spots present on forewings. Caterpillar: Greenish brown with dark brown head and prothorax and a reddish mesothorax. It posses five reddish brown wavy lines; one on the dorsal side and two on each of lateral sides.</p>	<p>leaflet and feeds by scraping the green matter within the gallery. In severe cases orchard gives a burnt appearance even from a distance. Later, bits of the leaf are added to the silken gallery and the length of gallery increases with the increase in the feeding activity.</p>
<p>RHINOCEROS BEETLE E: <i>Oryctes rhinoceros</i> Linnaeus, Scarabaeidae: Coleoptera.</p>	<p>Adult: Stout, black or reddish black beetle with a long horn projecting dorsally from the head. Grub: Creamy white and 'C' shaped.</p>	<p>Adult beetle feeds on the un opened central whorl of leaves in the crown of the plant. When the affected whorl opens up leaves show characteristic 'v' shaped clippings or holes in the leaflets. Frequent infestation results in stunted growth of trees and death of growing point in young plantations. This damage paves way for further fungal and bacterial infection.</p>
<p>RED PALM WEEVIL: <i>Rhynchophorus ferrugineus</i> Fab., Curculionidae: Coleoptera.</p>	<p>Adult: Reddish brown weevil with six dark spots on thorax. Head is prolonged into a long snout. Grub: Light yellowish with a reddish brown head and is apodous.</p>	<p>Newly hatched grubs bore into the trunk and crown and feed on the internal tissues and make tunnels. In the early stage of infestation, few small holes can be seen in the crown/ soft trunk from which pieces of chewed fibre protrude and brownish viscous liquid oozes. In many cases, the drying up of the young leaves or splitting of the petioles near the area of attack can be observed, the central shoot shows signs of wilting and the crown topples. Note the pupa is found within the fibrous cocoon.</p>
<p>COCONUT MITE:</p>	<p>Adult:</p>	<p>The mites inhabit the floral</p>

<p><i>Eriophyes gurreronis</i> Keifer, Eriophyidae: Acarina.</p>	<p>Minute pale/ whitish elongated and worm like having two pairs of legs. Larva: White in colour, resemble adult except in size.</p>	<p>bracts and tender portions and immature nuts covered by perianth. They suck sap from meristematic tissues. Initially, the damage appears as white later brownish triangular patches at the separation of the floral bracts and extends towards the free part of the nut. Ultimately longitudinal fissures appear 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.</p>
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EXPERIMENT NO. 6

CROP (AGRO-ECOSYSTEM) DYNAMICS OF A SELECTED INSECT PEST

The IPM has been evolving over the decades to address the deleterious impacts of synthetic chemical pesticides on environment ultimately affecting the interests of the farmers. The economic threshold level (ETL) was the basis for several decades but in modern IPM (FAO 2002) emphasis is given to AESA where farmers take decisions based on larger range of field observations. The health of a plant is determined by its environment which includes physical factors (i.e. soil, rain, sunshine hours, wind etc.) and biological factors (i.e. pests, diseases and weeds). All these factors can play a role in the balance which exists between herbivore insects and their natural enemies. Understanding the intricate interactions in an ecosystem can play a critical role in pest management.

Decision making in pest management requires a thorough analysis of the agro-ecosystem. Farmer has to learn how to observe the crop, how to analyze the field situation and how to make proper decisions for their crop management. This process is called the **AESA (Agro-Ecosystem)**. Participants of AESA will have to make a drawing on a large piece of paper (60 x 80 cm), to include all their observations. The advantage of using a drawing is that it requires the participants/farmers to observe closely and intensively. It is a focal point for the analysis and for the discussions that follow, and the drawing can be kept as a record.

AESA is an approach, which can be gainfully employed by extension functionaries and farmers to analyse field situations with regard to pests, defenders, soil conditions, plant health, the influence of climatic factors and their inter-relationship for growing healthy crop. Such a critical analysis of the field situations will help in taking appropriate decision on management practices. The basic components of AESA are:

- Plant health at different stages
- Built –in-compensation abilities of the plants
- Pest and defender population dynamics
- Soil conditions
- Climatic factors
- Farmer past experience

EXPERIMENT NO. 7

PLAN & ASSESS PREVENTIVE STRATEGIES (IPM MODULE) AND DECISION MAKING. CROP MONITORING ATTACKED BY INSECT, PEST AND DISEASES

PLAN AND ASSESSMENT OF PREVENTIVE STRATEGIES

7.1 Grow a healthy crop

- Select a variety resistant/tolerant to major pests
- Treat the seeds/seedlings/planting material with recommended pesticides especially bio-pesticides
- Select healthy seeds/seedlings/planting material
- Follow proper spacing
- Soil health improvement (mulching and green manuring wherever applicable)
- Nutrient management especially organic manures and biofertilizers based on the soil test results. If the dosage of nitrogenous fertilizers is too high the crop becomes too succulent and therefore susceptible to insects and diseases. If the dosage is too low, the crop growth is retarded. So, the farmers should apply an adequate amount for best results. The phosphatic fertilizers should not be applied each and every season as the residual phosphate of the previous season will be available for the current season also.
- Proper irrigation

7.2 Observe the orchard regularly (climatic factors, soil and biotic factors)

Farmers should

- Monitor the field situation of the orchard at least once a week (soil, water, plants, pests, natural enemies, weather factors etc.)
- Make decisions based on the field situation and P: D ratio
- Take direct action when needed (e.g. remove infested plants)

7.3 Plant compensation ability

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

Understand and conserve defenders

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

7.4 Insect zoo

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

7.5 Pest: Defender ratio (P: D ratio)

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

- Parasitoids
- Predators and
- Pathogens

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

7.6 Decision making

Farmers become experts in crop management

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

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

7.7 AESA methodology

- Go to the orchard in groups (about 5 farmers per group). Walk across the orchard and choose 10 trees /acre randomly. Observe the plant height, number of branches, crop stage, deficiency symptoms etc.
- Collect 5-6 samples/tree (fruits/leaves/ flowers/inflorescence/stem bark/roots/soil/insects) i.e. one sample from top, four samples from all the four sides (North, South, East, West) and one from bottom/soil. Observe keenly each of these samples and record your observations:
 - **Pests:** Observe and count pests.
 - **Defenders (natural enemies):** Observe and count parasitoids and predators.
 - **Diseases:** Observe and identify any visible disease symptoms and severity.
 - **Weeds:** Observe weeds in the field and their intensity.
 - **Water:** Observe the water situation of the field.
 - **Weather:** Observe the weather condition.
- While walking in the orchard, manually collect insects in plastic bags. Use a sweep net to collect additional insects. Collect plant parts with disease symptoms.
- Find a shady place to sit as a group in a small circle for drawing and discussion.
- If needed, kill the insects with some chloroform (if available) on a piece of cotton.
- Each group will first identify the pests, defenders and diseases collected.
- Each group will then analyze the orchard situation in detail and present their observations and analysis in a drawing (the AESA drawing).
- Each drawing will show a tree representing the orchard situation. The weather condition, water level, disease symptoms, etc. will be shown in the drawing. Pest insects will be drawn on one side. Defenders (beneficial insects) will be drawn on another side. Write the number next to each insect. Indicate the plant part where the pests and defenders were found. Try to show the interaction between pests and defenders.
- Each group will discuss the situation and make an orchard management recommendation.
- The small groups then join each other and a member of each group will now present their analysis in front of all participants.
- The facilitator will facilitate the discussion by asking guiding questions and makes sure that all participants (also shy or illiterate persons) are actively involved in this process.
- Formulate a common conclusion. The whole group should support the decision on what field management is required in the AESA plot.
- Make sure that the required activities (based on the decision) will be carried out.
- Keep the drawing for comparison purpose in the following weeks.

7.8 Data recording

Farmers should record data in a notebook and drawing on a chart. Keeping records of what has happened help us making an analysis and draw conclusions

Data to be recorded

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

Some questions that can be used during the discussion

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

Advantages of AESA over ETL

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

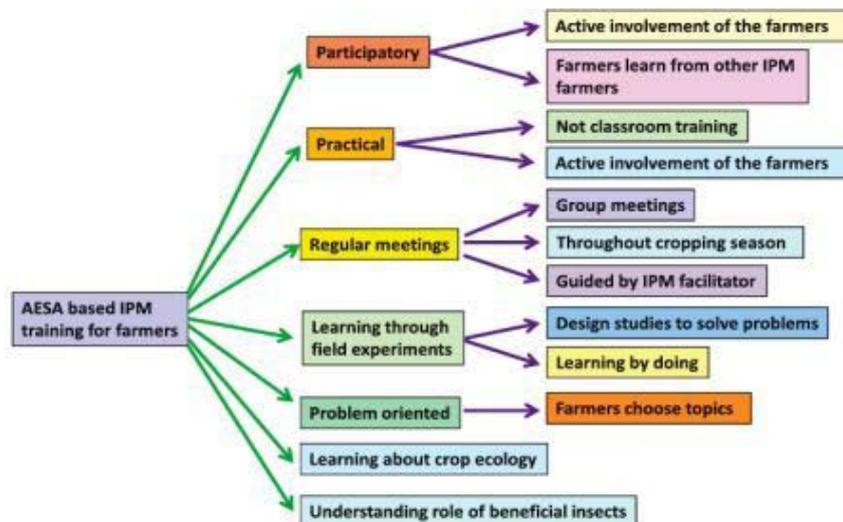
7.9 AESA and farmer field school (FFS)

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

7.10 Farmers can learn from AESA

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

FFS to teach AESA based IPM skills



Field scouting

AESA requires skill. So only the trained farmers can undertake this exercise. However, other farmers also can do field scouting in their own orchards at regular intervals to monitor the major pest situation. Surveillance on pest occurrence in the orchard should commence soon after crop establishment and at weekly intervals thereafter. In each orchard, select five spots randomly. Select five random plants at each spot for recording counts of insects as per procedure finalized for individual insects.

7.11 Sampling in fruit crops

In orchard, select five trees such that four are from four corners and one from the centre of the orchard. Two rows of trees alongside of boundary of orchard in all directions should not be selected for observations. The tree selection for pest observations during each weekly visit should be random. In each of the selected trees, the observations are to be made from four directions viz., East, South, West and North (make it a habit to start at East direction of a tree and follow anticlockwise direction). Use either beat or tap method for taking observations on pest's samples.

7.12 For insect pests

- **Woolly apple aphids, San Jose scales, and mites:** Count and record the number of both nymphs and adults on five randomly selected leaves per plant.
- **Blossom thrips:** Count and record the number of nymphs and adults of thrips present on five terminal leaves per plant (tapping method also can be used to count thrips).
- **Apriona, Dorysthenes, Lymantria:** Number of larvae of Apriona (stem borer), Dorysthenes (root borer) and Lymantria (foliage feeder) on individual plants should be counted using a suitable procedure.

7.13 For diseases

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

- **Root sampling:** Always check plants that appear unhealthy. If there are no obvious symptoms on plants, examine plants randomly and look for lesions or rots on roots and stems. Observe the signs of the causal organism (fungal growth or ooze). It is often necessary to wash the roots with water to examine them properly. If the roots are well developed, cut them to examine the roots for internal infections (discoloration & signs). Count the total number of roots damaged/infested/infected due to rot should be counted and incidence should be recorded.
- **Leaf sampling:** Examine all leaves and/or sheaths of each plant for lesions. Leaf diseases cause most damage during the seedling and flowering stages of plant growth. Observe for the symptoms and signs on the infected plant parts. Determine the percent

area of leaf/sheath infection by counting the number of leaves (leaf area diameter)/plant infected due to disease and incidence should be recorded.

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

7.14 For weeds

The goal of weed scouting is to assess the infestation level of known weeds as pests and detect new weeds that may be at very low levels so that action can be taken to control or prevent them from becoming an economic concern. In some cases, early detection of a weed can make eradication possible.

Begin scouting as soon as weeds appear in the field and continue until freeze-up. Record stages of growth of all the weeds and the number of each weed species/square metre.

Frequently, all scouting patterns must be used since weed habitat can be very species specific. Each field usually requires a pattern for a uniform sample and samples in low areas and field margins or ditches to assess immediate or future risk from problem weeds left uncontrolled. Detailed counts of the number of weeds per square metre provide the ideal record of a weed problem. If this is not possible, the following rating system may be useful:

Group I - Wild oats, stinkweed, wild buckwheat, lamb's-quarters, redroot pigweed, hemp-nettle, smartweed, rape, wild mustard, Russian thistle, tartary buckwheat, cow cockle, shepherd's-purse, kochia.

LIGHT	MEDIUM	HEAVY
1-10 plant/m ²	10-30 plant/m ²	30 OR OVER plant/m ²

Group II - Chickweed, green foxtail, corn spurry.

LIGHT	MEDIUM	HEAVY
1-20 plant/m ²	20-70 plant/m ²	70 OR OVER plant/m ²

Group III - Canada thistle, sow-thistle, dandelion

LIGHT	MEDIUM	HEAVY
1-2 plant/m ²	2-10 plant/m ²	10 OR OVER plant/m ²

These definitions can be used to help standardize ratings. With experience, infestations can be visually estimated. These groupings are based on the competitive characteristics and life cycles of these weeds.

Surveillance through pheromone trap catches for *Cydia*, *Argyresthia*, *Archips*, *Apriona*, *Dorysthenes*, and *Lymantria*

Pheromone traps @ 4-5/acre have to be installed, if available, for *Cydia*, *Argyresthia*, *Archips*, *Apriona*, *Dorysthenes* and *Lymantria*. Install the traps for each species separated by a distance of >75 feet. Fix the traps to the supporting pole at the height of mid canopy. Change of lures should be made at 2-3 week interval (regular interval) or based on loss of lure efficacy. During each week of surveillance, the number of moths/trap/week should be counted and recorded year round. The trapped moths should be removed and destroyed after each recording.

Yellow/blue water pan and sticky traps

Set up yellow water pan/sticky traps for monitoring woolly apple aphids and blue water pan/sticky traps for blossom thrips at the height of mid canopy @ 4-5 traps/acre. Locally available empty tins can be painted yellow/ blue and coated with grease/Vaseline/castor oil on outer surface may also be used.

Light traps

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

Nematode extraction

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

EXPERIMENT NO. 8

AWARENESS CAMPAIGN AT FARMERS FIELDS

REFERENCES AND BIBLIOGRAPHY

Dhaliwal, G.S. and Ramesh Arora 2001. Integrated pest management: Concepts and approaches, Kalyani Publishers, Ludhiana.

Larry P Pedigo 1991. Entomology and pest management, Prentice Hall of India Pvt. Ltd., New Delhi

Metcalf, R.L. and Luckman, W.H.1982. Introduction to insect pest management Wiley inter science publishing, New York.