Post-Graduate Degree Programme (CBCS)

in

ZOOLOGY

(M.Sc. Programme)

SEMESTER-IV

Theory Paper-Minor Elective

Agricultural Entomology

ZDSE(MN)T 407

Self-Learning Material

DIRECTORATE OF OPEN AND DISTANCE LEARNING

UNIVERSITY OF KALYANI

Kalyani, Nadia

West Bengal, India

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Director's Message

Satisfying the varied needs of distance learners, overcoming the obstacle of distance and reaching the unreached students are the threefold functions catered by Open and Distance Learning (ODL) systems. The onus lies on writers, editors, production professionals and other personnel involved in the process to overcome the challenges inherent to curriculum design and production of relevant Self Learning Materials (SLMs). At the University of Kalyani a dedicated team under the able guidance of the Hon'ble Vice-Chancellor has invested its best efforts, professionally and in keeping with the demands of Post Graduate CBCS Programmes in Distance Mode to devise a self-sufficient curriculum for each course offered by the Directorate of Open and Distance Learning (DODL), University of Kalyani.

Development of printed SLMs for students admitted to the DODL within a limited time to cater to the academic requirements of the Course as per standards set by Distance Education Bureau of the University Grants Commission, New Delhi, India under Open and Distance Mode UGC Regulations, 2020 had been our endeavour. We are happy to have achieved our goal.

Utmost care and precision have been ensured in the development of the SLMs, making them useful to the learners, besides avoiding errors as far as practicable. Further suggestions from the stakeholders in this would be welcome.

During the production-process of the SLMs, the team continuously received positive stimulations and feedback from Professor (Dr.) Kallol Paul, Hon'ble Vice- Chancellor, University of Kalyani, who kindly accorded directions, encouragements and suggestions, offered constructive criticism to develop it within proper requirements. We gracefully, acknowledge his inspiration and guidance.

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Their persistent and coordinated efforts have resulted in the compilation of comprehensive, learner-friendly, flexible texts that meet the curriculum requirements of the Post Graduate Programme through Distance Mode.

All the Self Learning Materials are self writing and collected from e-book, journals and websites.

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Theory (Discipline Specific Elective - Minor) –

ZDSE(MN)T 407 – Agricultural Entomology

Unit	Content	Credit	Page No.
I	Important insect pests of cereals, pulses, vegetables, spices and condiments, beverages and fibre crops	**2**	
II	Morphology, bionomics and management of: a) Rice Yellow stem borer (*Scirpophaga incertulas*). b) Rice brown plant hopper (*Nilaparvata lugens*) c) Sugar cane top borer (*Scirpophaga nivella*)		
III	Morphology, bionomics and management of: a) Tea mosquito bug (*Helopeltis theivora*) b) Diamondback moth (*Plutella xylostella*) c) Brinjal fruit and shoot borer (*Leucinodes orbonalis*)		
IV	Plant protection techniques		
V	Natural enemy diversity of agricultural pests in India and their potentiality		
VI	Economic decision levels for pest population; a) Concepts of economic levels b) Dynamics of economic injury levels c) Calculation of economic decision levels using economic levels		
	Total counseling session 6hrs		

Unit I

Important insect pests of cereals, pulses, vegetables, spices and condiments, beverages and fibre crops

Objective: In this unit you will learn about important insect pests of cereals, pulses, vegetables, spices and condiments, beverages and fibre crops

Introduction:

Insects are found in all types of environment and they occupy little more than two thirds of the known species of animals in the world. Insects affect human beings in a number of ways. Many of them fed on all kinds of plants including crop plants, forest trees, medicinal plants and weeds.

Insects that cause injury to plants are grouped into two major groups namely chewing insects and sucking insects. The former group chews off plant parts and swallow them thereby causing damage to the crops. Sucking insects pierce through the epidermis and suck the sap. Many of the sucking insects serve as vectors of plant diseases and also inject their salivary secretions containing toxins that cause severe damage to the crop.

A. CEREALS

A1. RICE

(i) **Brown planthopper**, *Nilaparvata lugens* (Stal) (Hemiptera : Delphacidae).

Both the nymphs and adults cause damage by sucking cell sap from the leaves which turn yellow, if the insect attacks during early stages of growth, the entire plant may dry up. In later stages, the tillering is adversely affected. Heavy infestation causes drying of the crop in patches called ‘hopper burn’. The insect transmits grassy stunt virus.

Management:

Cultural Methods

- Draining the rice field for 3-4 days is recommended during the early stage of infestation.
- Nitrogen application can be split to reduce Brown plant hopper buildup.
- Synchronous planting within 3 weeks of staggering and maintaining a free-rice period could also decrease the build-up of Brown plant hopper.
- There are varieties released by IRRI, which contain genes for Brown plant hopper resistance, like IR26, IR64, IR36, IR56, and IR72.
- Use resistant varieties like PY 3, CO 42, ADT 35, ADT 37, PTB 33 and PTB 21, Aruna, Kanaka, Karthika, Krishnaveni, Makon, Abhey, Asha, Divya.
- Avoid close planting and provide 30 cm rogue spacing at every 2.5 to 3.0 m to reduce the pest incidence.

Chemical Methods

- ETL : 2 / tiller when 1 spider / hill is present (or) 1 / tiller when spiders are not present (or) 1 hopper/ tiller in the absence of predatory spider and 2 hoppers /tiller when spider is present at 1/hill.

- Drain the water before use of insecticides and direct the spray towards the base of the plants.
- Avoid use of insecticides causing resurgence such as synthetic pyrethroids, methyl parathuion, fenthion and quinalphos.
- Spray any one of the following:
  Phosphamidon 40 SL 1000 ml/ha (or) Phosalone 35 EC 1500 ml/ha (or) Carbaryl 10 D 25 kg/ha (or) Methyl demeton 25 EC 1000 ml/ha (or) Acephate 75 SP 625 gm/ha (or) Chlorpyriphos 20 EC 1250 ml/ha Carbofuran 3 G 17.5 kg/ha (or) Dichlorvos 76 WSC 350 ml/ ha.
- Use of botanical methods : Neem oil 3% 15 lit/ha (or) Iluppai oil 6% 30 lit/ha (or) Neem seed kernel extract 5% 25 kg/ha

Biological Methods

- Release of natural enemies like Lycosa pseudoannulata, Cyrtorhinus lividipennis adult (200 – 250 bugs/ha) during the peak incidence of brown plant hopper at 10 days interval.
- The common parasites of the eggs are the hymenopteran wasps. Eggs are preyed upon by mirid bugs and phytoseiid mites. Both eggs and nymphs are preyed upon by mirid bugs. Nymphs and adults are eaten by general predators, particularly spiders and coccinellid beetles.
- Hydrophilid and dytiscid beetles, dragonflies, damselflies, and bugs such as nepid, microveliid, and mesoveliid eat adults and nymphs that fall onto the water surface.
- Fungal pathogens also infect brown plant hoppers

Trap Methods

- Set up light traps during night.
- Use yellow pan traps during day time.
- Care should be taken not to place light traps near seed beds or fields.
- Installation of light traps with incandescent light at 1-2 m height @ 4/ acre to monitor the population.
- At the base of light trap put a tub filled with water to which kerosene was added to kill the trapped insects

(ii) **Dark-headed striped borer**, *Chilo polychrysus* (Meyrick) (Lepidoptera: Pyralidae).

The caterpillars bore into the central shoot for feeding. Since the larvae bore into the outer leaves and leaf sheaths first, these are the first to die, followed by the inner whorl, and finally the entire plant from its core.

Management:

- The removal and destruction of stubble at the time of the first ploughing after harvesting the crop decreases the carry-over to the next crop.
- Ploughing and flooding the field is also effective in killing the larvae.
- Since the eggs of stem borer are laid near the tip of leaf, clipping of tips of seedlings before transplanting can reduce the carry over of eggs to the field.

- The fields showing more than 5 per cent dead hearts should be sprayed with 625 ml of phosphamidon 85 SL or 14 litres of monocrotophos 36 SL or 2.5 litres of chlorpyriphos 20 EC in 250 litres of water per ha. Alternatively, apply 7.5 kg of phorate 10G or 20 kg carbofuran 3G or quinalphos 5G per ha in the standing water in the field. Same chemical should not be used repeatedly.

(iii) **Green leafhopper**, *Nephotettix nigropictus* (Stal) and *N. virescens* (Distant) (Hemiptera : Cicadellidae).

The nymphs and adults suck the cell sap from the leaves. The plants lose vigour, turn yellow and ultimately brown *N. virescens* is also a vector of tungro virus.

Management: ETL: 60/25 net sweeps or 5/hill at vegetative stage or 10/hill at flowering or 2/hill in tungro endemic area. Nursery should not be located near the street lamps. Spray any one of the insecticides- Phosphamidon 40 SL 50 ml, Phosalone 35 EC 120 ml. maintain 2.5 cm of water in the nursery and broadcast anyone of the following in 20 cents- Carbofuran 3 G 3.5 kg, Phorate 10 G 1.0 kg

(iv) **Paddy gall fly**, *Orseolia oryzae* (Wood-Mason) (Diptera : Cecidomyiidae).

The damage is caused by the maggots which feed inside the stem. Besides causing physical damage, they produce galls on the basal portion of the central leaf or on the tillers. These galls ultimately become hollow giving a silvery shine called 'silver shoots'. The infested tillers do not bear tillers.

Management:

Biological Methods

Natural biological control agents such as platygasterid, eupelmid, and pteromalid wasps, which parasitize the larvae, is effective. Release of platygaster oryzae parasitized galls @ 1 per 10 sq.m in the main field on 10 DAT against gall midge.

The pupa is host to two species of eupelmid wasps. Phytoseiid mites feed upon the eggs, whereas spiders eat the adults.

(v) **Pale-headed striped borer**, *Chilo suppressalis* (Walker) (Lepidoptera: Pyralidae).

The injury to the plant is caused by caterpillars which tunnel through the stem and feed on the soft tissues, causing dead hearts in early stages and white ears in later stages.

Management:

The fields showing more than 5 per cent dead hearts should be sprayed with 625 ml of phosphamidon 85 SL or 14 litres of monocrotophos 36 SL or 2.5 litres of chlorpyriphos 20 EC in 250 litres of water per ha. Alternatively, apply 7.5 kg of phorate 10G or 20 kg carbofuran 3G or quinalphos 5G per ha in the standing water in the field. Same chemical should not be used repeatedly.

(vi) **Pink borer**, *Sesamia inferens* (Walker) (Lepidoptera : Noctuidae).

The damage is caused by caterpillars and the attacked young plants show dead hearts and are killed altogether. The older plants are not killed, but they produce a few tillers only.

Management:

- Light-trapping of adults helps to reduce the pest population.
- Spray any of the following insecticides at economic threshold level of 10 per cent damaged leaves : 625 ml of fenitrothion 50 EC, 425 ml of fenthion 1000 EC, 1.0 kg of carbaryl 50 WP in 250 litres ofwater per ha.

(vii) **Rice blue leafhopper**, *Typhlocyba maculifrons* (Motschulsky) (Hemiptera: Cicadellidae).

Both nymphs and adults suck cell sap from the leaves which, in the early stages of attack, exhibit whitish, waxy lines. As the damage progresses, the leaves show symptoms of withering.

Management:

Spray at economic threshold level of 5-10 insects per hill, 625 g of carbaryl 50WP or 625 ml of fenthion 1000 EC or 2.0 litres of quinalphos 25 EC or one litre of chlorpyriphos 20 EC in 250 litres of water per ha. Repeat application if hopper population persists beyond a week after application. While spraying nozzle should be directed at the basal portion of the plants.

(viii) **Rice bug**, *Leptocorisa acuta* (Thunberg) (Hemiptera : Coreidae).

The nymphs and adults suck juice from the developing grains in the milky stage, causing incompletely filled panicles or panicles with empty grains. Black or brown spots may appear around the holes made by the bugs on which a sooty mould may develop. The severely infested fields emit offensive smell.

Management:

The population can be sup pressed by killing the bugs by using light traps, collecting the adults with nets and destroying the weeds to remove alternative hosts. Chemical control measures are same as in case of rice grasshoppers.

(ix) **Rice caseworm**, *Nymphula depunctalis* Guenee (Lepidoptera : Pyralidae).

The insect attacks the crop in the early transplanted stage. The leaf blade is cut into small bits and a tubular case is constructed by the larva. The larva feeds by scraping the under surface of the leaf blade leaving the upper epidermis intact, resulting in white patches on leaf blades.

Management:

- ETL–2 FDL/hill (FDL- Fully Damaged Leaf)
- Encourage biological control agents like hydrophilid and dytiscid water beetles which feed on larvae and spiders, dragonflies, and birds which feed on adults.
- Spray phenthoate 50% EC @ 160 ml/ac.

(x) **Rice ear-cutting caterpillar**, *Mythimna separata* (Walker) (Lepidoptera: Noctuidae).

The newly hatched larvae feed on the epidermis of the tender leaves. The second and third instar larvae feed by cutting the leaf from the edge towards mid rib. The older larvae, besides damaging leaves, also cut off the panicles, mostly at the base.

Management:

- The pest can be suppressed by collecting and destroying the caterpillars.
- Spray 875 ml of fenitrothion 50 EC or 500 ml of dichlorvos 100 EC or 3 kg of carbaryl 50 WP or 1.25 litres of trichlorphos 50 EC or one litre of quinalphos 25ECin 425 litres of water per ha.

(xi) **Rice grasshoppers**, *Hieroglyphus banian* (Fabricius) and *H. nigrorepletus* Bolivar (Orthoptera : Acrididae).

The adults and nymphs feed on the leaves, leaving midribs and stalks. At the shot blade stage of the crop, they nibble at the florets or gnaw into the base of inflorescence stalks causing formation of white ears.

Management:

Dust carbaryl5 per cent or malathion 5 per cent @25 kg per ha.

(xii) **Rice hispa**, *Dicladispa armigera* (Olivier) (Coleoptera : Chrysomelidae).

The grubs mine into the leaves presenting blister spots towards leaf tip. The adults feed by scraping the green matter and produce parallel whitish streaks on the leaves. The damage starts in nurseries and spreads to the rice fields.

Management:

- The pest is suppressed if the infested leaf tips are clipped off and destroyed, while transplanting.
- Spray at economic threshold level (1 adult or 1-2damaged leaves per hill) with 300 ml of methyl parathion 25 EC or 625 ml of fenitrothion 50 EC or chlorpyriphos 20 EC in 250 litres of water per ha. If the attack continues, repeat spray after two weeks.

(xiii) **Rice leaf-folder**, *Cnaphalocrocis medinalis* (Guenee) (Lepidoptera: Pyralidae),

The young larvae feed on tender leaves without folding them. The older larvae fasten the longitudinal margins of leaf together with a sticky substance and feed inside the fold by scraping the green matter. The scraped leaves become membranous, turn white and finally wither.

Management:

- Light-trapping of adults helps to reduce the pest population.
- Spray any of the following insecticides at economic threshold level of 10 per cent damaged leaves : 625 ml of fenitrothion 50 EC, 425 ml of fenthion 1000 EC, 1.0 kg of carbaryl 50 WP in 250 litres ofwater per ha.

(xiv) **Rice mealy bug**, *Ripersia oryzae* Green (Hemiptera : Coccidae).

Both the nympphs and adults suck plant sap from the stem, resulting in stunted plant growth and yellowish curled leaves. When the attack is severe, the ear heads become smothered and are unable to grow out of their sheath.

Management:

Spray 625 ml of diazinon 20 EC after mixing in 250 litres of water per ha.

(xv) **Rice root weevil**, *Echinocnemus oryzae* (Marshall) (Coleoptera: Curculionidae).

The grubs of the rice root weevil, feed on the root hairs of the transplanted paddy crop. The plants become weak, stunted, pale yellow and ultimately dry up.

Management:

Apply 10 kg of phorate 10G or 25 kg of carbofuran 3G or 12.5 kg of diazinon 5G per ha in standing water.

(xvi) **Rice thrips**, *Stenchaetothrips biformis* (Bagnall) (Thysanoptera : Thripidae).

The larvae and adults lacerate the tender leaves and suck the plant sap causing rolling and drying of the leaf tips.

Management:

- ETL: 60 numbers in 12 wet palm sweeps or rolling of the first and second leaves in 10% of seedlings.
- Spray azadirachtin 0.15% @ 600-1000 ml/acre Thiamethoxam 25 WG @ 40 g/acre.

(xvii) **White rice leafhopper**, *Cofana spectra* (Distant) (Hemiptera : Cicadellidae).

Both the adults and nymphs suck cell sap and cause yellow discolouration of the leaves. When infestation is heavy, leaves turn brown, plants become stunted and fail to produce ears.

Management:

- Release of natural enemies like Lycosa pseudoannulata, Cyrtorhinus lividipennis adult (200 – 250 bugs/ha) during the peak incidence of brown plant hopper at 10 days interval.
- The common parasites of the eggs are the hymenopteran wasps. Eggs are preyed upon by mirid bugs and phytoseiid mites. Both eggs and nymphs are preyed upon by mirid bugs. Nymphs and adults are eaten by general predators, particularly spiders and coccinellid beetles.

(xviii) **White backed planthopper**, *Sogatella furcifera* (Horvath) (Hemiptera: Delphacidae).

The nymphs and the adults suck cell sap, particularly from the leaf sheath. The leaves of attacked plants turn yellow and later on rust red; symptoms starting from leaf tips move downwards. The attacked plants ultimately dry up in patches (hopper burn) without producing ears.

Management:

- Encourage biological control agents like hydrophilid and dytiscid water beetles which feed on larvae and spiders, dragonflies, and birds which feed on adults.
- Spray phenthoate 50% EC @ 160 ml/ac.

(xix) **Whorl maggot**, *Hydrellia philippina* Ferino (Diptera : Ephydridae).
The maggots attack the leaf blades even before unfurling and the initial damage is characterised by the presence of narrow stripes of whitish area in the blade margins. The tillers become stunted.
Management:
- Spray any one of the following- Cartap Hydrochloride 4% G 7.5-10 kg/ac, Chlorpyriphos 20% EC 500 ml/ac, Fipronil 5% SC 400-600g/ac, Fipronil 0.3% GR 7-10 kg/ac, Ethofenoprox 10 EC @ 200- 600 ml/ac.

(xx) **Yellow stem borer**, *Scirpophaga incertulas* (Walker) (Lepidoptera: Pyralidae).
The larvae feed inside the stem, causing drying of the central shoot or 'dead heart' in the young plants and drying of the panicle or 'white ear' in older plants.
Management:
- Release egg parasitoid, Trichogramma japonicum @ 2cc /ac 3 times at weely interval.
- Spray Neem seed kernel extract 5% or Azadirachtin 0.03% 400 ml/ac.
- Spray any one of the following insecticides
  Acephate 75 % SP 267-400 g/ac
  Carbofuran 3% CG 10 kg/ac
  Carbosulfan 6% G 6.7 kg/ac

(xxi) **Ziz-zag leafhopper**, *Recilia dorsalis* (Motschulsky) (Hemiptera : Cicadellidae).
As a result of insect's feeding on cell sap, mature leaves acquire an orange discolouration at the margins and become dry at the tips.
Management:
- Spray any one of the following:
  Phosphamidon 40 SL 1000 ml/ha (or) Phosalone 35 EC 1500 ml/ha (or) Carbaryl 10 D 25 kg/ha (or) Methyl demeton 25 EC 1000 ml/ha (or) Acephate 75 SP 625 gm/ha (or) Chlorpyriphos 20 EC 1250 ml/ha Carbofuran 3 G 17.5 kg/ha (or) Dichlorvos 76 WSC 350 ml/ ha.

A2. SUGER CANE

(i) **Green borer,** *Raphimetopus ablutellus* Zeller (Lepidoptera : Pyralidae).
The caterpillars attack the growing point of the plants, causing dead hearts.
Management:
- The larvae are parasitized by *Stenobracon deesae* (Braconidae) which results in some natural control.
- The timely removal and burning of stubble further help to suppress this pest.

- Rake 35 kg of carbaryl 10 per cent dust per ha into the soil at the time of planting of sugarcane.

(ii) **Gurdaspur borer,** *Bissetia steniella* (Hampson) (Lepidoptera : Pyralidae).

In the initial stages, the larvae feed gregariously in the top portion of the canes by making spiral galleries and thus killing the plants. Later on, it bores into the central portion of the cane and feeds in a single straight tunnel moving upwards. Large patches of dried canes appear in the field.

Management:

- Rogue out the canes showing withered tops in the afternoon every week from June to September.
- The tops should be cut off well below the point of attack.
- Do not ratoon a heavily affected crop.

(iii) **Internode borer,** *Chilo saccriphagus indicus* (Kapur) (Lepidoptera : Pyralidae).

The caterpillars bore the canes near the nodes, the entry holes being plugged with excreta. It's feeding causes tissues turn red.

Management:

- Release egg parasite, Trichogramma chilonis at the rate of 2.5 cc / release / ha. Six release at fortnightly intervals starting from 4^{th} month onwards.
- Setting pheromone traps at spindle level on 5th month of the crop at the rate of 6 traps per acre in a 15 metre grid. The pheromone septa need to be changed twice at 75 days interval.

(iv) **Stalk borer,** *Chilo auricilius* Dudgeon (Lepidoptera : Pyralidae).

The caterpillars feed inside the stem and have the habit of boring into one internode after another and moving from plant to plant, thus causing extensive damage.

Management:

- Do not ratoon a heavily infested crop; plough up the affected fields, collect the stumps and destroy them.
- Staple 100 tricho-cards (5 cm x 2.5 cm) to the underside of sugarcane leaves from July to October at 10 days interval. Each card should have approximately 500 parasitized eggs and be spread uniformly at 100 spots/ha. Normally 10-12 releases are required.

(v) **Sugarcane mealy bug,** *Saccharicoccus sacchari* (Cockerel) (Hemiptera: Pseudococcidae).

The mealy bugs are found under sheathing leaves in colonies and suck up the juice. Heavily infested clumps present a sickly appearance and befoul the canes by their mealy secretions and honeydew.

Management:

Physical method:

Detrash the crop on 150 and 210 DAP

Chemical method:

Apply any one of the following insecticides per ha and when the incidence is noticed spray on the stem only, methyl parathion 50 EC 1000 ml, malathion 50 EC 1000 ml.

(vi) **Sugarcane pyrilla,** *Pyrilla perpusilla* (Walker) (Hemiptera : Lophopidae).

Both the nymphs and adults suck the cell sap, usually from the underside of the leaves. The leaves turn pale yellow and shrivel up later. In severe cases, canes dry up and die.

Management:

- The reported parasitoids are *Ooencyrtus pyrillae* (Encyrtidae) and *Ageniopsis pyrillae* (egg parasitoids).
- Nymphal parasitoids: *Tetrastichus pyrillae* (Eulophidae), *Lestodryms pyrillae, Drynius pyrillae, Epipyrops melanoleuca* (Epipyropidae) etc.

(vii) **Sugarcane scale insect,** *Aulacaspis tegalensis* (Zehntner) (Hemiptera: Diaspididae)

The insects feed on stem parenchyma and by doing so prevent the accumulation of sucrose in the cane. Drying up of the canes may also result from heavy infestation.

Management:

Physical method:

Detrash the crop at 150th and 210th day of planting.

Biological method:

Release Chilocoris nigritus (or) Pharascymnus horni.

Chemical method:

Presoak the setts in 0.1% solution malathion.

Spray dimethoate 0.06% or 120th and 150th after detrashing.

(viii) **Sugarcane shoot borer,** *Chilo infuscatellus* Snellen (Lepidoptera : Pyralidae).

The caterpillars tunnel into the stem of young plants producing dead hearts, in which only the central leaf dries up and other leaves remain green fog a long time. When pulled out, dead heart gives offensive.

Management:

Biological method:

- Apply granulosis virus 1.1 x 10 5 IBS / ml (750 diseased larvae / ha) twice on 35 and 50 DAP.
- Release 125 gravid females of sturmiopsis inferens a tachinid parasite per ac.

Chemical method

- Apply any one of the following insecticides if the pest crosses ETL.

- Carboryl +Lindane (Sevidol) 4% G 12.5 kg, lindane 10 G 12.5 kg, Carbofuron 3G 33 kg (Soil application). The granular application should be immediately followed by irrigation.
- Chlorpyriphos 1000 ml a sticker like Teepol (250 ml / 500 l of water) can also be added to make the solution stick on to the surface of the crop and it is preferable to use high volume sprayer to be most effective.

(ix) **Sugarcane spotted fly,** *Neomaskellia bergii* (Signoret) (Hemiptera : Aleyrodidae).

The nymphs suck plant sap and in case of severe attack, cause stunting of canes and drying of leaves.

Management:

Mechanical Method:

Detrashing the puparia bearing leaves and immediately disposing by burning or burying to prevent emergence of adult white flies

Chemical Method:

Spray fenitrothion 50 EC @ 2 lit / ha (1000 lit spray fluid)

(x) **Sugarcane top borer,** *Scripophaga nivella* (Fabricius) (Lepidoptera: Pyralidae).

The damage is caused by the caterpillars which are generally found in the top portion of a cane. The feeding results in reddish brown charred dead hearts and shot holes in the leaves and galleries in the midribs. There is formation of side shoots resulting in bunchy tops.

Management:

Physical method:

Collect and destroy the egg masses.

Biological method:

Release Ichneumonid parasitized Gambroides (Isotima) javensis @ 100 pairs / ha as prepupal parasitoid.

Chemical method:

Application of Carbofuran 3G 1 kg a.i/ha or Thimet 10G 3 kg a.i/ha

(xi) **Sugarcane whitefly,** *Aleurolobus barodensis* (Maskell) (Hemiptera: Aleyrodidae).

Only the nymphs cause damage by sucking the cell sap. Yellow streaks appear on the attacked leaves and the crop acquires a polish green appearance. The black sooty mould on honeydew interferes with photosynthesis.

Management:

Mechanical Method:

Detrashing the puparia bearing leaves and immediately disposing by burning or burying to prevent emergence of adult white flies

Chemical Method:

Spray fenitrothion 50 EC @ 2 lit / ha (1000 lit spray fluid)

B. PULSES

About 250 insects have been recorded feeding on pulse crops. Of these, about one dozen insects including pod borers, stem borers, leaf miners, foliage caterpillars, cutworms, jassids, aphids and whiteflies are the most important. Some polyphagous insects also feed on these crops and cause considerable damage.

(i) **Bean aphid**, *Aphis Craccivora* Aphididae: Hemiptera

Damage Symptoms- Nymphs and adults suck sap, Excretion of honey dew attracts sooty mold

Management Practice- Avoid late sowing and excessive use of nitrogen fertilizers, Seed treatment with imidacloprid (5 g/kg seed), Release predator *Chrysoperla carnea* or *Coccinella septumpunctata, Syrphus* / *Scymnus* sp. Need based spray of dimethoate 30 EC or methyl demeton 25 EC

(ii) **Bean Fly** *Ophiomyia phaseoli* (Tryon) (Diptera : Agromyzidac)

Damage. As a result of severe infestation, the leaves turn yellow, giving the plants a dry appear ance. The stems turn brown, become swollen and break down. The spring crops usually suffer less infestation than the late summer crops in which infested plants may constitute over 70 per cent of the plant population. The attacked plants bear less pods which are mostly empty or else their seeds may be very small.

Management

a) Apply 625 ml of monocrotophos 40 EC or 750 ml of oxydemeton methyl 25 EC in 625 litres of water per ha at 15-day intervals during flowering stage.
b) Soil application of 10 kg of phorate 10 G is effective up to 40 days of sowing.

(iii) **Gram cut worm**, *Agrotis ipsilon* Noctuidae: Lepidoptera

Damage Symptoms- The caterpillar hide during the day and come out in the evening for damage, Irregular bore hole in red gram pod it also feeds on flower buds and seeds

Management Practice- Deep summer ploughing, Use well decomposed organic manure, Adapt crop rotation, Intercropping with wheat or linseed or mustard reduces infestation, In the early stages pick the insects and destroy, Conserve natural enemies such as Braconids, *Microgaster* sp.

(iv) **Green Nettle Slug-caterpillar** *Thosea aperiens* (Walker) (Lepidoptera: Cochlidiidac)

Damage. The larvae defoliate the plants. The field workers when accidentally touch the stinging hair of the caterpillars may develop painful rashes on their hands and arms.

Management. Chemical control measures are same as in case of gram pod-borer.

(v) **Gram pod borer**, *Helicoverpa armigera* Noctuidae: Lepidoptera

Damage Symptoms- Small larvae eat up the green portion of the plant, the larger larvae eat up the floral parts, flowers, leaves and pods, Circular bore holes on pulse pods plugged by the head of a larva

Management Practice- Use of short duration and resistant varieties, Deep summer ploughing Sowing should be done by the end of June to avoid pod borer attack, Installation of pheromone traps @10/ha for monitoring, Physical shaking of pigeon pea plants to dislodge larvae, Erection of bird perches, Spray of Ha-NPV at 500 LE with adjuvant like teepol, tinopal and jiggery etc.

(vi) **Lentil Pod-borer** *Etiella zinckenella* (Treitschke) (Lepidop tera :Phycitidae)

Damage. The larvae consume floral parts, newly formed pods and sceds inside the develop ing pods. The reduction in yield may be up to 5 per cent.

Management. At flower initiation, spray the cropwith 750 ml of endosulfan 35 EC or 2.25 kg of carbaryl 50 WP in 250 litres of water per ha and repcat the treatment after three weeks, if neces sary. Carbaryl should be used if the husk is to be fed to the cattle.

(vii) **Piume Moth** *Exelastis atomosa* (Waisingham) (Lepidoptera: Pterophoridae)

Damage. The larvae first scrape the surface of the pods and finally make holes into them and feed on the seeds, reducing crop yield.

Management. Chemical control measures are same as in case of gram pod-borer.

(viii) **Pulse beetle** *Callasobruchus Chinensis* Bruchidae: Coleoptera

Damage Symptoms- Grubs feed on the inner content of seed, infested stored seed can be recognized by the white eggs on the seed surface and the round exit holes

Management Practice- Dry the pods to optimum kernel moisture level of about 7 %, Fumigation with aluminium Phosphide.

(ix) **Red Gram Pod-fly** *Melanagromyza obtusa* (Malloch)(Diptera: Agromyzidae)

Damage. As a result of severe infestation, the leaves turn yellow, giving the plants a dry appear ance. The stems turn brown, become swollen and break down. The spring crops usually suffer less infestation than the late summer crops in which infested plants may constitute over 70 per cent of the plant population. The attacked plants bear less pods which are mostly empty or else their seeds may be very small.

Management

a) Apply 625 ml of monocrotophos 40 EC or 750 mlof oxydemeton methyl 25 EC in 625 litres of water per ha at 15-day intervals during flowering stage.
b) Soil application of 10 kg of phorate 10 G is effective upto 40 days of sowing.

(x) **Soybean leaf miner**, *Aproaerema Modicella* Gelechidae: Lepidoptera

Damage Symptoms-Larvae mines into the leaves and produces white blotches and in severe infestation the field gives burnt appearance

Management Practice- Growing groundnut as trap crop, Installation of pheromone traps @25 /ha, Need based spray of endosulfan or quinalphos

(xi) **Tur Pod Bug** *Clavigralla gibbosa* Spinola (Hemiptera : Corcidae)

Damage. Both the adults and the nymphs suck cell sap from the stem, leaves, flower-buds and pods. As a result of this damage, the pods show pale yellow patches and later on shrivel up. The grain inside remains small in size and the yield may be reduced significantly.

Management. Spray one litre of endosulfan 35 EC or 1.25 litres of monocrotophos 40 EC or one litre of trichlorphon 50 EC or fenitrothion 50 EC in 625 litres of water per ha. Two sprays during flowering and three during pod formation are quite effective.

C. VEGETABLES

C1. CUCURBITACEOUS VEGETABLE

The cucurbitaceous vegetables include ash gourd, bitter gourd, bottle gourd, ridge gourd, squash gourd, pumpkin, etc.

(i) **Cucurbit fruit fly**, *Bactrocera cucurbitae* (Coquillett) (Diptera : Tephritidae). The maggots cause serious damage to vines and the developing fruits, the attacked branches dry and the fruits get distorted and even drop from the creepers. The larvae tunnel the fruits contaminating them with frass.

Management:

- Expose the pupae by ploughing and turning over soil after harvest
- Use ribbed gourd as trap crop and apply carbaryl 0.15% or malathion 0.1% on congregating adult flies on the undersurface of leaves.
- Use poison baiting in severe infestation
- Mix methyl eugenol + malathion 50 EC at 1:1 ratio and keep 10 ml of the bait in polythene bags @ 25/ha.
- Keep 5 g of wet fishmeal in polythene bags (20 x 15cm) with six holes (3 mm dia)
- Add 0.1 ml of dichlorvos.
- Dichlorvos should be added every week and fishmeal renewed once in 20 days @ 5traps/ha.

(ii) **Red pumpkin beetle**, *Raphidopalpa foveicollis* (Lucas) (Coleoptera: Chrysomelidae). The grubs damage the plants by boring into the roots, underground stems and sometime into the fruits touching the soil. The adult beetles injure the cotyledons, flowers and foliage by biting holes into them.

Management:

- Plough the fields just after harvesting destroy the hibernating adults

- Collect and destroy adult beetles
- Spray malathion 50 EC @ 500 ml or dimethoate 30 EC 500 ml or methyl demeton 25 EC@ 500 ml/ ha

C2. TOMATO

(i) **Tomato fruit borer**, *Helicoverpa armigera* (Hubner) (Lepidoptera : Noctuidae). In the pre-fruiting stage, the caterpillars feed on tender foliage including leaves, flowers and buds and the crop gives a perforated look. After fruiting, they bore large, clear circular holes into fruits and feed on pulp. Infested fruits become unfit for consumption.

Management:

Biological control :

- Application of Nuclear Polyhedrosis Virus (NPV) at 3 x 10 12 POB /ha in evening hours at 7th and12th week after sowing.
- Conservation and augmentation of natural predators and parasitoids for effective control of the pest.
- Inundative release of egg parasitoid, Trichogramma spp., at 6.25 cc/ha at 15 days interval 3 times from 45 DAS
- Egg-larval parasitoid, Chelonus blackburnii and Predator Chrysoperla carnea at 1,00,000/ha at 6th, 13th and 14th week after sowing.
- ULV spray of NPV at 3 x 10 12 POB /ha with 10% cotton seed kernel extract, 10% crude sugar, 0.1% each of Tinopal and Teepol for effective control of Helicoverpa.
- Note: Dicofol, methyl demeton, phosalone are comparatively safer to Chrysoperla larva recording low egg mortality.

Chemical control :

- Discourage the indiscriminate use of insecticides, particularly synthetic pyrethroids.
- Use of proper insecticides which are comparatively safer to natural enemies such as endosulfan, phosalone, etc., at the correct dosage and alternating different groups of insecticides for each round of spray.
- Avoid combination of insecticides as tank mix. Adopt proper delivery system using spraying equipments like hand compression sprayer, knapsack sprayer and mist blower to ensure proper coverage with required quantity of spray fluid and avoid ULV applications or Akela spray applications.
- Proper mixing and preparation of spray fluid for each filling of spray fluid tank.

C3. BRINJAL

(i) **Brinjal lace-wing bug**, *Urentius sends* Distant (Hemiptera : Tingidae). The adults and nymphs suck the sap from leaves and cause yellowish spots which, together with the black scale-like excreta deposited by them, impart a characteristic mottled appearance to the infested leaves.

Management:
Spray dimethoate 30 EC @ 1 lit/ha or methyl demeton 25 EC @ 1 lit/ha

(ii) **Brinjal shoot and fruit borer**, *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae). The larvae bore into the petioles, midribs of fully grown leaves and tender shoots. The shoots infested with borer droop downward and dry up causing dead heart like condition. With the onset of fruiting, they bore into flower buds and fruits. Flower buds are normally shed, whereas infested fruits have a varying number of holes.
Management:
- Remove the affected terminal shoot showing boreholes.
- Remove the affected fruits and destroy.
- Avoid continuous cropping of brinjal crop
- Grow the varieties with long and narrow fruits in endemic areas
- Install pheromone trap@12/ha
- Encourage the activity of larval parasitoids: Pristomerus testaceus, Cremastus flavoorbitalis
- Avoid use of synthetic pyrethroids
- Avoid using insecticides at the time of fruit maturation and harvest
- Neem seed kernel extract (NSKE) 5 % or
- Spray Neem Seed Kernel Extract 5 % or any one of the following chemicals starting from one month after planting at 15 days interval

(iii) **Brinjal stem borer**, *Euzophera perticella* Rag. (Lepidoptera : Pyralidae). The caterpillars bore into the stem at leaf or branch axil and cover the hole with excreta and frass. The plants become stunted in growth and dry up.
Management:
Collect and destroy the damaged and dead plants
Light trap @1/ha to attract and kill adults
Spray neem oil 2ml/lit
Avoid using synthetic pyrethriods causing resurgence

(iv) **Hadda beetle**, *Epilachna vigintloctopunctata* (Fabricius) (Coleoptera; Coccinellidae).
The adults feed on the upper surface of the leaves and eat out regular areas of leaf tissues, whereas the grubs feed on the lower surface. In attacked leaves, all green tissues are eaten away leaving the epidermis intact, the leaves thus present a lace like appearance. They turn brown, dry up and fall off.
Management:
Collect damaged leaves with grubs and egg masses and destroy them
Shake plants to dislodge grubs, pupae and adults and destroy
Conserve natural enemies in brinjal ecosystem
Spray Carbaryl 50 WP @ 3g/lit

D. SPICES AND CONDIMENTS

D1. Turmeric

(i) **Skipper butterfly**- *Udaspes folus* Hesperidae: Lepidoptera,
Damage- Larvae fold the leave and feed inside them.
Management- Collection of butterfly with net and destroying them, need based spray of quinalphos.

D2. Cinnamon

(i) **Cinnamon butterfly**- *Chilasia clytia* Papilionidae: Lepidoptera,
Damage- Larvae feed voraciously on lamina and leaving only mid rib
Management- Collection of butterfly with net and destroying them, need based spray of quinalphos.

E. BEVERAGES

E1. TEA

(i) **Bunch caterpillar**, *Andraca bipunctata* Walker (Lepidoptera : Bombycidae). The damage is done by the caterpillars by feeding on the leaves, which results in defoliation of plants.
Management:
- The pest can be suppressed by collecting the caterpillars manually and destroying them.
- Spray 500ml of malathion 50EC in 500 liters of water per ha.

(ii) **Humped slug caterpillar**, *Spatulicraspeda castaneiceps* Hamps. (Lepidoptera: Cochlidiidae). The caterpillars mainly feed on the young leaves, which is the main commercial product and hence cause considerable damage to the crop.
Management: Spray 625g of malathion 50WP in 625 liters of water per ha.

(iii) **Red borer,** *Zeuzera coffeae* Nietner (Lepidoptera : Cossidae). The damage is done by caterpillars which feed by tunnelling the stem. The leaves of the attacked brunches wither, which eventually die. The attacked plant show pinkish excreta emerging out of the hole of the stem.
Management: Affected plants or twigs - cut and burnt. Field release of white muscardine fungus *B. bassiana* and braconid parasite *Amyosoma zeuzerae* for control of the red borer

(iv) **Red crevice tea mite**, *Brevipalpus phoenicis* (Geijskes) (Acari : Tenuipalpidae). All the active stages feed on the underside of the leaves, especially along the midrib and the base. The loss of cell sap causes yellowing of the leaves. The bark and the leaf petioles of the affected shoots split turn brown and dry up.
Management: Spray 1.25 liters of methyl demeton 25EC or 1.5 liters of dimethoate 30EC in 625 liters of water per ha.

(v) **Tea mosquito bug**, *Helopeltis theivora* Waterhouse (Hemiptera : Miridae). The damage is done by both adults and nymphs by sucking plant sap. The punctured areas dry up and die due to the toxic nature of the injected saliva. By the coalescence of a large number of such patches, the entire leaf may become black and shrivelled, and may fall off eventually.

Management:

- Collect nymph and adult with hand nets early in the morning or in the evening and destroy them.
- Spray the bushes with 500ml of malathion 50EC in 500liters of water per ha.

(vi) **Yellow tea mite**, *Polyphagotarsonemus lotus* (Banks) (Acari : Tarsonemidae). The mite is a serious pest of tea nurseries. The first two or three leaves and the buds are infested by this mite resulting in browning of leaves. The shoot growth is slowed down and production of terminal tea leaves is reduced considerably.

Management: Spray 1.25 liters of methyl demeton 25EC or 1.5 liters of dimethoate 30EC in 625 liters of water per ha.

F. FIBRE CROPS

F1. COTTON

(i) **American Bollworm** *Helicoverpa anigera* (Hubner) (Lepidop tera : Noctuidae)

Damage. Although they prefer food plants like gram and red gram, the larvae are polyphagous. They feed on the foliage, when young and on the seed in later stages, and thus reduce yield. A single larva may destroy 30-40 pods before it reaches maturity.

Mnagement: The economic threshold is 10 per cent incidence in reproductive parts.

- Organochlorine.2.5 litres of endosulfan 35 EC.
- Organophosphates. 2.0 litres of fenitrothion 50EC, 2.0 litres of quinalphos 25 EC, 1.25 litres of monocrotophos 36 SL, 1.0 litre of phenthoate 50 EC, 5.0 litres of chlorpyriphos 20 EC, 1.5 litres of triazophos 40 EC, 2.0 litres of cthion 50 EC, 2.0kg of acephate 75 SP, 1.25 litres of pro penophos 50 EC.
- Carbamate.2.5 kg of carbaryl 50 WP.
- Synthetic pyrethroids. 500 ml of cypermethrin 10 EC, 200 ml of cypermethrin 25EC, 400 ml of deltamethrin 2.8 EC, 250 ml of fenvalerate 20 EC, 300 ml of fluvalinate 25 EC, 250 ml of alphamethrin 10 EC or asymethrin 5 EC.

Trichogramma achaeae Nagaraja & Nagarkatti (Trichogrammatidae) parasitizes the eggs of this pest throughout India and the incidence is 6-27 per cent in North India. It appears late in the season and is common in area where pesticides are used sparingly. *Apanteles angaleti* Muesebeck (Braconidae) parasitizes 1-17 per cent of the larvae of the host.

(ii) **Cotton leaf roller** Syllepte derogata (Fabricius) (Lepidoptera : Pyralidac)

Damage. The larvae feed on cotton leaves and in years of serious outbreaks, the cotton plants may be completely defoliated. American cotton is preferred over desi cotton by this pest.

Management: In case the bollworm damage exceeds 5 per cent, the crop should be sprayed immediately and thereafter at 10- day interval with any of the following insecticides in 315-375 litres of water per ha:

- Organochlorine.2.5 litres of endosulfan 35 EC.
- Organophosphates. 2.0 litres of fenitrothion 50EC, 2.0 litres of quinalphos 25 EC, 1.25 litres of monocrotophos 36 SL, 1.0 litre of phenthoate 50 EC, 5.0 litres of chlorpyriphos 20 EC, 1.5 litres of triazophos 40 EC, 2.0 litres of cthion 50 EC, 2.0kg of acephate 75 SP, 1.25 litres of pro penophos 50 EC.
- Carbamate.2.5 kg of carbaryl 50 WP.
- Synthetic pyrethroids. 500 ml of cypermethrin 10 EC, 200 ml of cypermethrin 25EC, 400 ml of deltamethrin 2.8 EC, 250 ml of fenvalerate 20 EC, 300 ml of fluvalinate 25 EC, 250 ml of alphamethrin 10 EC or asymethrin 5 EC.

(iii) **Cotton Grey weevil** *Myllocerus undecimpustuletus* Faust (Cuculionidae: Coleoptera)

Damage. Both adults and grubs cause dam agc. The grubs feed underground on the roots of cotton seedlings and destroy them. One grub can destroy 9 seedlings in 40 days. The adults which feed on leaves, buds, flowers and young bolls cut prominent round holes.

Management

- The pest can be suppressed by disturbing the soil up to a depth of 7.5 cm and destroying the eggs, grubs and pupae.
- Spray 2.5 kg of carbaryl 50 WP in 375 litres of water per ha.

(iv) **Cotton Semi-looper** *Tarache notabilis* (Walker) (Lepidoptera : Noctuidae)

Damage the caterpillar feed on leaves and skeletonised them altogether. In years of heavy infestation the plant may be completely denuded of leaves.

Management:

- The incidence of next crop can be minimize by ploughing the field soon after cotton harvest or by growing clovers in rotation with this crop.
- Organophosphates. 2.0 litres of fenitrothion 50EC, 2.0 litres of quinalphos 25 EC, 1.25 litres of monocrotophos 36 SL, 1.0 litre of phenthoate 50 EC, 5.0 litres of chlorpyriphos 20 EC, 1.5 litres of triazophos 40 EC, 2.0 litres of cthion 50 EC, 2.0kg of acephate 75 SP, 1.25 litres of pro penophos 50 EC.
- Carbamate.2.5 kg of carbaryl 50 WP.

(v) **Cotton Stem Weevil** *Pemphenuus affinis* (Faust) (Coleoptera : Curculionidac)

Damage. The pest causes serious damage to Cambodia cotton in South India. As the grubs tunnel within the stem, that portion swells, and such symptoms are generally seen at the base of the plant. The younger plants when attacked suc cumb, while the older plants may survive but suffer in vigour. Under strong winds, the affected plants may break at the swellings. The pest causes plant mortality upto 25 per cent, especially during the early stages of growth.

Management. Collection and destruction of affected plants is recommended for the control of this pest.

(vi) **Pink Bollworm,** *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae)

Damage is caused in various ways. There is excessive shedding of the fruiting bodies. Of the total shedding, 52.4-88.8 per cent is caused by all the bollworms collectively, one half may be due to the attack of pink bollworm. The attacked bolls fall off prematurely and those which do mature do not contain good lint. The damaged seed-cotton gives a lower ginning percentage, lower oil extraction and inferior spinning quality. It is considered that by controlling the pink and spotted bollworms, the cotton yield can be increased up to 50 per cent.

Management: In case the bollworm damage exceeds 5 per cent, the crop should be sprayed immediately and thereafter at 10- day interval with any of the following insecticides in 315-375 litres of water per ha:

- Organochlorine.2.5 litres of endosulfan 35 EC.
- Organophosphates. 2.0 litres of fenitrothion 50EC, 2.0 litres of quinalphos 25 EC, 1.25 litres of monocrotophos 36 SL, 1.0 litre of phenthoate 50 EC, 5.0 litres of chlorpyriphos 20 EC, 1.5 litres of triazophos 40 EC, 2.0 litres of cthion 50 EC, 2.0kg of acephate 75 SP, 1.25 litres of pro penophos 50 EC.
- Carbamate.2.5 kg of carbaryl 50 WP.
- Synthetic pyrethroids. 500 ml of cypermethrin 10 EC, 200 ml of cypermethrin 25EC, 400 ml of deltamethrin 2.8 EC, 250 ml of fenvalerate 20 EC, 300 ml of fluvalinate 25 EC, 250 ml of alphamethrin 10 EC or asymethrin 5 EC.

Trichogramma achaeae Nagaraja & Nagarkatti (Trichogrammatidae) parasitizes the eggs of this pest throughout India and the incidence is 6-27 per cent in North India. It appears late in the season and is common in area where pesticides are used sparingly. *Apanteles angaleti* Muesebeck (Braconidae) parasitizes 1-17 per cent of the larvae of the host. It is widely distributed in India and the parasitoid is associated with the host throughout the year.

(vii) **Red Cotton Bug** *Dysdercus koenigiü* (Fabricius) (Hemiptera : Pyrrhocoridac)

Damage. The insects suck cell-sap from leaves and green bolls of cotton. Heavily attacked bolls open badly and the lint is of poorer quality. The seed produced may also have low germination and less oil. Moreover, the bugs stain the lint with their excreta or body juices as they are crushed in the ginning factories. The staining of lint by the growth of certain bacteria inside the bolls is also believed to be initiated by these bugs.

Management. Spray against red cotton bug be done at economic threshold level of 1-2 nymphs per leaf or when second grade injury symptoms (yellowing and curling at margins of leaves) appear in 50 per cent of the plants. Any one of the insecticides can be used in 250 litres of water per ha: 200 ml of phosphamidon 85 WSC, 750 ml of formothion 25 EC or oxydemeton methyl 25 EC, 625 ml of dimethoate 30 EC, 100 ml of imidacloprid 2000 SL.

(viii) **Spotted Bollworms,** *Earias insulana* (Boisduval) and *E. vittella* (Fabricius) (Lepidoptera : Noctuidae)

When cotton plants are young, the larvae bore into the terminal portions of the shoots, which wither away and dry up. Later on, they cause 30-40 per cent shedding of the fruiting bodies. The infested bolls open prematurely and produce poor lint, resulting in lower market value.

Management:

- The pest can be suppressed with clean cultivation and the destruction of alternative food plants, particularly when cotton or okra is not growing in that locality.
- Chemical control measures are same as in case of pink bollworm. The economic threshold level is 10per cent incidence in shoots or reproductive parts.
- Egg parasitoid, *Trichogrammatoidea* sp. near guamensis (Trichogrammatidae) is also associated with this pest. *Brachymeria nephantidis* Gahan (Chalcididac) has also been recorded from pupae of *Earias* sp. and parasitism ranges from 13 to 57 per cent in different months. The parasitoids associated with larvae of *P. gossypiella* are also associated with this pest.

F2. JUTE

(i) **Jute Mealy-bug** *Phenacoccus hirsutus* Cr. (Hemiptera : Pseudococcidae)

Damage. The nymphs and females feed on the apical parts of a plant which becomes stunted and shows bushy-top symptoms. The petiole becomes shortened, the lamina crumples and the internodal length is reduced, resulting in fibre deterioration and yield reduction.

Management. Spray 1.25 litres of dimethoate 30 EC in 625 litres of water per ha.

(ii) **Jute Semi-looper**, *Anomis sabulifera* (Guence) (Lcpidoptera : Noctuidae).

The attack is severe on half-grown plants which are one metre high. The second generation is the most damaging and sometimes up to 90per cent of the leaves may be eaten up. Generally, the top 7-9 leaves are damaged and plant growth is adversely affected, resulting in a considerable reduction in the yield of fibre.

Management

- The pest can be suppressed by ploughing the infested fields after harvest and thus killing the pupae.
- The caterpillars can be dislodged into kerosenized water by drawing a rope across the young crop.
- Spray 500 ml of fenitrothion 50 EC or endosulfan 35 EC in 500 litres of water per ha. Repeat the treatments three times at 15 day interval from mid June or at first appearance of the pest.
- Spray 625 ml of fenitrothion 50 EC or endosulfan 35 EC in 625 litres of water per ha.

(iii) **Jute Stem-girdler**, *Nupserha bicolor postbrunnea* Dutt (Coleoptera : Lamiidae).

The main damage occurs because of oviposition, resulting in the breakage of fibre length at several places. Thus, both the quality of fibre and the yield suffer. The damage is estimated at 6-30 per cent, being more in younger plants than in the older ones. Not much damage is caused by the feeding of larvae or adults.

Management

- In areas where the girdler is a severe pest, the growing of resistant species of jute (capsularis) is useful.
- Mix 25 kg of phorate 10 G per ha in the top soil followed by light irrigation.

(iv) **Jute Stem Weevil,** *Apion corchori* Marshall (Coleoptera : Apionidac).

Damage: The main damage to the quality of fibre is caused by weevils making oviposition holes. A female may make a number of holes before laying an egg and damages numerous stems in her life time. The fields suffering the most are those with nitrogen fertilizer and those which are sown early. The weevil has a number of alternate host plants but the *capsularis* varieties seem to be relished the most.

Management

- The pest may be suppressed by the removal and destruction of infested plants at the time of thinning the crop and by collecting and destroying the stubble after harvest.
- Spray 2.5 kg of carbaryl 50WP in 625litres of water per ha.

(v) **Indigo Caterpillar**, *Spodoptera exigua* (Hubner) (Lepidoptera : Noctuidae).

The damaged crop, on which larvae have fed, gives a webbed appearance. The older caterpillars, which feed in the morning and evening, have a voracious appetite and strip off quite large patches on the foliage. However, the young jute plants, less than two months of age, suffer the most. The early sown *capsularis* varieties suffer greater losses than those sown later.

Management

- The pest can be suppressed by collecting and destroying the egg masses and the caterpillars which are feeding within the webs.

Probable question:

1. Write the scientific name and damage symptoms of brinjal fruit and shoot borer.
2. Name any two species of rice stem borers and comment on the nature of damage caused by them.
3. Write down the scientific name of major insect pests of sugarcane (any four) and discuss the nature of damage caused by them.

Suggested Reading:

1. Awasthi, V.A. (2007). Agricultural Insect Pests and Their Control (2nd edition, 2017). Scientific Publishers (India) New Delhi - 110 002 India.
2. Austin, J. (2023). Agricultural Pests and their Management. (1st edition, 2022) Brilliance Publisher.
3. Nigam, R. et al. (2022). Agricultural Insect Pests and Their Management. (1st edition, 2022) Bio-Green Books Publisher

Unit II

Morphology, bionomics and management of: a) Rice Yellow stem borer (*Scirpophaga incertulas*) b) Rice brown plant hopper (*Nilaparvata lugens*) and c) Sugar cane top borer (*Scirpophaga nivella*)

Objective: In this unit we will discuss about morphology, bionomics and management of three pests Rice Yellow stem borer, Rice brown plant hopper and Sugar cane top borer.

Introduction

Bionomics means the branch of biology dealing with the relations and interactions between organisms and their environment, including other organisms.

Rice Yellow stem borer (*Scirpophaga incertulas*)

Among the stem borers infesting rice, the yellow stem borer, *Scirpophaga incertulas* (Walker) (Lepidoptera: Pyralidae), is an important pest of rice throughout tropical South and Southeast Asia. Its incidence is most predominant in tropical lowland rice and deep-water rice. The pest attacks all stages of the crop. Larval damage to tillers during the vegetative stage results in **'dead heart'** symptom (drying up of central shoot) and damage during the panicle initiation stage results in **'white ear'** (chaffy, unfilled grains). Stem borer adults are strongly attracted to light and signal the initiation of a fresh brood. Several factors strongly influence the relative abundance of stem borer populations like rainfall and humidity. However, development of stem borer life stages is strongly driven by temperature. Cooler temperatures and day length changes induce diapause or temporary arrest in development in mature larvae. One can easily observe adult moths attracted to light sources near rice fields during the season.

Fig: 'Dead heart' symptom


Fig: ‘white ear’ symptom

Morphology

- **Egg**:
  Eggs are creamy white, flattened, oval and laid in a mass which is covered with buff-coloured hairs. They are laid mostly near the tip of the leaves. Egg period is 5-8 days.
- **Larva**:
  Pale yellow with dark brown head having prothoracic shield. Larval period is 28 to 30 days.
- **Pupa**:
  White silken cocoon. Pupation takes place inside the rice stem, straw or stubble. Pupal period is 8 to 10 days.
- **Adult**:
  Female moth:
  Has bright yellowish brown with a black spot at the centre of the fore wings and a tuft of yellow hairs at the anal region. The wingspan of the male is 34 mm. Female fuscous brown with pale fuscous hindwings
  Male moth:
  The wingspan of the male is 18–22 mm with pale yellow forewings without black spot. Adult males are smaller than the females. Males are brownish ochreous. Forewings irrorated (sprinkled) with dark scales and with the veins slightly streaked with fuscous. A black spot found at lower angle of cell. There is an oblique fuscous line runs from apex to vein 2. A marginal black specks series can be seen. Hindwings ochreous white.

(a)

(b)

(c)

a. Egg
b. Larva
c. Adult

Bionomics

The rice yellow stem borer attacks all stages of the crop.

Eggs are laid on upper-surface (and upper half) of leaves in groups (average about 80) covered in tan scales from the female. Eggs hatch in 5-10 days, and the white larvae bore into the leaf sheath resulting in yellowish-white patches. Later, they invade the stem, and cause dead hearts or drying up of the central shoots (at the vegetative stage), and whiteheads (at the panicle stage).

When fully grown (20-40 days) the larvae are pale-yellow to yellowish-green with a brown head, up to 20 mm long. They pupate in white silk cocoons made in hollow stems at the base of the plant. In deep-water rice, the larvae and pupae may be beneath the water.

The larvae become dormant if dry periods occur or in seasons when rice is not grown. During rice-free times, the larvae remain in the stubble below the soil. Mortality is high (90%) during periods of dormancy, due to destruction of stubble, and possibly due to predation (spiders) and adverse environments (droughts).

The female moth has pale-yellow or light-brown forewings, each with a characteristic single, black spot. The smaller grey or light-brown male has two rows of small spots at the tip of each forewing. Females are 13 mm long with 32 mm wingspans.

Spread over short distances occurs as eggs on infested seedlings used for planting; as larvae that crawl from plant to plant and/or disperse on silken threads blown by the wind, as pupae in harvested stems, adults on the wing at night, and on farm machinery.

Symptom of damage:

- Presence of brown coloured egg mass near leaf tip
- Larva bores into central shoot of paddy seedling and tiller, causing drying of the central shoot known as **"dead heart"**
- If infestation occurs in grown up plant, the whole panicle becomes dried and known as **"white ear"**
- Affected shoots and panicles could be easily pulled by hand

Management

A. Biological control

Many egg parasitoids have been identified with *Telenomus* spp., *Tetrastichus* spp., and *Trichogramma* spp. being the most common. There are also predators of eggs, e.g., long-horned grasshoppers, and adults are vulnerable to spiders. Every effort should be made to preserve this fortunate situation. Only apply pesticides as a last (and not a first) resort.

B. Cultural control

a) Before planting:

i. Handpick and destroy egg masses in the seedbed (nursery) beforer transplanting the field.
ii. Before transplanting, cut the leaf-top to reduce carry-over of eggs from the seedbed to the field.
iii. Choose short-stature, early-maturing varieties.
iv. Prepare the land thoroughly ensuring vigorous plant growth when planted, and to destroy larvae and pupae from the previous crop.

b) During growth:

i. Try to synchronize planting in any area, avoiding overlapping crops and preventing pest populations moving from harvested to standing crops. Additionally, choose varieties with similar times to maturity.

ii. If the crop is seasonal, plant early. Two early-maturing crops may be less damaged than a single late-maturing variety.
iii. Raise level of irrigation water periodically to submerge any eggs deposited on the lower parts of the plant.
iv. Weed as soon as required to promote good crop growth.
v. Cut out the stems with deadhearts and remove from the field. Destroy the larvae or burn the stems. Note, this is labour intensive and not very effective as the pest may already have left the stem.
vi. Split applications of nitrogen fertiliser. High nitrogen application favours build-up of stem borers.

c) After harvest:

i. Harvest crops at ground level to remove the larvae and pupae in the stubbles.
ii. Plough remaining rice stubble into the soil to kill larvae and pupae, and avoid leaving unharvested or volunteer plants. Irrigate the field, if that is possible at this time.

C. Resistant varieties

Most of the modern semi-dwarf rice varieties now grown by farmers have a moderate level of resistance to stem borers, but efforts to produce highly resistant varieties through conventional breeding and wide hybridization with wild rice species have not been successful, but research continues. Genetic modification of varieties with crystal toxin genes from *Bacillus thuringiensis* has been done, but release is still under consideration.

D. Chemical control

i. The use of insecticides risks destroying natural enemies, and some products recommended for this and other stem borers are extremely toxic and risk harm to users and the environment (e.g., carbofuran, monocrotophos and phorate).
ii. Three others commonly recommended insecticides - diazinon, chlorpyrifos and fipronil - are all classified by WHO as Class II moderately hazardous pesticides. They are broad-spectrum insecticides. In addition, fipronil is highly toxic to fish, and it has been associated with colony collapse disorder of bees.

E. Biosecurity

Countries not yet infested by the rice yellow stem borer should consider all likely pathways for entry, and apply quarantine measures accordingly. Many countries throughout Africa, the Americas, the Caribbean, and Oceania are at risk. Pathways of introduction are likely to be via produce contaminated by pieces of rice stem infested with larvae and/or pupae.

Rice brown plant hopper (*Nilaparvata lugens*)

Brown planthopper (BPH, *Nilaparvata lugens* Stål) is the most devastating pest of rice in Asia and causes significant yield loss annually. Planthoppers constitute a large group of sap-feeding insects in the order Hemiptera. Their name refers to their jumping ability. It can infest the rice crop at all stages of plant growth. Due to feeding by both the nymphs and adults at the base of the tillers, plants turn yellow and dry up rapidly. During the early infestation stage, round yellow patches appear, which soon become brownish due to the drying up of the plants.

Morphology

- **Egg:** Eggs are laid in a group of 2 to 12 in leaf sheath (near the plant base or in the ventral midribs of leaf blades). White, transparent, slender cylindrical and curved eggs are thrust in straight-line in two rows. (They are covered with a dome-shaped egg plug secreted by the female. Only the tips protrude from the plant surface).
- **Nymph:** Freshly hatched nymph is cottony white, 0.6 mm long and it turns purple-brown, 3.0 mm long in the fifth instar.
- **Adult:** Adult hopper is 4.5-5.0 mm long and has a yellowish brown to dark brown body. The adults exist in two forms, macropterous and brachypterous. Macropterous adults or long-winged have normal front and hind wings, whereas brachypterous forms or the short-winged have reduced hind wings. A prominent tibial spur is present on the hind leg.

Bionomics

Macropterous females migrate into rice fields shortly after transplanting, laying groups of 5-15 eggs into the sheaths or midribs of leaves. The first instar nymphs hatch after 5-9 days; they molt five times during a period of 2-3 weeks. Initially, most of them develop into brachypterous adults: but as population density increases, or if food becomes scarce, the proportion developing into the macropterous form increases. During their adult lifespan of 10-30 days, macropterous females each produce about 100 eggs, brachypterous females 300 to more than 700. In the tropics, N. lugens is active all year round, and produces 3-6 generations per crop. It is not able to overwinter in temperate regions, so it migrates into these areas in the spring, often after traveling long distances.

Symptoms of damage:

i. Both nymphs and adults penetrate the tissues of their rice host plants with their piercing-sucking mouthparts in order to ingest phloem-sap. Loss of nutrients and obstruction of vessels cause yellowing of leaves. Later, the plants wilt, gradually drying up and eventually dying off.

ii. Affected plant dries up and gives a scorched appearance called "hopper burn".

iii. In addition to the direct damage it causes, *N. lugens* is an important vector of rice grassy stunt virus and rice ragged stunt virus and all stages excrete honeydew, thus promoting the growth of sooty mold.

iv. Honey dew is secreted by nymphs and adults which causes sooty mould at the base.

Fig: Nymphs and adults at base of tiller

Fig: Hopper burn

Management:

i. Avoid close planting and provide 30 cm rogue spacing at every 2.5 to 3.0 m.
ii. Control irrigation by alternate wetting and drying.
iii. Avoid excessive use of nitrogen
iv. Release of natural enemies like *Lycosa pseudoannulata, Cyrtorhinus lividipennis* adults (200-250 bugs/ha) during the peak incidence of BPH.
v. Set up light traps during night or yellow pan traps during day time
vi. Drain the water before use of insecticides and direct the spray towards the base of the plants.
vii. Apply Neem oil 3% 6 lit/ac or Azadirachtin 0.03% 400 ml/ac
viii. Apply insecticide.

Sugar cane top borer (*Scirpophaga nivella*)

Morphology

Adult sugarcane borers are straw-coloured moths with a pattern of black dots arranged in an inverted V-shape on the front wings (3/4 inch long). They lay eggs in clusters of two to 100 on the leaf surface. In less than one week, larvae emerge, crawl down the leaf, feed in the leaf sheath, and bore into the plant stem. Larvae are pale yellow-white in colour. In the summertime, they have a series of brown spots visible on the back. Overwintering larvae are a deeper yellow with no brown spots. Overwintering sugarcane borer larvae are usually found close to the plant crown. Larvae feed inside the stem for two to three weeks before chewing an exit hole in the stem and pupating. The pupae are brown, about 1 inch long and roughly cylindrical in shape. Adults emerge in about one week. There can have up to three generations per year in rice.

Bionomics

Life cycle: Adult moths are creamy white in colour with crimson coloured anal tuft of hairs in females. Males are slightly smaller, with a wing span of 25-30 mm. Fecundity is 150-300 eggs per female. Eggs are dull white, oval, laid in overlapping clusters of about 30 eggs on the under surface of the leaf and covered with buff-coloured hairs derived from the anal tuft of female. Incubation period is 5-7 days.

After hatching the larvae bore into the midrib and tunnel towards the stem for 24-48 hours and then enter the stem. Full grown larva is 25-30 mm long dull creamy white having shorter legs. Larval period is 25-40 days. Pupation takes place inside the stem in a chamber constructed by the larva just above the node. Pupal period is 10-20 days depending on temperature. Hibernation takes place in the larval stage.

Damage: Young larvae bore into the midrib, leaving red markings and small holes on the leaves. Then the larvae tunnel in the upper portion of the stem, resulting in drying of the central shoot, causing "dead heart". With the death of central shoot, side branches start growing from a lower node, giving a characteristic "bunchy top" appearance to the plant. Up to 25% mortality of shoots and 40% stunting has been recorded in northern India.

Management

i. Mechanical control is achieved by destroying crops in the infected part of the field and by collecting and destroying the egg masses.
ii. Chemical control is difficult but possible. Spraying low dosages of malathion, endosulfan or carbofuran during the period the moths lay their eggs

has been effective. It has also been recommended to dust crops with moderate concentrations of carbofuran or high concentrations of dieldrin, endrin or lindane during the period the adult moths emerge from their cocoons. Note that this information is very old, most of these products have been banned internationally for agricultural use.

iii. Biological control was successfully attempted by CIBC (Commonwealth Institute of Biological Control) by mass release programmes of exotic species of ***Trichogramma.*** The following parasitoids have been recorded on this pest:

iv. Egg parasites: ***Tetrastichus sp., Trichogramma intemedium, T. minutum.***

v. Larval parasites: ***Goniozus indicus, Stenobracon deesae, Amauromorpha accepta schoenobii, Isotima javensis, Syzeuctus sp., Sturmiopsis infenens.***

vi. Pupal parasites: ***Tetrastichus ayyari, Xanthopimpla pedator.***

Probable questions:

1. Write the differences between male and female Rice Yellow stem borer.
2. How Rice Yellow stem borer can be controlled by application of chemicals?
3. Discuss about the management procedure of Rice Yellow stem borer.
4. What is dead heart disease?
5. State the damage symptoms of Rice Yellow stem borer infestation.
6. How the *Nilaparvata lugens* infestation can be controlled?
7. Discuss the bionomics of *Nilaparvata lugens.*
8. What is hopper burn?
9. Discuss the bionomics of *Scirpophaga nivella.*
10. How *Scirpophaga nivella* can be controlled?
11. Name the host plant of *Scirpophaga nivella.*

Suggested Literature:

1. Agricultural insects pests of the tropics and their control, Hill, D. S., Cambridge University Press, UK
2. Agricultural pests of South-East Asia and their management - A.S Atwal & G.S. Dhallwal
3. Insect Plant Biology, Schoonhoven, L. M., van Loon, J.A., &Dicke, M., Publisher Oxford University Press, USA

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Unit III

Morphology, bionomics and management of: a) Tea mosquito bug (*Helopeltis theivora*) b) Diamondback moth (*Plutella xylostella*) and c) Brinjal fruit and shoot borer (*Leucinodes orbonalis*)

Objective: In this unit we will discuss about morphology, bionomics and management of three pests Tea mosquito bug, Diamondback moth and Brinjal fruit and shoot borer.

Introduction

Bionomics means the branch of biology dealing with the relations and interactions between organisms and their environment, including other organisms.

Tea mosquito bug (*Helopeltis theivora*)

Tea Mosquito Bug (TMB) is a serious pest in tea, cashew, cocoa which causes severe yield loss. The pest belongs to genus *Helopeltis* under order Hemiptera. *Helopeltis* is the dominant species infesting cotton. Nymph and adults suck the sap from leaves, stems, squares and bolls and cause considerable yield loss. It is a devastating piercing-sucking pest in tropical tea plantations.

Host range: Cashew, neem, moringa and guava are other host plants.

<u>Bionomics</u>

<u>Morphology</u> and Life cycle:

Adult is black with red thorax, black and white abdomen and greenish brown wings. Body is small, slender with long antennae. An erect knobbed process on the scutellum is characteristic of the species. Bugs are active in the early morning and late evening hours and hide in the bushes during the remaining period. White eggs with two filaments arising from the operculum are inserted into tender shoot. Egg period 5-7 days, nymphs greenish yellow, nymphal period 10 days with five nymphal instars.

Damage symptoms:

Adults and nymphs suck the sap from buds, young leaves and tender stems by puncturing with needle like stylets and injecting toxic saliva. These punctures appear as reddish-brown water-soaked spots. Later they coalesce together to form necrosis. Due to intensive feeding, leaves curl up, become badly deformed and remain small. Gradually, shoots dry up.

Figure. (a) *Helopeltis theivora* egg, (b) nymph and (c) adult on

[Source: https://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0718-58392013000300015]

Management

1. Collect and destroy the damaged plant parts
2. Spray any of the insecticides, profenofos 50 EC 800-1000 ml, Thiamethoxam 25 WG 100 g, endosulfan or phosalone or chlorpyriphos or dimethoate at 1000ml/ha with 500 L water/ha
3. Spray in early morning or late in the evening hours on trunks, branches, foliage and inflorescence for effective control.

Diamondback moth (*Plutella xylostella*)

Morphology

Egg: The oval and flattened eggs of the diamond back moth *(Plutella xylostella)* are initially yellow or pale green and later darken. They are deposited singly or in small groups of two or ten eggs on both the upper and lower surface of leaves, preferentially in depressions, and rarely on stems or petioles.

Larva: There are four larval instars. The body tapers at both ends and is green, sometimes suffused with pale yellow, with a few short hairs and small white patches. The larva has five pairs of prolegs; one pair of prolegs protrudes from the posterior end, forming a distinctive 'V' shape. Throughout their development, larvae remain quite small and active. Except for the first instar, which mines in the leaf tissue, the larvae are voracious surface feeders.

Pupa: The pupae of the diamond back moth *(Plutella xylostella)* are covered with a white, loose, silken cocoon, usually formed on the lower or outer leaves. They often stick to leaves and frequently hide in crevices near the bud. In cauliflower and broccoli, pupation may occur in the florets. Initially, the pupa is pinkish-white to pinkish-yellow and changes to brown before adult emergence.

Adult: The adult of the diamond back moth *(Plutella xylostella)* is slender, greyish brown with pronounced antennae. The hindwings are narrow, pointed toward the apex. The tips of the wings appear to turn upward slightly when viewed from the side. In males, the upper two-thirds of the forewings are dark, sometimes suffused with ochre or mixed with whitish scales. The lower one-third of the forewing is ochreous-white, with a nearly white upper edge. In females, the upper two-thirds of the forewings are light ochreous and the markings are like those of the males. The back is marked with a broad cream or light brown band along the back, which is sometimes constricted to form one or more light-coloured diamonds, thus the common name diamond back moth. The moths are weak fliers and can disperse, on average, only 13 to 35 m within a crop field, however, they are readily carried by the wind and as such can disperse 400 to 500 km per night.

Male Diamondblack

Caterpillar

Cocoon

Host range

Diamondback moth is restricted in its host range to plants of the family Brassicaceae. In addition to many other **brassicaceous** crops and weeds, host plants for the diamondback moth include: canola, mustard, cabbage, cauliflower, broccoli.

Bionomics

Life cycle

Diamondback moths exhibit complete metamorphosis, and often go through three generations per season. **Eggs** are laid on the undersides of leaves, giving rise to larvae in just a few days. **Larvae** enter the leaves and feed on internal leaf tissue. After about a week, larvae move to the outside of the plant, feeding on the undersides of leaves. Diamondback moth larvae can be distinguished from other similar larvae because when they are disturbed, the move backward rapidly and thrash their bodies, dropping from the plant on a fine silken thread. Larvae feed for 10-30 days depending on food supply and temperature. **Pupation** takes place in a delicate, white cocoon attached to the host plant. **Adults** emerge in 7-14 days and females' mate only once, laying eggs almost immediately. Moths are weak fliers and lay eggs after dark. All stages of the insect may be found on the plant at the same time. The first generation usually only has leaves to feed on and may not cause as much damage as the second generation. Moths do not overwinter in Montana and are carried on wind currents from the southern US in early May or June. Therefore, infestations vary widely from year to year.

Damage symptoms

The caterpillar is a surface feeder. They feed from the lower leaf surface, leaving the wax layer on the upper surface intact, thereby creating translucent windows. In cases of severe infestation, entire leaves may be destroyed, leaving only the veins. The larvae feed also on the chlorophyll-rich green areas of stems and pods causing whitening of the crop. Heavily damaged plants appear stunted and will, in most cases, die. On rapeseed, larvae also feed on flower buds, flowers and young seed pods, causing loss of pods and seeds.

Damage symptoms

Management:

i. Management depends on crop species, but in general, monitoring should begin early in the season at the seedling stage and continue until after flowering.

ii. Record diamondback larvae numbers twice-weekly, and monitor carefully early in the season for the arrival of adults and eggs. Adjacent fields and field edges where host crops are growing should also be monitored.

A. Biological Control

Natural enemies often effectively control diamondback moth in certain regions, but less so in Montana. The ichneumonid wasp, Diadegma insularis, has been identified as the most common parasite. *Trichogramma* spp. may also attack diamondback eggs. Various predators such as ground beetles, true bugs, syrphid fly larvae, birds, and spiders can be important factors in controlling populations.

B. Cultural Control

Eliminating cruciferous weeds as host plants will help reduce the successful establishment of the first-generation larvae. Rainfall will dislodge larvae and cool, cloudy weather reduces moth activity, reducing the number of eggs that are laid. Since diamondback moths do not overwinter in Montana, cultural control practices such as crop rotation is ineffective for controlling diamondback moths.

C. Chemical Control

Diamondback moths can be controlled by foliar insecticidal sprays, including the organically acceptable *Bacillus thuringiensis* (Bt) and the Entrust formulation of spinosad. It takes a severe infestation of small larvae to damage canola yields—the economic threshold for larvae is around 15 per square foot when the crop is young, and about 28 per square foot as flowering starts.

Brinjal fruit and shoot borer (*Leucinodes orbonalis*)

Fruit and shoot borer is a major and regular pest of brinjal causing damage to even 30 - 50% of fruits or more.

Host range: Brinjal, potato, other wild plants belonging to solanaceae, peas

Morphology

Egg: Female adult moth lays eggs underneath the leaves and on flower buds. Eggs are creamy white in colour. Egg stage lasts for 3 -5 days.

Larvae: Larvae looks pink in colour. This stage lasts for 12-15 days. Larva usually bores into shoots and fruits. After hatching, larvae bores into the shoots and fruits and feed inside.

Pupae: Pupae last on the ground over the dried leaves. This stage lasts for 6-17 days. Pupae are greyish in colour with boat shaped.

Adult: Medium sized moth. Forewings have black and brown patches and dots on white colour, hind wings are opalescent with black dots. Female adult moth lays about 250 eggs.

Fig: Adult Brinjal fruit and shoot borer

Bionomics

Life cycle:

Egg period: 3-4 days. About 150-350 creamy white eggs laid singly on leaves, tender shoots, flowers and developing fruits. Larva is stout, pink coloured with sparsely distributed hairs on warts on the body and brownish head. Larval period 15 days - 5 instars. Pupa: 6-8 days in tough greyish cocoon on plant itself, boat shaped cocoon. Medium sized adult with white wings, flashed with triangular brown and red markings on forewing. Total life cycle: 17-50 days.

Symptoms of damage:

- Withering of terminal shoots/dead hearts
- Bore holes on shoots and fruits plugged with excreta

- Shedding of flower buds
- Withering and drying of leaves

Management

- Remove the affected terminal shoot showing boreholes.
- Remove the affected fruits and destroy.
- Avoid continuous cropping of brinjal crop
- Grow the varieties with long and narrow fruits in endemic areas
- Install pheromone trap@12/ha
- Encourage the activity of larval parasitoids: *Pristomerus testaceus, Cremastus flavoorbitalis*
- Avoid use of synthetic pyrethroids
- Avoid using insecticides at the time of fruit maturation and harvest
- Neem seed kernel extract (NSKE) 5 % or Spray Neem Seed Kernel Extract 5 % or any one of the following chemicals starting from one month after planting at 15 days interval

Probable questions:

1. State the damage symptoms of *Helopeltis theivora.*
2. Describe the physical characters of Diamondback moth.
3. Describe the management process of diamondback moth.
4. Discuss the bionomics of *Leucinodes orbonalis.*

Suggested Literature:

1. Agricultural insects pests of the tropics and their control, Hill, D. S., Cambridge University Press, UK
2. Agricultural pests of South-East Asia and their management - A.S Atwal & G.S. Dhallwal
3. Insect Plant Biology, Schoonhoven, L. M., van Loon, J.A., &Dicke, M., Publisher Oxford University Press, USA

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Unit IV

PLANT PROTECTION TECHNIQUES

Objective: In this unit we will discuss about plant protection techniques.

Plant Protection Equipment

Selecting the right equipment for pesticide application is important for successful pest control. The correct usage of equipment and its proper maintenance are important factors which affect the ability to place pesticides on target more economically and effectively. The choice of equipment depends on its specific use and the need of a particular pest control measure.

Different Types of Plant Protection Equipment Generally Used

- Hand sprayers and atomizers
- Hand compressed sprayers
- Knapsack sprayers
- Tractor-mounted sprayer
- Motorized knapsack mist blowers
- Ultra low volume or controlled-droplet applicators (ULV/CDA)
- Fogging machines/fogair sprayers
- Hand-carried dusters
- Hand-carried granule applicators
- Power dusters
- Aerial application (Aircraft sprayers)
- Injectors and fumigation equipment.

Selection and Use of Spraying Equipment

Spraying equipment (Fig. 1) should be selected on the basis of:

- frequency of pesticide application,
- availability of diluent (water, oil, kerosene, etc.),
- availability of labor (human or animal power),
- area requiring treatment,
- characteristics of area (machine equipment for large areas, hand-operated equipment for smaller areas),
- durability of equipment,
- cost of equipment,
- availability of after sales service,
- operating cost, and
- speed required to treat an area (this will depend on type of crop, stage of crop growth, and volume of spray solution to be applied).

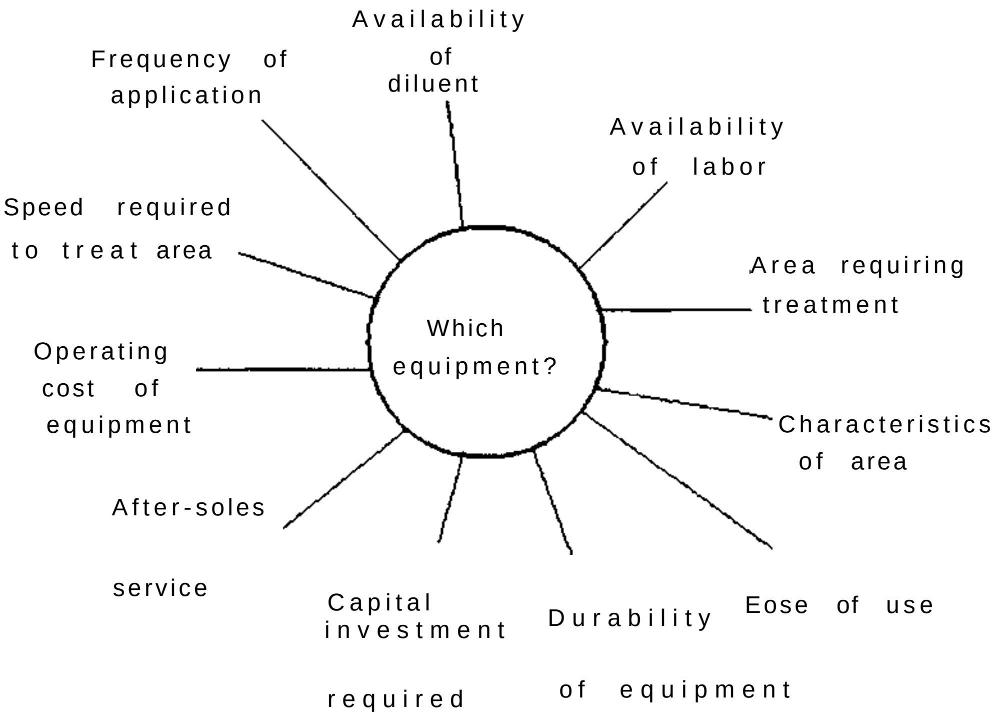


Figure 1. Factors governing the selection of spraying equipment.

Pesticide Application Techniques

The methods used to apply agricultural chemicals on crops and herbicides on weeds or on soil, are known as application techniques (Fig. 2). Appropriate dosage and even distribution of spray droplets on a target area are of paramount importance (Fig. 3 and 4). Chemicals are used in doses ranging from 100 g or less to as high as a few L and kg ha^{-1}. Carriers or diluents are mixed with chemicals to ensure even distribution. The most important diluent-carrier is water. When used as a pesticide carrier, its volume should be varied with the method of application (Table 1).

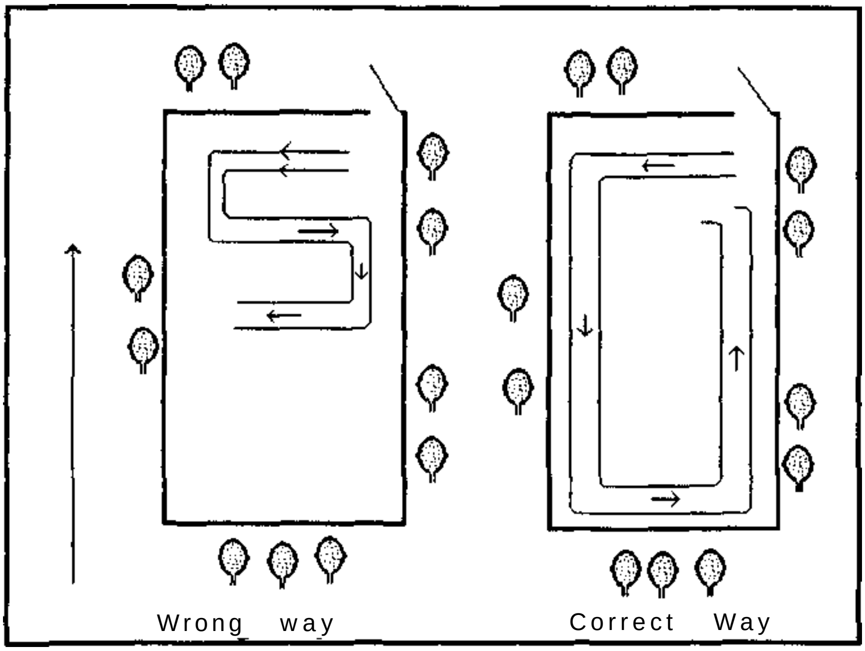


Figure 2. The correct and wrong ways of spraying.

Table 1. Volume of water or any diluent carrier at flowering stage.

Volume	Field crops (L ha^{-1})	Trees and bushes (L ha^{-1})
High volume (HV)	>600	>1000
Medium volume (MV)	200-600	500-1000
Low volume (LV)	50-200	200-500
Very low volume (VLV)	5-50	50-200
Ultra low volume (ULV)	<5	<50

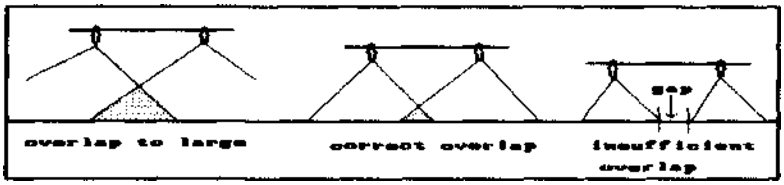


Figure 3. Overlap of spray swath.

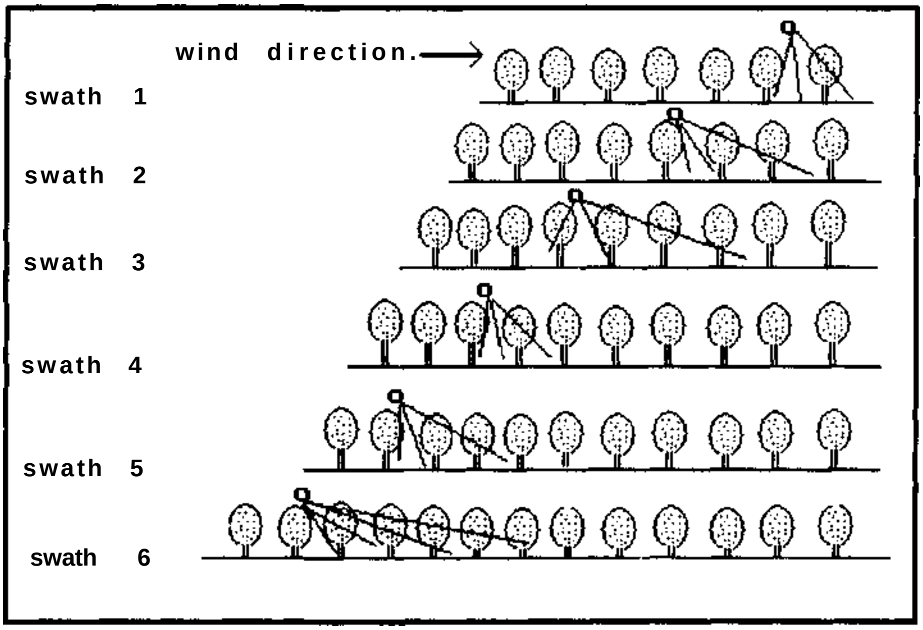


Figure 4. Overlapping of swaths as the operator moves upwind across a field.

The efficacy of a pesticide in any application technique is mainly influenced by the following three factors:

- Mean level of deposit (dosage): This refers to the total amount of toxicant (active ingredient) used in treating a unit of the target area;

- Distribution of deposit: The surface of the leaf may be completely covered by a chemical (active ingredient) deposit in the case of runoff (high volume) spray, but the deposit may be unevenly distributed; and

- Wetting agents tend to decrease droplet size and increase spreads, and low-volatility carriers help prevent the evaporation of small droplets (low and ultra low volumes) and ensure better distribution.

Importance of Droplet Size

Droplet size plays a very important role in pesticide application by minimizing environmental contamination. Pesticide sprays are generally classified according to droplet size. When drift is to be minimized, a medium or coarse spray is required irrespective of the volume applied (Table 2).

Table 2. Classification of sprays according to droplet size.

Volume medium diameter of droplet (µm)[1]	Classification of droplet size
<50	Aerosol
51 - 100	Mist
101 - 200	Fine spray
201 - 400	Medium spray
>400	Coarse spray

1. The most widely used parameter of droplet size is volume medium diameter (Vmd) which is measured in micrometers (µm). 1 mic = 1/1000 mm.

Commonly Used Spraying Equipment

1. Hand-operated hydraulic sprayers (knapsack sprayers)
2. Power-operated hydraulic sprayers (tractor-mounted sprayers)
3. Air carrier sprayers (mist blowers)
4. Electrodyne sprayers (electrostatic sprayers)
5. Birky sprayers (Birky knapsack sprayers)
6. Controlled-droplet application sprayers
7. Dusters

1. Hand-operated Hydraulic Sprayers

These sprayers are the most widely used. They are small and compact e.g., knapsack and hand compressed sprayers.

Knapsack sprayers (lever operated)

The lever-operated (piston/diaphragm type) knapsack sprayer is one of the most commonly used sprayers. In this equipment, liquid is drawn through a valve into a pump chamber with the first stroke. When the lever returns to its original position, the liquid in the pump chamber is forced past another valve into a pressure chamber. The valve between the pump and the tank is closed during this operation to prevent the return of the liquid into the tank. A good seal between the pump and cylinder is obtained by a 'cup washer' or 'O' ring. As liquid is forced into the chamber, air is trapped in a part of the pressure chamber and compressed. This forces the liquid from the pressure chamber through a hose into the nozzle. Compression sprayers, hand sprayers, and shoulder-slug compression sprayers fall under this category.

Calibration of spraying equipment

To achieve good results from spraying, the sprayer must be clean and in working condition. It must be calibrated before every major spraying operation so that the exact quantity of spray is delivered on the target, which may be plants in the case of insecticide application or soil in the case of herbicides.

The volume of application depends on the:

- droplet size the sprayer can deliver (depending on the size of the orifice of the nozzle tip),
- surface area to be sprayed/applied,
- weather conditions,
- pesticide formulations (EC, WP)
- availability of diluent,
- spraying pressure (maintain uniform pressure throughout the operation),
- uniform spray swath, and
- speed of an operator/tractor: maintaining a tractor's or operator's (in the case of manual operation) constant forward speed is essential.

Calibration of knapsack sprayers (refer to SDS no. 15 - Pest Control)

a. Rinse and clean the sprayer.
b. Determine nozzle discharge (by selecting a nozzle) in L min^{-1} at known pressure (V).
c. Calculate the walking speed of the operator (starting point, end point) in M min^{-1} (L).
d. Determine the width of the spray swath in meters (W).
e. Calculate the area sprayed in one minute (W x L) M^2 min^{-1}

Area sprayed min^{-1} = Swath width of spray x Forward speed min^{-1}.

f. The application rate for any given area:

$$\text{Volume of spray in L unit}^{-1}\text{ area} = \frac{\text{Nozzle discharge (L min}^{-1}\text{) x Area}}{\text{Area sprayed min}^{-1}}$$

or

$$L\ ha^{-1} = \frac{V \times 10000}{L \times W}$$

g. Calculate the number of spray loads ha^{-1}

$$\text{Loads ha}^{-1} = \frac{\text{Rate of application ha}^{-1}}{\text{Tank capacity of sprayer}}$$

Example: How many liters of the commercial formulation Rogor® 30 EC (dimethoate) is required to treat an area of 0.5 ha, if the recommended dose is 0.1%?

a. Compute the total volume of spray (in L) needed to treat the area

Volume of spray after sprayer calibration:	320 L ha^{-1}
EC form:	Rogor® 30 EC
Recommended dose:	0.1%
Area to be treated:	0.5 ha

320 L x 0.5 ha = 160 L

Formula:
$$\frac{\text{Amount of spray required} \times \text{\% of spray concentrate}}{\text{\% of ai (EC)}}$$

$$\frac{160\text{ L} \times 0.1}{45} = 0.533 \text{ or } 533\text{ mL.}$$

Therefore, 533 mL of Rogor® 30 EC must be mixed in 160 L of water to spray 0.5 ha.

2. Power-operated Hydraulic Sprayers

Tractor-mounted sprayers

The tractor-mounted boom sprayer with a pump driven from the power take off (PTO), is used to apply 50-500 L ha^{-1} on field crops over a large area. Tanks with a large capacity may be mounted on trailers or as saddle tanks along side the tractor engine to spread the load more evenly. Some large sprayers are self propelled. However, these are used only where sufficient flat land allows the use of booms up to 27 m wide.

The important components of power-operated sprayers are:

a. Tank mounted on a sprayer
b. Pumps: piston, centrifugal, gear, roller-vane, and diaphragm pumps.

c. Pressure controlling devices: Pressure gauge and Pressure Relief Valves (PRV).
d. Nozzles: hydraulic nozzles; impact nozzles: cone nozzles and fan nozzles.
e. Agitators.

Calibration of tractor-mounted sprayer

This sprayer is calibrated by allowing it to travel over a known distance and then measuring the volume of chemical applied (in liters). The width of the swath must be measured (in meters) while keeping the distance between the nozzle and ground level constant. The pump pressure and travelling speed must be constant. The following parameters are important for calibration:

- pressure in tank,
- nozzle size (tip),
- forward speed of tractor, and
- swath width of spray.

Example: Calibration of a tractor-mounted sprayer (Allman) for spraying 300 L ha^{-1}.

Number of nozzles:	28 (fitted 50 cm apart)
Swath width of boom:	14 m (50 cm x 28 nozzles)
Area to be sprayed:	1 ha

Distance travelled (forward speed) by tractor:	100 m min^{-1} (6 km h^{-1})
Area covered by tractor in one pass:	100 m x 14 m (swath) = 1400 m^2
Nozzle discharge min^{-1}:	1.5 L min^{-1} (one nozzle)
Discharge from 28 nozzles:	1.5 L x 28 = 42 L
Discharge of spray solution over an area of 1400 m^2:	42 L
Discharge of spray solution over 1 ha (10000 m^2):	$\frac{10000 \times 42}{1400} = 300$ L

Therefore, 300 L ha^{-1} can be obtained with these parameters.

Calibration of a tractor-mounted sprayer with various settings.

Calibration	Tractor gear	Throttle setting	Ground speed km h^{-1} (discharge L min^{-1})	Nozzle tip size	Pressure PSi	Output (L ha^{-1})
1	1st high	4th notch	7 km	1.0 LM^{-1}	28	265
2	4th low	3rd notch	6.5 km	1.25 LM^{-1}	32	290
3	4th low	2nd notch	6 km	1.5 LM^{-1}	35	300
			300 L ha^{-1}			

Sprayer calibration aims at obtaining a spray pattern and droplet size that will ensure optimum coverage of a target area with uniform sized droplets without causing runoff. Calibration should, therefore, take into account:

- Target area: canopy area to be sprayed (a large leaf area requires a large volume of water).

- Droplet size: fine droplets cover a large area with less volume and reduce runoff, but can cause more drift and evaporation losses under warm and windy conditions.

- Once the volume of spray and droplet size are determined, the nozzle size and their spacing on the boom should be decided keeping in view the height between the boom and the crop canopy.

- All hydraulic nozzles work effectively only within a given pressure range. The sprayer pump should, therefore, deliver the required volume with the correct pressure. To do so, the tractor must be driven at an optimum speed (engine rpm) in order to deliver power through PTO or hydrostatic drives to the pump input.

- Given that the type of nozzles, pressure obtained, tractor rpm, spray swath, etc., remain constant, the only variable that can be adjusted is the volume of spray/unit area with the speed of the tractor. This can be done by gear selection (if the engine speed is fixed).

- The volume ha'[1] can be regulated by slightly adjusting the pressure regulator or engine speed with little effect on pump output.

3. Air Carrier Sprayers (Mist Blowers)

The use of portable air carrier sprayers, known as motorized knapsack mist blowers, follows the development of light weight, two-stroke engine aeroplanes suitable for aerial spraying over large areas.

The fan in these sprayers produces a high velocity air stream which is diverted through a 90° elbow to a flexible discharge hose. The most common nozzle fitted in these sprayers is the shear nozzle (gaseous energy nozzle). Air is drawn into the fan at a high speed and discharged through a flexible tube in which a liquid flow nozzle is mounted. As the high velocity air stream passes over the nozzle, it makes the emerging liquid break into droplets which then enter the air stream and are sprayed.

Calibration of knapsack motorized mist blower

a. Check all the components of the sprayer to see if they are in working condition.
b. Fill the sprayer with water sufficient for at least 1 minute of spraying.
c. Record the time taken to spray the measured volume with a stop watch.

4. Electrodyne Sprayer (Electrostatic Sprays)

The functioning of the electrodyne sprayer is based on a system which atomizes and propels charged droplets of chemical spray by electrical forces set up between a nozzle with a positive high voltage charge. Since the charged droplets are readily deposited on an 'earthed' object, e.g., a plant, the total deposit on the foliage can be significantly increased compared to uncharged sprays.

The liquid pesticide is poured into a bottle and fed by gravity to the nozzle, where it picks up charged droplets (positive charges) generated by batteries. The liquid leaves the nozzle in a number of uniform ligaments which break up into electrically-charged droplets. The positively- charged droplets move along curved electrical field lines towards and around the plants, covering the visible as well as hidden surfaces. The size of the droplets range between 20 and 200 microns.

A special feature of this type of sprayer is that the formulations used in it come in a special bottle fitted with the particular nozzle required.

5. The Birky Sprayer

The Birky knapsack sprayer is the first low volume (LV) spinning disc sprayer which does not require batteries. The need to apply herbicides at very low volumes gave rise to this sprayer.

The spinning disc of the Birky sprayer is driven by air supplied by a pneumatic pump to a turbine. Since it has no batteries, it reduces spraying cost. The spray swath can be increased to about 1.6 m.

Some of the advantages of a Birky sprayer are:

- A low water requirement that makes it ideal where water is not readily available.
- Its one spray-load covers 1/4 of an hectare (20 L ha^{-1}).
- A working output of 3-4 ha day'^{1}, compared to one hectare by the knapsack sprayer.
- Requires less physical effort to operate and is less tiring for the operator.
- A pneumatically-driven disc.
- Easy to maintain and has a wider spray swath.
- Droplet size ranges between 250 and 300 microns.

Operation of a Birky sprayer:

- Calibrate the sprayer before spraying in the same way as is done in the case of a knapsack sprayer.
- Start operating the handle to obtain the correct speed of the spray disc (a whistling sound will be heard).
- Open the tap. Swing the spray tube sideways to check the proper flow and atomization of the spray solution.
- Start spraying and maintain a proper ground speed.
- Swing the spray tube sideways from time to time to check whether the sprayer is working properly.

6. Controlled-droplet Application (CDA) Sprayers

These sprayers (Fig. 5) apply the correct size and uniform droplets on a given target area so that optimimum use is made of the spray volume and dosage. It is a logical extension of the ultra low volume (ULV) concept.

The most promising method of controlling droplet size within fairly narrow limits is by using centrifugal energy nozzles (spinning discs or cups) which adjust droplet size by varying their rotational speed. A suitable formulation and flow rate are selected so that at a given rotational speed, droplet formation is from ligaments with a minimum number of satellite droplets.

The volume of spray depends not only on the droplet size selected but also on droplet density. Uniform droplet density can be obtained by using as little as 500 mL ha^{-1} of the formulation with a droplet size of 46 m or 1-8 L ha^{-1} at 70 μm or 200 L ha^{-1} at 340 μm droplets.

Spraying procedure

To avoid contact with the spray, the drift operator must walk progressively up-wind across the field through nontreated crops. The sprayer is held either with the handle across the front of the operator's body or over his shoulder, with the disc above the crop pointing downwind. The

Figure 5. Controlled-droplet application sprayer.

spinning disc is normally held 1 m above the crop. It may be necessary to hold it lower while spraying the first swath along the leeward side of a field in order to reduce the chemical's drift outside the treated area.

7. Dusters

Appliances that are used for distributing dust formulations are called dusters. Dusters may be manually or power operated. Machines used for applying dusts mainly consist of a hopper (dust chamber) with an agitator, an adjustable orifice or other metering mechanism, and delivery tubes. Some dusters are power operated, e.g., motorized mist blower-cum-dusters, tractor-mounted dusters, and rotary dusters.

The following types of power dusters are generally in use:

Tree duster

This duster has an upright metallic discharge tube varying in length from 1 to 4 feet, which helps carry the dust upwards to the trees. The height upto which the dust can be carried depends on the length of the tube and the engine's horsepower. Generally a long hose (10 feet) is used to dust tall trees.

Row crop duster

This duster has 4-8 outlets in the fan chamber. Each outlet is connected by flexible pipes meant to spread the dust, and arranged on an iron rod in the rear of the tractor for delivering the dust right on the crop. Crops grown in a row are most suitable for treating with these dusters. Row crop dusters can be fitted on to any vehicle or animal-drawn trolley and can dust vast areas.

All-purpose dusters

These range from the small knapsack and wheel barrow or skid type dusters to the large tractor or vehicle-mounted power dusters. They usually have a single delivery outlet connected to a 4-6 foot multidirectional flexible delivery pipe. They are used for all kinds of crops except tall trees, and can dust 20-30 acres day^{-1} depending on crop height and formulation dosage.

Self-propelled dusters

Power dusters of this type are mounted on a frame carried by 3 or 4 wheels driven by an engine.

Motorized knapsack sprayer-cum-dusters

These dusters are light in weight, generally powered by 0.5 -1.0 hp engines, and can be carried on an operator's back. The frame has a shock proof cushion with shoulder straps.

The hopper and delivery hose pipes are small and the tank can hold upto 8-10 kg of dust. The machine's total weight with the dust can be around 20 kg.

These dusters can be converted into a sprayer (mist blower) by removing the agitating tube from the tank and fixing the hose in the outlet of the chemical tank.

The advantages and disadvantages of dusting over spraying.

Advantages	Disadvantages
Treatment costs less	Higher cost of active ingredient
Covers a larger target area than spraying	Uneven deposition and poor adherence to the canopy
Equipment is light in weight and easy to handle	Limited choice of dust formulations
Dust formulations have a greater shelf life than EC and deteriorate less rapidly	Dusting cannot be done when very windy
	Weather condition is a constraint (dust washes off after rain)

Different Types of Nozzles and their Main Uses

Nozzles are an important part of spraying equipment. They vary in their delivery system.

Hydraulic Energy Nozzles

In this type of nozzle, liquid under pressure is forced through a small opening. The velocity of the liquid breaks it into droplets. Properties of the liquid, such as surface tension, specific gravity, and volatility influence the delivery of the spray mix.

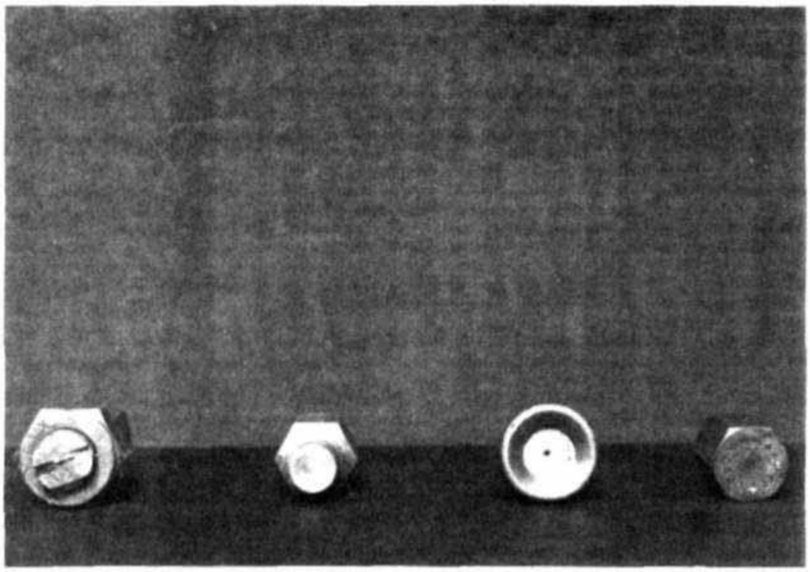
The various types of hydraulic energy nozzles are:

- Cone jet nozzles: Hollow cone jet and solid cone jet which are used for foliage sprays (Fig. 6).
- Flat fan: This is used for spraying on flat surfaces and in aerial spraying.
- Impact nozzle or flood jet: This is a low pressure nozzle with coarse spray, mainly used for herbicide application (Fig. 7).

- Other types: The adjustable nozzle (Fig. 8) and the swirl nozzles (Fig. 9) for spraying in two different directions.

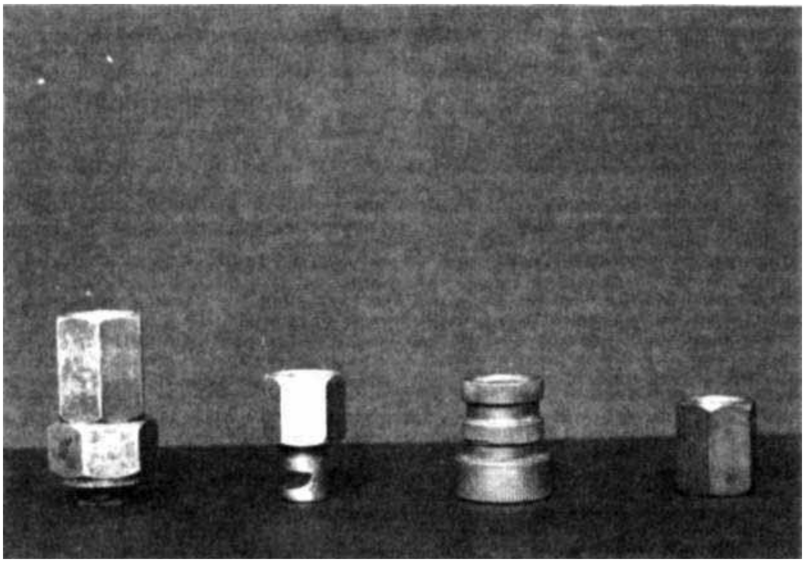
The main components of a hydraulic spray nozzle are:

- Body
- Cap
- Strainer-sieve
- Tip



Front view

(Types from left)
Flat fan
Flood jet
Hollow cone
Hollow cone



Side view

(Types from left)
Flat fan
Flood jet
Hallow cone
Hallow cone

Figure 6. Different types of nozzles.

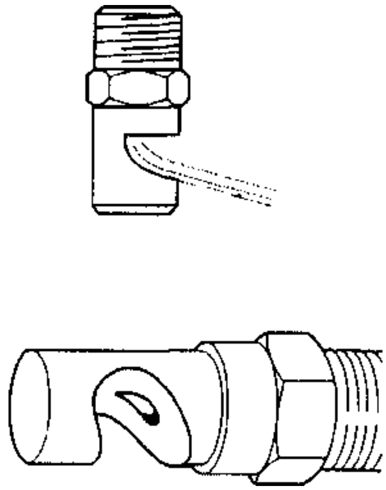


Figure 7. An impact nozzle.

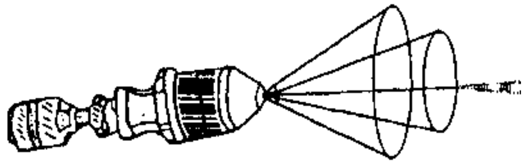


Figure 8. An adjustable nozzle for distant target.

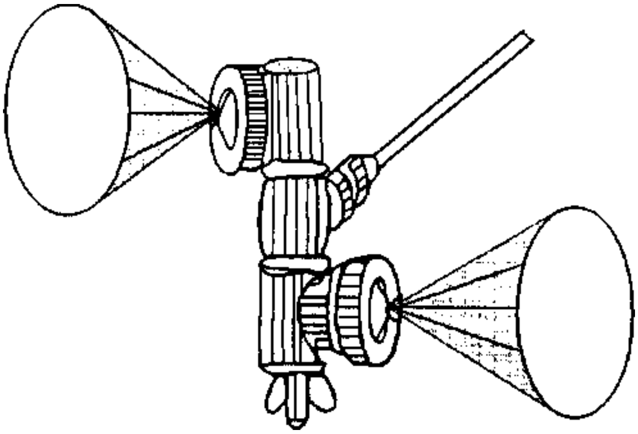


Figure 9. A swirl nozzle used for spraying in two different directions.

The pattern of droplet distribution and the amount of liquid sprayed (Fig. 10) depend on:

- type and design of nozzle,
- diameter of nozzle orifice,
- discharge angle of spray,
- operating pressure (P),
- fluid sprayed, and
- weather conditions.

Gaseous Energy Spray Nozzles ('Twin-fluid')

In this kind of nozzle, the liquid disintegrates into droplets by the impact of a high speed air stream on the spray liquid. Droplets are formed at a relatively low air pressure (less than 0.3 bar). However, when fine (aerosol) droplets are required, the volume of air must be increased. The rate at which the liquid flows into the nozzle depends on its viscosity. An increased flow of liquid and lower air speed result in large droplets which are mainly used for spraying on trees and bushes.

Centrifugal Energy Nozzles

The spray liquid is fed near the center of a rotating disc in these nozzles. The liquid is uniformly distributed to the serrated periphery of the disc by centrifugal force. It is propelled from the edge of the disc in the form of ligaments, and breaks down into droplets. A lower rotational speed and higher flow rate result in larger droplets. This nozzle is mainly used to apply low volumes with controlled droplet size and also in air-carrier sprayers.

The diameter of a single droplet (d) produced by a rotary nozzle can be calculated approximately thus:

$$d = \frac{\text{constant}}{\text{rpm}}$$

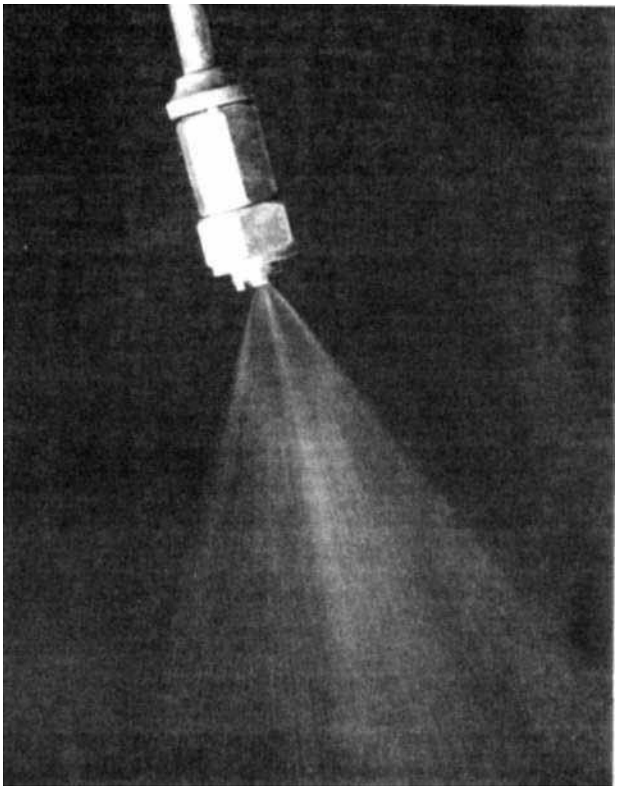
where d = droplet diameter (μm).

Effect of Droplet Size and Spray Coverage

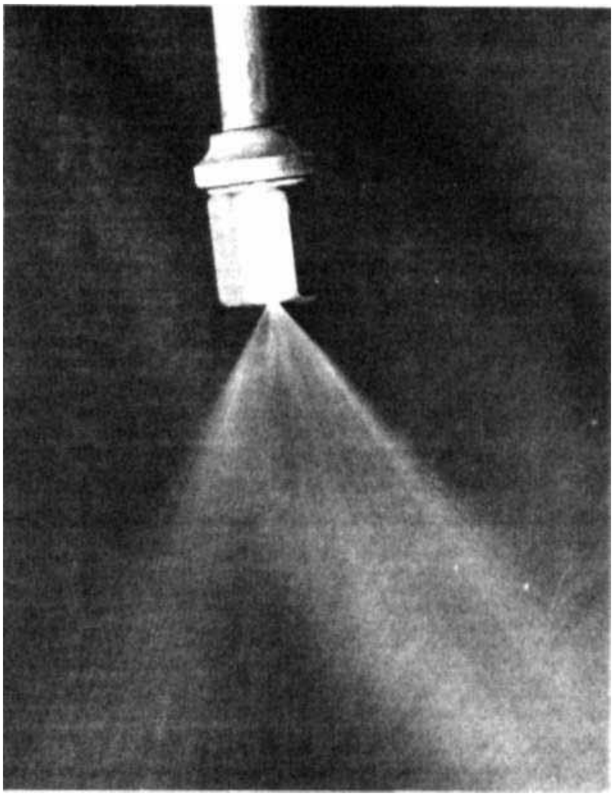
Distribution of spray. Droplet size, density, and penetration can be visible on water-sensitive papers tagged on to a plant at different heights. Droplets deposited on the plant surface spread and increase up to 3 times in size. The smaller the droplet, the greater the spread factor.

Nozzle Erosion and Spray Pattern

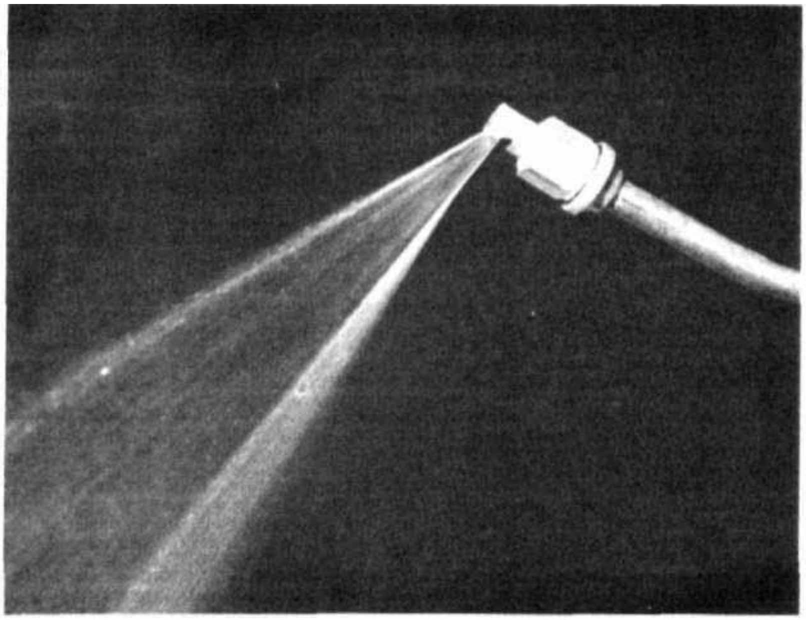
The accuracy of the deposition of spray droplets depends on the nozzle. The orifice of the nozzle tip gets enlarged over a period of time by the combined effects of the chemical action and the abrasive effect of the particles. These may be in the 'filler' portion of wettable powder formulations, where foreign particles are frequently suspended in the spray. This is referred to as nozzle-tip erosion and results in an increase in liquid flow rate, droplet size, and an alteration in spray pattern. An increased flow rate can lead to an overdose of pesticides. The discharge from a nozzle or group of nozzles can be measured with a patternator (Fig. 11), which monitors the liquid discharged through a flow meter. Water is sprayed into one, two or three nozzles on to a channelled table and collected in a sloping section which drains into calibrated collecting



Flat fan



Hollow cone



Flat jet

Figure 10. Nozzles and their spray pattern

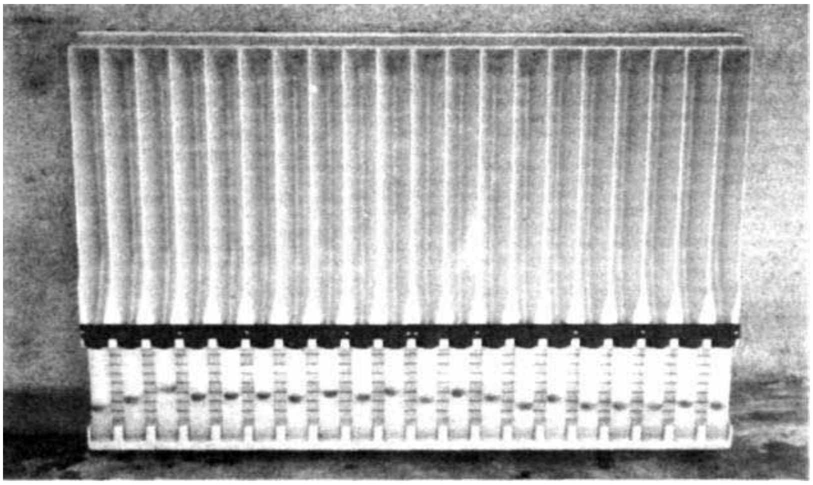


Figure 11. A patternator

tubes at the end of the channels. The nozzle is usually mounted 45 cm above the tray andconnected to a similar spray line. The patternator can be placed under a tractor boom to find out the variation in spray distribution along its length. The coefficient of variation of a boom pattern can be obtained when limits for individual nozzle patterns have been defined using a fluorescent tracer technique to determine liquid distribution.

Advantages and disadvantages of CDA over conventional spray applications.

Advantages	Disadvantages
Produces smaller and uniform size droplets	The smaller droplets tend to evaporate easily and drift from the target area
The smaller the droplet, the greater the spread factor and the better the coverage	Application has to be under ideal weather conditions
No diluent is required	Selective in use of formulations
Easy to carry, use, and maintain	Hazardous to operator and surroundings because of the use of high concentration of chemicals
Covers large areas in less time and with less inputs	Losses due to wind
Wider swaths and no runoff	Strict adherence to weather conditions

Calibration of Equipment

The spray volume can be calculated theoretically by the following formula:

$$\text{Application rate in L ha}^{-1} = \frac{600\ \text{L} \times \text{L min}^{-1}\ \text{(nozzle discharge)}}{\text{Swath width (m)} \times \text{Speed m min}^{-1}}$$

Maintenance and Safe Handling of Equipment

Regular preventive maintenance of equipment is required so that the components which are subject to wear and tear are replaced before they wear out. Proper maintenance of equipment is, therefore, essential.

Problems Associated with Spraying Equipment

Nozzle blockages

If a nozzle blockage occurs while spraying, the nozzle tip and filter should be replaced with clean points. The blocked nozzle should be cleaned and spares should be taken to the field. When spares are not available, water or a solvent should be taken to the site of operation to clean the blockage. The occurrence of blockages can be reduced by filtering the spray liquid while filling the chamber.Inefficient pumps

Pumps are fitted with 'O' ring seals or leather or synthetic cup washers. As the seals can get damaged due to suspended spray particles, they should be checked regularly. Apart from cleaning and replacing damaged parts, it may be necessary to change the formulations used or to improve the filtration of water before use.

Leakage

'O' ring washers and other types of seals are liable to wear and tear or damage when hose connections, trigger valves, and other components are unscrewed. Compression spray equipment and certain motorized knapsack mist blowers function properly provided they are airtight.

Maintenance and safe handling

a. Daily maintenance

- Clean after use.
- Check pump, nozzles, etc., before operation with water.
- Inspect mobile parts.

b. Periodic preventive maintenance of the following is important:

- Pumps
- Pipes and connections
- Pressure gauges and pressure regulators
- Agitator
- Nozzles and booms
- Tank components
- Engine

c. Off-season maintenance and storage. All plant protection equipment must be stored in a cool and dry place and in the shade.

- Equipment should be washed thoroughly with plain water before storage.
- Grease and lubricants should be applied to joints and surfaces wherever required to protect from rust.

Storage of Equipment

After each day's field work and at the end of the season, the sprayer's pump, control units, booms, hoses, and engine should be checked thoroughly before storing in a dry place. All spraying equipment should be kept locked and away from children, food, and farm animals, and measures taken to prevent rats from nibbling at hoses and other parts. Many small hydraulic sprayers are preferably stored upside down with the lid removed to allow complete drainage of formulation. If engines are to be stored for a prolonged period, the spark plug should be removed and a little oil, preferably formulated with anti-rust additives, poured into the crank case. The engine should be turned over a couple of times to enable the oil to spread evenly. At the end of each day, it is advisable to add some oil to any type of sprayer pump. This is not necessary if the sprayer is to be used again the following day.

Hints for Trouble-shooting

Two-stroke Engines

Problem	Remedies
Engine does not start	
<u>Fault in fuel system</u>	
Fuel cock has not been opened or is blocked	Ensure there is sufficient fuel in the tank. Open the fuel cock. If the fuel flow is not smooth, remove cock, clean, and replace.
Air vent in fuel tank filter is blocked	Clean vent.
Thimble filter in carburetor is blocked	Remove filter, clean, and replace.
Main jet in carburetor is blocked	Remove, clean, and replace.
Water in carburetor float bowl	Remove and clean. Check whether fuel in tank is contaminated with water.
Float needle sticking and stopping petrol supply	Remove needle. Check for burrs or rough surface. Remove rough surface. If not possible, replace with a new needle.
Too much fuel in engine (flooding)	Close fuel cock, and remove spark plug. Open throttle and pull recoil starter rope to turn engine over a few times. Clean and replace.
<u>Fault in ignition system</u>	
High-tension lead to spark plug is loose or disconnected or insulation is broken or burned	Fasten lead securely to plug. If badly damaged, replace.
Dirty spark plug; carbon or oil deposits on electrodes	Remove plug and clean. Set gap between points as recommended by manufacturer. If

porcelain insulation is damaged, replace	with a new plug.
Contact breaker points dirty or pitted	Clean and adjust to correct clearance when points are open. If honing fails to remove pitting, replace with a new set.
Exhaust blocked	Remove exhaust and clean or replace with a new one.

Engine runs erratically or stops

Dirt or floating debris in fuel system	Clean all fuel lines, filters, and carburetor bowl, and ensure there is no air in fuel line.
Main jet blocked	Remove, clean, and replace. Do not use nail, pin or wire to clear obstruction.
High-tension ignition lead is loose or 'shorting' on metal parts of the engine	Check that the lead is firmly affixed to the spark plug. Where it has been chafing on bare metal, either cover the bare wire with insulation tape or replace with a new lead.
Fuel running low in tank. Engine vibration or operator's irregular movement leaves outlet pipe uncovered, resulting in fuel starvation	Refill tank with correct fuel mix.

Engine lacks power

Choke is closed	Open choke.
Fuel starvation	Partially blocked pipes or filter should be removed and cleared.
Air cleaner blocked	Remove and clean by washing in petrol, and squirt a little light oil on the cleaner element. Conform to manufacturer's recommendations.
Dirty carburetor	Remove from engine. Dismantle carefully, clean, and examine all parts. Worn-out parts such as the float needle valve must be replaced.
Loose or leaking joint at carburetor flange to cylinder	Check gasket. Replace if worn-out or damaged and tighten nuts or studs.
If whistling noise is heard from the cylinder when the engine is running, there is a possibility of the cylinder head gasket being worn-out or damaged	Check carefully when the engine is running. If gases are escaping, remove head, fit new gasket, and tighten nuts evenly. On a new machine, it may be necessary to tighten the nuts evenly without fitting a new gasket. If heavy carbon deposits are seen on the piston crown or cylinder head when the head is removed, these should be scraped away carefully. The ring of hard carbon in the cylinder should not be disturbed.
Dirty exhaust	Remove exhaust. Clean carbon deposits if possible or replace with new part.

Engine backfires

Ignition may be badly retarded	Should only be attempted by trained or qualified workshop personnel. Magneto should be checked and reset to manufacturer's specification.
Carbon whisker bridging gap in spark plug	Remove plug, clean, adjust gap to correct clearance, and replace.

Overheating of engine

Incorrect mixture of petrol and oil in fuel tank	Drain tank. Refill with fuel and oil in the correct ratio (see handbook or markings on tank).
Incorrect size of main jet	Remove and refit one that complies with the manufacturer's specifica-tion.
Ignition retarded too far	To be checked and reset by a competent person.
Exhaust and silencer choked with carbon	Remove, dismantle, clean, and reassemble.

Faults with knapsack, lever-operated (piston or diaphragm) pumps.

Fault	Remedies
No spray	If resistance is felt on downward movement of lever when the cut-off valve is open, check nozzle for blockage, and clean if necessary. Check and clean filter or strainer in the handle of the cut-off valve. I f there is no resistance, check tank contents and fill if necessary. Ensure that the operating lever as well as all the connections to the pum p are tight. Check that when the lever is operated, the shaft or connecting mechanism and the piston or diaphragm all move together. Pump-valves and valve-seat should be checked. If worn-out or damaged these should be replaced. Dirt and debris should be rem oved.
No suction	Ensure that liquid is present in the container. Check whether the suction and discharge valves are not sticking and that the liquid ports that allow the flow from the tank to the pump are not blocked. If a piston-type pump is used, check whether the piston seal is not excessively worn-out or damaged, as this will allow the liquid to pass between the piston and cylinder wall.
No pressure	Check liquid contents of the container. Fill if necessary. After several strokes of the operating lever, check if air bubbles are rising to the tank's surface. If so, this could mean a leak in the pressure

	chamber. Where the pressure chamber is screwed onto the pump body, check that the seal is not damaged. Replace if necessary. Check both suction and discharge valves. Remove any accumulated dirt or debris from discs, balls, and valve seats. If discs are worn-out or damaged or the rubber is damaged, replace. If ball valves and seats are pitted or balls are no longer spherical, replace. If resistance is felt while pumping and no reading is seen on the pressure gauge, replace gauge. In a diaphragm-type pump, check whether it is seating correctly, is not damaged or split and that the rubber is not porous. Where a pressure-relief valve is embodied in the pressure chamber, check whether it is adjusted correctly and make sure that the spring-loaded valve is seating properly. Ensure that the openings between the pump inlet and outlet ports and the liquid container are not blocked. Check that the air vent in the filler cap is not blocked, as this could be the means of a vacuum forming in the container.
Abrupt fall in pressure	Check pressure chamber for leaks. Air bubbles seen rising to the liquid surface are a good indication. Check valves for discharge. The discharge rate may be higher than the pump capacity.
Liquid leaks on to operator	Where the pump is mounted on the base of the sprayer, a ruptured diaphragm, or one incorrectly assembled, will permit liquid under pressure to leak. In a piston-type pump, a worn-out piston seal or deep scratches in the cylinder wall will allow the liquid to escape and wet the operator. Check the container for cracks or leaking joints. Metal tanks can be soldered or brazed. Make sure that the lid of the container fits tightly.

Faults with compression sprayers (any tractor-mounted sprayer).

Fault	Remedies
No spray	Ensure the container has liquid. If the pressure gauge shows a reading and there is no spray when the cut-off valve is opened, close the valve and check the nozzle. If the nozzle is blocked, follow the procedure for clearing blocked nozzles. Check strainer in cut-off valve. Clean and replace. Check hose connections and tighten. If no reading is displayed on the pressure gauge, ensure that the gasket between the pump body and the liquid container is not leaking. Replace if leaking. Remove pump from container and check by giving a few strokes on the pump handle to test the valve. On each pressure stroke, the valve should 'grunt' or make a noise of escaping air. If the valve disc or ball is malfunctioning, it should be replaced. Where a dip-tube is part of the assembly, check that it is not blocked.
Leaks from pump	After the container has been filled with liquid spray to the required level, if on the first or second downward stroke of the pump handle

the liquid is forced up past the shaft and out through the guide, it is a sign that the valve requires attention. If strong resistance is felt on the downward stroke, it means the valve is faulty and that it has permitted liquid to enter the pump barrel and, as the liquid cannot be compressed, resistance is encountered.

Abrupt drop in pressure	Check that the filler cap or lid gaskets are serviceable and that the cap is properly secured. Also check that the safety valve is not leaking and is in working condition. Some compression sprayers have a constant-pressure valve fitted. Check that this is adjusted correctly and that there are no leaks from the point of entry to the tank. Ensure that all connections to the tank are tight and that all gaskets and washers are serviceable. Check the tank for leaking seams by pressurizing and immersing completely in water. Air bubbles rising to the surface indicate a leak. Leaking tanks cannot be repaired in the field. All repaired compression sprayers must be pressure-tested to at least twice the working pressure before being used.
Other faults	If the nozzle dribbles with the cut-off valve closed, it indicates that the '0' ring seal or the valve seat is damaged. Dismantle and check. Replace with new parts if unserviceable. In some plastic-type pressure gauges, the indicator sometimes becomes loose on its pivot, thereby giving a false pressure reading. By tapping the gauge against the hand, it can be seen whether or not it is loose. If it is, remove the protective glass front, replace the needle on the pivot loosely and, with it pointing to zero, press it firmly on to its mounting. Replace the glass and check with a master gauge.

Safety Precautions

The importance of taking safety precautions while handling and applying pesticides is often underestimated. An effort must be made to give a comprehensive account of the various aspects of the safe use of pesticides, especially for staff operating spraying equipment and handling chemicals.

Pesticide Selection

The most important step in pesticide safety is its proper selection. First of all, the pest problem must be correctly identified. Control measures need not be taken if the pest is not of economic importance. Once economic damage due to a pest has been established, the appropriate pesticide and method of treatment can be chosen. Buying an excess of pesticide should be avoided.

Handling and Mixing

The following safety guidelines should be followed while handling pesticides:

- Read the label on the pesticide container and leaflet carefully and follow the instructions therein.
- Make the calculations required for dilution.
- Obtain the application equipment required, including personal protective devices.
- Never work alone when handling highly toxic pesticides.
- Never leave pesticides unattended; children or animals may be affected.
- Mix chemicals in the open or in a well ventilated area.
- Measure and mix quantities accurately.
- Never eat, drink, smoke, rub eyes or face while working with pesticides.
- Do not use the mouth to siphon a pesticide from the container.

Disposal of Empty Containers and Unwanted Pesticides

- Empty the spray tank completely during spraying.
- Never empty the spray tank into irrigation canals, waterways, ponds or a well.
- Decontaminate and destroy devices such as empty containers, buckets, and measuring cups after use.
- Decontaminate all protective clothing and footwear.
- After handling pesticides, take a bath with plenty of water, detergent or soap.

All pesticides and pesticide containers must be disposed of carefully, failing which animal poisoning or environmental contamination can occur. Pesticide wastes should be buried. The site must be chosen carefully to prevent contamination of surface water runoff or groundwater. Pesticide wastes should be buried under at least 1/2 a m of soil mixed with lime to enhance degradation. Initially the pit should be lined with 5-10 cm of clay and coated with 2-3 cm of lime. Wastes should be added to the pit in layers not more than 10-15 cm deep and inter mixed with lime and bio degradable household waste, to assist in biological degradation.

Recognizing Pesticide Poisoning

The fundamental principle of safety in the use of pesticides is to prevent poisoning by exercising care. It is easier to prevent poisoning than to treat it. Different pesticides act differently on the human body, and the mechanism and mode of action varies for different insecticides. Some general symptoms however apply. They are listed below.

Symptoms of Organophosphorous poisoning

Headache, giddiness, nervousness, blurred vision, weakness, nausea, cramps, diarrhoea and discomfort in chest are some symptoms of poisoning. Other symptoms are sweating, excess salivation, rapid heart beat, and vomiting. Advanced stages of poisoning usually results in convulsions, loss of bowel control, loss of reflexes, and unconsciousness.

Symptoms of Carbamate poisoning

The symptoms of Carbamate poisoning are essentially the same as those caused by Organophosphorous pesticides.

Symptoms and signs of Organochlorine pesticide poisoning

Nervousness, nausea, diarrhoea, and convulsions may result from an exposure to a large dose. Liver and kidney damage have been observed in laboratory animals when administered repeated large doses.

First aid

Immediate medical attention can prevent pesticide exposure from turning into pesticide poisoning. All pesticides have recommended antidotes. Antidotes are drugs and chemicals which counteract the effect of pesticides. Though they do not prevent poisoning, once symptoms of poisoning develop, they counteract that action. Therefore, antidotes are not prophylactic and shouldn't be used routinely prior to handling pesticides.

In the event of pesticide exposure:

- remove patient from the source of contamination,
- remove contaminated clothing and give patient a bath,
- keep the patient calm, comfortable, and warm,
- give the patient immediate medical attention,
- identify the pesticide as accurately as possible, and
- if breathing has stopped, initiate artificial resuscitation.

Antidotes

Antidotes should be administered only under the supervision of a registered medical practitioner. Following are the antidotes generally used:

- Atropine: This antidote for Organophosphates or Carbamate poisoning is administered orally and in severe cases injected. In case of Organochlorine poisoning, this drug can become a lethal poison.

- Vitamin-K (Phytonadione): This is the prefered antidote for anticoagulant poisoning such as that caused by warfarin (Corax®).

- Calcium gluconate: This is administered intravenously and is effective against some Organochlorine insecticides.

- Amyl nitrate: Inhalation is effective against poisoning of hydrogen, cyanide, and calcium cyanide. Sodium nitrate and sodium thiosulphate may be given intravenously.

Personal Protective Equipment

Personal protective equipment (Fig. 12) prevents pesticides from coming in contact with the body or clothing. These also protect the eyes and prevent the inhalation of toxic chemicals. Personal safety gear includes clothing that covers the arms, legs, nose, and head. Gloves and boots are used to protect the hand and feet, and hats, helmets, goggles, and face masks to protect the hair, eyes, and nose. Respirators are used to avoid breathing dust, mist or vapour.

Different types of safety masks.

Spraying with a face mask on.

A Catridges face mask.

Figure 12. Safety in operation.

Body wear

Overall: Overalls made of cotton are the best but should not be worn without additional protective clothing. When there is a chance of contacting wet spray, large sleeves with cuff-buttons, and pants with buttons at the bottom offer good protection.

Aprons: Waterproof rubber or plastic aprons are effective. They should be long enough to protect the general clothing.

Head protection

Dust and mist settle easily on hair. Hats that are water resistant, wide brimmed with sweatbands are effective in protecting it. Many helmets provide attachments for face shields and goggles.

Goggles: These are used to protect the eyes from splashes, spills, mist, and droplets. Goggles with plain lenses and full side shields are preferable. The lenses may become coated with pesticide droplets during spraying; hence cleaning tissues or an extra pair of goggles are a must.

Face shield: A face shield is a transparent acetate or acrylic sheet which covers the face and prevents it from splashes or dust. Face shields allow better air circulation and provide a greater range of vision than goggles.

Hand and feet protection

Gloves: Dermal exposure occurs the most in the hand region. The use of gloves reduces this risk. Gloves should be up to 2 to 3" long below the elbow i.e., they should extend to the mid forearm. Waterproof gloves, such as those made of rubber, latex or PVC are preferable. After use, they should be discarded away from ponds, wells, and animals or even incinerated.

Footwear: Shoes made of rubber or synthetic materials like PVC and nitrite can be used to prevent dermal exposure of feet. Protective footwear should be calf-high and worn with the legs of the protective pants on the outside to prevent spray from getting in. Leather or fabric shoes should never be worn as they absorb pesticides. Shoes should be checked for any leakage or damage before use.

Respiratory equipment

A respirator is a device that offers protection to the lungs and respiratory tract. Different kinds of respiratory equipment are used based on the type and toxicity of pesticides. They include nose filters/disposable masks, cartridge respirators, canister-type respirators/gas masks, positive pressure breathing apparatus, self-contained breathing apparatus, and powered air cartridge respirator.

Safety in Application of Pesticides

Misuse of pesticides can be extremely dangerous. Apart from polluting the environment, they may prove fatal to human beings, animals, birds, and fish. Phytotoxicity often results when used in excess in plants. Judicious use, and careful and safe handling may prevent hazards. Safe handling of pesticides involves their proper selection and careful handling during mixing and application.

Safety During Application

This reduces risk and prevents pollution. It also ensures safety to animals, which may be nearby. The following precautions may be taken while applying pesticides.

- Wear clothing and use equipment that are protective.
- Spraying should be done in the windward direction, taking care to see that there are no animals, people, or animal feed nearby.
- Apply the correct dosage. Do not use higher dosages than recommended.
- Do not blow, suck or apply the mouth to any sprayer nozzle or other spraying equipment.
- Check the sprayer and spraying equipment for leaks before use. Use properly maintained and functioning equipment.
- If any irregular symptoms are noticed during application, medical attention should be sought immediately.

Suggested Books for Reading

Bindra, O.S., and Singh, H. 1971. Pesticide application equipment. New Delhi, India: Oxford and IBH.

David, B.V. 1992. Pest management and pesticides. Indian Scenario (Edi.) Namrutha Publications, Madras. 384 pp.

Anonymous 1983. Manual for pesticides users. New Delhi, India: Pesticides Association of India. 191 pp.

Matthews, G.A. 1979. Pesticide application methods. Longman, London. 334 pp.

Mehta, P.R., and Varma, B.K. 1968. Plant protection. New Delhi, India: Directorate of Extension, Ministry of Food, Agriculture, Community Development and Cooperation. 587 pp.

References:

(Source: Pal S.K & DasGupta S. K. 1996. Pesticide application. Skill Development Series No. 17, Training and Fellowships program. ICRISAT, Andhra Pradesh, India)

Probable questions:

1. Name different types of plant protection equipments.
2. Discuss when the Spraying equipments should be selected to protect plants.
3. Write notes on The Birky Sprayer.
4. State the advantages of use of a Birky sprayer.
5. How the Birky sprayer can be operated?
6. What is duster? How it is used?
7. What is Hydraulic Energy Nozzle? What are the components of Hydraulic Energy Nozzles? How it is used?
8. Write down the advantages and disadvantages of CDA over conventional spray applications.
9. Which safety guidelines should be followed while handling pesticides?
10. What are the perfect procedures of disposal of empty containers and unwanted pesticides?
11. Mention the Symptoms of Organophosphorous poisoning.
12. Write notes on antidotes? When it is applied?

Unit V

Natural enemy diversity of agricultural pests in India and their potentiality

Objective:

In this unit you will learn about Natural enemy diversity of agricultural pests in India and their potentiality

Introduction:

Natural enemies include those organisms that are capable and helpful in managing and suppressing the insect pests infecting field crops and causing economic damage. The natural enemies have a major key role to play in controlling insect pests attacking in agricultural field.

What are Natural Enemies?

Natural enemies are organisms that kill, decrease the reproductive potential, or otherwise reduce the numbers of another organism. In pest management, natural enemies are of interest because they can limit pest damage.

Major Characteristics of Natural Enemies:

(i) They should kill, reduce the rate of reproduction, inhibit growth, or shorten pest life.
(ii) They are usually specific to target species or to specific damaging life stages.
(iii) Their effectiveness may be affected by environmental conditions or host abundance.
(iv) The degree of control by naturally occurring pathogens may be variable.
(v) They are relatively slow acting; they may take several days or more to provide sufficient management.
(vi) They have the potential to generate epizootic outbreaks.
(vii) Microbial are nontoxic to humans in the conventional sense, safety precautions should be followed to minimize exposure.
(viii) They are non-toxic to animals and Eco- friendly in nature.

Naturally Occurring Bio-Control Agent:

Natural biocontrol is the reduction of a pest population by its natural enemies, without human intervention. The insect has several naturally occurring ‘natural enemies’ or ‘farmer’s friends’, these biological control agents are organisms that feed on insect’s egg, larval, pupal and adult stage. A major challenge is to develop conditions that allow these beneficial organisms to reach their full potential.

A. Predators:

Predators are free-living organisms that must consume various preys to complete their life cycle. They prefer to feed on prey that is smaller than them. Insect predators include coccinellid beetles, ground beetles, anthocorid bugs, syrphid flies, and predatory mites. Coleoptera, Neuroptera, Hymenoptera, Diptera, Hemiptera, and Odonata are the most common insect orders that prey on other insects and mites. Moreover, some kinds of mites and spiders feed on a wide variety of insects and mites. Some predators, such as praying mantids, dragonflies, and beetles, utilise biting or chewing mouth parts to eat their prey, whilst others, such as assassin bugs, lacewing larvae, and hover fly larvae, use piercing and sucking mouth parts to feed on their prey's body fluids. Sucking feeders frequently inject a potent poison that swiftly immobilises their prey.

Adult predators might be monophagous (only feed on one species), oligophagous (feed on several species), or polyphagous (feed on many species). Polyphagous predators, if extremely mobile, may be efficient in pest management in disturbed environments, whereas monophagous or oligophagous predators tend to be connected with prey in more stable systems. While many predators are carnivorous as juveniles and adults, others also eat on nectar, honeydew, or plant food. Female predators frequently deposit their eggs close to their prey. Predators frequently utilise visual and chemical cues to locate plants with prey, while prey pheromones may also be used as cues. Predators frequently concentrate on more common prey species, which may make them less efficient at controlling a pest at low densities but may make them especially successful at suppressing pest outbreaks.

Important Predators:

Predators are those insects which can catch hold of and feed on large number of insect preys in their entire life time. They can be either prey specific or general feeders. Few important predators are listed below.

1. **Tiger beetles:**
   They are cylindrical shaped, greenish elongated beetles with sharply pointed mandibles. The body is covered with whitish to yellowish spots and stripes.

2. **Ground beetles:**
   Ground beetles are generalist predators with powerful jaws that feed on nearly any soil-dwelling insect. There are many species of ground beetle, usually found under debris, in soil cracks, or moving quickly along the ground. Adult ground beetles are mostly black or brown with ridged wing covers and have long legs. Their abdomen is usually shiny and hard and have long antennae. Adults vary in size, depending on species.

Larvae live in leaf litter on the ground or in the topsoil. They have elongated bodies and distinct, curved mouthparts that extend from the head. Pupae are brown to yellow and are rarely observed since they pupate underground in a soil cell.

3. **Lady bird beetles or lady bugs or lady beetles:**
   They are tiny, hemispherical shaped beetles. The body colouration varies from light yellowish to dark reddish colour and with varyingly designed with spots and lines. The grubs are blackish in colour with spiny structures over the body. They are voracious predators on aphids, whiteflies, mealy bugs and other soft bodied insects.

4. **Fireflies or glow worms:**
   They are medium sized beetles with specialised light emitting organs. Both adults and grubs predate on soft bodied insects.

5. **Dragonflies and damselflies**:
   These are general predators and known for their aerial predation. Dragonflies are robust and active fliers, while damselflies are fragile and weak fliers. They predate on soft bodied insects and larvae.

6. **Aphid lions or green lace wings:**
   They are pale greenish coloured flies with characteristic golden coloured eyes and netted wings. They lay whitish stalked eggs and grubs are whitish, creamish or light greenish in colour and mostly covered under debris (camouflage). They are active predators of aphids.

7. **Preying mantids:**

These are large and active predators with varying body colouration. They usually mimic the flowers or the background where they are resting. They catch hold of moving insects with their snapping or raptorial forelegs. The mantids being general predators predate on large variety of insect pests.

8. **Cone nose bugs or reduviid bugs or kissing bugs:**
   They are usually blacking or reddish in colour with narrow head and elongate body. The abdominal region is laterally extended beyond the wings. They suck the body sap from soft bodied caterpillars and are active predators.

9. **Robber flies:**
   They are elongate flies with very prominent compound eyes. The body is covered with long bristles. The legs are stout, hairy and suited for capturing the prey. They are very active aerial predators feeding mainly on soft bodied insects.

10. **Flower flies or hover flies or syrphid flies:**
    they are actively flying, brightly coloured flies hovering over flowers and resembling honey bees. They lay whitish, cylindrical eggs near aphid colonies. The maggots with whitish to transparent body prey on aphids and adults feed on nectar and pollen. They areseen in large numbers during bright sunny days and adults aggregate in large numbers on Juniper plants.

11. **Spiders:**

    There are two types of spiders, hunters and web spinners. Both are active predators and feed on large number of insect pests and help in reducing the pest population.

B. Parasitoids:

Parasitoids are free-living organisms whose adults lay eggs inside or attached to a single host organism and their immature stage develops by feeding on or in a single insect host after which they are fully grown and pupate and eventually kill the host. The adults may also feed on other resources, such as honeydew, plant nectar or pollen. The parasitoids must be adapted to the life cycle, physiology and defences of their hosts species so that they have narrow host range and many are highly specialized such co-evolved parasitoids can exert a strong impact on populations of the insect and are thus good candidates and accurate identification of the host and parasitoid species is critical in the use of biological management programmes.

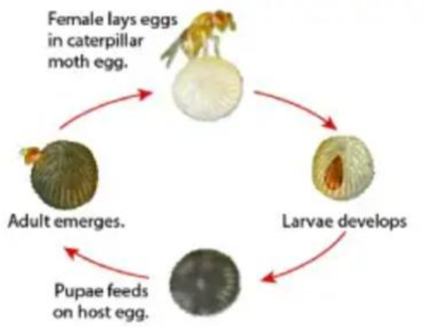
Important Parasitoids:

Parasitoids are those insects which insert their eggs into body of an insect host with the help of specialized ovipositor and the larvae or grubs which emerge from the eggs, feed on host tissue and cause death of host insect. Usually one parasitoid requires one host for completion of its life cycle. Mostly the parasitoids are host specific. Few important parasitoids are listed below.

I. PARASITIC WASP:

1. **Trichogramma wasps:**

   These are very tiny insects and rarely visible to naked eyes. They are egg parasitoids. The adult female inserts eggs into the eggs of other host insect and the grubs emerging feed on egg contents and cause mortality of the host eggs even before hatching. Internal parasites of insect eggs. *Trichogramma* spp. attack many types of insects, especially moths and sawflies. Some species prefer eggs of certain types of hosts while others prefer certain habi-tats and may be able to parasitize almost any insect egg in that environ-ment. Adults are 4s inch (1 mm) or less and often have wing hairs (setae) arranged in rows.



2. **Ichneumon wasps:**

   They are slender wasps with elongated body and ovipositor. The ovipositor is protruded outside and sometimes as long as the body. They are diurnal (active during day time) in behaviour and adults visit flowers and feed on pollen and nectar.

   External or internal parasites. Larvae or pupae of most types of insects are attacked by one or more species; beetles, caterpillars, and wasps are common hosts. Adults are usually slender (the abdomen is longer than the head and thorax combined) with a long ovipositor and 16 or more antennal segments. Genera include *Bathyplectes, Campoplex, Diadegma, Exochus, Hyposoter, Ophion,* and *Venturia*.

3. **Braconid wasps:**

   These are small, stout bodied insects with long slender abdomen which is longer than

head and thorax. The ovipositor is very prominent and used in piercing the body of host insect. The grubs feed on host tissues by staying inside the host body, but pupation occurs in silken cocoons on the body surface of host insect. They are usually gregarious (feed in groups) parasitoids and polyembryony (large number of grubs emerging from single egg) is the common phenomenon. Hosts include larvae of beetles, caterpillars, flies, and sawflies. Most larvae are internal parasites, but many emerge to pupate outside their dead hosts. Adults usually are less than % inch (13 mm) long with a slender abdomen longer than the head and thorax combined. Genera include Bracon, Chelonus, Cotesia (=Apanteles), and Opius.

4. **Chalcid wasps:**
   These are tiny wasps with well developed hind femur and coxa. The ovipositor is usually smaller in size and the body colour varies from shiny metallic black to light greenish black colour. Most of them are either larval or pupal parasitoids of lepidopteran insects.

5. **Bethylid wasps:**
   They are ant like tiny wasps, black in colour and the females are wingless. They are host specific larval parasitoids of lepidopteran insects.

6. **Yellow jacketed wasps or Hornets:**
   They are medium to large sized insects with yellow and black markings on the body. They construct papery nests with chewed wood and saliva. They capture and paralyse the caterpillars and deposit them in each cell in their nest and lay eggs over it. The grubs feed on paralysed eggs and pupate within the cell. They are diurnal in behaviour and very active during sunny days.

7. **Mud wasps or thread waisted wasps:**
   They are medium sized wasps with elongate and slender waist. The body colour varies from reddish to dark black colour. They construct earthen nests in the soil with saliva and red soil. The adults capture and paralyse the prey and provision it to grubs for feeding

in the nests.

II. **PARASITIC FLIES:**

1. **Tachinid flies or bristle flies:**
   They are small, brownish to blackish flies resembling house flies. The body is covered with long bristles. Adults pierce the body of host insect and lay their eggs. Maggots feed on host insect and pupate inside. They mainly parasitise on larvae and pupae of Lepidopteran and Coleopteran insects.

2. **Acroceridae, small-headed flies:**
   Internal parasites of spiders. Adults appear hunchbacked, with a small round head and globular abdomen. Eggs are laid on substrates in small clusters. Larvae hatch, move, and enter any spiders they contact.
3. **Bee flies:**
   Mostly internal and external parasites of Lepidoptera and Hymenoptera larvae; some species attack larvae of beetles, flies, and moths or eggs of grasshoppers. Most adults are stout, densely hairy, medium to large flies with a long, thin mouthpart (proboscis). Eggs are laid near hosts. Larvae crawl to hosts and enter them.
4. **Chironomidae, midges:**
   Most species have aquatic larvae that feed on decaying organic matter; others are external parasites of aquatic invertebrates, including mayflies and snails. Adults look like small, delicate mosquitoes and often swarm near water.
5. **Conopidae, thick-headed flies:**
   All are internal parasites, mostly of adult bees and wasps. Adults often pursue their host, grab it in flight, and insert their egg into the adult host's abdomen. Adult flies are medium sized, often yellow or brown, with a long slender abdomen and a head broader than their thorax.
6. **Cryptochaetidae, cryptochaetid flies:**
   All are internal parasites of scale insects. Only one species occurs in North America, Cryptochaetum iceryae, a small blackish blue fly that is an impor-tant parasite of cottony cushion scale.
7. **Nemestrinidae, tangle-veined flies:**
   Most species are internal parasites of locusts and beetle larvae and pupae. "Adults are medium sized and stout-bodied, with long mouthparts.
8. **Humpbacked flies:**
   Most species eat decaying organic matter; some are internal parasites of ants, bees, caterpillars, crickets, termites, moth pupae, and fly larvae. Adults are small to minute, with an enlarged, humped thorax and few wing veins.

9. **Pipunculidae, big-headed flies:**
   All are internal parasites, primarily of leafhoppers and planthoppers. Adults are small with a very large head com-posed mostly of eyes.

10. **Pyrgotidae, pyrgotid flies:**
    Internal parasites of adult June beetles and other Scarabaeidae. Adults are large, elongated flies with banded or colored wings; like their hosts, they are nocturnal and are rarely seen.
11. **Tachinidae, tachinid flies:**
    Most are internal parasites of immature beetles, butterflies, and moths. Other hosts include earwigs, grasshoppers, and true bugs. Adults are often dark, robust, hairy flies resembling a house fly, but with very stout bristles at the tip of their abdomen. Eggs are laid on hosts or on plants. Eggs on plants are eaten and then hatch inside the host or larvae hatch on plants and enter hosts that approach.

II. EGG PARASITES:

1. **Aphelinidae:**
   Hosts include aphids, mealybugs, psyllids, scales, and whiteflies. A diverse group of external or internal and pri-mary or secondary parasites. Some males develop as parasites off emales. Adults are usually 1 mm)long or less. Genera include Aphelinus
2. **Chalcididae:**
   Aphytis, Coccophagus, Encarsia, Eretmo-cerus, and Prospaltella (=Encarsia). One of the most important groups
3. **Aphidiidae:**
   Internal parasites of aphids. Aphids parasitized by aphidiids typically form tan or golden mummies, unlike aphids parasitized by aphelinids, which usually turn blackish. Small wasps, sometimes included in family Braconidae. Genera include Aphidius, Lysiphlebus, Praon, and rioxys.
4. **Chalcididae:**
   Mostly internal or external parasites of Diptera or Lepidoptera larvae or pupae, with some species attacking beetles or other wasps. Adults are robust, have a greatly enlarged hind femora (leg segment), and are often dark and shiny.
5. **Encyrtidae:**
   Internal parasites oft icks and various insect eggs, larvae, or pupae, including beetles, bugs, moths, mealybugs, and scales. Adults are usually less than 42 inch (2 mm) long. Genera include Anagyrus, Comperiella, Copidosoma, Encyr-tus, Leptomastix, Metaphycus, Pentalitomastix, and Psyllaephagus.
6. **Eulophidae:**
   Internal or external parasites of eggs, larvae, or pupae of flies, moths, and other wasps; also parasitize mites, spiders, scale insects, and thrips. Adults are small but usually 1 mm or larger. Genera include Aprostocetus, Chrysocharis, Diglyphus, Oomyzus, Tetrastichus, and Tamarixia.

7. **Mymaridae:**
   Internal parasites of insect eggs, including beetles, flies, grasshoppers, leafhoppers, and true bugs. Adults are less than 1 mm long and are distinguished by their stalked, narrow, elongate hind wings. Both wings are often fringed with fine hairs. Genera include Anagrus and Anaphes.
8. **Pteromalidae:**
   Mostly parasites ofb eetles, flies, and other wasps. Many are secondary parasites. Biology and appearance varies greatly among species. Adults are usually a little more than 1 mm long and black or metallic-green or bronze. Genera include Dibrachys, Perlampus, Pteromalus, and Scutellista.
9. **Scelionidae:**
   Internal parasites of spider and insect eggs, especially bugs and moths. Adults are usually less than 1 mm long. Females of some scelionids attach themselves to the female of the host and ride on it; when the host lays its eggs, the scelionid leaves the host and attacks the eggs (one insect attaching to another for transportation is called phoresy). Telenomus and Trissolcus are important genera.

Invasive insect pests and their natural enemies in India

The origin of species of insect is somewhere else, but they will spread into new areas, mayget established into the new natural environment and start causing economic and environmental damage, or harm to human health, and also disturbing their natural ecosystem, such species are called invasive species

1. **Fall armyworm:**
   Spodoptera frugiperda (J. E. Smith), (Noctuidae: Lepidoptera)

Natural enemies: The different kind of natural enemies of *S. frugiperda* are founds all over the world but in India, it becomes the most destructive insect pest species due to the absence of natural enemies. However different kinds of indigenous natural enemies were observed which were performing effectively against *S. frugiperda.* On this basis, recent studies describe the abundance of natural enemies of *S. frugiperda* such as larval parasitoids *Coccygidium melleum*, *Campoletis chlorideae*, *Eriborus sp*., *Exorista sorbillans*, and *Odontepyris sp*.; 3 predators *Forficula* sp., *Harmonia octomaculata*, and *Coccinella transversalis*; 1 entomofungal pathogen, *Nomuraearileyi*, were recorded were found attacking over the larvae of *S. frugiperda*.

2. **Nesting whitefly (Coconut):**
   Paraleyrodes minei Iaccarino, (Aleyrodidae : Hemiptera)

Natural enemies: *Serangium parcesetosum* Sicard is reported to be a predator of *P. minei*. Few parasitoids belonging to encyrtid were also recorded.

3. **Bondar's Nesting Whitefly (Coconut):**
   Paraleyrodes bondari Peracchi (Aleyrodidae: Hemiptera)

Natural enemies: Chrysopids and coccinellids have been reported to be effective predators of *P. bondari*, while no any species of parasitoid of the *P. bondari* is reported till now.

4. **Neotropical whitefly:**

   Aleurotrachelus atratus Hempel, (Aleyrodidae: Hemiptera).

Natural enemies:

Predators: Generally, *Dichochrysa astur* (Banks) (Neuroptera), *Jauravia pallidula* Motschulsky, *Chilocorus nigrita* (Fab.) (Coccinellidae) and *Cybochephalus* sp. (Nitidulidae) predators were found in whitefly infested fields.

Parasitoid: *Encarsia basicincta* Gahan, *Eretmocerus cocois* Delvare, *Encarsia* sp. and *Signiphora* sp. were found feeding in field conditions.

5. **Woolly whitefly:**

   Aleurothrixus floccosus (Maskell), (Aleyrodidae : Hemiptera).

Natural enemies:

Parasitoids: Two species of hymenopteran parasitoids, *Amituss piniferus* (Brethes) (Platygasteridae) and *Calesnoacki* How. (Aphelinidae), were introduced. In the northern regions *A. spiniferus* became well established and showed appreciable parasitic activity. *Cales noacki* was better able to adapt itself wherever it was introduced, reaching high level of parasitism on the whitefly nymphs everywhere. In the case of the absence of chemical control, *C. noacki* was found to parasitize 99 percent of *A. floccosus* young stages, and it isable to keep the population of whiteflies very low throughout the year. The development of *Cales noacki* may be slowing down due to the high range of temperature and relative humidity in the summer season, so that's the reason for the attack of pest whiteflies maybe increase in summer-early autumn. This increase of the pest whitefly population is, however, controlled again as conditions favor the development of *C. noacki*.

6. **Cassava mealybug:**

   Phenacoccus manihoti Matile-Ferrero, (Pseudococcidae,: Hemiptera)

Natural enemies:

Parasitoids: An effective natural enemy, *Apoanagyrus lopezi* (De Santis) (Hymenoptera: Encyrtidae) was found in South America. This parasitoid wasp was then introduced to West Africa for biological control of the mealybug.

Predators: *S. epeus* (Lepidoptera: Lycaenidae), *S. coccivora* (Coleoptera: Coccinellidae) and an unidentified anthocorid bug (Hemiptera: Heteroptera: Anthocoridae) are reported as a predator on *Phenacoccus manihoti*.

Scope for Employing Natural Enemies in Hill Agriculture:

The hill agriculture is practiced mainly in small distributed patches among the vast forest area. The crops cultivated are very diverse and cover very small area. Due to nonavailability of plant protection chemicals, farmers rely on use of plant extracts or cheaply available local insecticides which are broad spectrum in their action and less effective against insect pests but harmful to natural enemies. Instead of these low quality plant protection chemicals, farmers can resort their interest on landscape modification and encouraging population of natural enemies through artificial release. The reasons, why biological control would be successful in hill agriculture are:

a) Highly diverse cropping system that is capable of supplying insect predators and parasitoids with vast variety of insect hosts or preys along with pollen and nectar.
b) The forest trees and hedges along the fields act as beetle banks and resting and nesting sites for natural enemies during adverse climatic conditions.
c) The forest trees also provide alternate food source to natural enemies during off seasons.
d) The microclimatic conditions are very favourable for natural enemies to feed, breed and reproduce in large numbers and perpetuate to other adjacent fields.
e) The farmers mostly rely on natural pest control allowing some yield loss without much of chemical intervention. So, one or two artificial release of natural enemies would serve their purpose of insect pest management.
f) The diverse flora can support and build up the faunal diversity without much of human intervention after artificial release.
g) The pest population density is low and rarely reaches alarming stages because of both biotic and abiotic control over pest populations. So, biological control would be the best management method that can be employed for managing insect pests in hill agriculture.

Potential and suitable natural enemies of cabbage insect pests:
In case of Cabbage, potential and beneficial natural enemies of aphids (*Brevicornye brassicae*) are lady bird beetle, lacewing, syrphid fly larvae, spiders and braconid wasps; natural enemies of Dimond back moth (*Ptutella xyostella*) are Chalcid wasps (especially Trichogrammatidae), syrphid fly larvae and spiders; natural enemies of Cabbage butterfly (*Pieris brassicae*), lacewing, spiders and syrphid fly larvae; natural enemies of Cabbage semi lopper (*Trichoplusia ni*), Tachinidae fly and Chalcid wasps (especially Trichogrammatidae) and natural enemies of Cutworm (*Agrotis ipsilan*) were Tachinidae fly, Chalcid wasps (especially Trichogrammatidae), ground beetles, spiders and braconid wasps.

Potential and suitable natural enemies of Tomato insect pests:
In case of Tomato, potential and beneficial natural enemies of aphids(*Myzus persicae*) are lady bird beetle, lacewing, syrphid fly larvae, spiders and braconid wasps; natural enemies of Cutworm (*Agrotis ipsilan*) are Tachinidae fly, Chalcid wasps (especially Trichogrammatidae), ground beetles, spiders and braconid wasps; natural enemies of Fruit borer (*Helicoverpa armigera*) are Tachinidae fly, Chalcid wasps (especially Trichogrammatidae), ground beetles and spiders and natural enemies of white fly are lady bird beetle, lacewing, syrphid fly larvae, spiders and braconid wasps.

Potential and suitable natural enemies of Brinjal insect pests:
In case of Brinjal, potential and suitable natural enemies of aphids (*A. gossypii* and *Myzus persicae*) were lady bird beetle, lacewing, syrphid fly larvae, spiders and braconid wasps; natural enemies of Cutworm (*Agrotis ipsilan*) were Tachinidae fly, Chalcid wasps

(especially Trichogrammatidae), ground beetles, spiders and braconid wasps; natural enemies of flea beetle were spiders and braconid wasps and for Brinjal fruit and shoot borer (*Leucinodes orbonalis*), Tachinidae fly, Chalcid wasps (especially Trichogrammatidae)

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Probable questions

1. Write the name of larval parasitoids parasitized on *Spodoptera frugiperda* (any two)?
2. Mention the saline features of natural enemies of agricultural insect pests.
3. Write the management strategies of woolly whitefly by Natural enemies?
4. Briefly describe about the Potential and suitable natural enemies of cabbage insect pests?

Unit VI

Economic decision levels for pest population: a) Concepts of economic levels b) Dynamics of economic injury levels c) Calculation of economic decision levels using economic levels

Objective: In this unit we will discuss about economic decision levels for pest population which includes concepts of economic levels, dynamics of economic injury levels and calculation of economic decision levels using economic levels

(I) Concepts of economic levels:

Economic decision levels are the keystone of insect pest management programs. They indicate the course of action to be taken in any given pest situation.

D.L.Chant had termed the study of economic decision levels as 'Bioeconomics'.

Sensible pesticide use is possible only with an understanding of the insect population level that causes economic damage, without such knowledge we risk making absurd economic blunders, like spending more to suppress an insect than the value of the commodity the pest could destroy. Conversely, understanding and properly using economic decision levels in dealing with pests can increase producer profits and conserve environmental quality, by encouraging more rational use of insecticides.

Economic decision levels usually are expressed as number of insects per area, plant or animal unit, or sampling procedure. Such levels are given as degree of plant damage or combinations of both numbers and damage.

Now question arises:

- Is all insect attack to be computed as assessable damage?
- If not at what point does it become assessable?
- Is control work required when damage is below that point?

Economic damage and the damage boundary:

Economic damage was originally defined as the amount of injury which will justify the cost of artificial control measures.

Injury is the effect of pest activities on host physiology that is usually deleterious. Damage is a measurable loss of host utility, most often including yield quantity, quality or aesthetics. Injury is concentrated on the pest and its activities and damage is cantered on the crop and its response to injury.

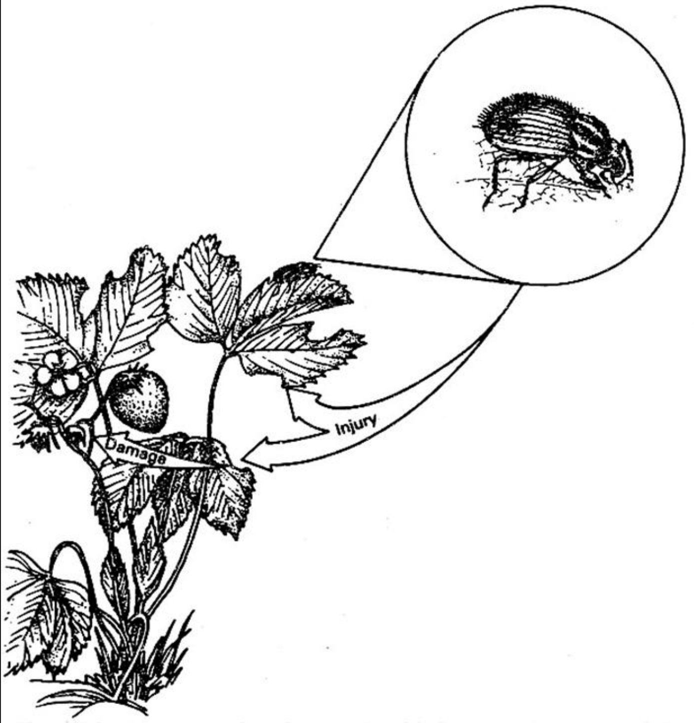


Fig.1 Diadram relating insect leaf injury to damage of the harvestable produce

Gain threshold: Management costs ($/acre)/ Market value ($/bushel) = bushels/ acre

For eg. If management costs for application of an insecticide are $10 per acre and harvested corn is marketed for $2 per bushel, then gain threshold would be 5 bushels per acre. In other words, at least five bushels per acre would need to be saved with an insecticide application for the activity to be profitable. Gain threshold therefore is very important measure because it is a worksheet standard: our margin for determining benefits of management and establishing decision indices.

Damage boundary: defined as the lowest level of injury where damage can be measured. The level is reached before economic damage occurs and is a necessary complement to the idea of economic damage.

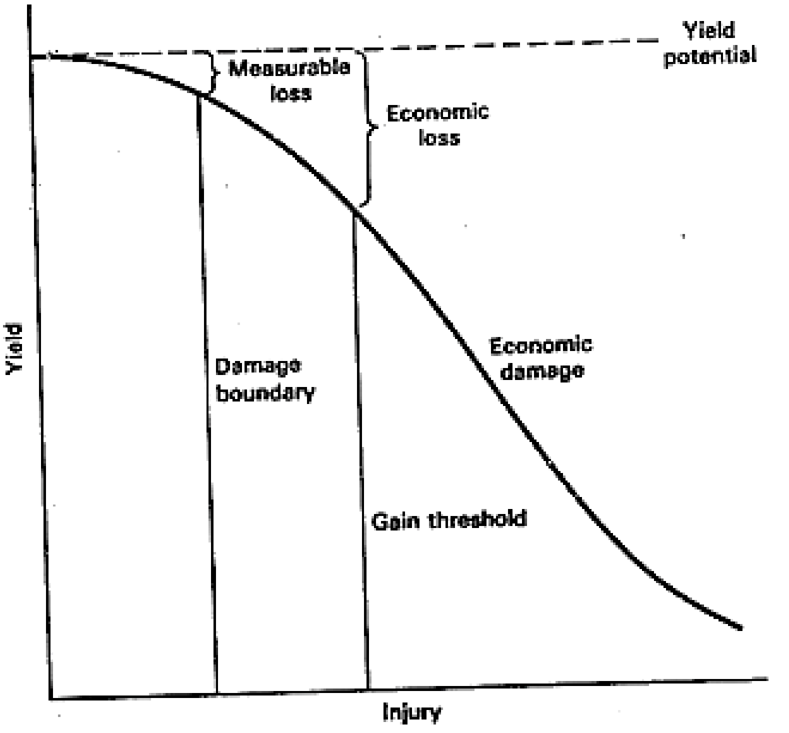
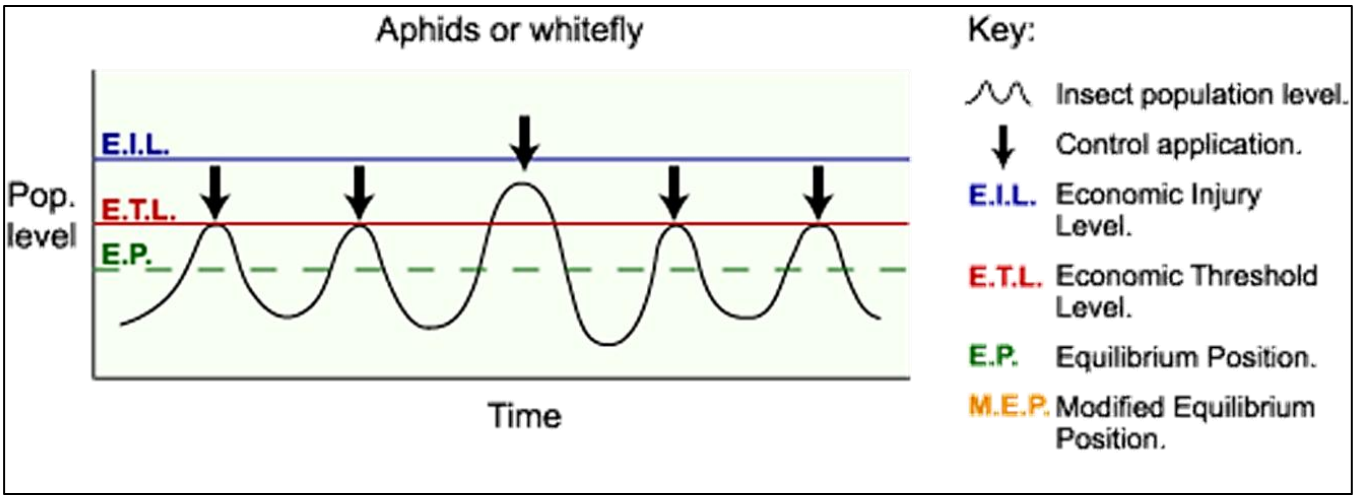
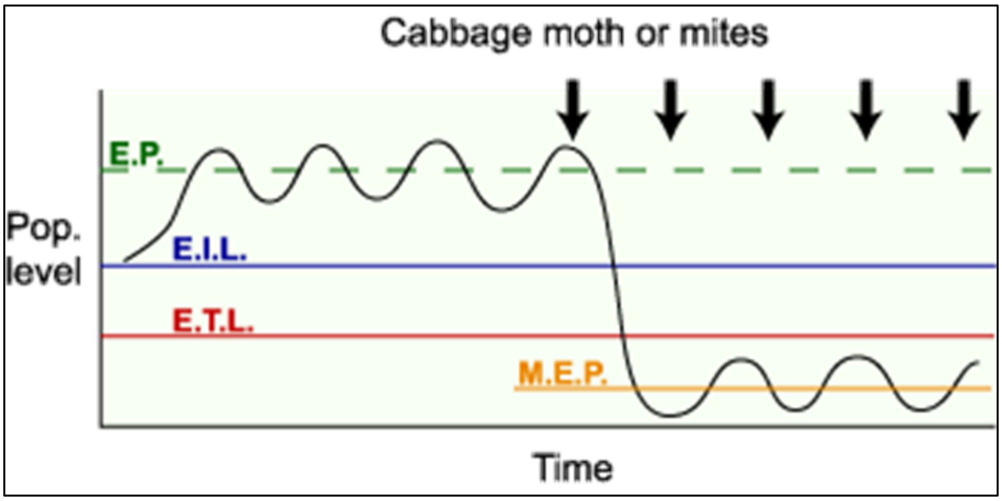


Fig.2 Graph showing relationship between the damage boundary and the gain thresold.

Relationship between Economic injury level EIL, Economic threshold level ETL, Equilibrium position EP and Modified Equilibrium position MEP:





E.T.L. Economic Threshold Level

The level of pest population that can be tolerated by the crop without affecting the economic or aesthetic value of the crop. However, the level of pest population has to be monitored and appropriate control measures need to be taken to prevent the pest population from reaching the Economic Injury Level.

E.I.T. Economic Injury Level

The level of pest population that can no longer be tolerated and control measure have to be taken to avoid any crop loss.

E.P. Equilibrium Position

Equilibrium position of a pest is the level of pest population which is stable in a region unaffected by control measures (see graph).

M.E.P. Modified Equilibrium Position

The level of pest population where control measure have been taken to lower the pest population below that of the Economic Threshold Level.

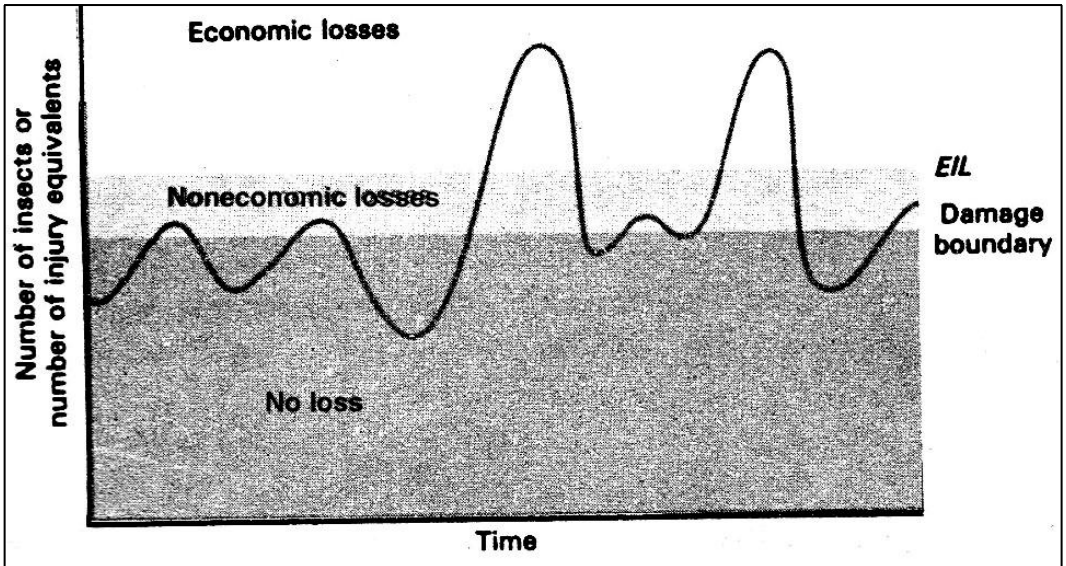


Figure 3 **Graph showing relationships of a hypothetical insect population with the damage boundary and the economic-injury level.**

Economic injury level: EIL is defined as the lowest number of insects that will cause economic damage or the minimum number of insects that would reduce yield equal to the gain threshold. It is usually easier to count insect numbers than it is to estimate the area of foliage removed by a pest population or the amount of juices sucked from plants.

In some instances, particularly when several pest species causing similar injury are present, insect equivalents may be considered instead of insect numbers. An insect equivalents is the amount of injury that could be produced by one pest through its complete life cycle.

To understand the development of an EIL using conventional insect numbers, let's consider the Gain threshold = 5 bushels/acre (previous eg.). Now if 1 insect/ plant causes 1 bushel/acre loss, then the EIL for the pest is 5 insects/plant.

In this eg 5 insects/plant potentially could consume enough plant tissue to reduce yields by 5 bushels/acre. Therefore, such an insect population is considered economic and management activities are justified. Insect populations below this level and whose potential growth will not allow them to reach this level are considered sub economic; no management is advised.

If management action can be taken quickly and loss can be averted completely, then the EIL can be expressed as follows: **VxIxPxD=C**

Where, V= market value per unit of produce (for eg $/acre)

I= injury units per insect per production unit (for eg % defoliation/insect/acre, expressed as a proportion)

P= density or intensity of insect population (for eg insects/acre)

D= damage per unit injury (for eg bushels lost/acre/% defoliation)

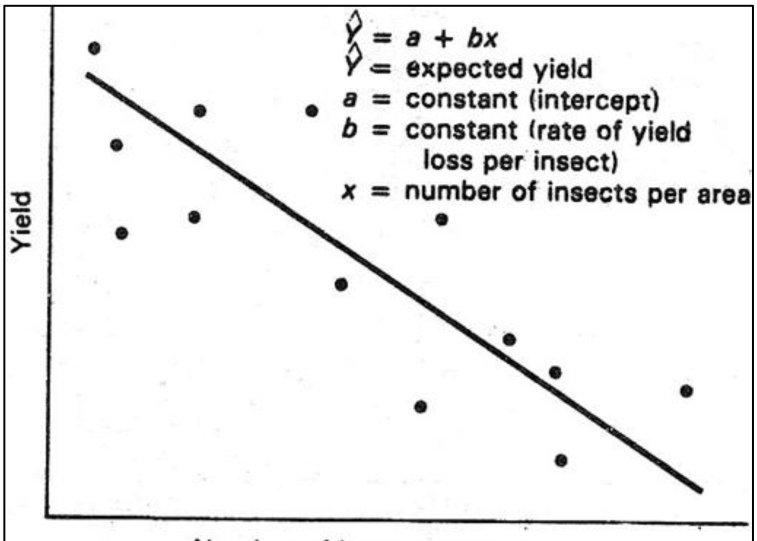
C= cost of management per area (for eg \$/acre)

Then, **P= C/VID and EIL=P …………(1)**

Modification of equation (1); P=C/VID or E=P

In instances where some loss from the insect is unavoidable, for example, if injury can be reduced only 80%, then the equation becomes P=C/VIDK, where K = proportionate reduction in injury (eg 0.8 for 80%).

With some insect pests, particularly piercing-sucking insects, the separation of the I and D variables presents a problem. This is because the I variable would represent, for plants, photosynthate removed, because these variables would be difficult to measure, a coefficient b representing loss per insect is substituted. These b coefficients are obtained from statistical regression analysis of data by using experimental populations and measuring yield losses. The b coefficient can be obtained from the following expression: Y=a+bx, where Y= yield/area; a= a constant (the y intercept); b= yield loss/insect and x= no. of insects/area; therefore EIL=C/Vb or EIL=C/VbK.

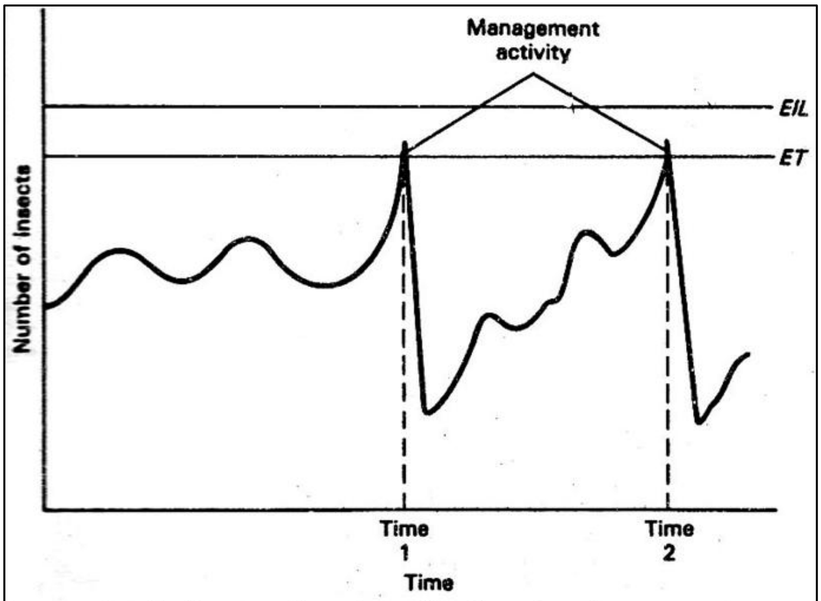


A linear-regression used in obtaining *b*, the loss per insect.

Economic threshold level ETL:

ETL indicates the no. of insects (density or intensity) when management action should be taken. It is also known as action threshold. ETL is actually a time parameter. If a pest population is growing as the season progresses, growth rates are predicted, and the ETL is set below the EIL. Therefore, we should take the action on an earlier date before reaching the EIL. No action is taken at levels below the ETL.

For the previous eg with an EIL of 5 insects/plant, we might set the ET at 4 insects/plant to obtain added reaction time and avoid some of the early losses.



Graph showing the relationship between the economic threshold (ET) and the economic-injury level (EIL) in taking action against an insect population.

(II) Dynamics of economic-injury levels:

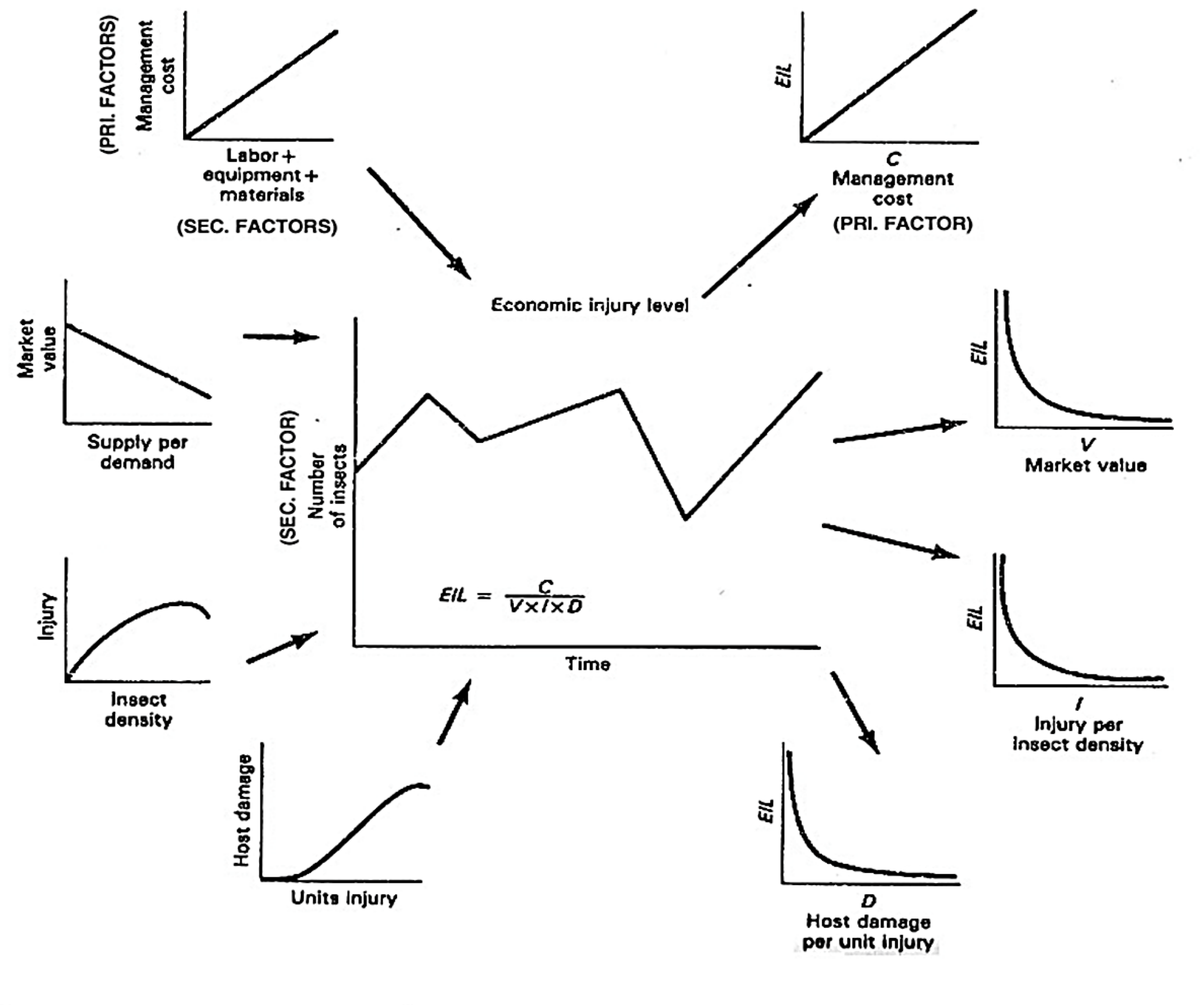
Economic levels are very dynamic. They change with changes in costs, values and production environments.

There are three kinds of forces: **Primary, secondary** and **tertiary variables** or forces behind change in economic decision levels.

Primary variables: crop value, management costs, degree of injury per insect, crop susceptibility to injury etc.

Secondary variables: host damage/ insect-injury relationship, labor+equipment+material cost etc.; they change the function of the primary variables.

Tertiary variables: weather, soil factors, biotic factors, human social environment; they change the function of the secondary variables.



Graphs showing relationships of the EIL components and their variables. Primary components graphs to left) are affected by sec. variables like insect density and labor costs. These variables cause fluctuations in the EIL eith time (central graph). Resulting responses of the EIL to changes components are shown in graphs at right.

Degree of injury per plant:

Some of the most detailed studies of insect injury have been conducted with plants. Plants can be placed into at least **six different categories**:

I. **Stand reducers:** Insects that reduce stand (for eg. Cutworms, Lepidoptera: Noctuidae) produce an immediate loss in plant biomass and decreased photosynthesis of the crop. The total effect of stand reduction is governed by number, timing and dispersion of plant loss.

II. **Leaf-mass consumers:** Leaf consumption by insects is believed to directly affect absolute photosynthesis per unit of the remaining leaf tissue. Effect of the injury on plant physiology can be accounted for by measuring leaf mass consumed per unit land area, timing of leaf consumption and vertical distribution or location of the defoliation.

III. **Assimilate sappers:** These comprise mostly piercing-sucking and rasping insects which remove plant carbohydrates and nutrients after carbon is taken up and before the plant can convert it to tissue.

IV. **Turgor reducers:** These pests represented by soil insects and stem feeders, influnce plant water and nutrient balances at root and stem sites ultimately destroying the conductive tissues of the plants. Severe instances of reduced water uptake result in decreased plant turgor, followed by reduced expansion of leaves, stems and fruits as well as reduced photosynthesis.

V. **Fruit feeders:** When insects injure fruits, they cause damage to the harvestable products. Such injury can affect quality, yield or both depending on utility of the product. Although injury to fruit may seem simple and straight to measure, but it is no so because yield losses usually are not proportional to % loss of reproductive sites.

VI. **Architecture modifiers:** Injury from these types of insects change plant morphology to reduce yield. For eg

(1) threecornered alfalfa hopper on a soybean stem causes the plants to lodge. These insects girdle the stem thus destroying the conductive tissues. The lodged plants may die outright or continue to live and grow in a "goose-neck" fashion.

(2) tillering of a corn plant caused by stalk borer, Papaipema nebris, feeding on the growing tip. This change can reduce physiological yield of the plant as well as harvestable yield.

Crop susceptibility to injury:

The relationship between injury and crop yield or utility is the most fundamental factor of the EIL. This relationship provides the biological foundation on which economic and practical constraints can be superimposed. 5 major factors involved in the injury/crop or plant-response relationship. They include the following:

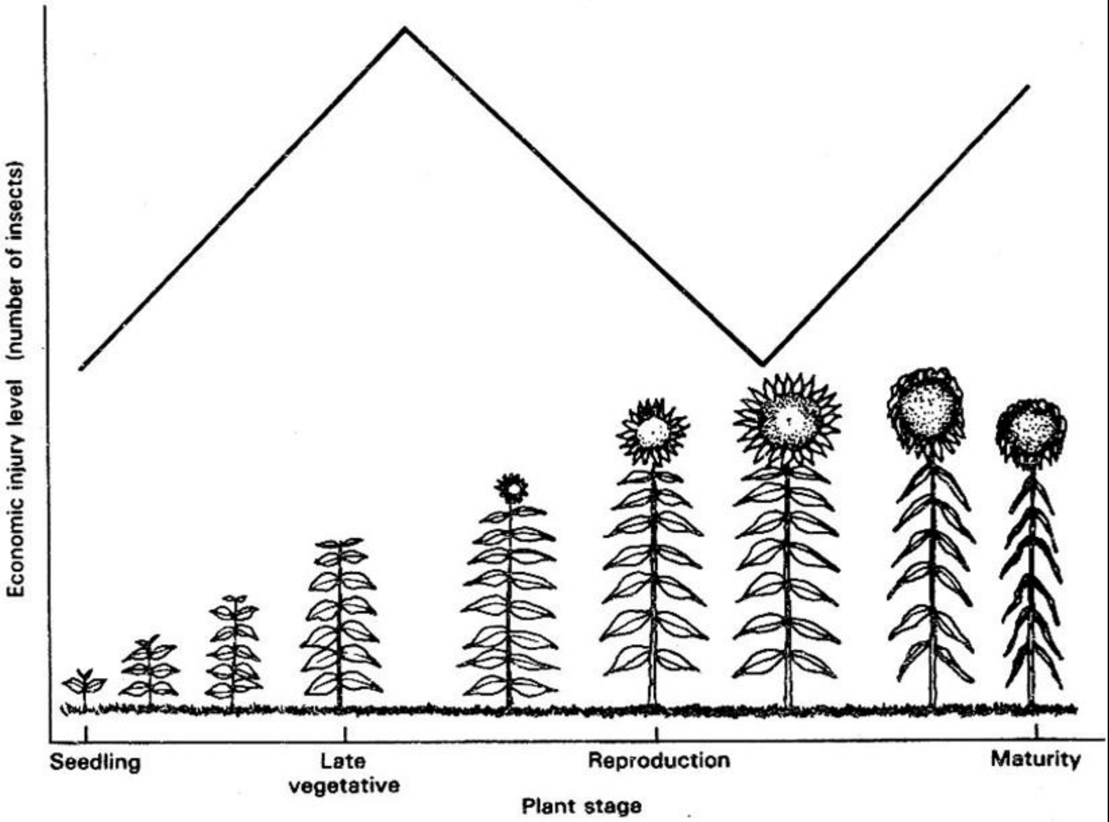


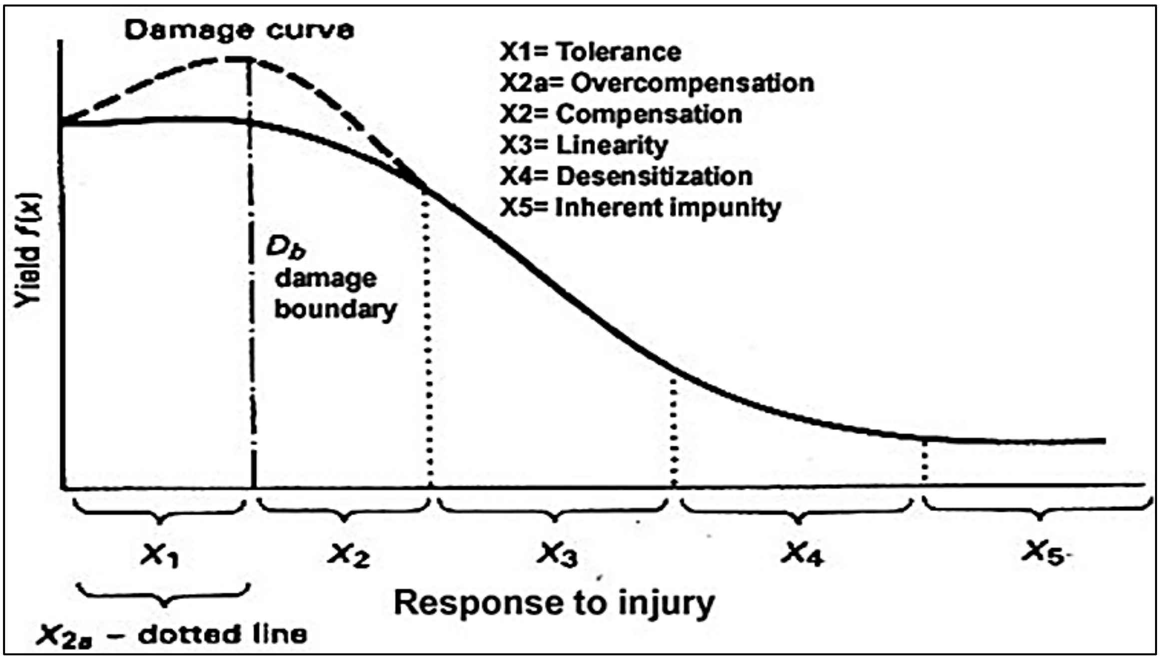
Figure ' Graph showing typical changes in the economic-injury level with changes in plant stage. Many plants are particularly vulnerable during reproductive stages.

1) **Time of injury**- Usually, seedlings are the most susceptible, whereas older plants are better able to tolerate or compensate for injury. The timing of pest injury is most often accommodated in EILs by recognizing a separate yield loss-to-injury relationship for each different stage of crop development.

2) **Plant part injured**- Usually, a distinction is made between injury to yield-forming organs (direct injury), and injury to nonyield-forming organs (indirect injury). In general, EILs are calculated for only one injury type, insects do not produce both direct and indirect injury simultaneously.

3) **Injury types**- It is important to note that the nature of the injury is fundamental to how a plant responds to different intensities of a particular form.

4) **Intensity of injury**- The relationship between the intensity or amount of injury and plant yield is the most important factor in the injury/crop-response relationship.



X1 Tolerance- no damage per unit injury, yield with injury equal yield without injury; f(x1) = a constant (zero slope).

X2a Overcompensation- negative damage (yield increase) per unit injury; f(X2a)= positive or decreasing slope.

X2 Compensation- increasing damage per unit injury.

X3 Linearity- maximum (constant) damage per unit injury.

X4 Desensitization- decreasing damage per unit injury.

X5 Inherent impunity- no damage per unit injury, yield with injury less than yield without injury; f(X5)= constant zero slope.

5) Environmental effect- Factors in the environment often play an important role in determining how plants respond to injury. Within a given season, environmental factors may influence how long a plant remains susceptible to a specific type of injury. Similarly, between seasons a plant's response to the same level of injury may be drastically changed. For eg soybean-yield response curves against the attack of green clover worm, *Plathypena* sp., shows higher economic damage curve during wet years than during dry seasons.

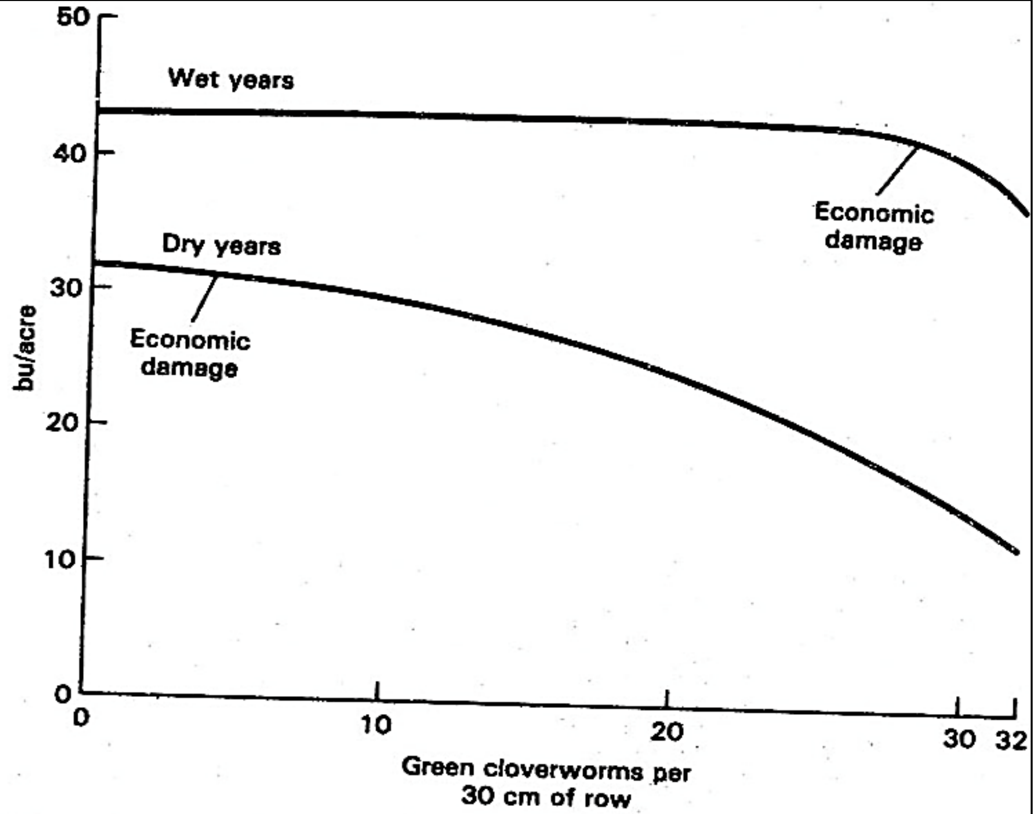


Figure Stylized soybean-yield response curves to defoliation of the green cloverworm, *Plathypena scabra*, in years of normal rainfall (wet) and those with below normal rainfall (dry). Note the differences in number of insects required to cause economic damage between the two types of years.

(III) Calculation of economic decision levels:

In developing economic indices for pest management decisions, the principal level to estimate is the EIL, because the EIL includes the basic damage potential of a given insect population. ET then determined from the knowledge of the EIL.

When several pest species causing similar injury, EIL is generally calculated by using the relation, EIL=C/VID (*vide supra*).

But with changes in the input variables EIL for an insect is a continuing process. Market value, management costs, plant susceptibility, degree of injury all are dynamic quantities i.e all change with time and condition. In that situation EIL is calculated as EIL= gain threshold /loss per insect.

For example: EIL calculation with the potato leafhopper, *Empoasca fabae*, on soybean plant. They cause leaf necrosis or hopper burn especially in young plants.

Yields were measured at season's end and statistical regression analysis that determined the loss per insect at each plant growth stage.

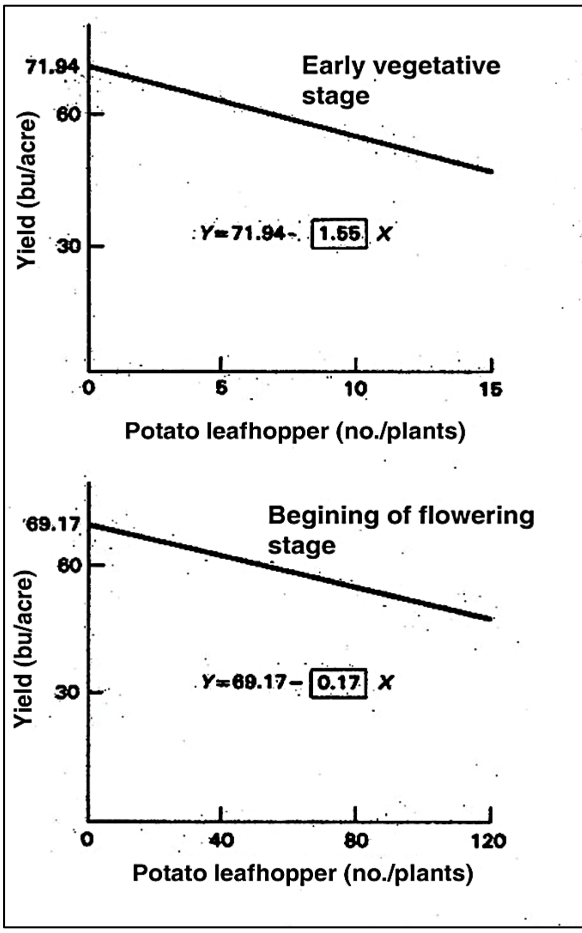


Fig. Statistical regression analysis of soybean yield on number of potato leafhoppers, *Empoasca fabae*, present per plant at three plant stages.

Again, Gain threshold= Market cost/ market value. Here for example, we estimate the cost of applying one pound of malathion insecticide by aircraft at $9.50/acre and the harvested gain say for $4.15/bushels, the Gain threshold= $9.50/acre / $4.15/bushels =2.29 bushels/acre.

Next, EIL can be calculated for each stage as follows:

Seedling stage EIL= 2.29 bushels/acre/1.55 bushels/acre/insect= 1.48 laefhopper/ plant.

Beginning of flowering stage EIL= 2.29 bushels/acre/0.17 bushels/acre/insect= 13.47 laefhopper/ plant.

Beginning of pod fill stage EIL= 2.29 bushels/acre/0.08 bushels/acre/insect= 28.63 laefhopper/ plant.

Implementation categories of economic thresholds:

The place and ultimate use of ETs in pest management programs becomes clearer when their state of development is categorized. Decision rules currently used can be placed in one of four categories:

(1) No thresholds- Decisions in this category were common in applied entomology prior to the late 1950s. Although using thresholds is considered an advance for most insect problems today, there are certain situations where they are not appropriate:

Pest sampling cannot be done economically. Practical response to cure a problem cannot be implemented in a timely way. Once detected the problem cannot be cured. ET is immeasurably low.

Populations are intense, where general level of fluctuation is always above the EIL. Management implementation in these situations usually must depend on prevention, rather than cure.

(2) Nominal thresholds- This category represents decision rules that are declared on the basis of a manager's experience. Such levels which may be used over broad regions tend to be static, unchanging with changes in the variables.

(3) Simple thresholds- These levels are calculated on the basis of average responses of hosts to injury caused by an insect. The four major inputs of market value, management costs, tissue destroyed per insect and yield reduction per tissue destroyed are used to make calculations. This threshold also failed to consider possible interactions of several pests and changes in the cropping environment that influence decisions.

(4) Comprehensive thresholds- Establishing comprehensive thresholds for crops is an intimate understanding of the host plant and its reaction to combined stressors, both biotic and physical. Such an understanding should include quantification of processes as dry-matter partitioning throughout the growing season and not only a simple measurement of yield as has been done in the past. It is only in this way that the effects of a pest community can be understood and thresholds developed in the context of the entire production system. Implementation of such thresholds requires advances in computer-based information delivery systems.

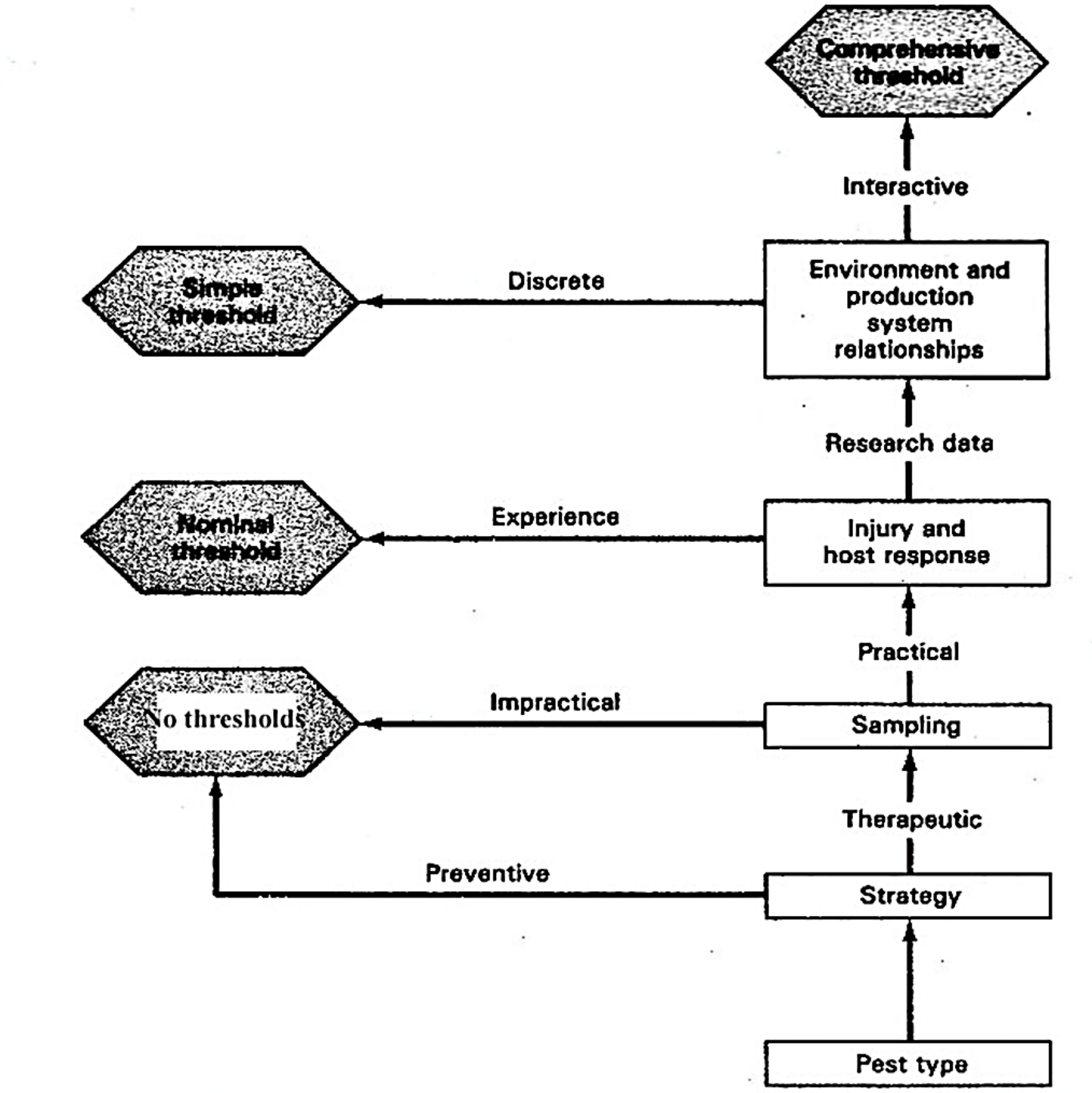


Diagram of the implementation categories of economic thresholds.

Limitations of the EIL concept:

i. Decision levels for management of some types of pest cannot be determined with EILs. Many vectors, medicinal pests, veterinary pests and pathogens often do not have a quantitative relationship between damage and injury, consequently they are not amenable to calculated EILs. Moreover, because the market value of human health and life is so high that it is virtually impossible to put an economic limit on the control of most medical pests.

ii. Economic considerations also limit our ability to use EILs for aesthetic pests. It is very difficult to place a monetary value on the reduction in aesthetic value associated with a given type of pest injury. Usually any assigned values are subjective, which greatly limits their usefulness in calculating EILs.

iii. A similar problem exists with forest pests. Almost all the components of EILs are difficult to estimate for forest insects, accurate market values are problems because projections often must be made many years in advance, management costs may vary greatly and frequently must include more environmental and social costs than in other pest management programs, and the injury/crop-response relationship may be difficult to determine because the growth of the crop spans many years.

iv. Some pests have a quantitative relationship to yield, but they are still difficult to manage with EILs. Pathogenic microorganisms on plants, although not entomological, are a good example of this. Here the yield reduction produced by many pathogens are usually quantitative related to pathogen number. Unfortunately sampling and quantifying the number or amount of these pathogens are usually impractical.

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Few questions related to the topic:

1. Name the secondary variables that change the function of primary variables in economic injury levels.
2. What is modified equilibrium position (MEP) of pest attack?
3. Enumerate the various limitations of the EIL (economic injury level) concept in pest management. The management costs for the application of carbamate is INR 260/ acre and the harvested crop is marketed for INR 20/ bushel. Calculate the gain threshold per acre.
4. State one condition of pest attack where the equation P= C/VID gets modified.
5. What is the significance of economic threshold level (ETL) of pest attack?

6. What is the difference between injury and damage caused by pest attack? The management costs for the application of Malathion is Rs 150 / acre and the harvested crop is marketed for Rs 12 / bushel. Calculate the gain threshold per acre.

Disclaimer:

The study materials of this book have been collected from books, various e- books, journals and other e-sources.