JHARKHAND Rai University
RANCHI

Laboratory Manual

Course- Pest of Crops and Stored Grain and their Management

Course Code- 13A.313

B.Sc. (Hons.) Agriculture Vth Semester

Department of Agriculture,

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Experiment 1: Identification of different types of damage. Identification and study of life cycle and seasonal history of various insect pests attacking crops and their produce: (a) Field Crops; (b) Vegetable Crops; (c) Fruit Crops; (d) Plantation, gardens, Narcotics, spices & condiments.

1. Rice: Rice (*Oryza sativa*, F: Poaceae), an important staple food crop throughout the globe which can be infested by more than 100 insect pest species and out of them many species have got major pest status due to their significant impact in yield reduction of rice crop. The important insect species associated with rice crop are given below with special emphasize to their taxonomic position, identifying characters, damage symptoms and their seasonality.

A. Yellow Stem Borer:

Taxonomic position

Sc. name: *Scirpophaga incertulas* (Walker), Family: Pyralidae, Order: Lepidoptera

Identifying characters: Adult: Female moth has bright yellowish fore wings with a black spot and a tuft of yellow anal hairs while male is smaller with pale yellow fore wings without black spot. **Caterpillar:** Caterpillar are creamy white in colour with brown to black colour head. Damage symptom Larva feeds on the stem and causes drying of the central shoot in the young seedlings known as "Dead Heart" which is very common during vegetative growth stage of the crop. Larval attack during reproductive stage of the crop results of the formation of chaffy grain ultimately leads to the formation of "White ear head".

Seasonality: This insect pest normally active from March to October and hibernates during November in the rice stubble and emerges as adult during March. The moth is active in dusk when they mate.

B. Leaf folder:

Taxonomic position

Sc. name: *Cnaphalocrocis medinalis* (Guenee), Family: Pyralidae, Order: Lepidoptera **Identifying characters**: **Adult:** Adult moths having orange coloured light brown wings with two distinct dark wavy lines on the forewing and one line on the hind wing. **Caterpillar:** Caterpillar is green colour with deep brown head.

Damage symptoms: Larva feed the chlorophyll by folding leaves longitudinally and bind the leaves margin with silken threads. Larva causes heavy damage during booting stage.

Seasonality: Infestation mostly observed during rainy season with 75-90% relative humidity and 25-30ºC, which is highly conducive for the larval growth and development.

C. Paddy skipper

Taxonomic position:

Sc. name: *Pelopidas mathias* (Fabricius), Family: Hesperiidae, Order: Lepidoptera

Identifying characters: Adult: Female with five distinct discal spot and male has four discal spots on the forewing. **Caterpillar:** Caterpillar movement can be easily noticed by their jumping from one leaf to another.

Damage symptoms: Newly hatched larvae are voracious feeder of young seedlings just after transplanting.

Seasonality: Observed mainly during rainy season just after transplanting of rice.

D. Brown plant hopper

Taxonomic position: **Sc. name:** *Nilaparvata lugens* (Stal.), Family: Delphacidae, Order: Hemiptera

Identifying characters: Adult: Adults are brown coloured forewing mainly found in lower portion of the plant can be easily distinguished by prominent spur in hind tibia. Female exits two forms viz. fully winged form (Macropterous) and partially developed form (Brachypterous). **Nymph:** Very small size and wingless.

Damage symptoms: Both nymphs and adults colonize base of the plant just above of the water level and suck sap form the tillers and inject toxic saliva while feeding which results "Hopper burn". They are the vector of Grassy stunt, Ragged stunt and Wilted stunt disease.

Seasonality: Prefer to infect paddy during kharif season with thick vegetation. Direct sown rice more preferred than transplanted rice.

E. White backed plant hopper:

Taxonomic position: **Sc. name:** *Sogatella furcifera* (Horvath), Family: Delphacidae, Order: Hemiptera

Identifying characters: **Adult:** Forewing hyaline with dark veins and a dark spot in the middle of posterior edge. **Nymph:** Nymphal stage looks like adult but wingless.

Damage symptoms: Both nymphal and adult stage are harmful which suck sap from tiller cause stunted growth and "Hopper burn" leading to yield loss.

Seasonality: Normally found during kharif paddy cultivation and dominate during vegetative phase of the crop.

F. Green leaf hopper

Taxonomic position: Sc. name: *Nephotettix virescens* (Distant) and *Nephotettix nigropictus* (Stal.), Family: Cicadellidae, Order: Hemiptera

Identifying characters: **Adult:** Green colour small insect. In case of *Nephotettix virescens*, two black spots in the middle of the forewing do not extend up to the black distal portion, whereas in *Nephotettix nigropictus* two black spot extend up to the black distal portion. **Nymph:** Nymphs are small and wingless.

Damage symptom: Both nymph and adult suck the plant sap from leaves causing yellowing, stunting and wilting of plants. They are the vector of Rice tungro virus, Rice yellow dwarf, Rice transitory yellowing virus.

Seasonality: Adults and nymphs initiate infestation during first week of September and continue up to October. Peak population reaches during middle week of October.

G. Gundhi Bug

Taxonomic position: **Sc. name:** *Leptocorisa acuta* (Thunberg), Family: Alydidae, Order: Hemiptera

Identifying characters: Adult: Large greyish colour insect and adult release bad odour when they touch from their Coreid gland. **Nymph:** They are wingless, light green in colour.

Damage symptoms: Both adult and nymph are considered as damaging stage. They suck the milk of the developing grain (milking stage) and make the panicle chaffy leads to reduction of crop yield.

Seasonality: Insect appear during the flowering stage of the crop and continues until the panicles ripen. Mostly kharif paddy are very to infestation than Boro paddy.

2. Maize: Maize (*Zea mays*; F: Poaceae), known as "Queen of Cereals" have been infested more than 130 insect pest species throughout the globe. The important species are given below with special emphasize to their taxonomic position, identifying characters, damage symptoms and their seasonality.

A. Fall army worm:

Taxonomic position: Sc. name: *Spodoptera furgiperda* (Smith), Family: Noctuidae, Order: Lepidoptera

Identifying characters: **Adult:** Adult is greyish colour forewing with complex pattern of creamy streaks and pale lines along the veins. **Caterpillar:** Larva has prominent "Y" shaped marking (Epicranial suture) on the front and presence of four black spot on the penultimate abdominal segment.

Damage symptoms: Larva mainly voracious foliage feeder. Feeding results to the destroy of the growing portion of the plant as well as destruction of the developing cobs. Presence of moist frass material near the feeding place indicate their presence.

Seasonality: Mostly larva attack the plant during winter season at vegetative growth stage of the plant. New invasive insect species of maize reported from Karnataka during 2018.

B. Cob worm:

Taxonomic position: Sc. name: *Helicoverpa armigera* (Hubner), Family: Noctuidae, Order: Lepidoptera

Identifying characters: **Adult:** Yellowish to orange colour forewings in female and greenish-grey in males. Slightly darker transversal band is present at the distal end. **Larva:** Larva having distinct brown lateral stripe and dorsal stripe. Colouration varies with the feeding content and ranges from bluish green to brownish red.

Damage symptom: Larva is the damaging stage. Caterpillars invade the ears and feed on tender grains and later on bores into cob. Secondary attack caused by bacterial and fungal infections. Due to their feeding, qualitative and quantitative loss of the cob occurred.

Seasonality: During kharif Maize cultivation, cob worm initiates their infestation during last week of August and continue up to last week of September. In winter maize, infestation occurs during mid-week of January and continue up to March.

3. Sugarcane: Sugarcane (*Saccharum officinarum*, F: Poaceae), an important cereal crop has been infested by near about 200 insect pest species and among them only a dozen is recognized as major. Important insect species are given below with special emphasize to their taxonomic position, identifying characters, damage symptoms and their seasonality.

A. Sugarcane early shoot borer:

Taxonomic position: Sc. name: *Chilo infuscatellus* (Snellen), Family: Crambidae, Order: Lepidoptera

Identifying characters: **Adult:** Adult moth is light straw to brownish grey colour and larvae with five distinct stripes. **Caterpillar:** Caterpillar is white colour with black head capsule. Number of black spots present on dorsal surface.

Damage symptoms: Larvae feed the base portion of the growing shoot causing "Dead heart" which can be easily pulled out. A number of bored holes present on the shoot just above the ground. From the infected shoot offensive odour come out.

Seasonality: The insect is active from March to November and passes winter as a full-grown larva in the stubble. The larvae pupate sometime in February and emerge as moths during March.

B. Top shoot borer:

Taxonomic position: Sc. name: *Scirpophaga nivella* (Fabricius), Family: Crambidae, Order: Lepidoptera

Identifying characters: **Adult:** Adult is milky white in colour and tuft of brownish silken hairs present at the tip of abdomen. **Caterpillar:** Caterpillar sluggish and pale white in colour. **Damage symptoms**: Caterpillars attack the plant during tillering stage and feed the growing shoot. Death of growing shoots and formation of numerous side shoots causes "Bunchy top" appearance. Dead Heart formation takes place but it cannot easily pull out.

Seasonality: The insect is active from March to November and passes winter as a full-grown larva in the stubble. The larvae pupate sometime in February and emerge as moths during March.

C. Sugarcane Pyrilla:

Taxonomic position: **Sc. name:** *Pyrilla perpusilla* (Walker), Family: Lophopidae, Order: Hemiptera

Identifying characters: **Adult:** Soft bodied insect with prominent snout and straw colour wings. **Nymph:** Newly hatched nymph milky white in colour and they posses a characteristics feather like structure covered by wax.

Damage symptoms: Most destructive foliage sucking pest cause yellowish white appearance of leaves. They release carbohydrate rich compound Honey dew which invite Sooty Mould fungus. This fungus covers the foliage and affects photosynthesis.

Seasonality: Mainly attack sugarcane crop during summer season.

4. Pigeon pea: Pigeon pea (*Cajanus cajan*, F: Fabaceae) is an important pulse crop traditionally grown during Kharif season sown in June-July with onset of Monsoon in various agro-climatic zones of India. Pigeon pea is mainly attacked by gram pod borer and pod fly.

A. Gram pod borer:

Taxonomic position: Sc. name: *Helicoverpa armigera* (Hubner), Family: Noctuidae, Order: Lepidoptera

Identifying characters: **Adult:** Yellowish to orange colour forewings in female and greenish-grey in males. Slightly darker transversal band at the distal end. **Caterpillar:** Caterpillar having distinct brown lateral stripe and dorsal stripe. Colouration varies with the feeding content and ranges from bluish green to brownish red.

Damage symptoms: First instar larva feed the foliage by scrapping the green tissue. Mature larva bore into locules and consume the developing grain. During feeding larva is seen with the head alone thrust inside the grain and rest of the body part hanging out.

Seasonality: Peak incidence occurred during October.

B. Pod fly:

Taxonomic position: Sc. Name: *Melanagromyza obtusa* (Malloch), Family: Agromyzidae, Order: Diptera

Identifying characters: Adult: The small metallic, black fly is about 5 mm in length with strong legs and ovate abdomen. Wings clear veined and brownish yellow at the base. Eggs are laid in the wall of an immature pod. **Maggot:** Creamy white in colour.

Damage symptoms: The maggots feed under the epidermis of the seed and enter inside the seed. Pod fly infested pods do not show external evidence of damage until the fully grown larvae make hole in the pod walls. This hole provides an emergence "window" through which the adults exit from the pod. Pod fly damaged seeds will not germinate and are unfit for human consumption. The white maggots feed on the developing seed and reach a length of 3 mm before pupation. The brown puparium is formed between the remnant of the seed and the pod wall.

Seasonality: Peak incidence of the pest occurred during December.

5. Chick pea: Chick pea (*Cicer arietinum*, F: Fabaceae) is also an important pulse crop during winter season which is mainly infested by pod borer and cut worm causing huge yield loss in severe infestation.

A. Gram pod borer:

Taxonomic position: **Sc. name:** *Helicoverpa armigera* (Hubner), Family: Noctuidae, Order: Lepidoptera

Identifying characters: **Adult:** Yellowish to orange colour forewings in female and greenish-grey in males. Slightly darker transversal band at the distal end. **Caterpillar:** Caterpillar having distinct brown lateral stripe and dorsal stripe. Colouration varies with the feeding content and ranges from bluish green to brownish red.

Damage symptoms: First instar larva feed the foliage by scrapping the green tissue. Mature larva bore into locules and consume the developing grain. During feeding larva is seen with the head alone thrust inside the grain and rest of the body part hanging out.

Seasonality: Prefer the plant to attack during December to January when pod formation initiate.

B. Cutworm

Taxonomic position: Sc. Name: *Agrotis ipsilon* (Hufnagel), Family: Noctuidae, Order: Lepidoptera

Identifying characters: Adult: The adult moth measures about 25 mm from head to tip of abdomen and having dark or blackish with greyish patches on the back and dark streaks on the fore wings. Eggs lay in clusters of about 30 on the under surface of the leaves or in the soil by the females. **Caterpillar:** The caterpillar is slightly yellowish ranging from 1.5 - 45 mm long with a shiny, black head and a black shield on the prothorax and later on become dark brown with a plump and greasy body.

Damage symptoms: The young larvae feed on the epidermis of the leaves, while mature one live in the heap of grasses, cracks and holes of the soil at day time and come out at night time which

fell the plants cutting their stems, either below the surface or above the ground. The cut branches are also dragged into the holes where the leaves are eaten at leisure. The pupation takes place in the soil by covering with earthen chamber.

Seasonality: Peak incidence during March-April.

6. Lentil: Lentil (*Lens culinaris*, F: Fabaceae) second one important winter season pulse crop mainly infested by pod borer and aphid.

A. Pod borer:

Taxonomic position: **Sc. name:** *Helicoverpa armigera* (Hubner), Family: Noctuidae, Order: Lepidoptera

Identifying characters: **Adult:** Yellowish to orange colour forewings in female and greenish-grey in males. Slightly darker transversal band at the distal end. **Caterpillar:** Caterpillar having distinct brown lateral stripe and dorsal stripe. Colouration varies with the feeding content and ranges from bluish green to brownish red.

Damage symptoms: First instar larva feed the foliage by scrapping the green tissue. Mature larva bore the pod and consume the developing grain.

Seasonality: Prefer the plant to attack during December to January when pod formation initiate.

B. Aphid:

Taxonomic position: **Sc. name:** *Aphis craccivora* (Koch), Family: Aphididae, Order: Hemiptera

Identifying characters: Adult: Black or dark brown colour insect with a prominent cauda and cornicles. **Nymph:** Nymphs are small, wingless.

Damage symptoms: Both adult and nymph suck the plant sap form the soft tissue which turn the plant stunted. Due to heavy infestation leaves become yellowish and secretion of honey dew leads to the development of Sooty mould fungus which inhibit the normal photosynthesis process.

Seasonality: Prefer the plant to attack during December to January when pod formation initiate.

7. Rapeseed and Mustard: Rapeseed and Mustard (*Brassica sp.*, F: Brassicaceae) has been considered major oil yielding field crops mainly infested by Mustard aphid, Leaf webber and Saw fly.

A. Mustard aphid:

Taxonomic position: **Sc. name:** *Lipaphis erysimi* (Kaltenbach), Family: Aphididae, Order: Hemiptera

Identifying characters: Adult: Soft bodied green colour insect measuring about 1-2 mm. **Nymph:** Nymphs are very tiny, wingless.

Damage symptoms: Both adult and nymph suck the plant sap from the succulent tissue and cause the deformation of the pods and curly leaf tip. Infested plants can be easily identified by the presence of Sooty mould fungus due to honey dew secretion. Both alate (winged) and apterous (wingless) form can be found in the colony.

Seasonality: Infestation mainly starts after the commencement of the flowering stage during mid-week of January and continue up to plant maturity.

B. Leaf webber:

Taxonomic position: **Sc. name:** *Crocidolomia binotalis* (Zeller), Family: Pyralidae, Order: Lepidoptera

Identifying characters: **Adult:** Adult female moth is lacking of dark tuft hairs on the anterior margin of each forewing. **Caterpillar:** Leaf webber caterpillar can be easily identified by their distinct three yellowish white stripes on dorsal and two on lateral regions.

Damage symptom: The caterpillars make the silken web around the growing tip portion of the plant and feed the young leaves making them completely skeletonized. They also feed the young pods and flower buds.

Seasonality: They prefer hot humid areas and cause serious damage during dry season.

C. Mustard saw fly:

Taxonomic position: Sc. name: *Athalia lugens proxima* (Klug), Family: Tenthredinidae, Order: Hymenoptera

Identifying characters: Adult: Adult is orange yellow in colour with black margins on the body. **Caterpillar:** Caterpillar is greyish in colour with five black dorsal stripes on the body. **Damage symptoms:** Larva attack the plant during vegetative growth stage and feed the foliage. Infestation leads to drying of seedlings. Seasonality The insect pest normally found during October to November just after sowing of the mustard crop.

8. Sunflower: Sunflower (*Helianthus annuus*, F: Asteraceae), mainly grown as a crop for its edible oil and edible fruits. The crop is mainly infested by Head Borer.

A. Head borer or Capitulum borer:

Taxonomic position: Sc. name: *Helicoverpa armigera* (Hubner), Family: Noctuidae, Order: Lepidoptera

Identifying characters: **Adult:** Yellowish to orange colour forewings in female and greenish-grey in males. Slightly darker transversal band at the distal end. Larva having distinct brown lateral stripe and dorsal stripe. Colouration varies with the feeding content and ranges from bluish green to brownish red.

Damage symptom: Caterpillar is the most damaging stage and feeds on the developing seeds and damage the head.

Seasonality: They mostly prefer the plant during the reproductive stage of the crop.

9. Jute: Jute (*Corchorus capsularis* and *Corchorus olitorius*, F: Tiliaceae), an important fibre crop mostly grown in West Bengal mainly infested by Stem weevil, semi looper and yellow mite.

A. Stem weevil

Taxonomic position: **Sc. name:** *Apion corchori* (Mshll), Family: Apionidae, Order: Coleoptera **Identifying characters**: **Adult:** Adult is small, black in colour with prominent snout. **Grub:** Grub mainly apodous with brown head and adults are mainly black and body covered with white setae.

Damage symptoms: Grub mainly feed inside the stem and which leads to drying up tip of the plants. Larval feeding leads to development of knotty fibre which reduces the fibre quality. **Seasonality:** Stem weevil prefer to infect the plant during April to July.

B. Jute semilooper:

Taxonomic position: Sc. name: *Anomis sabulifera* (Guenee), Family: Noctuidae, Order: Lepidoptera

Identifying characters: **Adult:** Adult insect can be identified by fore wing with dark margins. **Caterpillar** is slender, green in colour and dark dorsal and lateral stripes.

Damage symptom: Caterpillar feed the tender foliage and destroy the growing tip of the plant. Severe infestation leads to reduction of fibre quality.

Seasonality: Infestation mainly observed during May to June.

C. Yellow mite

Taxonomic position: Sc. name: *Polyphagotarsonemus latus* (Banks), Family: Tarsonemidae, Order: Trombidiformes

Identifying characters: Adult: Adults are oval, light yellow in colour with four pairs of legs. **Nymph:** Nymphs are normally three pairs of legs.

Damage symptom: Mite colonize ventral surface of the leaves and suck the plant sap from the tender plant parts which leads to drying of leaves and turn into coppery brown and fall prematurely. Infestation leads to shortening of internodes and developing pods are also affected. **Seasonality**: Mite infestation mainly found during June to August.

10. Brinjal: Brinjal (*Solanum melongena*, F: Solanaceae), an important solanaceous vegetables mostly grown tropical and subtropical regions of the world. The crop is very much susceptible to infestation by Brinjal Fruit and Shoot Borer (BFSB), Hadda beetle, Jassids, Brown leaf hopper, Aphids, whitefly and Red spider mite. Those important insect species associated with brinjal are

given below with special emphasize to their taxonomic position, identifying characters, damage symptoms and their seasonality.

A. Brinjal Fruit and Shoot Borer:

Taxonomic position: **Sc. name:** *Leucinodes orbonalis* (Guenee), Family: Pyralidae, Order: Lepidoptera

Identifying characters: **Adult:** Adult forewing has black and brown patches **Larva:** Caterpillar is about 18-22 mm long and pink in colour.

Damage symptoms: Larva bores into tender shoots causing Drooping or Drying of tip of the shoots and bore into the developing fruits. Bored hole is plugged with excreta and make the fruit unfit for marketing.

Seasonality: The infestation is maximum during kharif season and highest infestation during fourth to fifth week after transplanting.

B. Hadda beetle:

Taxonomic position: **Sc. name:** *Epilachna vigintioctopunctata* (Fabricius), Family: Coccinellidae, Order: Coleoptera

Identifying characters: Adult: Adult with orange-yellow colour and sometimes turn dark brown. Each elytron has 7-14 spots. **Grub:** Grub is small, yellowish in colour and contain six rows of spines.

Damage symptoms: Both adult and grub cause damage by feeding on the upper surface of leaves. Due to their feeding, leaves become completely skeletonize, turn brown, dry up and fall of from the plant.

Seasonality: The insect pest normally active during March-April and hibernate during winter among heaps of dry plants and crevices in the soil.

C. Jassid:

Taxonomic position: **Sc. name:** *Amrasca biguttula biguttula* (Ishida), Family: Cicadellidae, Order: Hemiptera

Identifying characters: Adult: Adult is yellowish green with two prominent black spots near the tip of the forewing. **Nymph:** Nymph looks like adult but smaller than adult and wingless. Both adult and nymph moves diagonally.

Damage symptoms: Both adult and nymph suck the sap from the lower surface of leaves and infested leaves curl upward along the margins, which may turn yellowish.

Seasonality: The insect normally infects the plant during summer months (March to May).

D. Brown leaf hopper

Taxonomic position: Sc. name: *Cestius phycitis* (Distant), Family: Cicadellidae, Order: Hemiptera

Identifying characters: **Adult:** Adults are small, brown in colour. **Nymph:** Nymphs are creamy white and wingless.

Damage symptoms: Both adult and nymph suck the sap from the lower surface of leaves and infested leaves turn yellowish. They transmit "Little leaf of Brinjal" disease.

Seasonality: They prefer to attack the plant during summer months (April to June).

E. Aphid:

Taxonomic position: **Sc. name:** *Myzus persicae* (Sulzer), Family: Aphididae, Order: Hemiptera **Identifying characters**: **Adult:** Adults are green in colour with a dark patch on the back. **Nymph:** Nymphs are yellowish green and wingless.

Damage symptoms: Both adult and nymph suck the sap from the lower surface of leaves and infested leaves turn yellowish. They release carbohydrate rich compound (Honey dew) which leads to formation of Sooty mould fungus on the plant surface. Formation of sooty mould hamper the photosynthesis.

Seasonality: They prefer to attack the plant during summer months (March to June).

F. White fly:

Taxonomic position: **Sc. name:** *Bemisia tabaci* (Gennadius), Family: Aleyrodidae, Order: Hemiptera

Identifying characters: **Adult:** Adults are small white colour insect. **Nymph:** Nymphs are small and wingless.

Damage symptoms: Both adult and nymph suck the sap from the lower surface of leaves and infested leaves turn yellowish and fall of prematurely. Heavy infestation leads to formation of Sooty mould fungus on the plant surface.

Seasonality: They mostly prefer to attack the plant during summer months (March to June) with high temperature and relative humidity.

G. Red spider mite:

Taxonomic position: **Sc. name:** *Tetranychus urticae* (Koch), *Tetranychus ludeni* (Zacher), *Tetranychus neocaledonicus* (Andre), *Tetranychus macfarlanei* (Baker and Pritchard), Family: Tetranychidae, Order: Trombidiformes

Identifying characters: **Adult:** Adults are small, wingless with red colouration possess 4 pair of legs. **Nymph:** Nymphs are wingless with 3 pair of legs.

Damage symptoms: Adult web the spin underside of the leaves and both adult and nymph suck the sap from the lower surface of leaves and infested leaves turn yellowish and fall of prematurely.

Seasonality: They mostly prefer to attack the plant during summer months (March to June) with high temperature and relative humidity.

11. Tomato: Tomato (*Solanum lycopersicum*, F: Solanaceae), a well-known solanaceous vegetable crop which is mostly grown during winter times across the globe. Tomato is mainly infested by Serpentine leaf miner, Fruit borer, White fly. Details of these insect pests emphasizing on their taxonomic position, identifying characters, damage symptoms and seasonality are described below.

A. Serpentine leaf miner:

Taxonomic position: **Sc. name:** *Liriomyza trifolii* (Burgess), Family: Agromyzidae, Order: Diptera

Identifying characters: Adult: Adults are yellowish head with red colour eyes. **Maggot:** Maggots are apodous and colourless. Become yellowish with the maturity.

Damage symptoms: Maggots mine into the upper and lower leaf surface and feed the mesophyll tissues. The mine gradually prominent with the larval maturity.

Seasonality: They prefer to attack the plant during January to March.

B. Fruit borer:

Taxonomic position: **Sc. name:** *Helicoverpa armigera* (Hubner), Family: Noctuidae, Order: Lepidoptera

Identifying characters: **Adult:** Yellowish to orange colour forewings in female and greenish-grey in males. Slightly darker transversal band at the distal end. **Caterpillar:** Caterpillar having distinct brown lateral stripe and dorsal stripe. Colouration varies with the feeding content and ranges from bluish green to brownish red.

Damage symptoms: First instar larva feed the foliage by scrapping the green tissue and make the skeletonization of the leaves. Mature larva bore into the fruit and feed the internal content of the fruit. During feeding larva is seen with the head alone thrust inside the grain and rest of the body part hanging out.

Seasonality: Prefer the plant to attack during January to March when the fruiting occurs.

C. White fly:

Taxonomic position: Sc. name: *Bemisia tabaci* (Gennadius), Family: Aleyrodidae, Order: Hemiptera

Identifying characters: **Adult:** Adults are small white colour insect. **Nymph:** Nymphs are small and wingless.

Damage symptoms: Both adult and nymph suck the sap from the lower surface of leaves and infested leaves turn yellowish and fall of prematurely. They transmit "Tomato leaf curl virus". Heavy infestation leads to formation of Sooty mould fungus on the plant surface.

Seasonality: They mostly prefer to attack the plant during last week to January and continue up to March.

12. Chilli: Chilli (*Capsicum annuum*, F: Solanaceae), a solanaceous vegetable crop mainly used as spice purpose. Chilli is mainly attacked by Fruit borer, Tobacco caterpillar, White fly, Thrips and Yellow mites.

A. Fruit borer:

Taxonomic position: Sc. name: *Helicoverpa armigera* (Hubner), Family: Noctuidae, Order: Lepidoptera

Identifying characters: **Adult:** Yellowish to orange colour forewings in female and greenish-grey in males. Slightly darker transversal band at the distal end. **Caterpillar:** Caterpillar having distinct brown lateral stripe and dorsal stripe. Colouration varies with the feeding content and ranges from bluish green to brownish red.

Damage symptoms: First instar larva feed the foliage by scrapping the green tissue and make the skeletonization of the leaves. Mature larva bore into the fruit and feed the internal content of the fruit. During feeding larva is seen with the head alone thrust inside the grain and rest of the body part hanging out.

Seasonality: Prefer the plant to attack during last week of August to November.

B. Tobacco caterpillar:

Taxonomic position Sc. name: *Spodoptera litura* (Fabricius), Family: Noctuidae, Order: Lepidoptera

Identifying characters: Adult: Forewings are greyish in colour and contain a complex pattern of creamy streaks and pale lines along the veins. **Caterpillar:** Caterpillar having distinct "Y" shaped Epicranial suture and a pale colour mid dorsal line. Dorsal surface with orange and black stripes.

Damage symptoms: First instar larva feed the foliage by scrapping the green tissue and make the skeletonization of the leaves. Mature larva bore into the fruit and feed the internal content of the fruit. Seasonality Prefer the plant to attack during last week of August to October.

C. White fly:

Taxonomic position: Sc. name: *Bemisia tabaci* (Gennadius), Family: Aleyrodidae, Order: Hemiptera

Identifying characters: Adult: Adults are small white colour insect. **Nymph:** Nymphs are small and wingless.

Damage symptoms: Both adult and nymph suck the sap from the lower surface of leaves and infested leaves turn yellowish. Heavy infestation leads to formation of Sooty mould fungus on the plant surface.

Seasonality: They attack the plant throughout its growing period.

D. Thrips:

Taxonomic position: Sc. name: *Scirtothrips dorsalis* (Hood), Family: Thripidae, Order: Thysanoptera

Identifying characters: **Adult:** Adults are small white colour insect and later turn into yellowish. **Larva:** Body transparent and legs are long.

Damage symptoms: Both adult and nymph lacerate the leaf tissue and suck the sap from leaves which causes "Upward curling" of leaves. Heavy infestation causes dropping of flower buds and fruits. Seasonality Peak infestation has been found during May to June and gradually decline.

E. Yellow mite:

Taxonomic position: Sc. name: *Polyphagotarsonemus latus* (Banks), Family: Tarsonemidae, Order: Trombidiformes

Identifying characters: **Adult:** Adults are oval, light yellow in colour with four pairs of legs. **Nymph:** Nymphs are small with three pairs of legs.

Damage symptom: Nymphs and adults suck the sap from the lower surface of leaves causing "Downward curling" of leaves which looks like inverted boat shape. Seasonality Mite infestation mainly found during August to November.

13. Cauliflower and Cabbage: Cauliflower (*Brassica oleracea* var. *botrytis*, F: Brassicaceae) and Cabbage (*Brassica oleracea* var. *capitata*, F: Brassicaceae) are two important winter growing vegetable crops which are mainly infested by Diamond Back Moth (DBM), Cabbage butterfly, Cabbage green semi lopper and Cabbage aphid. Those important insect species

associated with cauliflower and cabbage are given below with special emphasize to their taxonomic position, identifying characters, damage symptoms and their seasonality.

A. Diamond Back Moth:

Taxonomic position: **Sc. name:** *Plutella xylostell*a (Linnaeus), Family: Plutellidae, Order: Lepidoptera

Identifying characters: Adult: Adults are greyish brown in colour. At rest, three or four diamond shaped areas are formed by the forewings at dorsal surface hence the name is Diamond Back Moth. **Caterpillar:** Caterpillar greenish in colour and tapering at the both ends. They move backward when disturbed.

Damage symptoms: Larva feed the young and mature leaves. They prefer to feed the lower leaf surface and keep the upper epidermis intact and thereby creating "Window Panning" effect. Severe feeding arrests the growth and development of head of cauliflower and cabbage. **Seasonality:** They can be found throughout the growing season of the crop, but preferentially attack the plant during January to March.

B. Cabbage green semi lopper:

Taxonomic position: **Sc. name:** *Trichoplusia ni* (Hubner), Family: Noctuidae, Order: Lepidoptera

Identifying characters: Adult: Forewings of adults are greyish brown in colour and contain silvery white spot centrally. **Caterpillar:** Caterpillar greenish in colour and having 3 pairs of prolegs. During movement, it forms a semi loop loke structure.

Damage symptoms: Caterpillars start scrapping and feeding on the leaves initially and later defoliate entire plant leaving midribs and main veins. More damage is evidenced in nurseries than in main field.

Seasonality: They infest the plant during November to February.

C. Cabbage aphid:

Taxonomic position: **Sc. name:** *Brevicoryne brassicae* (Linnaeus), Family: Aphididae, Order: Hemiptera

Identifying characters: Adult: Adults are greenish in colour. Cauda present at the tip of abdomen and cornicle (siphunculi) present at the fifth abdominal segment. **Nymph:** Nymphs are small size and looking similar with adult but they are wingless.

Damage symptoms: Both adult and nymph colonize at the soft and succulent part of the plant and suck the plant sap. Due to heavy feeding the plant lost vigour and head formation drastically effected. They release carbohydrate rich compound (honey dew) which invite Sooty Mould fungus (*Capnodium* sp.). Sooty mould fungus covers the plant impede photosynthesis. **Seasonality:** Aphid mostly attack the plant when temperature is rising during mid-week of February to last week of March.

14. Pumpkin: Pumpkin (*Cucurbita maxima*, F: Cucurbitaceae), a widely cultivated cucurbitaceous vegetables mostly infested by Red pumpkin beetle, Hadda beetle and Melon fruit fly.

A. Red pumpkin beetle:

Taxonomic position: **Sc. name:** *Aulacophora foveicollis* (Lucas), Family: Chrysomelidae, Order: Coleoptera

Identifying characters: Adult: Adults are approximate 7 mm long with red orange body colour. **Grub:** Grub is creamy white in colour and slightly darker oval shield on the back. Damage symptoms Grub live in the soil and feed on the plant roots and stem whereas adult beetles make irregular holes on the cucurbit leaves. Adult also damages flower buds and flowers.

Seasonality: They appear from the last week of November and remain active up to April.

B. Hadda beetle:

Taxonomic position: **Sc. name:** *Epilachna vigintioctopunctata* (Fabricius), Family: Coccinellidae, Order: Coleoptera

Identifying characters: Adult: Adult with orange-yellow colour and sometimes turn dark brown. Each elytra has 7-14 spots. **Larva:** Grub is small, yellowish in colour and contain six rows of spines.

Damage symptoms: Both adult and grub cause damage by feeding on the upper surface of leaves. Due to their feeding, leaves become completely skeletonize, turn brown, dry up and fall of from the plant.

Seasonality: The insect pest normally active during February-April and hibernate during winter among heaps of dry plants and crevices in the soil.

C. Melon fruit fly:

Taxonomic position: **Sc. name:** *Bactrocera cucurbitae* (Coquillett), Family: Tephritidae, Order: Diptera

Identifying characters: Adult: Adult fly is 6-8 mm in length. Dorsal region with reddish yellow colour and thorax is light yellow markings. **Maggot:** Maggot is creamy white in colour, absent of legs and head.

Damage symptoms: Maggot feed on the pulp and seeds inside. Infected fruits become soft and rotten due to secondary infection caused by fungus and bacteria and fall prematurely.

Seasonality: The insect pest become serious problem during rainy season (July to August).

15. Mango: Mango (*Mangifera indica*, F: Anacardiaceae), is an important fruit crops native to Indian subcontinent having huge economic importance. Among the insect pest, Mango hopper, Mango fruit fly, Leaf webber, Mango stem borer and mealy bug are important which are discussed below along with their taxonomic position, identifying characters, damage symptoms and seasonality.

A. Mango hoppers:

Taxonomic position: **Sc. name:** *Idioscopus niveosparsus* (Lethierry), *Idioscopus clypealis* (Lethierry), *Amritodus atkinsoni* (Lethierry), Family: Cicadellidae, Order: Hemiptera

Identifying characters: *Idioscopus niveosparsus*: Three spots on scutellum and white band across the wing *Idioscopus clypealis*: Two spots on scutellum and dark spot on vertex *Amritodus atkinsoni*: Two spots on scutellum

Damage symptoms: Both adult and nymph suck the plant sap from tender shoots and inflorescence resulting drying of inflorescence and withering and shedding of flower buds and

wilting and drying of shoots and leaves. The flower stalks and inflorescence become sticky due to release of honey dew which encourages the development of sooty mould fungus.

Seasonality: The insect become dominant become February to April (Spring generation) and June to August (Summer generation).

B. Mango fruit fly:

Taxonomic position: Sc. name: *Bactrocera dorsalis* (Hendel), Family: Tephritidae, Order: Diptera

Identifying characters: **Adult:** The body length is about 8 mm long along with yellow and dark brown to black markings on thorax. **Maggot:** Maggot is creamy white in colour, absent of legs and head.

Damage symptoms: Maggot feed on the pulp and seeds inside. Infected fruits become soft and rotten due to secondary infection caused by fungus and bacteria and fall prematurely. Oozing of fluid is also observed due to infestation. Seasonality The insect pest become serious problem during rainy season (July to August).

C. Leaf webber:

Taxonomic position:

Sc. name: *Orthaga exvinacea* (Hampson), Family: Noctuidae, Order: Lepidoptera

Identifying characters: Adult: Adult is greyish with brownish wings and has wavy lines on forewings. **Caterpillar:** Caterpillar is pale greenish with brown head.

Damage symptoms: Larvae web up leaves into clusters and feed within. Leaves surface are scraped and they wither and dry up.

Seasonality: The insect pest become serious problem during July to February with peak infestation during November.

D. Mango stem borer:

Taxonomic position: Sc. name: *Batocera rufomaculata* (De Geer), Family: Cerambycidae, Order: Coleoptera

Identifying characters: **Adult:** Adult is greyish to brownish colour with long antenna which is backwardly directed. Pronotum with one pair of lateral spines. **Grub:** Grub is cream colour with brown head.

Damage symptoms: Grubs bore into the wood and make irregular tunnels and holes on the mango stem and oozing of sap and protrusion of frass from the bored holes. Feeding on the vascular tissues resulting drying of branches or entire tree. Seasonality The insect pest become serious problem during July to November.

E. Mango mealy bug:

Taxonomic position: Sc. name: *Drosicha mangiferae* (Stebbins), Family: Margarodidae, Order: Hemiptera

Identifying characters: **Adult:** Adult female white in colour and covered with numerous minute hairs and wingless. Adult male is crimson coloured with brownish black forewings. **Nymph:** Nymphal stage can be characterized by reddish brown to black body surface and later the entire body is covered with white waxy coating.

Damage symptoms: Nymphs and wingless female congregate in the fruits, inflorescence and leaves and suck the plant sap. They release honey dew which help in the formation of black colour Sooty mould fungus which cover the plant surface and hamper the photosynthesis process. Yield is drastically reduced by their infestation.

Seasonality: The insect pest become serious problem during December to February.

16. Citrus: Citrus (*Citrus* sp., F: Rutaceae) are native to tropical and subtropical Asia, which is mainly infested by Lemon butterfly and citrus leaf miner.

A. Lemon butterfly:

Taxonomic position:

Sc. name: *Papilio demoleus* (Linnaeus), Family: Papilionidae, Order: Lepidoptera

Identifying characters: Adult: Adult having wingspan at about 80-100 mm and hindwing has tail like projections. **Caterpillar:** Matured caterpillar is cylindrical shaped and tapered posteriorly and has paired forked like structure known as "osmeterium".

Damage symptoms: Caterpillar is the damaging stage and feed the foliage voraciously. Serious problem under nursery condition and orchards also.

Seasonality: The insect pest become serious problem during rainy season (July to September).

B. Citrus leaf miner:

Taxonomic position:

Sc. name: *Phyllocnistis citrella* (Stainton), Family: Gracillariidae, Order: Lepidoptera

Identifying characters: Adult: Adult is 2 mm in length and white with silvery scales.

Prominent black spot present at the tip of each forewing. **Caterpillar:** Caterpillar is translucent with greenish yellow colour.

Damage symptoms: Caterpillar feed in epidermis of leaves making serpentine silvery mines on ventral and dorsal leaf surface. Feeding leads to curling of leaves which ultimately dry up and fall down. Serious problem in nursery and orchards.

Seasonality: The insect pest become serious problem during April (Spring flush) and September (Autumn flush).

17. Guava: Guava (*Psidium guajava*, F: Myrtaceae), a common tropical fruit widely grown in India which is mainly infested by Guava fruit fly, Spiralling white fly, scale insect and Anar butterfly.

A. Guava fruit fly:

Taxonomic position:

Sc. name: *Bactrocera dorsalis* (Hendel), Family: Tephritidae, Order: Diptera

Identifying characters: Adult: The body length is about 8 mm long along with yellow and dark brown to black markings on thorax. Maggot: Maggot is creamy white in colour, absent of legs and head.

Damage symptoms: Maggot feed on the pulp and seeds inside. Infected fruits become soft and rotten due to secondary infection caused by fungus and bacteria and fall prematurely. Oozing of fluid is also observed due to infestation.

Seasonality: The insect pest become serious problem during rainy season (July to August).

B. Spiralling white fly:

Taxonomic position:

Sc. name: *Aleurodicus dispersus* (Russell), Family: Aleyrodidae, Order: Hemiptera

Identifying characters: **Adult:** Adult usually contain white colour wings and pale or dark spot on forewing. **Nymph:** Nymphs are small, white colour.

Damage symptoms: Both adult and nymph suck the sap from the lower surface of leaves and infested leaves turn yellowish and fall of prematurely. Heavy infestation leads to formation of Sooty mould fungus on the plant surface which affects photosynthesis.

Seasonality: They mostly prefer to attack the plant during winter months (December to February).

C. Scale insect:

Taxonomic position:

Sc. name: *Pulvinaria psidii* (Maskell), Family: Coccidae, Order: Hemiptera

Identifying characters: **Adult:** The body of adult scale insect is oval shaped and covered with waxy coating. **Nymph:** Nymphs are small, white colour and sedentary in nature.

Damage symptoms: Both adult and nymph suck the sap from the lower surface of leaves and infested leaves turn yellowish and fall of prematurely. Heavy infestation leads to formation of Sooty mould fungus on the plant surface which affects photosynthesis.

Seasonality: They mostly prefer to attack the plant during December to March.

D. Fruit borer/Anar butterfly:

Taxonomic position: **Sc. name:** *Virachola isocrates* (Fabricius), Family: Lycaenidae, Order: Lepidoptera

Identifying characters: Adult: Adult usually bluish brown in colour and "V" shaped patch on forewing. **Caterpillar:** Full grown caterpillar is dark brown with short hair and white patches all over the body.

Damage symptoms The caterpillars bore into ripening fruits, feed on the seeds and affected fruits rot and drop. Bore holes often plugged by the anal segment of the caterpillar or its excreta are seen on infested fruits.

Seasonality: They mostly prefer to attack the plant during rainy season (August to September) and continue up to November.

18. Banana: Banana (*Musa* sp., F: Musaceae) is widely growing tropical fruits which is mainly infested by Rhizome weevil and Banana stem weevil.

A. Rhizome weevil / Corm weevil:

Taxonomic position: **Sc. name:** *Cosmopolites sordidus* (Germar), Family: Curculionidae, Order: Coleoptera

Identifying characters: Adult: Adult usually brown in colour, having a prominent snout and absent of depression on pronotum. **Grub:** Matured grub is white colour with dark reddish-brown colour head.

Damage symptoms: Grub bore into rhizome and feed the internal tissue resulting wilting of the plants. Due to their infestation withering of outer leaves occurs which ultimately leads to death of the plant.

Seasonality: They mostly prefer to attack the plant during May to July with high temperature and high relative humidity.

B. Banana pseudostem weevil:

Taxonomic position: Sc. name: *Odoiporus longicollis* (Oliver), Family: Curculionidae, Order: Coleoptera

Identifying characters: Adult: Adult usually dark black in colour, having a prominent snout. **Grub:** Grub is yellowish, fleshy and apodous.

Damage symptoms: Both adult and grub bore the pseudo stem and oozing of slimy exudation from bored holes is the initial damage symptom. After flowering, when tunnelling occurs the fruit does not develop properly. Due to secondary infection of pathogens, rotting occurs and a foul odour is emitted.

Seasonality: They mostly prefer to attack the plant during May to July with high temperature and high relative humidity.

19. Coconut: Coconut (*Cocos nucifera*, F: Arecaceae) is an important oil yielding plantation crops as well as widely used for consumption purpose. Different types of insect and mite species have been reported from coconut and among them Red palm weevil, Rhinoceros beetle and Coconut eriophyid mite.

A. Red palm weevil:

Taxonomic position: **Sc. name:** *Rhynchophorus ferrugineus* (Olivier), Family: Curculionidae, Order: Coleoptera

Identifying characters: Adult: Adult usually dark brown in colour, having a prominent snout and black spot present on pronotum region. **Grub:** Grub is yellowish or creamy white in colour, fleshy and brownish or blackish head capsule.

Damage symptoms: Adult and grub bore the trunk and from the bored holes oozing of brown liquid occurs. Feeding leads to yellowing of inner leaves and gradual wilting of central shoot in the crown ultimately formation of "Crown toppling" in coconut.

Seasonality: Mainly infect the host plant during dry season (March to May).

B. Rhinoceros beetle:

Taxonomic position: **Sc. name:** *Oryctes rhinoceros* (Olivier), Family: Scarabaeidae, Order: Coleoptera

Identifying characters: Adult: Adult is stout, black in colour and projecting a horn dorsally from the head. In female, horn is short than male. **Grub:** Grub is creamy white in colour, "C" shaped, fleshy and brownish or blackish head capsule.

Damage symptoms: Adult attack the palm in the crown region and cut across leaf in folded condition. They cut the leaf in Geometrical or Diamond shape (V-cut). Damage can be easily recognized by presence of chewed materials plugging the entry hole.

Seasonality: Mainly infect the host plant during dry season (March to May).

C. Coconut eriophyid mite:

Taxonomic position: Sc. name: *Aceria guerreronis* (Keifer), Family: Eriophyidae, Order: Trombidiformes

Identifying characters: Adult: Adult is very minute, vermiform body shape, white in colour and 2 pair of legs. **Nymph:** Nymphs are small, with 2 pair of legs but lacking of genital region. **Damage symptoms:** Both adult and nymph colonize in the coconut perianth. Initial symptoms exhibit as triangular pale white or yellow patches close to the perianth. Continuous feeding results in necrosis of tissues leading to formation of brown colour patches, longitudinal fissures and splits on the outer surface of the husk; oozing of brown gummy exudation; reduced nut size, copra content and malformation of nuts.

Seasonality: Mainly infect the host plant during dry season (March to May) and less active during winter months.

20. Turmeric and Ginger: Turmeric (*Curcuma longa*), is a perennial herbaceous plant of the ginger family (Zingiberaceae), the tuberous rhizomes, or underground stems, of which have been used from antiquity as a condiment, a textile dye, and medically as an aromatic stimulant. Native to Southeast Asia (southern India and Indonesia) and is grown commercially in that region, primarily in India. Ginger, *Zingiber officinale* (Rosc.) is an important spice and medicinal crop grown in India. Among the insect pest, shoot borer, rhizome scale, rhizome fly, leaf roller, thrips and bihar hairy caterpillar are important which are discussed below along with their taxonomic position, identifying characters, damage symptoms and seasonality.

A. Shoot borer:

Taxonomic position: **Sc. name:** *Conogethes punctiferalis*, Family: Pyralidae, Order: Lepidoptera

Identifying characters: Adult: Medium sized moth with a wingspan of about 20 mm; the wings are orange-yellow with minute black spots. **Larva:** Larva is long, pale greenish with a pinkish dorsally, head and pro-thoracic shield brown in colour and body covered with sparse hairs. **Damage symptoms**: The larvae bore into pseudostems and feed on internal tissues resulting in yellowing and drying of leaves of infested pseudostems. The presence of a bore-hole on the pseudostem through which frass is extruded and the withered and yellow central shoot is a characteristic symptom of pest infestation.

Seasonality: Pest population is higher in the field during September-October. The pest is most active from July to October.

B. Rhizome scale

Taxonomic position: Sc. name: *Aspidiotus hartii*, Family: Diaspididae, Order: Hemiptera **Identifying characters: Adult:** Female scales are circular (about 1mm diameter) and light brown to gray and appear as encrustations on the rhizomes. Male is orange coloured with transparent wings, distinct head, thorax and abdomen.

Damage symptoms: Adult (female) scales feed on sap and when the rhizomes are severely infested, they become shrivelled and desiccated affecting its germination. In initial stage of infestation, the white coloured scales are seen scattered on rhizomes and later they congregate near the growing buds. When the infestation is severe the rhizome and buds shrivel and ultimately the entire rhizome dries.

Seasonality: The rhizome scale infests rhizomes in the field (at later stages) and in storage.

C. Rhizome fly:

Taxonomic position: Sc. name: *Mimegralla coeruleifrons*, Family: Micropezidae, Order: Diptera

Identifying characters: **Adult:** Adult flies are dark blackish. Wings are transparent with three light ashy bands. Tarsi of forelegs are white in colour. **Maggot:** Maggot is creamy white, apodous and 9 mm long.

Damage symptoms: Maggots mine into the mid-rib of leaves and enter into the rhizome through the petiole. It results in the rotting of rhizomes and dead hearts.

Seasonality: The pest is mainly active and damage more during August to October under field conditions.

D. Leaf roller:

Taxonomic position: Sc. name: *Udaspes folus*, Family: Hesperiidae, Order: Lepidoptera **Identifying characters**: **Adult:** Adults are medium sized with brownish black wings with eight white spots on forewings and one large patch on hind wing. **Larva:** Fully grown larvae are dark green with black head and constricted neck.

Damage symptoms: Larvae webs leaves with silken threads, cut and fold the leaves into a tubular form, remain within and feed on them, pupate inside the leaf.

Seasonality: The pest is abundant in the field during August - October.

E. Thrips:

Taxonomic position: **Sc. name**: *Panchaetothrips indicus*, Family: Thripidae, Order: Thysanoptera

Identifying characters: Adult: Thrips are very small, have elongated abdomens and are yellowish or blackish in color. Adults have fringed wings, though they do not usually fly. They are often found on plants throughout all growth stages, from sprout development to tuber maturation.

Damage symptoms: Thrips damage the undersides of leaves by sucking their plant sap. They damage young and soft parts of plants such as new leaves and shoots. Leaves become rolled up, and turn pale and gradually dry up. Severe infestation causes young leaves to wilt and dry out. **Seasonality:** Favaourable condition for pest abundance is warm and humid weather (June-August).

F. Bihar hairy caterpillar:

Taxonomic position Sc. name: *Spilarctia* (*Spilosoma*) *obliqua*, Family: Arctiidae, Order: Lepidoptera

Identifying characters: Adult: Adult moth is brown with a 40-50 mm wing span and a red abdomen. **Larva:** The larvae are covered with long yellowish to black hairs and are up to 5 cm long.

Damage symptoms: Young larvae feed gregariously on the under surface of the leaves and cause loss by way of defoliation. Sometimes, after defoliated the crop larvae feed on the capsules. In severe cases only stems are left behind.

Seasonality: The pest is found active during September.

21. Onion: Onion (*Allium cepa* L.; Family: Amaryllidaceae) is one of the most important commercial vegetables as well as spice crop. It is grown in western, northern as well as in

southern India. Among the pests attacking onion, onion thrips and onion maggots requires attention as they are the most destructive.

A. Onion thrips

Taxonomic position: Sc. name: *Thrips tabaci*, Family: Thripidae, Order: Thysanoptera **Identifying characters**: **Adult:** About 1.5 mm long; elongate, yellow and brown body with two pairs of fringed (hairy) wings. **Nymph:** White to pale yellow, elongate and slender body. Resemble adult, but without wings. Antennae are short and eyes are dark in colour.

Damage symptoms: Both nymphs and adults remain at leaf bases and whorls of onion and suck sap. The infestation causes pale white blotches on leaves. In severe infestation, the leaves dry from top to bottom.

Seasonality: This pest is active throughout the year and breeds on onion and garlic from November to May.

B. Onion maggot:

Taxonomic position: **Sc. name:** *Delia antiqua*, Family: Anthomyiidae, Order: Diptera **Identifying characters**: **Adult:** Onion flies are slightly smaller than houseflies. They have longer legs, are slender, and overlap their wings when at rest. **Maggot:** The legless maggots are tapered, creamy-white in colour, and reach a length of about 1/3 inch (8mm).

Damage symptoms: Only the larva causes damage by using its hooked mouth parts to enter the base of the plant. Damaged seedlings first wilt, eventually become flaccid, and die. Frequently, attacked seedlings die before the maggots are fully grown, forcing them to move to adjacent plants. Second generation maggot feeding on developing bulbs usually results in distorted

growth accompanied by rotting tissue. Feeding by third generation maggots on late season onion bulbs results in an unmarketable product.

Seasonality: The pest is abundant in the field during July-September.

22. Tobacco: Tobacco, *Nicotiana tabacum* L. is an herbaceous annual or perennial plant in the family Solanaceae grown for its leaves. The tobacco plant has a thick, hairy stem and large, simple leaves which are oval in shape. Tobacco contains the alkaloid nicotine, a stimulant. Tobacco use is a risk factor for diseases affecting the heart, liver and lungs. Among different insect pests, tobacco caterpillar, stem borer, gram pod borer, whitefly and aphid are the most important.

A. Tobacco caterpillar:

Taxonomic position: **Sc. name:** *Spodoptera litura*, Family: Noctuidae, Order: Lepidoptera **Identifying characters: 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 marking is seen on anterior and posterior region in early stages.

Damage symptoms: During early instar, caterpillars scrape chlorophyll content of leaf lamina giving it a papery white appearance. During later instars, skeletonizes the leaves leaving only veins and petioles. Seasonality The pest breeds throughout the year.

B. Stem borer:

Taxonomic position: Sc. name: *Scrobipalpa heliopa*, Family: Gelechiidae, Order: Lepidoptera **Identifying characters:** Adult: Dark brown moth. Caterpillar: Slender, dark headed and pinkish.

Damage symptoms: Caterpillar mines into the leaf axil and then into stem. Bored stems become hollow, swollen and forms a gall.

Seasonality: The pest attack found mostly in the nursery.

C. Gram pod borer:

Taxonomic position: **Sc. name:** *Helicoverpa armigera*, Family: Noctuidae, Order: Lepidoptera **Identifying characters**: **Adult:** Moth is stout, medium sized with brownish/greyish forewings with a dark cross band near outer margin and dark spots near costal margins, with a wing expanse of 3.7 cm. **Larva:** Caterpillars are of varying colour, initially brown and later turn greenish with darker brown lines along the side of the body.

Damage symptoms: During the vegetative phase larvae feed on bud leaves and surrounding leaves. During flowering/ capsule formation stage larvae feed on flower buds, flowers and capsules Seeds are eaten severely and completely hollowed out. While feeding the caterpillar thrust its head inside leaving the rest of the body outside. Bored capsules with round holes. Damaged bud leaves, shoots and buds.

Seasonality: The activity of Helicoverpa starts on green gram, summer vegetables and maize and continues their generation by October-November months synchronizing with main crop.

D. Whitefly:

Taxonomic position: **Sc. name:** *Bemisia tabaci*, Family: Aleyrodidae, Order: Hemiptera **Identifying characters**: **Adult:** Minute insect with yellowish body and whitish wings. **Nymph:** Oval scale like and yellowish in colour.

Damage symptoms: Both nymphs and adults suck sap from lower side of leaves. It results in reduction of plant vigour which ultimately leads to shedding of flowers. Sooty mould develops on infested leaves due to excretion of honey dew and it hampers the photosynthetic activity. Vector of tobacco leaf curl disease.

Seasonality: It attacks both nursery and main field.

E. Aphid

Taxonomic position: **Sc. name:** *Myzus persicae*, Family: Aphididae, Order: Hemiptera **Identifying characters**: **Adult & Nymph:** Aphids are small, soft-bodied, pearl-shaped insects that have a pair of cornicles (wax-secreting tubes) projecting out from the fifth or sixth abdominal segment. Greenish/ light pink. Winged female has a black head and greenish abdomen with one/two transverse dark bands and four lateral dark spots.

Damage symptoms: 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 curl down, fade gradually and finally dry up. Black sooty mould develops on honey dew excreted by the aphids, which falls on leaves. They transmit tobacco ring spot virus and rosettes disease.

Seasonality: Incidence of aphids reaches its peak from December and to first week of January.

4. Rose: Rose (*Rosa spp*., Family: Rosaceae), acclaimed as the queen of flowers, native to Asia, is one of the most beautiful nature's creations. Among different insect pests, rose thrips, aphids and red spider mite is important.

A. Rose aphid:

Taxonomic position: Sc. name: *Macrosiphum rosae, M. rosaeformis,* Family: Aphididae, Order: Hemiptera

Identifying characters: Adult & Nymph: Small pear shaped soft-bodied aphids, light green to dark blackish green in colour. Apterous form has an elongated body, large red eyes, black cornicles and yellowish green tip at the abdomen.

Damage symptoms: Both nymphs and adults of aphids cause damage by sucking the plant-sap. Aphids often colonize and concentrate on tender growing tissues, like terminals and flower buds; they can cause distorted or stunted growth. Aphids excrete a sticky substance known as honeydew, which contains large amounts of undigested sugars. Honeydew accumulates on leaves and supports a black fungal growth known as sooty mold.

Seasonality: Most active during spring and summer seasons.

B. Rose thrips:

Taxonomic position: **Sc. name:** *Rhipiphorothrips cruentatus*, Family: Thripidae, Order: Thysanoptera

Identifying characters: Adult: Dark brown, black in colour. Nymph: Nymphs are reddish in colour.

Damage symptoms: Nymph and adult lacerate leaves from the under surface of the leaves and flower buds. As a result, white streaks appear on the infested leaves. Leaves show brown patches and get distorted, finally wither and drop down. Infested flowers do not open, flowers fade and drop down prematurely.

Seasonality: Peak incidence during December to January.

C. Red spider mite:

Taxonomic position: **Sc. name:** *Tetranychus cinnabarinus*, Family: Tetranychidae, Order: Acarina

Identifying characters: Adult & Nymph: Both nymphs and adults are red in colour. About 200 whitish, spherical eggs laid on the ventral surface of the leaves and measure about 0.1 mm in diameter.

Damage symptoms: Nymphs and adults feed on the undersurface of the leaves and are found covered with silken webs. As a result, yellow spots appear on the upper surface, which gradually turn reddish. Affected leaves finally wither away. Growth and flower production are adversely affected.

Seasonality: Peak incidence during November-December.

Experiment 2: Identification of insect pests and Mites associated with stored grain

Objective: To identify the insect pests of stored grains and their symptoms of damage

Materials: Stereo-binocular microscope, watch glass, forceps, camel hair brush

INTERNAL FEEDERS:

1. Rice weevil

Taxonomic position

Sc. name: *Sitophilus oryzae*, Family: Curculionidae, Order: Coleoptera

Identifying characters: **Adult:** Reddish brown/ dark brown/ black weevil with a long slender snout and four reddish spots on elytra. **Grub:** Small white and apodous with yellowish brown head.

Damage symptoms: Infest grain both in store and field. Both grubs and adults damage the grain by feeding inside the kernels. Adults cut a circular hole on the grain.

2. Lesser grain borer

Sc. name: *Rhyzopertha dominica*, Family: Bostrychidae, Order: Coloeoptera

Identifying characters: **Adult:** Dark brown beetle with head deflexed under thorax with a blunt abdominal end. **Grub:** Dirty white with light brown head and elongated body.

Damage symptoms: Both grubs and adults feed inside the grains and reduce them to mere shells having many irregular holes.

3. Angoumois grain moth

Sc. name: *Sitotroga cerealell*a, Family: Gelechiidae, Order: Lepidoptera

Identifying characters: Adult: Yellowish white moth with pale forewings and uniformly grayish pointed hind wings having fringe of hairs. **Caterpillar:** White with yellowish brown head.

Damage symptoms: Caterpillar feeds on the internal content of grains. Before pupation, it prepares the way for the moth emerges out of the grain, leaving only a thin layer of seed coat intact.

4. Pulse beetle

Sc. name: *Callosobruchus macculatus, Callosobruchus chinensis* Family: Bruchidae, Order: Coleoptera

Identifying characters: **Adult:** Reddish brown beetle with two ivory spots on the centre of elytra. **Grub:** White cylindrical, fleshy with light brown head.

Damage symptoms: Grubs feed on inner contents of pulses. Damaged seed contains a circular hole.

EXTERNAL FEEDERS

5. Red flour beetle

Sc. name: *Tribolium castaneum*, Family: Tenebrionidae, Order: Coleoptera

Identifying characters: **Adult:** Reddish brown flat beetle. **Grub:** Yellowish white initially, but later turns reddish yellow, body hairy.

Damage symptoms: They cause considerable damage to the flour products and also to the grains already damaged. In case of severe infestation, flour turns grayish, mouldy and emits characteristic offensive odour.

6. Khapra beetle

Sc. name: *Trogoderma granarium*, Family: Dermestidae, Order: Coleoptera

Identifying characters:

Adult: Dark brown beetle with no distinct divisions between head, thorax and abdomen. Body convex and oval in shape.

Grub: Yellowish brown with brownish head, body clothed with hairs.

Damage symptoms: Only grubs damage wheat near the embryo. In case of severe infestation, they reduce the grain into mere frass.

7. Rice moth

Sc. name: *Corcyra cephalonica*, Family: Galleridae, Order: Lepidoptera

Identifying characters: Adult: Grayish brown moth. **Caterpillar:** Creamy white with a prominent broad, yellowish head.

Damage symptoms: Caterpillars web the grains together and feed within. Also attack broken grains and flour.

SECONDARY PEST

8. Saw toothed grain beetle

Sc. name: *Oryzaephilus surinamensis*, Family: Silvanidae, Order: Coleoptera

Identifying characters: Adult: Slender, dark brown flat beetle with a row of six teeth like structures on either side of thorax. **Grub:** Slender pale cream with two dark patches on each segment. **Damage symptoms:** Both grubs and adults feed on grain surface by scraping.

Experiment 3: Determination of insect infestation by different methods

Objective: To determine different methods for detection of insect infestations of stored grains and the moisture content analysis of grain sample, and to familiarize with various grain sampling methods practiced under storage condition

Detection methods of insect infestation in stored grains:

For the detection of insect infestation of stored grains, several methods have been developed such as visual inspection, detection probe, staining of the kernel, Berlese funnel method, visual lures and pheromones, acoustic techniques, uric-acid method, egg-plugs, ninhydrin method, X-ray imaging, nuclear magnetic resonance imaging, Near-infrared spectroscopy, thermal imaging, solid-phase micro-extraction method etc. All these methods are categorized under two broad groups i.e. physical methods and chemical methods for the detection of hidden infestation by insects in storage condition.

I. PHYSICAL METHODS

1. Visual examination: It is a preliminary method. Damaged grains in the samples is indicated by loss in its natural luster- dull -lifeless. Trained worker can very easily determine the qualities of grain by its appearance.

2. Germ damage and insect emergence holes: Very simple and gives a good index of deterioration or damage to the field workers. Does not indicate the damage going on inside the kernels. Per cent kernels damaged by insects including the germ eaten kernels is assessed. 100 g of grain sample is evenly spread out on a glass plate, the damaged kernels are picked up to assess the percentage of insect damaged kernels.

3. Determination of foreign matter, insect infestation etc.: Using sieves insect debris, webbing, larvae, their cast off exuviae etc., physically separated and handpicked. This will provide a rough idea of the damage. Foreign matter is also examined under microscope.

4. Total damage (Quality test): Damage by heat, sprouted, mould and rotten wheat kernels are physically separated. This method is followed to assess the quality of grains–in commercial.

5. Germination tests: Viability of the wheat and other food grains is reported in terms of percentage of kernels developing strong sprouts under controlled conditions. 10 g seeds on the moist filter paper at optimum temperature. Reduced viability indicates increase in deterioration.

6. Loss in weight: Estimated by determining volume weight ratio. A decrease in volume/weight ratio indicates an increase in damaged kernels.

Mass loss (%) = (U$Nd-DNu$) ×100 /U ($Nd+Nu$)

Where, Nu = Number of undamaged grains; Nd = Number of damaged grains; U = Dry mass of undamaged grains; and D = Dry mass of damaged grains

7. Acoustic method: Sounds produced by the insects due to their movement or feeding has been utilized in detecting insect infestation quantitatively. Possibility of detecting the dead insects are serious limitation.

8. X-ray radiographic method: Internal insect infestation can be detected. All stages of development of the insects can be observed rapidly. Recently Polaroid radiographic media are using for this purpose.

9. Traps: TNAU Insect traps are excellent insect detection devices and more effective in the detection of stored grain insects.

10. Near Infrared Spectrometer (NIRS): Detects and measures the chemical composition of biological materials. Molecules comprising organic matter vibrate at frequencies corresponding to wavelengths in the infrared region. Optical sensors measure this absorption and quantified.

11. Development of a new loss-assessment method [MM]: This method is capable of determining the frass activity of beetles tunneling through the dried chips. The increase in inner volume of a cassava chip is measurable by means of vacuum equipment and can be converted into weight loss.

II. CHEMICAL METHODS

1. Use of stains

a) Acid fuchsin

➢ Mix 50 ml. glacial acetic acid in 950 ml of distilled water and add 0.5 g acid fuchsin.

➢ Soak grain samples in warm water for 5 minutes.

➢ Then immerse the soaked grain samples in the stain for 2 to 5 min.

➢ Remove excess stain by washing in tap water.

➢ Observe under microscope – egg plug stains show bright cherry red.

➢ While feeding punctures including mechanical injuries in light pink.

b) Gentian violet

➢ Prepare 1% aqueous stock solution of gentian violet in 50 ml of 95% ethanol.

➢ Immerse the sample for 2 minutes in a solution containing 10 drops.

➢ Observe under microscope – egg plug stains show purple colour.

c) Berberine sulphate

➢ Kernels are immersed in dilute solution of the dye (20 parts per million) for one minute.

➢ Rinsed and examined under ultra violet light.

➢ Egg plug stains show intense greenish yellow under ultra violet light.

2. Floatation or density method: Involves the use of two solutions of different specific gravity. Sodium silicate in water (sp. gravity 1.160 to 1.190) and Methyl chloroform (sp. gravity 1.30) with debase oil. Grain is immersed in the fluids. A three-layer separation occurs. Non-infested kernels sink to the bottom. Infested one floats and light weight kernels including those infested by early stages of insect hang in the line of separation between the two fluids.

3. Gelatinization method: In this method the grain is boiled for ten minutes in 10% solution of sodium hydroxide. The treatment renders the kernels translucent, thereby, revealing the presence of internal infestation.

4. Cracking floatation method: Cleaned grain is coarsely ground to release the internal insects. Soaked either in a water-alcohol mixture or in boiling water. Mix with gasoline or mineral oil. Insects floats with the oil layer in a flask. Collect it on a filter paper and count it.

5. Fragment count or acid hydrolysis method: Presence of insect's fragments such as elytra, head capsules, mandibles, counted basically involving a flotation technique but in a modified way. A mixture of oil and aqueous phase (besides surfactants) is used in making the fragments to float. Test involves digestion of a sample with an acid, wet sieving, or a de-fating treatment using a detergent or solvent. Insect fragments which are oleophilic, are separated from food particles by the attraction of the oil phase (light) mineral oil in an oil- aqueous mixture). Floating fragments are trapped or filtered and examined under a microscope. Infestation detection by the fragment count chocolate and powdered spices.

6. Spectrophotometric analysis: De-hydroxyphenol occurring in insect cuticle is estimated by spectrophotometer. Phenols produce certain dyes and are reacted with dichloroquinne chlorimide.

7. Ninhydrin colour reaction (chemical indicator technique): Insects body fluid produces a colour with ninhydrin impregnate filter paper (0.7% solution in Acetone). High sensitivity and specifically suitable to mechanization. A machine has also been manufactured in which wheat kernels are crushed on a treated strip of paper tape and the same observed for stains. The machine is known as "Ashman Simon Hidden Infestation Detector".

8. Carbon dioxide determination method: Quantity of carbon dioxide produced by a given sample of grain in 24 hours, is measured and the extent of internal infestation can be estimated. Representative grain sample free from moving insects in incubated for 24 hours at 35°C. The concentration of CO2 is measured with the help of gasometric method accurate to ± 0.2%.

Experiment 4: Assessment of losses due to insects

Objective: To acquainted with various types of loss assessment due to insect damage

Estimation of Insect Pests Damage:

A species that interferes with activities of plant and cause damage to yield is known as pest. The total yield losses by different pests to all agricultural crops at global level is estimated to be 42.1% of attainable production. Estimation of crop losses caused by insects to economic crops are exceedingly difficult because,

1. They variable in nature of damage.

2. Insect population fluctuates both in time and space.

The nature of damage caused by insect pests of crop plants is a function of pest population. So it is mostly insect capacity to increase in number rather than the nature of damage. The following four points should be kept in view to estimate the losses.

1. Any insect which cause some kind of the damage to crop can become pest when its population increase above a critical level. The critical level depends upon the nature of the damage caused by the insect. E.g. In case of leaf feeders, the leaf eaten is near index of the losses caused by caterpillars. In case of insect vectors of virus of disease, a very small population of infective individuals can spread the disease to whole crop.

2. The losses caused vary both in time and space from 0 to 100%. The estimation is fairly easy at these two extremes, but there are large numbers of factors which tend to invalidate any estimation in between these extreme limits.

3. The loss may be either quantitative or quality. In case of quantitative loss reduced yield is observed, where as in qualitative loss, quality may be affected. E.g. In case of wheat bug (Eurygastor integriceps) is known to affect adversely the baking quality of wheat.

4. Insect losses in terms of money are also objected. That the selling price of the commodity would be reduced, if insect infestation were to be greater extent. The measures generally followed for estimating the losses caused by insect pests are based on either growing a crop as free from insect infestation as possible and then comparing its yield with that of check crop in which insect activity has been normal, or by making use of differential infestation and comparing the yield. The above ones are used in the following methods for estimating the crop losses. The methods are as follows,

1. Mechanical protection of crop from insect pest damage

2. Chemical protection of the crop

3. Comparison of yields in different fields having different degrees of pest infestation

4. Comparison of average yield of healthy plant with that of infested plants

5. The average amount of damage caused by individual insect

6. Manipulation of natural enemies

7. Simulated damage

1. Mechanical protection of crop from insect pest damage The crop is grown under the enclosures of wire gauze or cotton cloth. These enclosures keep the pest away from the crop. Then, the yield of crop under such enclosures is compared with the yield obtained from the

infested crop under similar conditions. This technique has been used with that various modifications for estimating the losses caused by leaf hoppers and whitefly to cotton. 2. Chemical protection of the crop The crop is protected from pest damage by best scheduled chemical recommendation of pesticides. Then, the yield of treated crop is compared with that subjected to normal insect infestation. This technique has been very widely used and it can be adopted on a large scale in cultivator's field. 3. Comparison of yields in different fields having different degrees of pest infestation The yield is determined per unit area in different fields having different degrees of pest infestation. The correlation between the yield and degrees of infestation is worked out to estimate the loss in yield. 4. Comparison of the average yield of healthy plants with that of attacked plants In this process individual plants from the same field are examined for the pest incidence and their yield is determined individually. The loss in yield is estimated by comparing the average yield of healthy plants with that of plants showing different degrees of infestation. The same data can also use for working out the correlation between the yield and infestation on the basis of infested individual plants. Pradhan and Prasad worked out the correlation between damage by Chilo partellus and the yield of sorghum in the following equation; Y = 6.6204 X1- 0.9257X2 -27.17 Where, Y = Yield of sorghum grain per plant X1= Number of ears per plant X2= Percentage of stalk length infested 5. The average amount of damage caused by individual insect For this method, the preliminary information is obtained from studies on biology of the pest species. The details regarding the amount of damage caused by different stages or stages of the insect, and the exact nature and amount of loss caused are then worked out. E.g. It has been estimated in the case of phadka grasshopper (Hieroglyphus negrorepletus), it consumes on average 42 grams of green leaves of maize during its life time. It was estimated that this insect would cause 18% loss in yield of maize at a population level of 10

grasshoppers per square yard. 6. Manipulation of Natural Enemies The manipulation of natural enemies of a pest species offers a means of evaluating plant damage. This technique has not been widely used. The pest is controlled by introducing predators or parasites into the field and the yield of such crop is compared that on which no such pest control measures have undertaken. This method is feasible only in small plots and is not practicable on field. 7. Simulated damage Many investigators have attempted to simulate pest injury by removing or injuring leaves or other parts of the plant. The simulated damage may not always be equivalent to the damage caused by an insect. Insects may persist over a period of time or inject long acting toxins rather than producing their injury. Feeding on margins of leaf may not be equivalent to tissue removal from the centre of the leaves. Insect feeding is usually extended over a period of time and is difficult to incorporate the concept of rate of injury.

Experiment 5: Calculations on the doses of insecticides application technique

Objective: To calculate the dosage of insecticides for field application. To calculate the strength of the spray solution and to calculate the amount or quantity of insecticide required to apply in a given cropped area.

Insecticides are applied mainly in two form either in solid form (granules, wettable powder or dust etc.) or liquid form (emulsifiable concentrate, suspension concentrate, soluble liquid etc.).

(A) To find out the quantity of insecticide required for treating an area at a required strength, the following formula may be adopted:

(i) For solid formulations

Quantity of insecticide (Kg/ha) = Amount of a.i. recommended (Kg/ha) ×100/Strength of formulation

Example: A recommendation for aphids calls for using Malathion at 2 kg active ingredient/hectare. How much Malathion 40% WP would be needed per hectare?

Solution: Kg/ha of Malathion 40% WP needed = 2 ×100/40 = 5 kg.

(ii) For liquid formulation-

(a) Quantity of insecticide = (Total quantity of spray solution required × Concentration of the spray solution desired)/Strength of the formulation

Example: Find out the amount of Flubendiamide 48 SC when it was sprayed at 0.01% concentration for treating 2500 square metres area of field @ 500 litres of water/ha.

Solution: Here, total quantity of spray solution required = 500 × 2500/10000 = 125 lit. Required strength = 0.01%, Known strength = 48 SC, Quantity of insecticide = 125 × 0.01/48 = 0.026 lit.

(b) Quantity of insecticide = Recommended a.i. in kg/ha × 100/Strength of the formulation

Example: How much Malathion 50% EC would be needed per ha if a recommendation for borer pest calls for 0.2 kg a.i. malathion per ha?

Solultion: Amount of malathion 50 EC needed = 0.2 × 100 50 = 0.4 lit.

(B) To obtain the strength/concentration of a finished spray solution, when a known quantity of chemical is added to a known quantity of water, the following formula may be adopted:

Concentration of spray fluid = (**Quantity of formulation used** × **Strength** (%) **of the formulation**)/**Quantity of finished spray solution required**

Example: For the control of groundnut leaf miner, farmer has mixed 300 ml of chlorpyriphos 20 EC in 300 lit. of water and sprayed in his field. Find out the concentration of spray fluid he has applied in his field.

Solution: 300 ml of chlorpyriphos 20% EC is added to 300 lit. of water. So, 300 ml = 0.3 lit. The strength/concentration of chlorpyriphos in the spray liquid is- = 0.3 × 20 300 = 0.02%

(C) To calculate the dose of a formulated product, the following formula may be adopted-
Amount of formulated product (g or ml/lit. of water) = (Re**commended a.i./ha** × **100**)/(S**trength of the formulation** ×**spray volume** (**lit./ha**)

Example: Calculate the dose of Imidacloprid 17.8 SL or Thiamethoxam 25 WG for the control of aphids in mustard if the recommended a.i./ha is 20 g/ha for Imidacloprid and 15 g a.i./ha for Thiamethoxam, respectively. The recommended spray solution is 500 lit./ha.

Solution: Dose of Imidacloprid = (20 × 100)/(17.8 × 500) = 0.22 ml/litre of water. Dose of Thiamethoxam = (15 × 100)/(25 × 500) = 0.12 g/litre of water.

Experiment 6: Fumigation of grain store / godown

Objective: To acquainted with the basic concept of fumigation in godowns.

Fumigation is the process of releasing and dispersing a toxic chemical so it reaches the target organism in a gaseous state. Fumigants are the most effective control measures for stored product insect and mite pests. The most effective way to reach pests in their most remote hiding places is through fumigation, the use of poisonous gases to kill pests in an enclosed area. To be effective, fumigants must reach target pests as gases.

What is Fumigant?

In modern terminology "fumigant is a chemical which at required temperature and pressure can exist in the gaseous state in sufficient concentration to be lethal to a given pest organism". This definition implies that a fumigant is a toxic chemical or mixture of compounds that kills pests as a volatile gas within a range of temperatures. They are volatile pesticides whose vapors enter the insect's body through the body wall or breathing system. Chemicals applied as aerosols, smokes, mists, and fogs are suspensions of particulate matter in air and are not fumigants. Fumigants penetrate to many areas of a building not reached by sprays or dusts, even penetrating to the burrows of wood-infesting insects, as well as to the center of tightly packed commodities, such as cotton bales, cases or grain in large silos or bulk bins.

Types of Fumigation

Fumigation in godowns or warehouses are performed by following ways-

1. Bulk grain storage fumigation and capsule truck fumigation

2. Grain in silo

3. Stack Fumigation

4. Space Fumigation

5. Container Fumigation

Commonly Used Fumigants:

These are some commonly used fumigants-

1) Ethylene dichloride – $C_2H_4Cl_2$

2) Hydrogen cyanide - HCN

3) Sulfuryl fluoride – SO_2F_2

4) Methyl bromide – CH_3BR

5) Phosphine – PH_3

6) Carbon tetrachloride – CCl_4

In India, there are only four registered fumigants. These are aluminium phosphide, methyl bromide, EDCT mixture (ethylene dichloride + carbon tetrachloride) and magnesium phosphide plates. However, for treating food grains, phosphine (aluminium phosphide solid and powder formulations) and ethylene dichloride-carbon tetrachloride (EDCT) mixture alone have been approved. Methyl bromide is allowed for quarantine and pre-shipment (QPS) fumigations only. Magnesium phosphide plates 56% used for export tobacco fumigation.

Methyl bromide is an ozone depleting gas, its use is legally restricted only for quarantine and pre-shipment fumigation purposes in India and governed by Directorate of Plant Protection, Quarantine and Storage (DPPQS) which authorizes and issues licenses to fumigators. The most effective method to ensure food safety against pests is fumigation with phosphine (PH3) gas. Phosphine fumigation is preferred because of leaving little amount of residuals and ease of application. 650 ppm phosphine gas concentration of the storage atmosphere in the fumigation is determined as the optimum value for pest control.

Fumigation with Phosphine:

➢ Fumigators must remember that the exposure period is deemed to start from the time that the fumigant is first found to be evenly distributed inside the fumigation enclosure. Before gassing an enclosure for fumigation, a warning placard with a warning symbol must be displayed.

➢ Aluminium phosphide (ALP) products usually release 33% Phosphine from the total weight of the product i.e. tablets weigh approximately 3 grams and release 1 gram of phosphine gas and pellets weigh approximately 0.6 grams and release 0.2 grams of phosphine gas.

➢ The generation of phosphine generated from ALP formulations may be delayed by about 15 minutes after they are exposed to air. In hot, humid conditions, phosphine is produced almost immediately on exposure to the air, so the dispensing process must be completed within 15 minutes.

➢ ALP Formulation Dose: (a) Tablets: keep @ 10 tablets (10 tablets x 3 grams = 30 grams) in a cloth bag (or) (b) Sachets: 34 grams sachet.

➢ Fumigation period – at least 7 Days for the control of all live stages.

➢ Target Phosphine concentrations more than 700 ppm for 7 days for grains in flat storage.

➢ Increasing the dosage above the rate(s) recommended on the label will not compensate for poor gas-tightness.

➢ Post Fumigation Protection of Fumigated stacks: Prophylactic spray with approved agents like Deltamethrin 2.5%WP as per recommended dose on all sides of the stack.

Precautions to be taken during Phosphine fumigation:

Phosphine must not be used-

➢ when there is no trained, qualified and properly protected fumigation team.

➢ in unsealed enclosures.

➢ when the temperature is below 10°C.

➢ where resistance to it is known to exist in an insect population.

➢ where a rapid treatment is required, i.e. less than 7 days.

➢ in immediate vicinity to workspaces and places where people live.

Experiment 7: Identification of rodents and rodent control operations in godowns

Objective: To study the characteristics and nature of damage of different rodents and birds which damage grains stored in godowns.

Rodents: Rodents are a matter of concern to a food grains and farm produces. Rodents are important pests not only due to their omnipresence but also because of their high rate of multiplication. Generally, rodents attack takes place in storage structure as well as in open or field storage. Rodents not only feed on grains but also contaminate 20 times more than what they consume with their faeces, urine, hair and even some times with their own dead bodies. Some of the important rodent species found in storage are given below.

1. HOUSE RAT (*Rattus rattus*): It eats up all food materials and can damage wood, plastic, rubber and even soft metals also. As it is responsible for plague, it is considered as the most expensive rat of India.

Identification:

▪ Soft grey to black coloured. Dorsal colour rufous; hairs of belly rough with rusty tinge.

▪ It has small eyes, large sparsely hairy ears.

▪ Snout is pointed.

▪ Tail is thin uniformly dark coloured and is equal to the size of the body plus head.

▪ Adult weighs 150-200 gms.

▪ Generally, the droppings arc found scattered and banana shaped.

▪ Female has 10 mammae.

2. HOUSE MOUSE (*Mus musculus*): Their infestation imparts a typical smell to store rooms and stocks. They feed on cereals, cereal products, vegetables, meat, fats, carbohydrates etc. and can damage wooden furniture, paper, clothes, rubber, plastic and leather goods etc.

Identification:

▪ Colour is dark brown to sandy brown with smooth short hairs and under parts whitish to light grey.

▪ Weight 23-35 gms.

▪ Tail is usually longer than head and body.

▪ Rounded ears can be stretched up to eyes.

▪ Female has 8 mammae. The droppings are scattered and spindle shaped.

3. BROWN RAT OR NORWAY RAT (*Rattus norvegicus*): Feeds on grain. Damages containers *i.e.* bags/cartons. Pollutes grain with excreta, droppings and hairs.

Identification:

▪ Soft skinned brownish grey with whitish belly.

▪ Weight 200-330 gms.

▪ Snout wide and blunt.

▪ Tail not uniformly tapered shorter than head & body.

▪ Ears small, thick, furred, opaque and do not reach upto eyes when stretched.

▪ Mammae 12.

▪ Droppings found in groups and spindle shaped.

4. LESSER BANDICOOT RAT (*Bandicota bengalensis*):

Identification:

▪ Body is robust and blocky.

▪ Colour is dark brown to black.

▪ Head is short, truncated, stumpy and pig like.

▪ Ears are big, found thick opaque and without hairs.

▪ Eyes are small.

▪ Tail is having scaly rings, normally smaller but sometimes equal to head and body.

▪ Weight is approximately 300 gms.

▪ Fur is short, rough with erectile spine, like "guard hairs" which are raised when excited.

▪ Mammae range from 12-18.

▪ Droppings are scattered and oval shaped.

DETECTION OF RODENT INFESTATION:

❖ Visual sighting and typical noise.

❖ Rat burrows.

❖ Rat droppings and urine marks.

❖ Feet or tail marks on dusty floors, greasy marks left by rats.

❖ Gnawed articles (tom bags and spilled grains or damaged doors and windows).

❖ Pet excitement.

❖ Disappearance of bait.

RODENT CONTROL:

1. Non chemical:

a) Physical methods

(i) Rat proofing: If the entry of rats is barred in houses, stores and godowns, a lot of problems of rat control are solved. While constructing new godowns, care should be taken to construct them rat proof.

(ii) Hygiene and sanitation: Rats need two things for their survival, food and protection. If any of the two can be eliminated, they will not stay. A standard of house/godown hygiene can be maintained. Wherever possible, food should be kept in rat proof containers. Left over foods and empty food tins should be kept in dust bin with tightly fitting lids. Food stocks should be stored in such a way that they can be inspected from all sides at frequent intervals. Piles of rubbish, timber and bricks should not be allowed to accumulate in or near the godowns. Best time for removing rubbish is just before taking temporary control measures. By using rat repellent in stores. By using ultra sonic sound waves.

b) Mechanical methods:

(i) Trapping

(ii) Killing of solitary rats by sticks, brooms and some other ways by individuals.

2. Chemical

Compounds which kill the rats by their chemical action are known as rodenticides. These poisonous rodenticides can be divided into two groups-

a) Single dose poison: Zinc phosphide, Barium carbonate, Red squill are some of the compounds which have been/are being used as rat poisons. These are also called acute poisons as these are highly toxic in nature i.e., they show immediate fatal results. The defect of acute poisons is that these create poison shyness and bait aversion in rodents.

b) Multiple dose poison: The modem way to kill rodents in houses or godowns is by using anticoagulants. A number of them available in the market. These are hydroxy coumarin compounds, which if consumed regularly in sufficient quantity for a prolonged period cause blood haemorrhage in mammals. These are easy to handle and involve no health hazard to man. Unlike single dose poisons, these do not create bait shyness. A good effective control can be obtained without any danger of secondary poisoning. Examples are difenacoum, diphacinone, bromadiolone, chlorophacinone, brodifacoum.

Fumigation of rat burrows: Fumigation of rat burrows gives quick results as problems like new object reaction and bait shyness do not arise. The successful fumigants which were used in India are cyano gas and phosphine.

Experiment 8: Identification of birds and bird control operations in godowns

The damage done by birds to food grains in fields and stores is appreciable (both quantitatively and qualitatively). Average consumption by birds ranges from 8.25 g per day. Besides eating grain in the fields and godowns, they are also responsible for spoilage, contamination with excretes feathers and dead bodies. Some of them are responsible for spreading diseases. They also create nuisance and unhygienic conditions in ware houses.

1. Blue rock pigeon or Common pigeon (*Columbo livia*)

Characteristics:

▪ Mainly grainivorous. It eats food grains in grain mandies, godowns etc.

▪ They contaminate the grains with their excreta, feathers etc.

▪ They are also responsible for transmission of some disease and even food poisoning.

▪ Total body length is 33 cm.

▪ It is grey in colour with glistening metallic green, purple and magenta on neck and upper breast, 2 dark bars on wings and one across the tail.

2. House sparrow (*Passer domesticus*)

Characteristics:

- It is the most important avian in the storage. It is grainivorous and lives in house or enters in warehouses.
- In open storage maximum losses are noticed by sparrows. Besides this contamination with excreta, feathers and dead bodies occurs.
- Sexual dimorphism is distinct.
- The female is earthy brown, streaked with blackish and rufous with whitish under parts.
- Male has a loud monotonous and aggravating song tsi-tsi or cheer-cheer.

3. Crows (*Corvus splendens*)

Characteristics:

▪ Crow is very omnivorous feeding on kitchen wastage to dead animals and hence considered as the best scavengers.

▪ It feed on grain mixed up in refuge sweepings spoilage around warehouses.

▪ It enters inside warehouse only if unattended for long.

▪ The maximum damage is done in the threshing yards and open storage.

▪ In fields considerable damage is done to maize, wheat, jowar and other grains groundnuts, fruits and chillies.

▪ It is the most familiar birds with grey neck and black body measuring 43 cms from beak to tail.

4. Large Indian parakeet or Parrot (*Pisttacula krameri*)

Characteristics:

▪ Normally frugivorous, it attacks ripening cereal crops and food grains in open storage.

▪ The damage is more than what they actually consume.

▪ It is a parakeet grass green in colour with typical short stout deeply hooked red bill and a black and rose-pink ring around the collar.

▪ The female has no collar ring.

▪ It has a fine pointed tail, short legs and climbing feet. It is one of the ornamental birds.

▪ Some species are good mimics. Makes noise crying keeak- keeak while flying or at rest.

Birds control methods:

1. Physical methods

a) Preventive methods: Godowns and its windows, ventilators and other possible entries can be equipping by putting mesh size (6.6 cm) to prevent the birds entry. However, these methods cannot be adopted in fields.

b) By putting up dummies: Dummies are prepared rough by similar to man and are pitched in fields at different places. Alternatively, dead crows or sparrows are hung from tree tops or godowns roof for scaring away birds.

c) Use of bird scarcer: A loud bumping noise created with rope and pulley arrangement oxygen and acetylene gas is burnt which creates a bumping noise at irregular intervals. This should preferably to kept at a height for example, hung at the ceiling of godowns or on tree tops for getting better results.

2. Mechanical methods: Practice of destroying bird nests and eggs helps in reducing the bird population drastically. Use of air guns, bird traps and nets are some of the other methods for temporary relief.

3. Biological methods: Other predator animals/birds (may be trained *i.e*., hawks, owls etc.) could be utilized for bird control.

4. Chemical method: This method is not recommended.

Experiment 9: Determination of moisture content of grain

The moisture content of the food grains and other agricultural products is the most important attribute influencing grain quality and storability. Its estimation in grain quality assessment is vital. It is expressed either on wet weight basis or dry weight basis. In seed testing, always expressed on wet weight basis. The moisture content of grains can be determined either by using moisture meter or hot air oven method.

Objective: To determine the moisture content of grains by methods suitable for routine use. **Definition:** It is defined as the amount of water that can be removed without alternation of chemical structure of grains. Or, the term grain moisture content normally denotes the quantity of water present in a grain sample per unit mass of its dry matter and moisture combined. It is expressed as percentage of the weight of the original sample.

Principle: Removal of moisture from wet materials takes place by vaporization and it depends on the rate of heat and mass transfer, which is related with the two basic phenomena namely vaporization of moisture from surface of material and movement of moisture from internal parts of materials to its surface. Movement of moisture takes place because of diffusion, cell contraction and vapour pressure gradient.

Method: Moisture estimation of grains by Hot Air Oven method

Material required: Mixer, 4 mm sieve, 2 containers, metal tray, hot air oven, electronic weighing balance, desiccators.

Procedure:

1. Take weight of empty containers along with their covers and name them like S1 and S2.

2. Take 20-30 gm of the grain sample and grind it in mixer.

3. Separate the grain sample in two fractions with the 4 mm sieve and take the sample which is retain on screen of the sieve.

4. Take 2 sample in two containers S1 and S2.

5. Weight both the sample along with electronic weighing balance and note the readings upto three decimal places.

6. Remove the covers of container and keep the sample in hot air oven with inverted covers to allow escape of moisture.

7. The temperature of oven should be raised to 60°C.

8. Remove the sample after 1 hour with the help of thick hand gloves.

9. Keep both the sample in desiccators for cooling for 1.5 hrs.

10. Take weight of dried sample.

Observation:

Sl. No.	**Item**	**Sample No.**	**Weight**
1.	**Initial Weight of Sample Before Drying**	**1**	
		2	
		3	
2.	**Final Weight of Sample After Drying**	**1**	
		2	
		3	
3.	**Container Weight Without Sample**	**1**	
		2	
		3	

Calculation:

Moisture content (wet basis) % = (Initial weight of sample − Final weight of sample) X 100/Initial weight of sample

Moisture content (dry basis) % = (Initial weight of sample − Final weight of sample) X 100/ Dry weight of sample

Experiment 10: Methods of grain sampling under storage condition

Definition of Sampling: Sampling is the scientific technique to collect the sample from sample area.

Necessity of grain sampling under storage condition: The harvested grain sample should be sampled properly in stored condition for obtaining the good yield.

The main reasons of proper grain sampling under storage condition are described as follows:

1. To prevent the harvested grain from attack of the stored product insect pests.

2. To prevent the harvested grain from any kind of disease infection under stored condition.

3. To monitor the grain properly frequently.

4. To separate the infected grain from healthy grain.

5. To obtain the optimum yield from the harvested grain.

Working sample size: The minimum working sample size is varied with the types of the crops. Working sample should be analyzed properly for at least 10 to 20 minutes for better result. The standard minimum working sample sizes for different crops are given below:

Name of the Crop	**Minimum working sample size**
Paddy	15 g
Wheat	25 g
Maize (Small grain)	200 g
Maize (Large grain)	250 g
Sorghum	25 g
Millet	10 g
Cowpea	150 g

Equipment for obtaining grain samples under storage condition

There are different types of equipment which can be properly utilized for better grain sampling under stored condition. The description of the equipment is given below.

1. Simple bag sampling spears

These are the most commonly-used instruments for taking samples from bags, being relatively cheap, simple and quick. Generally, sampling spears having a maximum external diameter of about 12 mm are designed for small grains such as wheat, while 25 mm diameter spears are suitable for larger grains. To obtain a good cross-sectional sample the spear should be 40 to 45 cm in length.

2. Double-tube sampling spears

These spears comprise two metal tubes, one fitting closely inside the other and each with several common slots. Spears may vary in length from 45 cm to 3.5 m, and in width from 12 mm to 50 mm. Turning the inner tube through 180° opens or closes the intake apertures, and so collects grain from a transverse section of the bag. Double-tube sampling spears are designed primarily for obtaining samples from vertical lines of penetration in bulk grain, although small versions may be used for sampling bagged grain. They are superior in many ways to the simple bag sampling spear, but are still instruments of haphazard rather than representative sampling.

3. The Produce-Flow sampler

This sampler was designed at the Tropical Products Institute, now a part of NRI, as a representative sampling device for bagged grain. Grain is tipped into the hopper and falls through onto a cone, which is positioned to ensure that the flow is evenly distributed. Some of the grain is trapped by four vents arranged equidistantly around the base of the cone, and directed via a separate spout into a sample collector. The size of the sample depends upon the dimensions of the vents, which are interchangeable. Sampling of a 100 kg bag of grain is complete within 20 seconds of starting the flow.

4. Manually-operated deep bin probes

The simplest probe of this type consists of a hollow spear head, which serves as a sample cup, with a spring-loaded cap attached to a metal or wooden rod about 1 metre long. Extension rods

are attached to increase the depth of penetration. When the sampling point has been reached a slight upward pull on the rod lifts the cap of the spear head, allowing grain to fill the cup. The probe is then withdrawn completely and the sample removed. A single probe yields up to 300 g of sample material. The deep bin fin-probe consists of a double-tube sampler with a set of extension rods. When the sampling position is reached a twist of the extension rod opens the sample intakes. This action is facilitated by the fin which prevents the outer tube from turning. A reverse twist closes the sample intakes before the probe is withdrawn from the grain. Up to 600 g of sample representing a 1.5 m long vertical 'cut' may be obtained. A considerable amount of physical effort is required to push any of these probes into grain. None can be expected to penetrate more than approximately 5 metres.

5. Pneumatic grain samplers

Pneumatic grain samplers overcome the main disadvantages of manual operation by using powered-suction to penetrate the static bulk of grain, and by taking a continuous sample. They are quicker to operate than manual samplers, and can be used easily to obtain samples from the sides and floors of bulk grain containers.

6. Auger-type sampler

The sampler consists of a tube approximately 1.4m long and 5cm wide, open at the bottom end and housing a motor-powered auger. Grain lifted by the screw is collected in a bag at the outlet spout. It is necessary to insert the device into the grain at an angle in order to obtain sample material. There are no extension pieces which would permit sampling deeper than the half metre or so the sampler penetrates. The sampler is therefore of limited usefulness.

7. The Pelican sampler

The Pelican sampler consists of a cowhide pouch attached to a metal frame at the end of a hardwood or tubular metal handle. It is used to obtain samples from freefalling grain, e.g., from a spout discharge to the hold of a ship. If the spout is sloping, the components of the grain stream are likely to be stratified. It is important, therefore, to cut the sampler through the stream from one side to the other in a single motion to obtain a good sample. The force behind a stream of

grain may be very great. It is essential to observe appropriate safety measures when sampling in this manner.

8. The Ellis Cup sampler

This is a hand-held scoop designed for obtaining small samples from bulk grain on moving conveyor belts. When properly used, the cup will obtain a vertical section of the flowing grain at the point where it is inserted into the stream. Samples taken in this way are used for making spot checks on the condition of grain and are not intended as substitutes for representative samples obtained elsewhere in the system. Sampling with the Ellis cup is hazardous. Extra safety precautions are necessary, as with the Pelican sampler.

9. Limpet-type sampler

This type of sampler is clamped or bolted to the outside of the delivery spout. A tube is inserted through a hole drilled into the spout wall. The tube usually is open at both ends and has an inlet slot in the upper side projecting into the grain stream. Sampled material is removed either by means of a motorised worm screw, or a plunger operated by compressed air. Worm screw extractors can be made to operate continuously or at intervals. Plunger sample extractors remove samples of fixed size at intervals. The limpet sampler is capable only of extracting material from part of a grain stream. If there is any appreciable stratification of material in the stream, samples cannot be regarded as representative.

10. The diverter-type sampler

The diverter-type sampler is probably the best device yet invented for obtaining representative samples from bulk grain. The sampler is designed to take a complete cross section of a stream of grain, by means of a powered diverter head which takes a cut through the stream, on a preset schedule. During periods of inactivity the aperture of the diverter head is sealed to prevent it collecting dust. Grain extracted from the main stream by the sampler may be fed directly into a secondary sampler, which reduces the sample to a manageable size before it is delivered via spouting to the grain inspection laboratory.

Experiment 11: Visit to Indian Storage Management and Research Institute, Hapur and Quality Laboratory, Department of Food., Delhi

Date of visit: …….

Observations: …….

Experiment 12: Visit to nearest FCI godowns

Date of visit: …….

Observations: …….