

AEN 201

PRINCIPLES OF APPLIED ENTOMOLOGY (2+1)



LECTURE NOTES

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DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

CENTRE FOR PLANT PROTECTION STUDIES

TAMIL NADU AGRICULTURAL UNIVERSITY

COIMBATORE - 641 003

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AEN 201 PRINCIPLES OF APPLIED ENTOMOLOGY

(2+1)

LECTURE SCHEDULE

THEORY

1. [Principles of applied entomology – economic classification of insects.](#)
2. [Bee species – comparison – castes of bees – bee behaviour and bee dance.](#)
3. [Apiary management practices – bee pasturage – foraging – seasonal variations.](#)
4. [Role of bees in cross pollination – their exploitation – case studies with selected crops.](#)
5. [Bee products – their properties and uses.](#)
6. [Effect of agricultural inputs on bee activity – pesticide poisoning.](#)
7. [Role of pollinators, weed killers and other beneficial insects.](#)
8. [Management of household pests, vectors of human diseases and pests of cattle and poultry.](#)
9. [Insect ecology – definition – balance of life in nature – reproductive potential and environmental resistance.](#)
10. [Population dynamics – role of biotic factors – competition – parasitoids and predators. Life table – Interspecific and intraspecific relationship.](#)
11. [Abiotic factors – physical, nutritional and host plant associated factors on insect population. Bioresources in ecosystems.](#)
12. [Pests – definition, categories and causes for outbreak of pests. Losses caused by pests.](#)
13. [Pest monitoring – pest surveillance and forecasting – objectives, survey, sampling techniques and decision making. Economic Threshold Level and Economic Injury Level. Factors influencing Economic Injury Level and Economic Threshold Level.](#)
14. [Pest Management – definition – need – objectives, requirements for successful pest management programme. Components of pest management.](#)
15. [Cultural methods – definition – characteristics, requisites – farm level practices and community level practices, advantages and disadvantages.](#)
16. [Physical methods – definition – use of heat, moisture, light, electromagnetic energy and sound energy – Mechanical methods – definition – mechanical destruction and exclusion – merits and demerits.](#)
17. [Mid semester examination.](#)
18. [Legal methods – definition – pest introductions – quarantine – phytosanitary certificate – pest legislation.](#)
19. [Host plant resistance – definition – types and mechanisms, ecological and genetic resistance.](#)
20. [Host-plant resistance in pest management – compatibility with other pest management practices – merits and demerits.](#)
21. [Biological control – definition – history and development – classical examples – factors governing biological control.](#)
22. [Predators and parasitoids of agricultural importance – role in pest management.](#)
23. [Chemical control – definition – history of insecticide development – toxicity parameters – ideal qualities of an insecticide.](#)
24. [Classification of insecticides based on mode of entry, mode of action and chemical nature.](#)
25. [Insecticides Act 1968 – insecticide residues and waiting periods. Role of pesticides in pest management.](#)

26. [Semiochemicals – definition – intraspecific semiochemicals – allomone, kairomone, synomone and apneumone.](#)
27. [Interspecific semiochemicals – pheromone, sex pheromone, alarm and trail marking pheromone. Pheromones in Integrated Pest Management.](#)
28. [Sterility methods – definition – principles – methods – requirements and limitaitons.](#)
29. [Insect growth regulators – moult inhibitors – Juvenile Hormone mimics – mode of action and uses. Insect antifeedants and repellents – mode of action, groups and uses.](#)
30. [Pesticide application technology – principles and methods.](#)
31. [Pesticide compatibility, safety and hazards – antidotes – safe handling – impact of pesticides on agroecosystems. Impact of global warming on pests.](#)
32. [Integrated Pest Management – history, principles and strategies – relationship between different components and economics.](#)
33. [Integrated Pest Management : Issues and options. Eco friendly Integrated Pest Management – Indigenous/traditional technologies in Integrated Pest Management.](#)
34. [Specific Integrated Pest Management practices for rice and cotton. Biotechnology in pest management.](#)

PRACTICAL

1. [Identification, morphology, life history and structural adaptations of bees.](#)
2. [Bee keeping appliances.](#)
3. [Economics of bee keeping - bee enemies and diseases – their management.](#)
4. [Lac insect – life history, natural enemies, lac products.](#)
5. [Observations on characters of insect predators – Odonata, Coleoptera, Diptera, Hymenoptera and non-insect predators.](#)
6. [Observations on characters of parasitoids – Trichogrammatidae, Ichneumonidae, Braconidae, Chalcididae, Bethylidae and Tachinidae.](#)
7. [Mass production methods of biocontrol agents.](#)
8. [Visit to apiary / biocontrol laboratory.](#)
9. [Observations on symptoms and types of damage caused by sucking, biting and chewing insects, subterranean insects, *in situ* counting and sampling.](#)
10. [Assessment of insect population and damage in selected crops.](#)
11. [Traditional methods of pest control – cultural, physical and mechanical.](#)
12. [Practising the use of pheromone, light, fish meal and yellow sticky traps.](#)
13. [Pesticides – groups, formulation and label information - do's and dont's.](#)
14. [Pesticide application technology – spraying, dusting, soil application, whorl application, fumigation and other techniques.](#)
15. [Preparation of spray fluid for field application – preparation and application of plant products, viruses, bacteria and fungi.](#)
16. [Pesticide appliances – types and uses of high volume and low volume sprayers and dusters.](#)
17. [Practical examination.](#)

REFERENCE BOOKS

1. Ayyar, T.V.R. 1963. Hand Book of Economic Entomology for South India – Govt. Press, Madras, 516 p.
2. David, B.V. and T. Kumaraswami. 1982. Elements of Economic Entomology – Popular Book Depot, Madras, 536 p.
3. David, B.V. and M.C. Muralirangan and M. Meera. 1992. Harmful and Beneficial Insects – Popular Book Depot, Madras, 304 p.
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Principles of Applied Entomology

The field of entomology may be divided into 2 major aspects.

1. Fundamental Entomology or General Entomology
2. Applied Entomology or Economic Entomology

Fundamental Entomology deals with the basic or academic aspects of the Science of Entomology. It includes morphology, anatomy, physiology and taxonomy of the insects. In this case we study the subject for gaining knowledge on Entomology irrespective of whether it is useful or harmful.

Applied Entomology or Economic Entomology deals with the usefulness of the Science of Entomology for the benefit of mankind. Applied entomology covers the study of insects which are either beneficial or harmful to human beings. It deals with the ways in which beneficial insects like predators, parasitoids, pollinators or productive insects like honey bees, silkworm and lac insect can be best exploited for our welfare. Applied entomology also studies the methods in which harmful insects or pests can be managed without causing significant damage or loss to us.

In fundamental entomology insects are classified based on their structure into families and orders etc. in applied entomology insects can be classified based on their economic importance i.e. whether they are useful or harmful.

Economic classification of insects

Insects can be classified as follows based on their economic importance.

This classification is according to TVR Ayyar.

Insects of no economic importance:-

There are many insects found in forests, and agricultural lands which neither cause harm nor benefit us. They are classified under this category. Human beings came into existence 1 million years ago. Insects which constitute 70-90% of all animals present in this world came into existence 250- 500 million years ago.

Insects of economic importance

A. Injurious insects

a) Pests of cultivated plants (crop pests)

Each cultivated plant harbours many insects pests which feed on them reduce the yield of the crop. Field crops and horticultural crops are attacked by many insect species. (eg) cotton bollworm, Rice stem borer.

b) Storage pests

Insects feed on stored products and cause economic loss. (eg) Rice weevil, Pulse beetle.

c) Pest attacking cattle and domestic animals

Cattle are affected by pests like Horse fly, Fleshfly, Flea and Lice. They suck blood and sometimes eat the flesh.

d) House hold and disease carrying insects

House hold pests include cockroach, ants, etc.. Disease carrying insects are mosquitoes, houseflies, bed bugs, fleas etc.

B. Beneficial insects

a) Productive insects

- i) **Silk worm:-** The silk worm filament secreted from the salivary gland of the larva helps us in producing silk.
- ii) **Honey bee:-** Provides us with honey and many other byproducts like bees wax and royal jelly.
- iii) **Lac insects:-** The secretion from the body of these scale insects is called lac. Useful in making varnishes and polishes.
- iv) **Insects useful as drugs, food, ornaments etc,**

(a) **As medicine** eg. Sting of honey bees- remedy for rheumatism and arthritis
Eanthoridin - extracted from blister beetle –useful as hair tonic.

(b) **As food** - for animals and human being.

For animals- aquatic insects used as fish food.

Grass hoppers, termites, pupae of moths.

They have been used as food by human beings in different parts of the world.

(c) Ornaments, entertainers

-Artists and designers copy colour of butterflies.

- Beetles worn as necklace.

- Insect collection is a hobby

(d) Scientific research

Drosophila and mosquitoes are useful in genetic and toxicological studies respectively.

(II) Helpful insects

- (i) **Parasites:** These are small insects which feed and live on harmful insects by completing their life cycle in a host and kill the host insect.

Eg egg, larval and pupal parasitoids

- (ii) **Predators:** These are large insects which capture and devour harmful insects.

Eg Coccinellids, Predatory mites.

(iii) **Pollinators:** Many cross pollinated plants depend on insects for pollination and fruit set.

Eg Honey bees, aid in pollination of sunflower crop.

(iv) **Weed killers:** Insects which feed on weeds, kill them thereby killers. Eg Parthenium beetle eats on parthenium. Cochneal insect feeds in Opuntia dillenii.

(v) **Soil builders:** soil insects such as ants, beetles, larval of cutworms, cri kets, collun bola, make tunrels in soil and facilitate aeration in soil. They become good manure after death and enrich soil.

(vi) **Scavengers:** Insects which feed on dead and decaying matter are called scavengers. They important for maintaining hygiene in the surroundings.
Eg Carrion beetles, Rove beetles feed on deade animals and plants.

d) House hold and disease carrying insects

i) Pests which cause damage to belongings of human being like furniture, wool, paper etc. Eg. Cockroaches, furniture beetle, sliver fish etc.

ii) Pests which cause painful bite, inject venoms. Eg. Wasps, bees sting us. Hairy caterpillar nettling hairs are poisonous. Mosquitoes, bugs bite, piece and suck blood from us.

iii) Disease causing Mosquito- Malaria, Filariasis ,dengue fever. Housefly- Typhoid, Cholera, Leprosy, Anthrax

Honey bees:- History of bee keeping

Honey bees and their usefulness are known to man from prehistoric times. Mention of bees are found in vedas, Ramayan and Quran. The modern bee keeping became possible after the discovery of movable frame hive in 1851 by Rerd. L.L.Langshoth. In India beekeeping was introduced in 1882 in Bengal. Rerd. Newton introduced beekeeping to south India in 1911. But still India is much behind USA, Canada, Europe, Australia and Newzealand in beekeeping.

Bee species

There are five important species of honey bees as follows.

1. *Apis dorsata*: The rock bee Apidae.
2. *Apis cerana indica*: The Indian hive bee Apidae.
3. *Apis florea* : The little bee Apidae.
4. *Apis mellifera*: The European or Italian bee Apidae.
5. *Melipona irridipennis*: Danner bee, Meliporidae stingless bee.

Apis dorsata:-

1. They construct single comb in open (About 6ft long and 3ft deep)
2. They shift the place of the colony often.
3. Rock bees are ferocious and difficult to rear.
4. They produce about 36 Kg honey /comb/year.
5. The bees are the largest among the bee described.

Apis florea

1. They also construct comb in open of the size of palm in branches of bushes, hedges, buildings, caves, empty cases etc.
2. They produce about 1/2Kg honey/year/hive.
3. They are not rearable as they frequently change their palce.
4. The size of the bees is smallest among 4 Apis Sp. Described. (smaller than Indian bee).
5. They distributed only in plains and not in hills above 450M.

Apis cerana indica (Indian bee/Asian bee)

1. They make multiple parallel combs on trees and cavities in darkness.
2. The bees are larger than Apis florae but smaller than Apis mellifera.
3. They produce about 5Kg of honey/year/hive.
4. They are more prone to swarming and absconding.
5. They are native of India/Asia.

Apis mellifera (Italian bee or European bee)

1. They also make multiple parallel combs in cavities in darkness.
2. They are larger than Indian bees but smaller than Rock bees.
3. They have been imported from European countries.(Italy)
4. They yield on an average 35Kg/hive/year.
5. They are less prone to swarming and absconding.

Honey bee castes

Every honey bee colony comprises of a single queen, a few hundred drones and several thousand worker castes of honey bees. Queen is a fertile, functional female, worker is a sterile female and the drone is a male insect.

Duties of a queen

1. The only individual which lays eggs in a colony .(Mother of all bees).
2. Lays upto 2000/day in *Apis mellifera*.
3. Five to Ten days after emergence, she mates with drones in one or more nuptial flights.
4. When her spermatheca is filled with sperms, she will start laying eggs and will not mate any more.
5. She lives for 3 years.
6. The secretion from mandibular gland of the queen is called queen's substance.
7. The queen substance if present in sufficient quantity performs following functions.
 - a) Prevent swarming and absconding of colonies.
 - b) Prevent development of ovary in workers.
 - c) Colony cohesion is maintained.
8. The queen can lay either fertilized or sterile eggs depending on the requirement.

Duties of a drone

1. Their important duty is to fertilize the queen.
2. They also help in maintenance of hive temperature.
3. They cannot collect nectar / pollen and they do not possess a sting.

Duties of a worker

1. Their adult life span of around 6 weeks can be divided into
 - a) First three weeks- house hold duty.
 - b) Rest of the life- out door duty.

House hold duty includes

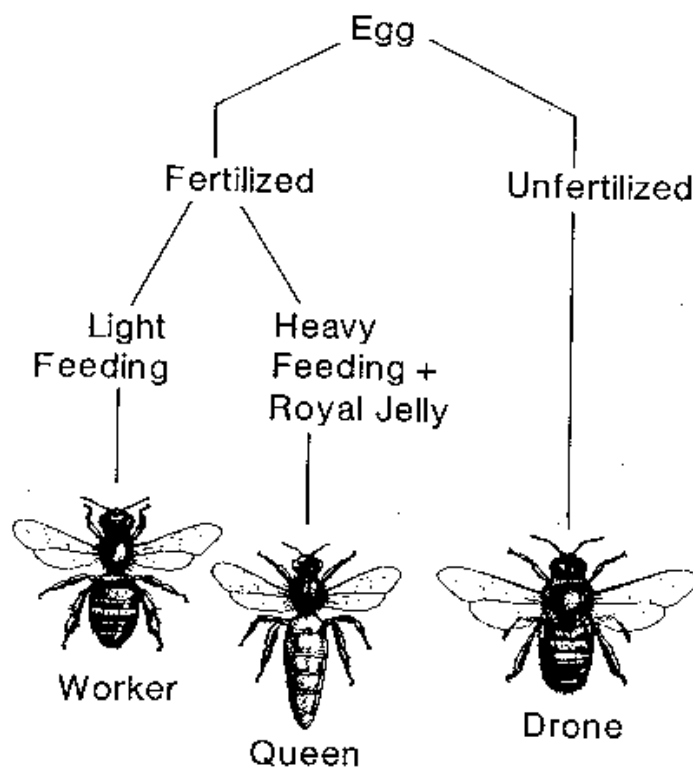
- a. Build comb with wax secretion from wax glands.
- b. Feed the young larvae with royal jelly secreted from hypopharyngeal gland.
- c. Feed older larvae with bee-bread (pollen+ honey)

- d. Feeding and attending queen.
- e. Feeding drones.
- f. Cleaning, ventilating and cooling the hive.
- g. Guarding the hive.
- h. Evaporating nectar and storing honey.

Outdoor duties

- 1. Collecting nectar, pollen, propolis and water.
- 2. Ripening honey in honey stomach.

Sex differentiation in bees



Bee behaviour

- a) **Swarming:** Swarming is a natural method of colony multiplication in which a part of the colony migrates to a new site to make a new colony. Swarming occurs when a colony builds up a considerable strength or when the queen's substance secreted by queen falls below a certain level. Swarming is a potent instinct in bees for dispersal and perpetuation of the species.

Steps involving in swarming

- 1. Strong colonies develop the instinct of swarming.
- 2. Development of drone brood and emergence of large number of drones is first sign of swarming.
- 3. New queen cells are built at the bottom of comb.

4. When the queen cells are sealed after pupation the old queen along with 1/3 rd or half colony strength moves out of the hive.
5. They first settle in a nearby bush and hang in a pendant cluster.
6. The scout bees go in search of appropriate place for colonization and later the entire colony moves to the suitable site.
7. The first swarm which comes of the parent colony with the old queen is called primary swarm.
8. The new queen which emerges kills all other stages of queen present inside the queen cell.
9. Sometimes the new queen is not allowed to destroy stages of other queens.
10. In this case the new queen leaves the hive along with a group of workers. This is called after swarm or cast.

Supersedure:

When a old queen is unable to lay sufficient eggs, she will be replaced or superseded by supersedure queen. Or when she runs out of spermatheca in her supermatheca, and lays many unfertilized eggs from which only drones emerge.

In this case, one or 2 queen cells are constructed in the middle of the comb and not at the bottom. At a given time both new and old queens are seen simultaneously. Later the old queen disappears.

Emergency queen

In the event of death of the queen the eggs (less than 2½ days old) in worker cells are selected and the cell extended like a queen cell. It is fed with abundant royal jelly and covered into queen. In this case many queen cells are built in the middle of the comb. The first queen which comes out of the emergency queen cells kills other stages of queen inside the cells and then go for mating. After mating they laying fertile eggs.

Laying workers

In the event of loss of a queen and in the event of absence of worker eggs less than 2½ days old the chance of producing new queen is lost. In this case, the worker status laying eggs. Since the worker cannot mate, they lay unfertilized eggs. From these eggs only drones emerge. Moreover, a worker lays more than one egg per cell and there is competition among the larva, stunted drones are produced.

Colony odour: Every colony has a specific odour. This is brought about by scent fanning of secretion of vasanov gland present in last abdominal segment of worker bees recognise colony odour and return to same hives.

Hive temperature maintenance: Brought about by fanning of wings in hot weather to reduce temperature. In cold weather they sit on the brood and prevent heat loss.

Division of labour: Each and every caste of bees have their own role to play as described earlier.

Queen controls colony with her queen's substance Guarding the hive:- The workers perform this duty by sitting at hive entrance and preventing and stinging intruders.

Royal fidelity or Blossom faithfulness

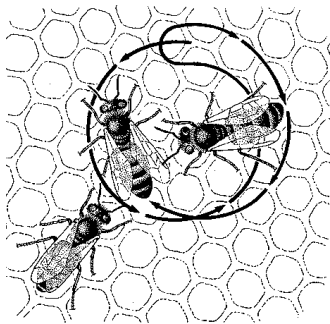
Bees restrict themselves to a single source of pollen and nectar until it is available. Only if the pollen and nectar from a plant species is exhausted they move to the next plant species.

Communication in bees

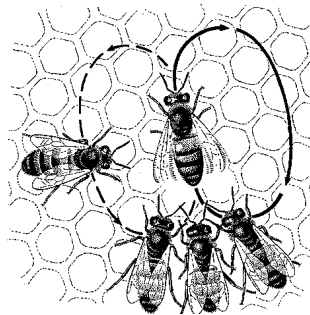
Bees communicate using various phenomena, including the queen's substance, vomeriferous gland secretion, alarm pheromone emitted from sting and secretion of tarsal gland. In addition the bees also communicate by performing certain dances.

When scout bees return to the hive after foraging they communicate to the other foragers present in the hive about the direction and distance of the food source from the hive by performing dances. The important types of dances are noticed.

1. **Round dance** is used to indicate a short distance (Less than 50m in case of *A. mellifera*). The bee runs in circles, first in one direction and then in opposite direction, (clockwise and anticlockwise).



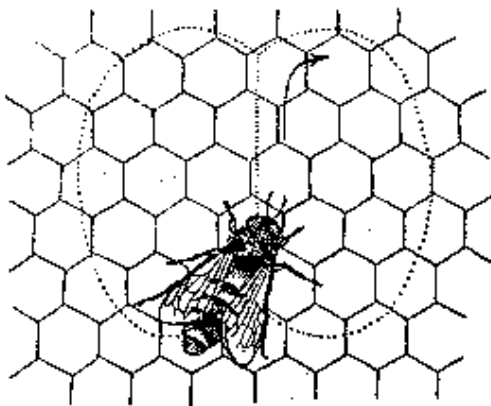
Round dance



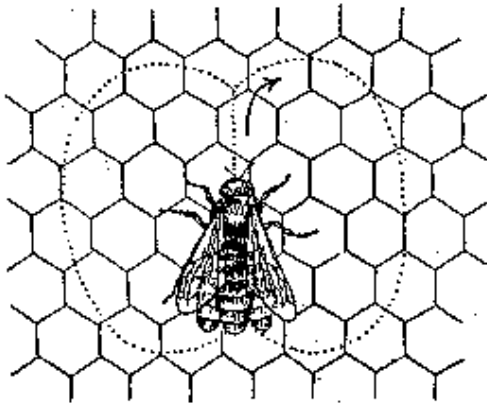
Wag tail dance

2. Tail wagging dance or Wag-tail dance.

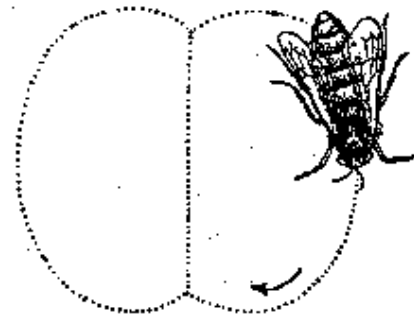
This is used to indicate long distance (more than 50m in case of *A. mellifera*). Here the bee makes two half circles in opposite directions with a straight run in between. During the straight run, the bee shakes (wags) its abdomen from side to side, the number of wags per unit time inversely proportional to the distance of the food (more the wags, less the distance). The direction of food source is conveyed by the angle that the dancing bee makes between its straight run and top of the hive which is the same as between the direction of the food and direction of the sun. The bees, can know the position of the sun even if it is cloudy.



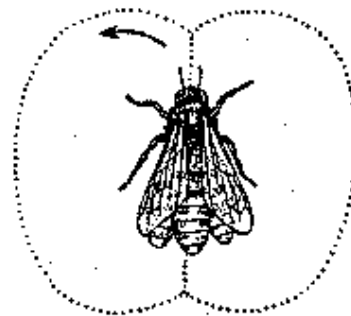
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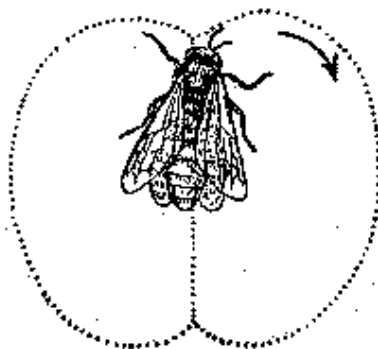
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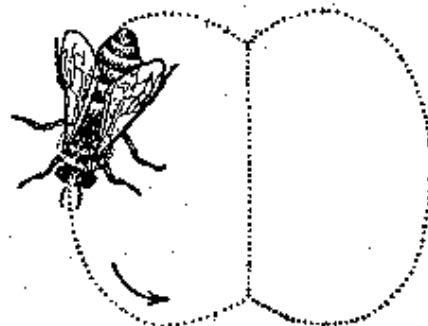
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e



c



f

Wag tail dance to communicate the direction and distance of food source

APIARY MANAGEMENT

Pre-requisites to start beekeeping

- a. Knowledge/Training on beekeeping
- b. Knowledge on local bee flora
- c. Sufficient on local bee flora
- d. If necessary practice migratory beekeeping

Apiary site requirements

- a. The site should be dry without dampness. High RH will affect bee flight and ripening of nectar.
- b. **Water** - Natural source/Artificial provision
- c. **Wind breaks** - Trees serve as wind belts in cool areas
- d. **Shade** - Hives can be kept under shade of trees. Artificial structures can also be constructed
- e. **Bee pasturage/Florage** - Plants that yield pollen/nectar to bees are called bee pasturage/florage

General apiary management practices

- i. **Hive inspection** - Opening the hive atleast twice a week and inspecting for following details.
 - Presence of queen
 - Presence of eggs and brood
 - Honey and pollen storage
 - Hive record to be maintained for each hive
 - Presence of bee enemies like wax moth, mite, disease
- ii. **Expanding brood net**
 - Done by providing comb foundation sheet in empty frame during honey flow period.
- iii. **Sugar syrup feeding**
 - Sugar dissolved in water at 1:1 dilution
 - Used to feed bees during dearth period
- iv. **Supering (Addition of frames in super chamber)**
 - This is done when brood chamber is filled with bees on all frames are covered
 - Comb foundation sheet or constructed comb provided in super chamber
- v. **Honey extraction**
 - **Bee escape board** - Kept between brood and super chamber
 - Bees bushed away using **brush**

- Cells uncapped using uncapping knife
- Honey extracted using honey extractor
- Combs replaced in hive for reuse

vi. Swarm management

- Remove brood frames from strong colony and provide to weak
- Pinch off the queen cells during inspection
- Divide strong colonies into 2 or 3
- Trap and hive primary swarm

vii. Uniting bee colonies - Done by Newspaper method

- Bring colonies side by side by moving 30 cm/day
- Remove queen from weak colony
- Keep a newspaper on top of brood chamber of queen - Right colony
- Make holes on the paper
- Keep queenless colony on top
- Close hive entrance (the smell of bees will mix)
- Unite bees to the brood chamber and make it one colony

SEASONAL MANAGEMENT

- Pollen and nectar available only during certain period
Honey flow season (surplus food source) x Dearth period (Scarcity of food)
- Extremes in climate like summer, winter and monsoon - Need specific management tactics

Honey flow season management (Coincides with spring)

- Provide more space for honey storage by giving CFS or built combs
- Confine queen to brood chamber using queen excluder
- Prevent swarming - As explained
- Prior to honey flow - Provide sugar syrup and build sufficient population
- Divide strong colonies into 2-3 new colonies - if colony multiplication need
- Queen rearing technique may be followed to produce new queens for new colonies

Summer management

- Bees have to survive intense heat and dearth period
- Provide sufficient shade (under trees or artificial structure)
- To increase RH and reduce heat - Sprinkle water twice a day on gunny bag or rice straw put on hive
- Increase ventilation by introducing a splinter between brood and super chamber
- Provide sugar syrup, pollen supplement/substitute and water

Winter management

- Maintain strong and disease free colonies
- Provide new queen to the hives
- Winter packing in cooler areas (Hilly areas)

Management during dearth period

- Remove empty combs (and store in air tight container)
- Use dummy division board to confine bees to small area
- Unite weak colonies
- Provide sugar syrup, pollen supplement/substitute

Rainy season/monsoon management

- Avoid dampness in apiary site. Provide proper drainage
- In rain when bees are confined to the hive, provide sugar syrup feeding

BEE PASTURAGE/BEE FORAGE

Plants that yield pollen and nectar are collectively called bee pasturage or bee forage.

Plants which are good source of nectar

- | | |
|-----------------|-------------------------------|
| 1. Tamarind | 6. Moringa |
| 2. Neem | 7. <i>Prosopis juliflora</i> |
| 3. Soapnut tree | 8. <i>Glyricidia maculata</i> |
| 4. Eucalyptus | 9. <i>Tribulus terrestris</i> |
| 5. Pungam | |

Plants which are good source of pollen

- | | |
|--------------------------------------------|-----------------|
| 1. Sorghum | 6. Sweet potato |
| 2. Maize | 7. Tobacco |
| 3. Millets like Cumbu, Tenai, Varagu, Ragi | 8. Coconut |
| 4. Roses | 9. Castor |
| 5. Pome granate | 10. Date palm |

Plants which are good source of Pollen and Nectar

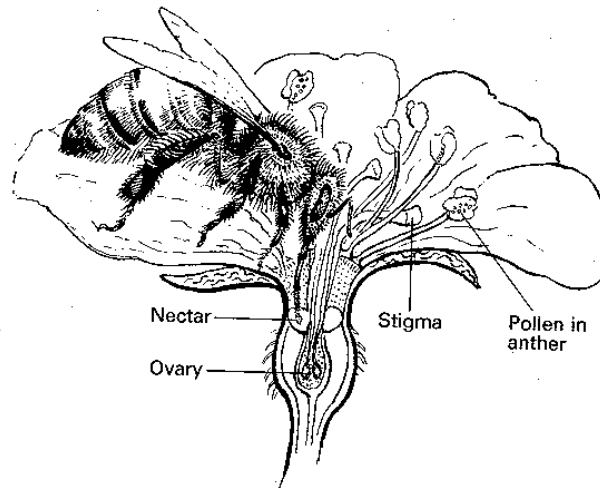
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|------------|---------------|
| 1. Banana | 7. Peach |
| 2. Citrus | 8. Guava |
| 3. Apple | 9. Sunflower |
| 4. Berries | 10. Safflower |
| 5. Pear | 11. Mango |
| 6. Plum | |

FORAGING

Refers to collection of nectar and pollen by bees.

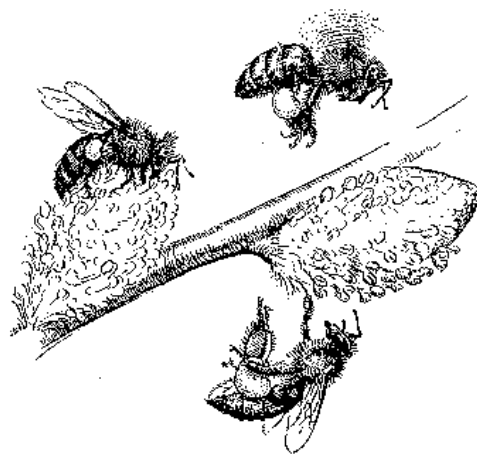
Nectar foragers

- Collect nectar from flowers using lapping tongue
- Passes the nectar to hive bees
- Hive bees repeatedly pass the nectar between preoral cavity and tongue - to ripen honey
- Later drops into cell



Pollen foragers

- Collects pollen by passing flower to flower. Pollen sticking to body removed - Using pollen comb
- Packed using pollen press into corbicula
- A single bee carries 10-30 mg pollen (25% of bee's wt)
- Dislodge by middle leg into cell
- Mix with honey and store



Floral fidelity

- A bee visits same species of plant for pollen/nectar collection until exhausted.
- Bees travel 2-3 km distance to collect pollen/nectar.

ROLE OF HONEY BEES IN CROSS POLLINATION - THEIR EXPLOITATION - CASE STUDIES WITH SELECTED CROPS

For SEXUAL reproduction in flowering plants transfer of anther to stigma is essential - Pollination

Self pollination

- * Transfer to stigma of same plant
- * No external agents are involved

Cross pollination

- * Transfer pollen from one plant to stigma of another plant
- * External agents are involved

External agents involved in pollination

A. Abiotic agents

a. Wind (Anemophily)

- * Wind carries pollen from one plant to another
- * Flowers are small, inconspicuous, unattractive
- * Pollen are dry and light in weight
- * Stigma feathery with large surface area
eg: Maize, barley, wheat, sugarcane

b. Water (Hydrophily)

- * Water carries pollen from one plant to other

B. Biotic agents

- * Bird, bat and insects are important biotic agents
- * Among insects honey bees play major role
- * Honey bees and flowering plants have coevolved
- * In insect pollinated plants, flowers are large, brightly colour, distinct fragrance, presence of nectar and sticky pollen
- * True honeybees (*Apis* spp.) - Most valuable pollinators of commercial crop

Qualities of honeybees which make them good pollinators

1. Body covered with hairs and have structural adaptation for carrying nectar and pollen.
2. Bees - Not injurious to plants
3. Adult and larva feed on nectar and pollen - Available in plenty
4. Superior pollinators - Since store pollen and nectar for future use
5. No diapause - Need pollen throughout year
6. Body size and proboscis length - Suitable for many crops

7. Pollinate wide variety of crops
8. Forage in extreme conditions also (weather)

Effect of bee pollination on crop

- It increases yield (seed yield, fruit yield) in many crops
- It improves quality of fruits and seeds
- Bee pollination increases oil content of seeds in sunflower
- Bee pollination is a must in some self incompatible crops for seed set

Crops benefited by bee pollination

Fruits and nuts	Vegetable and vegetable seed crops	Oil seed crops	Forage seed crops
Almond	Cabbage	Sunflower	Lucerne
Apple	Cauliflower	Niger	Clover
Apricot	Carrot	Rape seed	
Peach	Coriander	Mustard	
Strawberry	Cucumber, Melon	Safflower	
Citrus	Onion, Pumpkin	Gingelly	
Litchi	Radish, Turnip		

Per cent increase in yield due to bee pollination

Crop	Botanical name	Per cent yield increase
Mustard	<i>Brasica</i> sp	43
Sunflower	<i>Helianthus annus</i>	32 - 48
Cotton	<i>Gossypium</i> sp.	17-19
Lucerne	<i>Medicago sativa</i>	112
Onion	<i>Allium cepa</i>	93
Apple	<i>Purus malus</i>	44

Scope of beekeeping for pollination in India

- Total area under bee dependant crops - 50 million ha
- At the rate of 3 colonies/ha - 150 million colonies needed
- In India only 1.2 million colonies exist - There is scope

Management of bees for pollination

- Place hives very near the field (source) - to save bee's energy
- Migrate colonies near field at 10% flowering
- Place colonies at 3/ha - Italian bee; 5/ha - Indian honey bee
- The colonies should have 5-6 frame strength of bees, possess sealed brood, have young mated queen
- Allow sufficient space for pollen and honey storage

Pollination by bees - Cross studies with selected crops

1. Sunflower

- It is a cross-pollinated crop
- Self incompatibility noticed - i.e. The pollen a plant cannot fertilize ovary of same plant
- Pollen should come from different plant
- Honey bees - Most important mode of pollination in sunflower
- Yield increase due to bee pollination - Even upto 600%
- Improves quality and quantity of seeds
- Oil content increases by 6.5% in seeds
- Requires 5 strong 4 *C. indica* colonies or 3 *A. mellifera* colonies
- Irrigated crop is preferred by bees

2. Cucurbitaceous vegetables

- Monoecious - Staminate and pistillate flowers in same plant
- 30-100% increase in fruit set due to bee pollination

3. Alfalfa or Lucerne

- Tubular flower - has 5 petals joined at base
- One large standard petal
- 2 smaller petals on sides
- 2 keel petals holding staminal column
- When bee sits on keel petal, staminal column strikes against standard petal and pollen shatters
- This is called TRIPPING
- Only if bee sits to trips the flowers seed set occurs

4. Coriander

- Yield increase upto 187% noted when pollinated by bees

5. Cardamom

- Important commercial crop depending on bee pollination. Yield increase upto 21-37%

6. Gingelly

- Another oilseed crop, bee pollination causes 25% increase in yield

7. Apple

- Only if pollinated by bees - feed set occurs
- Fruit is formed around seeds only
- If improper seed set - Fruit shape is lopsided (market value decreases)

Migratory Vs. Stationary beekeeping

- Migratory beekeeping - Advantageous to beekeeper and farmer

BEE PRODUCTS - THEIR PROPERTIES AND USES

1. Honey
2. Bees Wax
3. Royal Jelly
4. Bee Venom
5. Propolis
6. Pollen

1. Honey

- A sweet, viscous fluid - Produced by honey bees
- Collected as nectar from nectaries at base of flower
- Also collected from extra floral nectaries (nectar secreted by parts other than flowers)
- Collected also from fruit juice, cane juice

Collection and ripening of honey

- Bee draws nectar by its tongue (proboscis)
- Regurgitated by field bees
- Collected by hive bees - Deposited in cells in comb
- Nectar contains 20-40% sucrose
- Invertase converts sucrose into dextrose (glucose) and levulose (fructose)
- Invertase is present in nectar itself and in saliva of honey
- Ripening of honey is by action of enzyme and by evaporation of water by fanning of wings

Composition of fully ripened honey

	Per cent (Approx.)
Lrvulose	41.0
Dextrose	35.0
Sucrose	1.9
Dextrins	1.5
Minerals	2.0
Water	17.0
Undetermined (Enzymes, Vitamins, Pigments, etc.)	1.6

Pigments

Carotene, Chlorophyll, Xanthophyll

Minerals include

Potassium, Calcium, Phosphorus, Sodium, Magnesium, Manganese, Copper, Sulphur, Silica, Iron.

Vitamins

Vit B₁ (Thiamine), B₂ (Riboflavin), Nicotinic acid, Vit. K, Folic acid, Ascorbic acid, Pantothenic acid.

Physical properties of honey

1. Honey is hygroscopic. If exposed to air it absorbs moisture
2. Honey is a viscous fluid. Heating of honey reduces viscosity
3. Specific gravity of pure honey is 1.35 - 1.44 gms/cc
4. Refractive index of honey - Helps to find moisture content measured using refractometer

Purity test for honey

1. Measure specific gravity of honey using hydrometer
2. If the specific gravity is between 1.25-1.44 it is pure honey

Aroma and flavour of honey

1. Acquired from the nectar of the flower
2. Lost if heated or exposed to air for long time

Colour of honey

1. Depends on the nectar of flower (plant species)
2. Darker honey has stronger flower
3. Lighter honey has more pleasant smell

Fermentation of honey

- Honey containing high moisture can ferment
- Sugar tolerant yeast present in honey cause fermentation
- Fermentation more at 11-21°C
- Fermentation leads to formation of alcohol and carbondioxide
- Alcohol later converted into acetic acid
- Fermented honey sour in taste due to acidity
- Heating honey to 64°C for 30 min destroys yeast and prevents fermentation

Crystallization or granulation of honey

- This is a natural property of honey (particularly at low temperature)
- Dextrose present in honey granulate and suffer down
- Levulose and water remain top - More prone to fermentation
- High ratio of Levulose/Dextrose (L/D) - Less granulation
- High ratio of Dextrose/Water (D/W) - More granulation

EFFECT OF AGRICULTURAL INPUTS ON BEE ACTIVITY – PESTICIDE POISONING

The use of pesticides has become inevitable in modern agriculture. Most of crops are attacked by some or the other pests. The control of insect pests, diseases and weeds, in most cases is done by applying some pesticide. Pesticides used on field crops for the control of pests have their own side effects, one of which is their toxicity to honey bees. Honeybees are susceptible to many pesticides, especially insecticides. Each year honeybee colonies are damaged or destroyed by pesticides, primarily insecticides. Such losses have devastating impact on the beekeepers, who may have to relocate damaged hives or perhaps even be forced out of business. It is very difficult to assess the extent of losses of bees from pesticides. Three types of harmful effects evident in agriculture are:

1. Loss in production of honey.
2. Contamination of bee products.
3. Reduction in the yield of cross-pollinated crops.

These effects may happen as a result of the direct exposure of bee fauna to pesticides or through indirect contact with their residues. Direct exposure occurs from treatment of bee hives with pesticides for disinfestation purpose or honey bees visiting the fields at the time of spray. While the indirect exposure occurs from spray drift from nearby fields or bee foraging in sprayed crops. Honeybees may also come in contact with spray fluid spilled inadvertently or thrown in the watercourses.

Symptom's of bee poisoning

1. Dead or dying bees near the entrance of hives /colonies.
2. Dead bees on the top of frames or bottom board.
3. Lack of recognition of guard bees.
4. General aggressiveness.
5. Fighting among bees at the entrance or inside of colonies.

6. Paralysed or stupefied bees crawling on nearby objects of the colony and also on blades of the grass.
7. Sudden cessation of food storage and brood rearing.
8. Dead and deserted brood in the hive.
9. Poor recognition of pollen and nectar.
10. And finally a depleted population of the colony.

Causes of poisoning

Bee poisoning mainly occurs when pesticides are applied to crop during bloom. It may also be caused by drift of toxic chemicals onto non-target areas or bees contacting residues of pesticides on plants for pollen and nectar and also bees drinking or contacting contaminated water in watercourses or spillage. If the chemical is highly poisonous the bees may get killed in or near the field. However, if the chemical has delayed action the bees may reach their hives but die near the entrance. Some of workers may even enter the hive and store nectar and pollen inside and thus, result in exposure of the nurse bees to the contaminated pollen, carried by the foragers and stored in the comb. The resultant cumulative effect of the contaminated pollen may lead to depletion of brood, death of young ones, nurse bees and other workers. Hence, not only the population of colony decreases substantially but also results in contamination of bee products.

Factors of bee poisoning

Many factors involving pesticides affect the potential for honey bee poisoning. The important factors are described below.

Plant growth stage: Severe bee poisoning most often results from spraying insecticides directly on flowering plants, either the crop itself or flowering weeds within its margins.

Relative toxicity of chemical: Pesticides vary in their toxicity to honeybees. Among the pesticides, most fungicides and herbicides are relatively less toxic to honeybees. Insecticides are most toxic. Honeybees are most vulnerable to broad-spectrum insecticides. Insecticides that are highly toxic can not be applied to blooming crop when bees are present without causing serious to colonies. Insecticide like dimethoate, malathion, methyl parathion etc. carbaryl come

under this category. However, insecticides like endosulfan are less toxic (Table 1).

Choice of formulation: different formulations even of same pesticide, often vary considerably in their toxicity to bee. Dust formulations are typically more hazardous than sprays because they are picked up on bee hairs. A wettable powder such as Sevin 80 S, would usually remain toxic in the field for a longer time than Sevin XLR Plus, an emulsifiable concentrate. Granular insecticides are less hazardous to bee. However, microencapsulated materials such as PennCap-M are particularly dangerous to use around bees because, the capsules have a tendency to adhere to bees due to their size and electrostatic charge.

Residual action: Residual activity of an insecticide is an important factor in determining its safety to pollinators. An insecticide that degrades rapidly can generally be applied with minimum risk when bees are not foraging.

Drift: Drift of spray application can cause significant bee poisoning, particularly when drift reaches colonies adjacent flowering weeds. In general sprays should not be applied when wind speed exceeds 10 km/hr.

Temperature: Temperature can have a substantial effect on bee poisoning hazard. If temperatures following treatment are unusually low, insecticide residues can remain toxic to bee many times longer than if normal temperature prevails.

Distance from treated fields: the most severely damaged colonies are usually closest to fields where insecticides are being applied. However, during periods of pollen or nectar shortage, hives within 6 – 7 km of the treated areas can be injured.

Time of application: evening application of a short residual insecticide can greatly reduce any potential for bee damage.

Minimizing pesticide hazards to bees / management practices

Proper understanding of above-mentioned principles can go a long way in reducing pesticide hazards to honey bees. The basic principle, of course, is that honey bees should not get exposed to the toxic effects of insecticides as far as possible. Reducing pesticide injury to honeybees requires communication and cooperation between beekeepers and farmers. Since both mutually benefit from honeybees, the beekeeper in terms of its products and the farmer in terms of

increased production of crops. While it is unlikely that all poisoning can be avoided, a balance must be struck between the effective use of insecticides, the preservation of pollinators and the rights of all – the beekeeper, farmers and the community.

GUIDELINES FOR BEEKEEPERS

- It is most desirable that bee colonies should be maintained where use of pesticides or drift from pesticides is minimum. For this, the beekeeper should be fully conversant with the type of pesticides used in their locality, which in turn depends upon the cropping pattern and the pest complex. He / she should also be aware of normal wind currents prevalent in that area to protect against the harmful effects from drift.
- If ever disinfestation of beehives becomes necessary he / she should use only the recommended chemicals, safe to the bees, for the purpose.
- During bloom if the crops in the surrounding areas are being sprayed with the insecticides, it is always advisable to confine the bee within the hives. If it is apprehended that the spray programme will continue for a longer period, it is better to move the hives away to the safe location free from the drift in advance.
- Apiarists and farmers should have close cooperation so that beneficial activity of bee is not jeopardized by the irrational use of pesticides by the latter.
- Feeding of colonies with sugar syrup following pesticide application to reduce bee foraging may help substantially in reducing the exposure of bees to pesticides
- Bee repellent like Methyl salicylate and MGK 874 (2 – hydroxyethyl – N octyl sulphide) also reduces bee foraging
- Addition of (adjuvant) Sylgard 309 silicone surfactant reduced honey bee mortality for some insecticides
- Carbolic acid and creosote reduced activity of bees on cotton for few hours

GUIDELINES FOR FARMERS

- The golden principle for the farmers is to use insecticides only when necessitated. For this purpose, integrated pest management approaches are available on most crops, which should be strictly practiced.
- It is in the mutual interests of both that the farmer should intimate the spray programme in advance to the bee keeper.
- If there is a choice for insecticides, the use should be restricted to the chemicals in the less hazardous groups.
- The spray operation in the evening is always preferable as it not only gives better deposit and distribution (because of invert current) but also bee activity subsides.
- Apply granules or sprays in preference to dusts. Pesticide formulation containing attractants like Sevamol, used for fruit fly control, should be discouraged as far as possible during the crop in bloom.
- Examine fields and field margins before spraying to determine if bees are foraging on flowering weeds. Where feasible eliminate weeds by mowing or tillage.
- Give careful consideration to position of bee colonies relative to wind speed and direction. Changing spray nozzles or reducing pressure can increase droplet size and reduce spray drift.

Table 1 Select list of insecticides according to bee hazard categories

Insecticide	Formulation
<i>High hazard class category</i>	
Carbaryl	D, WP
Cypermethrin	EC
Deltamethrin	EC
Diazinon	D, EC
Dichlorvos	EC
Dimethoate	EC
Fenitrothion	EC
Fenthion	EC
Fenvalerate	D, EC
Malathion	D, ULV, EC
Monocrotophos	EC
Methyl parathion	D, EC
Methomyl	D, WP
<i>Low hazard category</i>	
Endosulphan	EC

Fenthion	G
Phorate	G
Aldicarb	G
Carbofuran	G
Phosalone	EC
Fluvalinate	EC
Menazon	EC

Since pesticides are indispensable for crop protection, as an alternative scientists are continuously looking for such chemicals which are selective and repellent to bees, in addition to the development of a bee strain resistant to toxic effects of pesticides.

Beekeepers on their own through their organizationz may approach the enforcement agency for amendments in The Insecticides Act, 1968 for getting protection to these beneficial insects which is possible by restricting use of pesticides in apiculture zones.

ROLE OF POLLINATORS, WEED KILLERS AND OTHER BENEFICIAL INSECTS

I. Role of pollinators

- Pollination refers to the transfer of anther to stigma in flowering plants for sexual reproduction.
- Insects aid in cross pollination in fruits, vegetables, ornamentals, cotton, tobacco, sunflower and many other crops.
- Insect pollination helps in uniform seed set, improvement in quality and increase in crop yield.

Entomophily refers to cross pollination aided by insects

Pollination classes	Type of insects
Melitophily	Bees
Cantharophily	Beetles
Myophily	Syrphid and Bombylid flies
Sphigophily	Hawk moths
Psychophily	Butterflies
Phalaeophily	Small moths

1.Honeybees as pollinators

- All bee species aid in pollination
- Value of honey bees in pollination is 15-20 times higher than that of the honey and wax it produces.

Per cent increase in yield due to bee pollination

Mustard	-	43%
Sunflower	-	32 - 48%
Cotton	-	17 - 19%
Lucerne	-	112%
Onion	-	93%
Apple	-	44%
Cardamom	-	21-37%

2. Hoverflies *Syrphus* sp. (Syrphidae:Diptera)

- Brightly coloured flies
 - Body is striped or banded with yellow or blue
 - Resemble bees and wasps
 - Larval stage predatory, adults are pollinators
- Crops pollinated - carrot, cotton, pulses

3.Carpenter bee, *Xylocopa* sp. (Xylocopinae:Anthophoridae)

- Robust dark bluish bees with hairy body
- Dorsum of abdomen bare, pollen basket absent
- Adults are good pollinators
- Construct galleries in wood and store honey and pollen

4. Digger bees, *Anthophora* sp. (Anthophoridae:Hymenoptera)

- Stout, hairy, pollen collecting bees
- Abdomen with black and blue bands

5. Fig wasp *Blastophaga psenes* (Agaonitae:Hymenoptera)

Fig is pollinated by fig wasp only. There is no other mode of pollination. There are two types of fig Caprifig and Symrna fig.

(i) Caprifig

- It is a wild type of fig - not edible
- Has both male and female flowers
- Pollen is produced in plenty
- Natural host of fig wasp

(ii) Smyrnafig

- It is the cultivated type of fig - Edible
- It has only female flowers
- Pollen not produced
- Not the natural host of fig wasp

Fig wasp: Male - wingless, present in caprifig
Female - winged

E wasp lays eggs in caprifig, larvae develops in galls in the base of the flowers
Γ mates with female even when the E is inside gall

Mated E wasp emerges out of flower (caprifig) with lot of pollen dusted around its body.

- The Efig wasp enters smyrna fig with lot of pollen and deposits it on the stigma
- But it cannot oviposit in the ovary of symrna fig which is deep seated
- It again moves to capri fig for egg laying. In this process smyrna fig is pollinated
- Caprifig will be planted next to smyrna fig to aid in pollination

6. Oil palm pollinating weevil: *Elacidobins kamerunicus* (Curculionidae : Coleoptera)

Aid in increasing oil palm bunch weight by 35% and oil content by 20%

7. Other pollinators

- Butterflies (eg *Deilaphila* spp.) and moths (*Acherontia* spp.)
- Ants, flies, stingless bees, beetles etc.,

II. WEED KILLERS

Insect which help in controlling weeds by feeding on them are called weed killers.

1. *Dactylopius tomentosus* cochineal insect to control prickly pear *Opuntia dillenii*

This insect was introduced into India in 1925. Within 5-10 years it controlled the weed.

2. Aristalochia butterfly, *Papilio aristolochiae* (Papilionidae:Lepidoptera). It feeds on Arista lochia which a weed.
3. Caotropis butterfly - *Danaus chrysippus* (Nymphalidae:Lepidoptera) - feeds on calotropis.
4. AK Grosshopper - *Poecilocerus pictus* (Actididae:Orthoptera)
 - Feeds on Calotropis and controls it

5. Water hyacinth weevil *Neochetina eichhorniae* and *N. bruchi*

The larvae tunnel and feed inside the petioles. Ten pairs of adults and progeny controls plant growth in 0.58 m².

6. Parthenium weed killer, *Zygogramma bicolorata* (Chrysomelidae:Coleoptera)

Adults and grubs feed on leaves and flowers. 2 beetles controls and destroys one plant in 45 days.

A successful weed killer has following qualities

- Should not be a pest of cultivated plants - at present or in future
- Effective in damaging and controlling the weed
- Should be a borer or internal feeder of the weed
- Should not be affected by parasitoids/predators

III. SCAVENGERS

Insects which feed on dead and decaying plant and animal matter are called scavengers.

- Remove decomposing material and prevents health hazard

- Convert complex material into simple substances
- a. Rove beetles (Staphylinidae:Coleoptera)
Adults and larvae feed on decaying matter
- b. Chafer beetles (Scarabaeidae:Coleoptera)
- c. Darkling beetles (Tenebrionidae:Coleoptera)
- d. Nitidulids (Nitidulidae:Coleoptera)
- e. Water scavenger beetle (Hydrophilidae:Coleoptera)
- f. Daddy long legs (Tipulidae:Diptera)
- g. Muscid flies (Muscidae:Diptera)
- h. Termites (Isoptera)
- i. Ants (Hymenoptera)

IV. INSECTS OF AESTHETIC VALUE

Insects which are beautiful are admired

1. Jewel beetle (Buprestidae:Coleoptera)
- necklaces, bracelets and made of whole insects
2. Nymphs of scale insects - made as stings
3. Butterflies - symbol of beauty

V. SOIL BUILDERS

Insects which live in soil, make tunnels. During this process, the soil disintegrates, and soil aeration is facilitated. Subsoil is brought to the surface. Excreta of insects also enrich the soil.

eg. Beetles, ants, cutworms, larvae of flies, crickets, termites, wasps etc.,

VI. INSECTS OF SCIENTIFIC VALUE

1. Fruitflies - *Drosophila melanogaster*

Useful in biological investigations such as cytology, and genetics for studying principles of inheritance.

These flies have short life cycle, easy to culture and multiply - They have large chromosomes and easily recognizable heritable variations.

2. Mosquitoes - Used in bioassay of insecticide residues
3. Cockroaches - Used in Zoology and Entomology courses, also used in nutritional studies

VII. INSECTS AS FOOD

- Termites, grubs of beetles are being used as food
- They are rich in protein

MANAGEMENT OF HOUSEHOLD PESTS, VECTORS OF HUMAN DISEASES AND PESTS OF CATTLE AND POULTRY

I. HOUSEHOLD PESTS AND VECTORS OF HUMAN DISEASES

1. Housefly *Musca nebulosa* (Muscidae: Diptera)

Biology: Larvae - feed on decaying organic matter, faeces etc.,
Adults - Frequent human dwelling and transmits diseases

Damage

- Source of nuisance
- Transmits many diseases in human beings such as diarrhoea, dysentery, cholera, typhoid, enteric fevers, tuberculosis, leprosy, anthrax, trachoma, gonorrhoea and many helminthic diseases.

Management

- ☞ Proper disposal of manure, garbage, sewage, human excrement, dead animals etc., Covering manure pits with soil.
- ☞ Inside houses, spraying with malathion/diazinon 2%, lindane 1% or trichlorophen 0.5%. The deposits are effective for long periods.
- ☞ Smearing doors and windows with malathion 3% or diazinon 1.5% emulsion with a brush.
- ☞ Using fly swatters to manually kill flies.
- ☞ Protecting eatables from flies to prevent transmission of diseases.
- ☞ Use of poison baits such as formaline + sweetened milk (or) fermented banana + milk or cheese + sugar + insecticide

2. Mosquitoes

Culex sp., *Anopheles* sp., and *Aedes* sp. → Culicidae : Diptera

More than 2500 sp world wide

Mosquitoes

Biology	:	Egg, larval and pupal stages spent in water, marshy lands, stagnant ponds etc., Adults cause problem to humans and animals.
Damage	:	Their bite causes itching and irritation (Females only bite and suck blood)

Diseases transmitted

- *Anopheles* sp. transmits malaria (caused by *Plasmodium* sp.)
- *Culex* sp. transmits filariasis (caused by *Wuchereria bancrofti*)
- *Aedes* sp. transmits dengue fever, encephalitis and yellow fever

Management of mosquitoes

- ☞ Stagnant water should be drained (or) treated with 0.025% malathion emulsion. Kerosine oil can also be used.
- ☞ Grasses and weeds around buildings should be cut or sprayed with 1% malathion every week when mosquitoes are active.
- ☞ Mosquito nets or repellents such as citronella oil (creams).
- ☞ Adults can be killed with space sprays of proprietary products such as pyrethrins, dichlorvos, synthetic pyrethroids.
- ☞ Spray human dwellings, cattle shed with lindane 0.5 g/m² and propoxur, fenitrothion and malathion 2 g/m².

3. Sandflies *Phlebotomus argentipes* (Psychodidae:Diptera)

Larvae found in decaying organic matter.

Damage

- Adults cause painful bite, itching and swelling
- Transmits diseases in man like kala-azar, three day fever, tropical ulcer etc.,]
- Transmits anthrax in cattle

Management

- ☞ Cleanliness in and around human habitations
- ☞ Surface spraying with Lindane 5% as residual spray
- ☞ Insecticides recommended for mosquito control
- ☞ Pyrethrum ointment to repel the sand flies

4. Eye flies *Siphunculina funicola* (Chloropidae : Diptera)

Breeds in decomposing organic matter, near latrines, stables and drains.

Damage

- Frequents the eye with buzzing sound and feeds on eye secretions
- Transmits diseases like *Conjunctivitis* and *Ophthalmia*

Management

- 4 Good sanitary and hygienic condition

5. Human lice

Head louse <i>Pediculus capitis</i>	}	Pediculidae: Siphunculata or Phthiraptera
Body louse <i>Pediculus humanus</i>		
Crab louse <i>Phthirus pubis</i>		

Damage

- Biting causes cutaneous lesions, itching

- Severe infestation by lice is called pediculosis - discolouration hardening and ulceration of skin
- Transmits diseases like typhus, trench fever, European relapsing fever

Management

- ☞ Powder containing malathion 2% or lindane 1% is effective in delousing on clothes
- ☞ On infested head/body lindane 0.2% mixed in hair oil or lotions containing 0.2% lindane
- ☞ Cleanliness to have constant relief

6. Rat fleas: *Xenopsylla cheopsis* (Pulicidae:Siphonaptera)

Damage

- Painful bites - cause irritation, itching on skin

Transmits bubonic plague - caused by bacterium *Pasteurella pestes* which affects both rats and humans.

Also transmits endemic or murine typhus

Management

- ☞ Keep houses rat free by poison baits
- ☞ Cleanliness, proper ventilation and occasional spraying with malathion 0.5% or lindane 1%

7. Cockroaches

Periplaneta americana, *Blattella germanica*, *Blattella orientalis* →
Blattellidae:Dictyoptera

Live in dark unclean kitchens, restaurants, filthy places

Damage

- Starchy material are ruined by excreta, offensive smell
- Feed on damp books and leather articles

Management

- ☞ Observing cleanliness
- ☞ Sealing pipelines and drains leading to basement
- ☞ Spraying room with malathion / chlorpyrifos 0.5% without contaminating food material
- ☞ Combined application of dichlorvos 0.5% (quick knock down) and persistent insecticide (Chlorpyrifos)

8. Crickets *Grylloides sigillatus*, *Acheta domesticus* → Gryllidae:Orthoptera

Damage

- Nuisance and disturbance to humans by producing monotonous chirping sound produced at night
- Eat food and clothings

Management

Dusting corner and floors with malathion / carbaryl 5% dust at night (care not to contaminate food)

9. Bed bugs

	legion	
<i>Cimex hemipterus</i> (Tropical)	}	Cimicidae:Hemiptera
<i>Cimex lectularius</i> (Temperate)		

Damage

- Nymphs and adults suck blood and inject toxic saliva during night- (irritating, painful, itching) (Does not transmit any diseases)

Management

- ☞ Exposing bed, bedsheets to hot sun will kill bed bugs
- ☞ Using steel cots instead of wooden cots
- ☞ Applying kerosine, turpentine or petroleum oils in furniture
- ☞ Treating furniture with malathion 1% or lindane 0.1%

10. Silverfish

Lepisma saccharina, *Thermobia domestica* → Lepismatidae : Thysanura

Management

- ☞ Cleaning and ventilation.
- ☞ Use of naphthalene balls in cupboards

11. Other minor household pests

Ants, termites, book lice, wood boring, beetles, carpet beetles, cloth moth.

MANAGEMENT OF PESTS OF CATTLE AND POULTRY

Farm animals are attacked by pests under following categories

1. Blood sucking flies (Adults - flies suck blood)

2. Myiasis flies (Tissues eaten by maggots of flies)
3. Lice - (a) sucking lice (b) biting lice
4. Fleas
5. Arachnids - (a) Ticks (b) Mites

I. Blood sucking flies

- a. Sand flies: *Phlebotomus argentipes* (Psychodidae:Diptera)

Damage

- Both male and female flies suck blood from horses, dogs, man and cattle
- Causes weakening and reduction of milk
- Transmits anthrax in animals

- b. Horseflies: *Tabanus striatus* (Tabanidae:Diptera)

Other species → *Chrysopa* sp., *Hamatopota* sp.

Damage

- Females are blood suckers - even on running animals
- Animal weakened, loses lot of blood
- Transmits anthrax
- Attacks horse, cattle, camel, elephant, rarely man

- c. Stableflies *Stomoxys calcitrans* (Muscidae:Diptera)

Damage

- Bite causes itching, pain, restlessness in animals
- Reduction in milk yield
- Transmits diseases like anthrax, surra, swamp fever, *Trypanosomiasis* and *Leishmaniasis* in animals

- d. Hornflies: *Haematobia irritans* (Tabanidae:Diptera)

Damage

- Both sexes suck blood from neck region from cattle, goats, horses, dogs and sheep
- Transmits anthrax

- e. Dogflies: *Hippobosca maculata* (Hippoboscidae:Diptera)

Damage

- Permanent ectoparasites on cattle, horse, dog, goat, sheep
- Painless but irritating bite cause annoyance

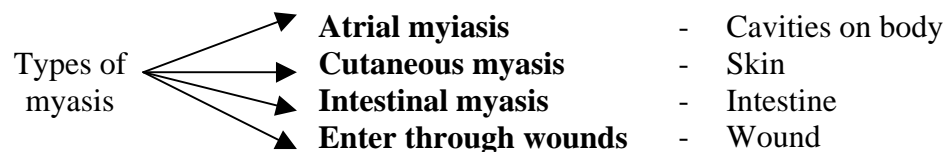
Management of blood sucking flies on cattle

- ☞ Elimination of breeding of flies through cleanliness
- ☞ Residual spray of cattle shed with lindane 5% or diazion 1%
- ☞ Draining stagnant water to prevent breeding
- ☞ Spraying 0.1% pyrethrin + 1% piperonyl butoxide at 1-2 lit/animal, twice or thrice a week
- ☞ Cover or dry the fresh dung as it attracts egg laying by hornflies
- ☞ To manage dog flies, apply malathion 5% dust on neck, back and flanks of animal every 10-14 days

II. MYIASIS FLIES

Myiasis refers to an infestation of living organs or tissues of man and other mammals by maggots (larvae) of flies (order Diptera) and disturbances resulting therefrom

- caused by insects belonging to *Calliphoridae* (Blousflies)
- *Oestridae* (Botflies, warble flies), *Sarcophagidae* (Flesh flies)



a. Botflies

1. Horse botfly - *Gastrophilus intestinalis*, *G. nasalis* (Oestridae:Diptera)

Damage

- Eggs laid on body of animal - while licking gets into intestine - larva develops inside intestine
- Maggots injure tongue, stomach and intestine
- Animal dies if not treated

Management

- 4 If larva detected in faeces - give 25 ml tolerance or 1.5 g carbon disulphide / 100 kg body weight in gelatin capsule to horse.

2. *Oestrus ovis* Sheep bot fly (Oestridae:Diptera)

Maggots attacks nasal passage of sheep - discharge of mucus, distress to the sheep.

Management

- ☞ Irrigating the sheep's nostrils with 3% lysol
- ☞ Carbonsulphide + Paraffin injection into nostrils

3. Warble fly/Heal fly: *Hypoderma lineatum* (Oestridae:Diptera)

- Cutaneous/subcutaneous myiasis caused
- Causes holes in skin - less value
- Even causes eye myiasis

Management

- ☞ During monsoon, hair close to loof may be cut to prevent egg laying
- ☞ Treating animal with 1% trichlorphon or 0.05% rotenone every 45 days when warbles appear on skin

b. Blowflies

Chrysomya bezziana (Calliphoridae:Diptera)
Cochliomyia hominivorax, *Calliphora*, *Lucilia*, *Phormia* sp.

- Also called screw worms
- Cause cutaneous myiasis by entering through wound/sores

Management of blowflies

- ☞ Disposal of carcasses to prevent egg laying
- ☞ Removing maggots with forceps after spraying with 5% chloroform
- ☞ Dressing wounds with pine oil which is a repellent

III. LICE

a. Sucking lice: Has sucking mouth parts

1. Cattle louse: *Haematopinus eurysternus* (Haematopinidae:Siphunculata)

- Ectoparasites on cattle, cling, bite and irritate

Management (Delousing) DELOUSNG CATTLE

- ☞ Applying linseed oil all over the body could kill lice
- ☞ Malathion 5% dust or 0.5% suspension spray/dip of animal

b. Biting lice: Has biting and chewing MP

1. *Bevicola caprae* (on goat) *B. ovis* (on sheep); *B. bovis* (on cattle) (Trichodectidae:Mallophaga)

2. *Menopon gallinae* (Menoponidae:Mallophaga)
 Shaft louse of focol (on birds)
 Feed on feathers of birds and cause annoyance
3. *Menacanthus stramineus* (Chicken body louse)

Prefers skin to feathers

Management of biting lice on birds (Delousing birds)

1. Spray individual chicken or in groups with 0.5% carbaryl or malathion (5 lit/100 birds)
2. Apply 5% Malathion / Carbaryl dust on individual birds @ 500 g/100 birds
3. On walls and ceiling spray 3% malathion

Delousing birds not only removes the lice but also poultry tick and fleas.

IV. FLEAS

- a. Poultry stick fast fleas *Echidnophaga gallinacea* (Hectosyllidae : Siphonaptera)
 - Attack comb, wattle, around eyes, beaks
 - Birds become anaemic and egg production reduced

V. ARACHNIDS

- a. Ticks (1) *Boophilus microplus* → cattle tick
 - Cause inflammation and haemorrhage
 - Produce tick paralysis
 - Transmits tick fever, texas fever, tularemia

Management

- Careful removal with hand/forceps along with capitulum
 - Use 1% lindane dust or 5% malathion dust
2. Poultry tick: *Argas persicus* (Fowl tick)
 - Suck blood, causes weakness, annoyance
 - Transmits fowl diseases
 - b. Mites: *Sarcoptes scabiei* called mange mite
 - Mite damages or eats the skin
 - Ecto parasite on horse, cattle, mule, sheep, goat

Management

- ☞ Repeated application of powdered sulphur in vegetable oil

INSECT ECOLOGY AND BALANCE OF LIFE

Ecology:

The term ecology is derived from the Greek term “oikos” meaning “house” combined with “logy” meaning “the science of” or “the study of”. Thus literally ecology is the study of earth’s household comprising of the plants, animals, microorganisms and people that live together as interdependent components. The term ecology was coined by a German biologist Ernst Haeckel (1869).

Definition of Ecology

- Ecology can be defined as the science of plants and animals in relation to their environment.
- Webster’s dictionary defines ecology as “totality of pattern of relation between organisms and their environment.”
- Eugene P. Odum defined ecology as “the study of organisms at home”
- Insect Ecology may be defined as the understanding of physiology and behaviour of insects as affected by their environment.

Ecology related terminology

- i. **Habitat** is the place where the organism lives.
- ii. **Population** denotes groups of individuals of any kind of organism. Insect populations are groups of individuals set in a frame that is limited in time and space.
- iii. **Community** in the ecological sense includes all the populations of a given area. Community can also be defined as interacting ‘web’ of populations where individuals in a population feed upon and in turn are fed upon by individuals of other populations (Fig. 1)
- iv. **Ecosystem**
 - Ecosystem or ecological system is the functioning together of community and the nonliving environment where continuous exchange of matter and energy takes place.
 - In other words ecosystem is the assemblage of elements, communities and physical environment.
 - Ecosystem is the ultimate unit for study in ecology as they are composed of living organisms and the nonliving environment.

Examples of natural ecosystem: Ponds, lakes and forests ecosystem (Fig.2)

- v. **Biosphere** is the term used for all of the earth's ecosystems functioning together on the global scale.

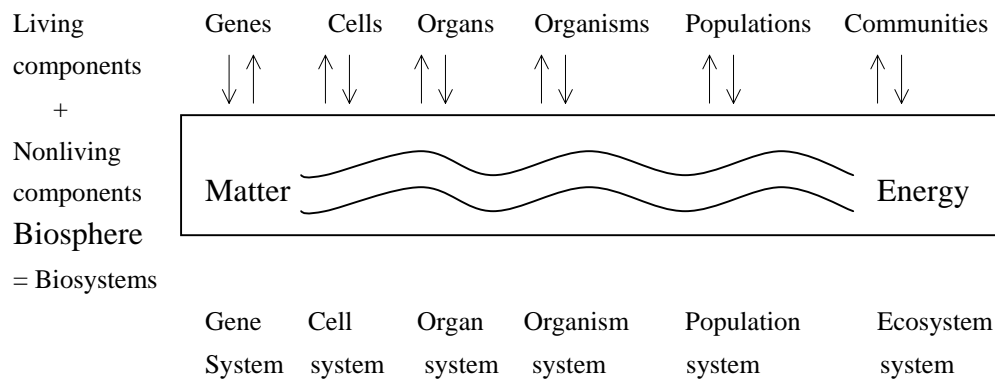


Figure 3. Flow of matter and energy in an ecosystem

Agroecosystem is largely created and maintained to satisfy human wants or needs. It is not a natural ecosystem but is man made. Agroecosystem is the basic unit of pest management - a branch of applied ecology.

A typical agroecosystem (Fig. 4) is composed of

- i. more or less uniform crop-plant population
- ii. weed communities
- iii. animal communities (including insects)
- iv. microbiotic communities
- v. and the physical environment the react with.

Unique features of Agroecosystem

- Dominated by plants selected by man
- No species diversity and no intraspecific diversity. Genetically uniform
- Phenological events like germination, flowering occur simultaneously
- Lack of temporal continuity - due to various agricultural operations carried out by man like ploughing, weeding, pesticide application etc.
- Plants contain imported genetic material
- Nutrients are added
- Outbreak of pests, weeds and diseases occur frequently

Balance of Nature

Balance of Nature is defined as the natural tendency of plant and animal population resulting from natural regulative processes in an undisturbed ecosystem (environment) to neither decline in numbers to extinction nor increase to indefinite density.

In unmanaged ecosystems, a state of balance exists or will be reached, that is species interact with each other and with their physical environment in such a way that on average, individuals are able only to replace themselves. Each species in the community achieves a certain status that becomes fixed for a period of time and is resistant to change which is termed as the balance of nature.

When man begins to manage creating new ecosystem (agroecosystem) where natural ecosystem existed previously, the balance is altered. The exceptionally strong forces react in opposition to our imposed change toward a return to the original system (e.g. outbreak of a pest is one of the forces). So insect pests are not ecological aberrations. Their activities counter wants and needs of human populations.

Factors that determine insect abundance

i) Biotic potential

It is the innate ability of the population to reproduce and survive. It depends on the inherited properties of the insect i.e., reproduction and survival. **Potential natality** is the reproductive rate of the individuals in an optimal environment. Survival rate depends on the feeding habits and protection to young ones (eg. Viviparity). Generally insects with high reproductive rate tend to have low survival rate and vice versa.

Insect pests with high reproductive rate and low survival rate are called **r strategists** named after the statistical parameter r , the symbol for growth rate coefficient. Such pests succeed because of sheer numbers. E.g. Aphids.

K strategists reproduce slowly but effectively compete for environmental resources and so their survival rate is high. (K letter denotes flattened portion of growth curve) eg. Codling moth of apple.

Birth rate or natality is measured as the total number of eggs laid per female per unit time. Factors determining birth rate are fecundity, fertility and sex ratio.

Death rate or mortality denotes the number of insects dying over a period.

A single moth of *Earias vitella* (Bhendi fruit borer) lays about 200 eggs per female. Life cycle is completed in 1 month

If a single moth can produce this much, they will cover 24.32 above earth surface in 1 year. But in reality only a fraction of progeny completes life cycle due to environmental resistance.

1. Biotic factors - includes
 - a) Competition (interspecific and intraspecific)
 - b) Natural enemies (predators, parasites and pathogens)
2. Abiotic factors -
 - a) Temperature
 - b) Light
 - c) Moisture and water
 - d) Substratum and medium

Ecosystem comprises of biological communities and non-living environment. e.g. Agro ecosystem, pond ecosystem, etc.). **Bioresources refers to the biodiversity of various organisms living in that ecosystem.**

e.g. The different pests of cotton, its natural enemies, hyperparasitoids, microbes, etc. are referred to the bioresources in cotton ecosystem.

The ecosystem should have more bioresources. Such ecosystem will be more stable. Insecticides will deplete the bioresources in ecosystem and make it less stable and prone to pest outbreak.

Natural control will be high when bioresources (e.g. Parasitoids and Predators) are more.

POPULATION DYNAMICS AND ROLE OF BIOTIC FACTORS

Attributes of a population

- i. **Density** : Population size per unit area
- ii. **Birth rate (Natality)** : Rate at which new individuals are added to the population by reproduction
- iii. **Death rate (Mortality)** : The rate at which individuals are lost by death.
- iv. **Dispersal** : The rate at which individuals immigrate into and emigrate out of the population.
- v. **Dispersion**: the way in which individuals are distributed in space. It may be of 3 types.
 - a) Random distribution
 - b) Uniform distribution
 - c) Clumped distribution
- vi. **Age distribution**: the population of individuals of different ages in the group.
- vii. **Genetic characteristics** : adaptiveness, reproductive fitness, persistence.
- viii. **Population growth form**: the way in which population changes / grows as a result of natality, mortality, and dispersal.

Population dynamics.

Populations grow in two contrasting ways. They are

- i. J- shaped growth form (Fig 1a)
- ii. S- Shaped or sigmoid growth form (Fig 1b)

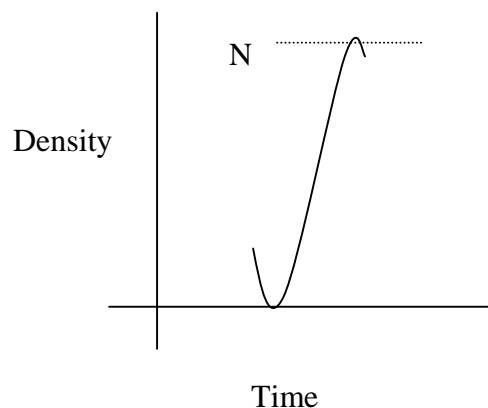


Fig. 1a. J- shaped growth form

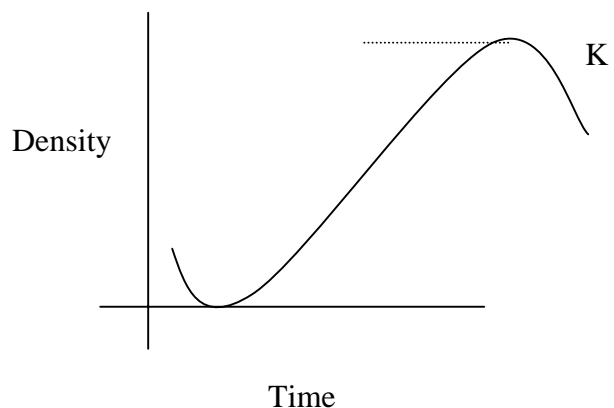


Fig. 1b. S - shaped growth form.

In the J - shaped growth form, the population density increases in exponential or geometric fashion; for example 2,4,8,16,32 ... and so on until the population runs out of some resource or encounters some limitation (limit N, Fig 1a). Growth then comes to a more or less abrupt halt and density declines rapidly. Populations with this kind of growth form are unstable. Their reproductive rate is high and survival rate is less and so they are r strategists. Factors other than density regulates the population.(eg; Aphids).

In the S-shaped growth pattern (Fig 2) the rate of increase of density decreases as the population increases and levels off at an upper asymptote level K, called the carrying capacity, or maximum sustainable density. Their reproductive rate is less and survival rate is more. So they are K strategists. This pattern has more stability since the population regulates itself.(eg Hymenopterans).

The population growth rate or change is worked out using the formula,

$$N_t = N_0 e^{(b-d)t} - E_t + I_t$$

Where N_t = number at the end of a short time period

N_0 = number at the beginning of a short time period

e = base of natural logarithm = 2.7183

b= birth rate

d= death rate

t= time period

E= emigration

I = immigration.

Life table: Life tables are tabular statements showing the number of insects dying over a period of time and accounting for their deaths.

Example of a life table for a lepidoperan insect

Stage	Number living beginning of stage	Number dying by end of stage	Cause of death	Percent reduction during stage
Egg	200	10.0	Parasites	15
		20.0	Other	
Early larva	170	136.0	Dispersal	80
Late larva	34	13.6	Parasites	90
		6.8	Disease	
		10.2	Other	
Pupa	3.4	0.3	Parasites	25
		0.5	Other	
Adult	2.5	0.5	Miscellaneous	20

Factors influencing population growth.

- a) Biotic factors or density dependent factors.
- b) Abiotic factors or density independent factors.

Biotic factors

1) **Competition** : For at least part of the lifetime the members of an insect species are likely to be competing with one another or with members of another species for limited resources like food, mates, suitable site for oviposition or pupation. Such competition operates whenever the population is increasing and the resources are limited.

a) **Intraspecific competition**: When members of population of the same species compete for resources we call it intraspecific competition. Examples are as follows

- Cannibalism in American bollworm larvae
- Cannibalism in later stage grubs of Chrysopid
- Crowding in aphids result in alate (winged) form for migration
- Reduction in fecundity (egg laying) in rice weevil, *Sitophilus oryzae* during overcrowding
- Crowding in honeybees leads to swarming

b) **Interspecific competition**. This is the competition occurring between members of two or more species. Two or more competing species with identical requirements cannot coexist in a same place for a long time. The elimination of one species by another as a result of interspecific competition has come to be known as the **competitive exclusion principle or Gause's principle**.

- For example when flour beetles *Tribolium castaneum* and *Tribolium confusum* were grown in the same jar of flour, one species eliminates the other. Under high temperature and RH conditions *T. castaneum* eliminates *T. confusum* and vice versa under low temperature and RH conditions.
- Accidental introduction of oriental fruit fly *Dacus dorsalis* into Hawaii eliminated Mediterranean fruit fly *Ceratitis capitata*.

2) Predators and Parasites

Predators : Predators are free living organisms that feed on other animals, their prey, devouring them completely and rapidly.

- Predators may attack immatures and adults.
- More than one individual of prey required for predator to reach maturity

- Major insect predators are birds, fish, amphibians, reptiles, mammals and arthropods

Parasites: An organism that is dependent for some essential metabolic factor on another throughout its all life stages, which is always larger than itself

- A parasite weakens or kills the host while feeding
- Many parasites on a single host
- Requires only one part of one host to reach maturity

Eg. Virus, fungi, bacteria, protozoa, nematodes and other arthropods.

Parasitoid: An insect parasite of an arthropod that is parasitic in its immature stage killing the host in the process of development and adults are free living.

Interactions between predator and prey are different from the parasite host relationship in that the predator and prey maintain equilibrium more dynamically than the parasite and its host. The parasites in general when the rate of parasitism is high, cause death and result in elimination of hosts. But the predator never eliminates the prey completely.

ABIOTIC FACTORS ON INSECT POPULATION

- Physical factors
- Nutritional factors
- Host associated factors

Physical factors

- Temperature, light, wind, soil conditions influence development, longevity, reproduction and fecundity of insects
- Population density fluctuates depending on weather
- Extreme weather causes mortality of pests

Temperature

- Insects are poikilothermic - do not have mechanism to regulate body temperature
- Body temperature depends on environmental conditions

- ☞ Preferred or Optimum temperature is the temperature at which normal physiological activities take place - insects survive at this temperature.
- ☞ Upper lethal limit - 40-50°C (even upto 60°C survival in some stored product insects)
- ☞ Lower lethal limit - Below freezing point e.g. snow fleas
- ☞ The total heat required for completion of physiological processes in life - history is a constant - thermal constant.
- ☞ At low temperature (winter) insect takes more days to complete a stage (larval or pupal stage)
- ☞ At high temperature (summer) it takes less than to complete a stage.
- ☞ Some insects when exposed to extremes of temperature
- ☞ Undergo - Aestivation (during summer) or Hibernation (during winter)
- ☞ During this period, there is a temporary developmental arrest, metabolic activities suspended. When temperature is favourable, they resume activity.
- ☞ Eggs undergo aestivation in summer
- ☞ Larva, pupa commonly undergo hibernation in winter

Influence of temperature on fecundity (egg laying)

Grasshopper lays 20-30 times more eggs at 32°C compared to 22°C

Oviposition of bed bug inhibited at 8-10°C

Other effects of temperature

- **Early shoot borer of sugarcane attacks more high temp.**
- Larval period of sugarcane internode borer
 - very short 16-24 days in summer
 - prolonged 141-171 days in winter
- Swarm migration of locust occurs at 17-20°C

MOISTURE/HUMIDITY

- Moisture required for metabolic reactions and transportation of salts in insects
- Wax layer of cuticle prevents water loss
- Other adaptations - Morphological, physiological prevent moisture loss in insects
- Moisture scarcity leads to dehydration and death of insects - but very rare
- Excessive moisture can be harmful in following ways
 - i. Affects normal development and activity of insects
 - ii. Encourages disease causing pathogens on insects

Examples

- White halo fungus *Verticillium lecanii* on coffee green scale *Coccus viridis* requires high RH for multiplication and spread
- High RH induces BPH in rice and aphids in other crops
- Termites prefer high humidity 90-95% RH
- Low RH in rainfed groundnut crop induces leaf mines incidence

Light

The following properties of light influence insect life

- i. Intensity and illumination
- ii. Quality or wavelength
- iii. Duration or Photo period

Photoperiodism

The response of organisms to environmental rhythms of light and darkness

Photo period

Each daily cycle inclusive of a period of illumination followed by a period of darkness

- Photo period influences induction of diapause (a resting stage) in most of the insects e.g. Long day during embryonic development causes adult to lay diapausing eggs in *Bombyx mori*.
- Seasonal dimorphism occurs in aphids due to change in photo period
 - Short day - Sexual forms
 - Long day - Asexual - Parthenogenetic forms
- Some insects are active in night - Nocturnal
Some are active during the day - diurnal
Some active during dawn and dusk - Crepuscular
- Fruit flies lays eggs in dark
- Lepidopterans like cotton bollworm, Red hairy caterpillar (RHC) oviposit in **dark**

Rainfall

- Rainfall is essential for adult emergence of cutworms and RHC
- Heavy rain washes aphids, diamond back moth (DBM)

- Intermittent low rain increases BPH and thrips

Wind

- Interferes with feeding, mating, oviposition
- Wind aids in dispersal of insects
- Aphids, mites (Eriophyid mites also) disperse through wind
- Helicoverpa flies upto 90 km with the aid of winds

Topography

Mountains, lakes, sea, etc. act as physical barrier for spread of insects

Soil Type

Wire worm, multiplies in clay soil with poor drainage

White grubs and cut worm - multiply in loose soil with good drainage

Water Current

Standing water aids in multiplication of mosquitoes

Running water is preferred by Odonata and Caddis flies

NUTRITIONAL FACTORS

Insects heterotrophic - cannot synthesize their own food

- depend on plants for food

The quantity and quality of food/nutrition plays important role in survival, longevity, distribution, reproduction and speed of development

a. Quantity of food

- Short supply of food causes intraspecific and interspecific competition
- Also affects parasitoids and predators of insects hosts whose food is of short supply

b. Quality of food

- This depends on nutritional availability of plants
- Crop varieties/species differ in nutritional status which affects insects

Host plant associated factors

Antixenosis or non preference

Host plant **not preferred** by insects for feeding, oviposition or shelter due to morphological characters like thorns, wax, hairyness, etc. or due to presence of some chemicals (called allelochemicals)

Antibiosis

This refers to adverse effect of the host plant on biology (survival, dept, reprdn.) of insects and their progeny due to

- Presence of toxic substance in plant
- Absence of essential substances
- Presence of enzymes which affect digestion of insects

Example

DIMBOA in corn leaves affects European corn borer *Ostrinia nubilalis*

Gossypol in cotton affects *H. armigera* and *S. litura*

Tolerance

Ability of host plant to withstand insect population sufficient to damage susceptible plants

- No adverse effect on insect infestation
- Tolerance by plant vigour, regrowth of damaged tissues, etc.

PEST - DEFINITION, CATEGORIES, CAUSES FOR OUTBREAK, LOSSES CAUSED BY PESTS

PEST - Derived from French word 'Peste' and Latin term 'Pestis' meaning plague or contagious disease

- Pest is any animal which is noxious, destructive or troublesome to man or his interests
- A pest is any organism which occurs in large numbers and conflict with man's welfare, convenience and profit
- A pest is an organism which harms man or his property significantly or is likely to do so (Woods, 1976)
- Insects are pests when they are sufficiently numerous to cause economic damage (Debacli, 1964)
- Pests are organisms which impose burdens on human population by causing
 - (i) Injury to crop plants, forests and ornamentals
 - (ii) Annoyance, injury and death to humans and domesticated animals
 - (iii) Destruction or value depreciation of stored products.
- Pests include insects, nematodes, mites, snails, slugs, etc. and vertebrates like rats, birds, etc.

Depending upon the importance, pests may be agricultural forest, household, medical, aesthetic and veterinary pests.

CATEGORIES OF PESTS

Based on occurrence following are pest categories

Regular pest: Frequently occurs on crop - Close association e.g. Rice stem borer, Brinjal fruit borer

Occasional pest: Infrequently occurs, no close association e.g. Caseworm on rice, Mango stem borer

Seasonal pest: Occurs during a particular season every year e.g. Red hairy caterpillar on groundnut, Mango hoppers

Persistent pests: Occurs on the crop throughout the year and is difficult to control e.g. Chilli thrips, mealy bug on guava

Sporadic pests: Pest occurs in isolated localities during some period. e.g. Coconut slug caterpillar

Based on level of infestation

Pest epidemic: Sudden outbreak of a pest in a severe form in a region at a particular time e.g. BPH in Tanjore, RHC in Madurai, Pollachi

Endemic pest: Occurrence of the pest in a low level in few pockets, regularly and confined to particular area e.g. Rice gall midge in Madurai, Mango hoppers in Periyakulam

Parameters of insect population levels

General equilibrium position (GEP)

The average density of a population over a long period of time, around which the pest population over a long period of time, around which the pest population tends to fluctuate due to biotic and abiotic factors and in the absence of permanent environmental changes.

Economic threshold level (ETL)

Population density at which control measure should be implemented to prevent an increasing pest population from reaching the ETL.

Economic injury level (EIL)

The lowest population density that will cause economic damage

Damage boundary (DB)

The lowest level of damage which can be measured. ETL is always less than EIL. Provides sufficient time for control measures.

PEST CATEGORIES ACCORDING TO EIL, GEP AND DB

(i) Key pest

- Most severe and damaging pests
- GEP lies above EIL always
- Spray temporarily bring population below EIL
- These are persistent pests
- The environment must be changed to bring GEP below EIL
e.g. Cotton bollworm, Diamond backmoth

(ii) Major pest

- GEP lies very close to EIL or coincides with EIL
- Economic damage can be prevented by timely and repeated sprays e.g. Cotton jassid, Rice stem borer

(iii) Minor pest/Occasional pest

- GEP is below the EIL usually
- Rarely they cross EIL
- Can be controlled by spraying e.g. Cotton stainers, Rice hispa, Ash weevils

(iv) Sporadic pests

- GEP generally below EIL
- Sometimes it crosses EIL and cause severe loss in some places/periods e.g. Sugarcane pyrrilla, White grub, Hairy caterpillar

(v) Potential pests

- They are not pests at present
- GEP always less than EIL
- If environment changed may cause economic loss e.g. *S. litura* is potential pest in North India

CAUSES OF PEST OUTBREAK

Activity of human beings which upsets the biotic balance of ecosystem is the prime cause for pest outbreak. The following are some human interventions - Reason for outbreak

i. Deforestation and bringing under cultivation

- Pest feeding on forest trees are forced to feed on cropped
- Biomass/unit area more in forests than agricultural land
- Weather factors also altered - Affects insect development

ii. Destruction of natural enemies

- Due to excess use of insecticides, natural enemies are killed
- This affects the natural control mechanism and pest outbreak occurs, e.g. Synthetic pyrethroid insecticides kill NE.

iii. Intensive and Extensive cultivation

- Monoculture (Intensive) leads to multiplication of pests
- Extensive cultivation of susceptible variety in large area - No competition for food - multiplication increases
e.g. Stem borers in rice and sugarcane

iv. Introduction of new varieties and crops.

Varieties with favourable physiological and morphological factors cause multiplication of insects. e.g.

- Succulent, dwarf rice varieties favour leaf folder
- Combodia cotton favours stem weevil and spotted bollworm
- Hybrid sorghum (CSH 1), cumbu (HB1) favour shoot flies and gall midges

v. Improved agronomic practices

- | | |
|------------------------|--------------------------------------|
| Increased N fertilizer | - High leaf folder incidence on rice |
| Closer planting | - BPH and leaf folder increases |
| Granular insecticides | - Possess phytotonic effect on rice |

vi. Introduction of new pest in new environment

- Pest multiplies due to absence of natural enemies in new area
- Apple wooly aphid *Eriosoma lanigerum* multiplied fast due to absence of *Aphelinus mali* (Parasit)

vii. Accidental introduction of pests from foreign countries (through air/sea ports) e.g.

- a. Diamondback moth on cauliflower (*Plutella xylostella*)
- b. Potato tuber moth *Phthorimaea operculella*
- c. Cottony cushion scale *Icerya purchasi* on wattle tree
- d. Wooly aphid - *Eriosoma lanigerum* on apple
- e. Psyllid - *Heteropsylla cubana* on subabul
- f. Spiralling whitefly - *Adeyrodichus dispersus* on most of horticultural crops

viii. Large scale storage of food grains

- Serve as reservoir for stored grain pests
- Urbanisation - changes ecological balance
- Rats found in underground drainage

Resurgence

Tremendous increase in pest population brought about by insecticides despite good initial reduction in pest population at the time of treatment.

- | | |
|-----------------------------------|-----------------------------|
| Deltamethrin, Quinalphos, Phorate | - Resurgence of BPH in rice |
| Synthetic pyrethroids | - Whitefly in cotton |
| Carbofuran | - Leaf folder in rice |

Losses caused by pests

Crop loss from all factors - 500 billion US \$ annually world wide

- | | |
|-----------------|----------------------------|
| Insect pests | - 15.6% loss of production |
| Plant pathogens | - 13.3% |
| Weeds | - 13.2% |

Estimated crop loss in various crops in India

	Crop	Loss in yield %
1.	Wheat	3.0
2.	Rice	10.0
3.	Maize	5.0
4.	Sorghum	5.0
5.	Cotton	18.0
6.	Pulses, groundnut	5.0
7.	Sugarcane	10.0
8.	Coffee	8.0
9.	Fruits	25.0
10.	Coconut	5.0

Source: (Pradhan (1964)

Estimated annual crop loss in India by insect pests = Rs.29,240 crores

(Dhaliwal and Arora, 1996)

PEST MONITORING - PEST SURVEILLANCE AND FORECASTING - OBJECTIVES, SURVEY, SAMPLING, TECHNIQUES AND DECISION MAKING - ETL AND EIL. FACTORS INFLUENCING EIL AND ETL.

Pest Monitoring

- Monitoring phytophagous insects and their natural enemies is a fundamental tool in IPM - for taking management decision
- Monitoring - estimation of changes in insect distribution and abundance
 - information about insects, life history
 - influence of biotic and abiotic factors on pest population

Pest Surveillance

- Refers to the constant watch on the population dynamics of pests, its incidence and damage on each crop at fixed intervals to forewarn the farmers to take up timely crop protection measures.

Three basic components of pest surveillance

Determination of

- a. the level of incidence of the pest species
- b. the loss caused by the incidence
- c. the economic benefits, the control will provide

Pest Forecasting

Forecasting of pest incidence or outbreak based on information obtained from pest surveillance.

Uses

- Predicting pest outbreak which needs control measure
- Suitable stage at which control measure gives maximum protection

Two types of pest forecasting

- a. Short term forecasting - Based on 1 or 2 seasons
- b. Long term forecasting - Based on affect of weather parameters on pest

Objectives of Pest Surveillance

- to know existing and new pest species
- to assess pest population and damage at different growth stage of crop
- to study the influence of weather parameters on pest
- to study changing pest status (Minor to major)
- to assess natural enemies and their influence on pests
- effect of new cropping pattern and varieties on pest

Survey

Conducted to study the abundance of a pest species

Two types of survey - Roving survey and fixed plot survey

Roving survey

- Assessment of pest population/damage from randomly selected spots representing larger area
- Large area surveyed in short period
- Provides information on pest level over large area

Fixed plot survey

Assessment of pest population/damage from a fixed plot selected in a field. The data on pest population/damage recorded periodic from sowing till harvest. e.g. 1 sq.m. plots randomly selected from 5 spots in one acre of crop area in case of rice. From each plot 10 plants selected at random. Total tillers and tillers affected by stem borer in these 10 plants counted. Total leaves and number affected by leaf folder observed. Damage expressed as per cent damaged tillers or leaves. Population of BPH from all tillers in 10 plants observed and expressed as number/tiller.

Qualitative survey - Useful for detection of pest

Quantitative survey - Useful for enumeration of pest

Sampling Techniques

Absolute sampling - To count all the pests occurring in a plot

Relative sampling - To measure pest in terms of some values which can be compared over time and space e.g. Light trap catch, Pheromone trap

Methods of sampling

- In situ* counts - Visual observation on number of insects on plant canopy (either entire plot or randomly selected plot)
- Knock down - Collecting insects from an area by removing from crop and (Sudden trap) counting (Jarring)
- Netting - Use of sweep net for hoppers, odonates, grasshopper
- Narcotised collection - Quick moving insects anaesthetised and counted
- Trapping
 - Light trap - Phototropic insects
 - Pheromone trap - Species specific*
 - Sticky trap - Sucking insects*
 - Bait trap - Sorghum shootfly - Fishmeal trap*
 - Emergence trap - For soil insects*

f. Crop samples

Plant parts removed and pest counted e.g. Bollworms

Stage of Sampling

- Usually most injurious stage counted
- Sometimes egg masses counted - Practical considerations
- Hoppers - Nymphs and adult counted

Sample Size

- Differs with nature of pest and crop
- Parger sample size gives accurate results

Decision Making

- Population or damage assessed from the crop
- Compared with ETL and EIL
- When pest level crosses ETL, control measure has to be taken to prevent pest from reducing EIL.

Economic Injury Level

- Defined as the lowest population density that will cause economic damage (Stern *et al.*, 1959)
- Also defined as a critical density where the loss caused by the pest equals the cost of control measure

EIL can be calculated using following formula

$$EIL = \frac{C}{V \times I \times D \times K} \quad (\text{or}) \quad \frac{C}{VIDK}$$

where,

EIL = Economic injury level in insects/production (or) insects/ha

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

V = Market value per unit of yield or product (Rs./tonne)

I = Crop injury per insect (Per cent defoliation/insect)

D = Damage or yield loss per unit of injury (Tonne loss/% defoliation)

K = Proportionate reduction in injury from pesticide use

Worked examples of EIL

Calculate EIL in terms of pest population/ha with following figures

C = Management cost per unit area = Rs.3,000/- per ha

V = Market value in Rs./unit product = Rs.1,000/tonne

- I = Crop injury/pest density = 1% defoliation/100 insects
D = Loss caused by unit injury = 0.05 tonne loss/1% defoliation
K = Proportionate reduction in injury by pesticide application = 0.8 (80% control)

$$EIL = \frac{C}{VIDK} = \frac{3000}{1000 \times 0.01 \times 0.05 \times 0.8}$$

$$EIL = 7500 \text{ insects/ha}$$

Economic threshold level (ETL) or Action threshold

- ETL is defined as the pest density at which control measures should be applied to prevent an increasing pest population from reaching Economic Injury Level (EIL)
- ETL represents pest density lower than EIL to allow time for initiation of control measure

Factors Influencing ETL and EIL

- | | | |
|----------------------------------|---|-------------------|
| a. Market value of crop | } | Primary factors |
| b. Management costs | | |
| c. Degree of injury per insect | } | Secondary factors |
| d. Crop susceptibility to injury | | |

- a. Market value of crop

When crop value increases, EIL decreases and vice-versa

- b. Management of injury per insect

When management costs increase, EIL also increases

- c. Degree of injury per insect

- Insects damaging leaves or reproductive parts have different EIL (Lower EIL for Rep. part damages)
- If insects are vectors of disease EIL is very low even 1 or 2 insects if found - management to be taken
- If insects found on fruits - Marketability reduced - EIL very low

- e. Crop susceptibility to injury

- If crop can tolerate the injury and give good yield. EIL can be fixed at a higher value
- When crop is older, it can withstand high pest population - EIL can be high

Tertiary factors

Weather, soil factors, biotic factors and human social environment

These tertiary factors cause change in secondary factors thereby affect the ETL and EIL.

PEST MANAGEMENT - DEFINITION - NEED - OBJECTIVES - REQUIREMENTS FOR SUCCESSFUL PEST MANAGEMENT PROGRAMME - COMPONENTS OF PEST MANAGEMENT

Pest Management (or) Integrated Pest Management – Definition IPM definition by FAO (1967)

Integrated Pest Management (IPM) is a system that, in the context of associated environment and population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains pest populations at levels below those causing economic injury.

IPM definition by Luckmann and Metcalf (1994)

IPM is defined as the intelligent selection and use of pest control tactics that will ensure favourable economical, ecological and sociological consequences.

Need for Pest Management (or) Why Pest Management

1. Development of resistance in insects against insecticides e.g. OP and synthetic pyrethroid resistance in *Helicoverpa armigera*.
2. Out break of secondary pests e.g. Whiteflies emerged as major pest when spraying insecticide against *H. armigera*.
3. Resurgence of target pests e.g. BPH of rice increased when some OP chemicals are applied.
4. When number of application increases, profit decreases.
5. Environmental contamination and reduction in its quality.
6. Killing of non-target animals and natural enemies.
7. Human and animal health hazards.

Stages in crop protection leading to IPM

- | | | | |
|----|-----------------------------|---|-------------------------------------------------------------------------------------------------------------------|
| 1. | Subsistence phase | : | Only natural control, no insecticide use |
| 2. | Exploitation phase | : | Applying more pesticides, growing HY varieties and get more yield and returns |
| 3. | Crisis phase | : | Due over use pesticides, problem of resurgence, resistance, secondary pest out break, increase in production cost |
| 4. | Disaster phase | : | Due to increased pesticide use - No profit, high residue in soil - Collapse of control system |
| 5. | Integrated Management Phase | : | IPM integrates ecofriendly methods to optimize control rather than maximise it. |

Objectives of pest management

1. To reduce pest status below economic injury level. Complete elimination of pest is not the objective.
2. To manage insects by not only killing them but by preventing feeding, multiplication and dispersal.
3. To use ecofriendly methods, which will maintain quality of environment (air, water, wild life and plant life)
4. To make maximum use of natural mortality factors, apply control measures only when needed.
5. To use component in sustainable crop production.

Requirements for successful pest management programme

1. Correct identification of insect pests
2. Life history and behaviour of the pest
3. Natural enemies and weather factors affecting pest population
4. Pest surveillance will provide above data
5. Pest forecasting and predicting pest outbreak
6. Finding out ETL for each pest in a crop
7. Need and timing of control measure - Decision
8. Selection of suitable methods of control
9. Analysis of cost/benefit and benefit/risk of each control measure
10. Farmer's awareness and participation
11. Government support
12. Consumer awareness on use of pesticides free products

TOOLS OR COMPONENTS OF INTEGRATED PEST MANAGEMENT (Arranged in increasing order of complexity)

- i. Cultural method or use of agronomic practices
 1. Crop rotation
 2. Crop refuse destruction
 3. Tillage of soil
 4. Variation in time of planting or harvesting
 5. Pruning or thinning
 6. Fertilizer management
 7. Water management
 8. Intercropping
 9. Trap crop
- ii. Host plant resistance - Antixenosis, antibiosis, tolerance
- iii. Mechanical methods of pest control
 1. Hand destruction
 2. Exclusion by screens, barriers
 3. Trapping, suction devices, collecting machine
 4. Crushing and grinding

iv. Physical methods

1. Heat
2. Cold
3. Energy - light trap, irradiation, light regulation
4. Sound

v. Biological methods

1. Protection and encouragement of NE
2. Introduction, artificial increase and colonizing specific parasitoids and predators
3. Pathogens on insects like virus, bacteria, fungi and protozoa
4. Use of botanicals like neem, pongam, etc.

vi. Chemical methods

1. Attractants
2. Repellents
3. Insecticides - OC, OP, carbamates, pyrethroids, etc.
4. Insect growth inhibitors
5. Chemosterilants

vii. Behavioural methods

1. Pheromones
2. Allelochemicals

viii. Genetic/biotechnology method

- Release of genetically incompatible/sterile pests
- Transgenic plant

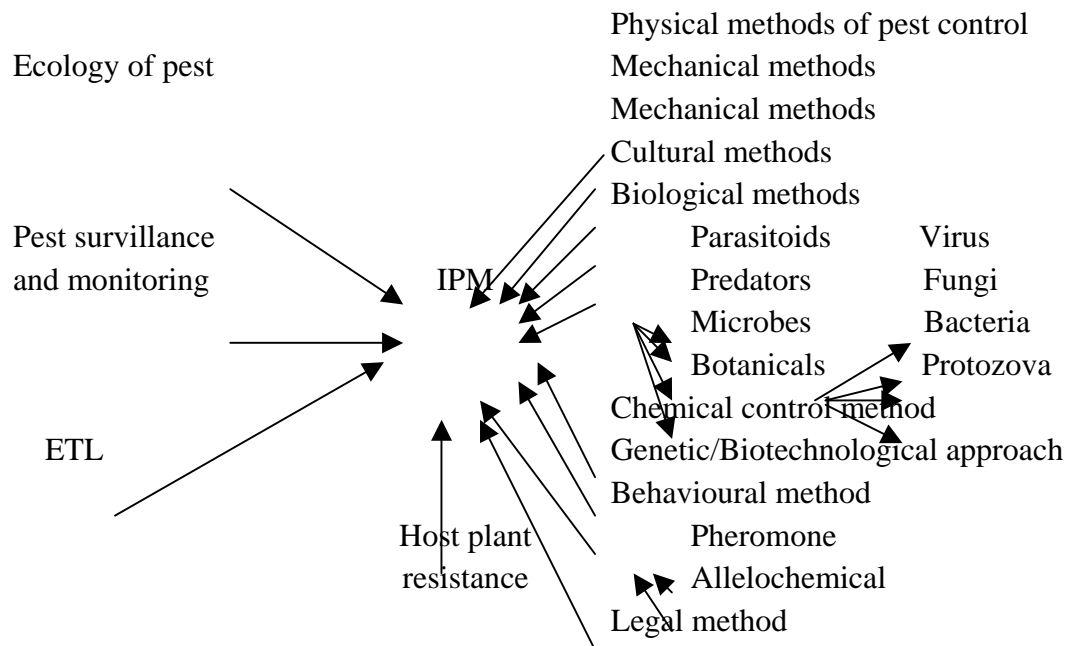
ix. Regulatory/legal method

- Plant/animal quarantine
- Eradication and suppression programme

TOOLS OR COMPONENTS OF INTEGRATED PEST MANAGEMENT

Inputs/Requirements

Components of IPM



TRADITIONAL METHODS OF PEST CONTROL

CULTURAL CONTROL

Definition : Manipulation of cultural practices to the disadvantage of pests.

I. Farm level practices

S.No.	Cropping Techniques	Pest Checked
1.	Ploughing	Red hairy caterpillar
2.	Puddling	Rice mealy bug
3.	Trimming and plastering	Rice grass hopper
4.	Pest free seed material	Potato tuber moth
5.	High seed rate	Sorghum shootfly
6.	Rogue space planting	Rice brown planthopper
7.	Plant density	Rice brown planthopper
8.	Earthing up	Sugarcane whitefly
9.	Detrashing	Sugarcane whitefly
10.	Destruction of weed hosts	Citrus fruit sucking moth
11.	Destruction of alternate host	Cotton whitefly
12.	Flooding	Rice armyworm
13.	Trash mulching	Sugarcane early shoot borer
14.	Pruning / topping	Rice stem borer
15.	Intercropping	Sorghum stem borer
16.	Trap cropping	Diamond back moth
17.	Water management	Brown planthopper
18.	Judicious application of fertilizers	Rice leaf folder
19.	Timely harvesting	Sweet potato weevil

II. Community level practices

1. Synchronized sowing : Dilution of pest infestation (eg) Rice, Cotton
2. Crop rotation : Breaks insect life cycle
3. Crop sanitation
 - a) Destruction of insect infested parts (eg.) Mealy bug in brinjal
 - b) Removal of fallen plant parts (eg.) Cotton squares
 - c) Crop residue destruction (eg.) Cotton stem weevil

Advantages	Disadvantages
1. No extra skill	1. No complete control
2. No costly inputs	2. Prophylactic nature
3. No special equipments	3. Timing decides success
4. Minimal cost	
5. Good component in IPM	
6. Ecologically sound	

PHYSICAL CONTROL

Modification of physical factors in the environment to minimise (or) prevent pest problems. Use of physical forces like temperature, moisture, etc. in managing the insect pests.

A. Manipulation of temperature

1. Sun drying the seeds to kill the eggs of stored product pests.
2. Hot water treatment (50 - 55°C for 15 min) against rice white tip nematode.
3. Flame throwers against locusts.
4. Burning torch against hairy caterpillars.
5. Cold storage of fruits and vegetables to kill fruitflies (1 - 2°C for 12 - 20 days).

B. Manipulation of moisture

1. Alternate drying and wetting rice fields against BPH.
2. Drying seeds (below 10% moisture level) affects insect development.
3. Flooding the field for the control of cutworms.

C. Manipulation of light

1. Treating the grains for storage using IR light to kill all stages of insects (eg.) Infra-red seed treatment unit (Fig.1).
2. Providing light in storage goes down as the lighting reduces the fertility of Indian meal moth, *Plodia*.
3. Light trapping.

D. Manipulation of air

1. Increasing the CO₂ concentration in controlled atmosphere of stored grains to cause asphyxiation in stored product pests.

E. Use of irradiation

Gamma irradiation from Co⁶⁰ is used to sterilize the insects in laboratory which compete with the fertile males for mating when released in natural condition. (eg.) cattle screw worm fly, *Cochliomyia hominivorax* control in Curacao Island by E.F.Knipling.

F. Use of greasing material

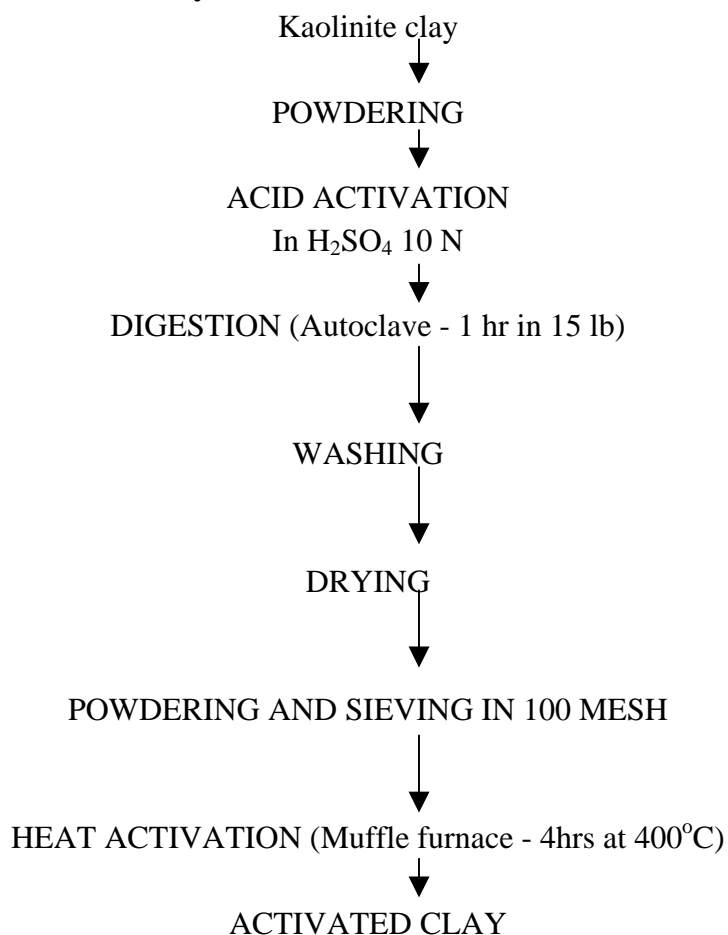
Treating the stored grains particularly pulses with vegetable oils to prevent the oviposition and the egg hatching. eg., bruchid adults.

G. Use of visible radiation : Yellow colour preferred by aphids, cotton whitefly : yellow sticky traps.

H. Use of Abrasive dusts

1. Red earth treatment to red gram : Injury to the insect wax layer.
2. Activated clay : Injury to the wax layer resulting in loss of moisture leading to death. It is used against stored product pests.
3. Drie-Die : This is a porous finely divided silica gel used against storage insects.

Preparation of activated clay :



MECHANICAL CONTROL

Use of mechanical devices or manual forces for destruction or exclusion of pests.

A. Mechanical destruction : Life stages are killed by manual (or) mechanical force.

Manual Force

1. Hand picking the caterpillars
2. Beating : Swatting housefly and mosquito
3. Sieving and winnowing : Red flour beetle (sieving) rice weevil (winnowing)
4. Shaking the plants : Passing rope across rice field to dislodge caseworm and shaking neem tree to dislodge June beetles
5. Hooking : Iron hook is used against adult rhinoceros beetle
6. Crushing : Bed bugs and lice
7. Combing : Delousing method for Head louse
8. Brushing : Woolen fabrics for clothes moth, carper beetle.

Mechanical force

1. **Entoletter** : Centrifugal force - breaks infested kernels - kill insect stages - whole grains unaffected - storage pests.
2. Hopper dozer : Kill nymphs of locusts by hording into trenches and filled with soil.
3. Tillage implements : Soil borne insects, red hairy caterpillar.
4. Mechanical traps : Rat traps of various shapes like box trap, back break trap, wonder trap, Tanjore bow trap.

B. Mechanical exclusion

Mechanical barriers prevent access of pests to hosts.

1. Wrapping the fruits : Covering with polythene bag against pomegrante fruit borer.
2. Banding : Banding with grease or polythene sheets - Mango mealybug.
3. Netting : Mosquitoes, vector control in green house.
4. Trenching : Trapping marching larvae of red hairy catepillar.
5. Sand barrier : Protecting stored grains with a layer of sand on the top.
6. Water barrier : Ant pans for ant control.
7. Tin barrier : Coconut trees protected with tin band to prevent rat damage.
8. Electric fencing : Low voltage electric fences against rats.

Advantage of mechanical control

1. Home labour utilization
2. Low equipment cost
3. Ecologically safe
4. High technical skill not required in adopting.

Disadvantages

1. Limited application
2. Rarely highly effective
3. Labour intensive

Appliances in controlling the pests

1. Light traps : Most adult insects are attracted towards light in night. This principle is used to attract the insect and trapped in a mechanical device.
 - a) Incandescent light trap : They produce radiation by heating a tungsten filament. The spectrum of lamp include a small amount of ultraviolet, considerable visible especially rich in yellow and red. (eg.) Simple incandescent light trap (Fig. 2), portable incandescent electric (Fig.3). Place a pan of kerosenated water below the light source.
 - b) Mercury vapour lamp light trap : They produce primarily ultraviolet, blue and green radiation with little red. (eg.) Robinson trap (Fig.4). This trap is the basic model designed by Robinson in 1952. This is currently used towards a wide range of Noctuids and other nocturnal flying insects. A mercury lamp (125 W) is fixed at the top of a funnel shaped (or) trapezoid galvanized iron cone terminating in a collection jar containing dichlorvos soaked in cotton as insecticide to kill the insect.
 - c) Black light trap : Black light (Fig.5) is popular name for ultraviolet radiant energy with the range of wavelengths from 320-380 nm. Some commercial type like Pest-O-Flash, Keet-O-Flash are available in market. Flying insects are usually attracted and when they come in contact with electric grids, they become elctrocuted and killed.
2. Pheromone trap : Synthetic sex pheromones are placed in traps to attract males. The rubberised septa, containing the pheromone lure are kept in traps designed specially for this purpose and used in insect monitoring / mass trapping programmes. Sticky trap (Fig.6), water pan trap (Fig.7) and funnel type (Fig.8) models are available for use in pheromone based insect control programmes.
3. Yellow sticky trap : Cotton whitefly, aphids, thrips prefer yellow colour. Yellow colour is painted on tin boxes and sticky material like castor oil / vaseline is smeared on the surface (Fig.9). These insects are attracted to yellow colour and trapped on the sticky material.
4. Bait trap : Attractants placed in traps are used to attract the insect and kill them. (eg.) Fishmeal trap: This trap is used against sorghum shootfly. Moistened fish meal is kept in polythene bag or plastic container inside the tin along with cotton soaked with insecticide (DDVP) to kill the attracted flies (Fig.10&11).
5. Pitfall trap helps to trap insects moving about on the soil surface, such as ground beetles, collembola, spiders. These can be made by sinking glass jars

(or) metal cans into the soil. It consists of a plastic funnel, opening into a plastic beaker containing kerosene supported inside a plastic jar (Fig. 12).

6. Probe trap : Probe trap is used by keeping them under grain surface to trap stored product insect (Fig.13).
7. Emergence trap : The adults of many insects which pupate in the soil can be trapped by using suitable covers over the ground. A wooden frame covered with wire mesh covering and shaped like a house roof is placed on soil surface. Emerging insects are collected in a plastic beaker fixed at the top of the frame (Fig.14).
8. Indicator device for pulse beetle detection : A new cup shaped indicator device has been recently designed to predict timely occurrence of pulse beetle *Callosobruchus spp.* This will help the farmers to know the correct time of emergence of pulse beetle. This will help them in timely sun drying which can kill all the eggs.

TAMIL NADU AGRICULTURAL UNIVERSITY
CENTRE FOR PLANT PROTECTION STUDIES
DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
MID-SEMESTER EXAMINATION – MODEL QUESTION PAPER
AEN 201. Principles of Applied Entomology (2+1)

Date : 14-6-2002

Time : 1hr.

Marks : 20

PART- A

Match the following (any eight)

8 x 0.5 = 4

- | | |
|------------------------------|-------------------------------------|
| A1. Drones | - Pollination by honeybees |
| A2. Sun drying of foodgrains | - Transmits bubonic plague |
| A3. Sudden outbreak of pest | - Inactivity of insects in winter |
| A4. Gause's principle | - Emerge from unfertilized eggs |
| A5. Myiasis | - Communication in bees |
| A6. Newspaper method | - Pest epidemic |
| A7. Mellitophily | - Competitive exclusion |
| A8. Rat flea | - Infestation of tissues by maggots |
| A9. Karl von Frisch | - Kills stored product insects |
| A10. Hibernation | - Uniting bee colonies |

PART - B

Answer any six

6 x 1 = 6

- | | |
|---------------------------------|-----------------------------------------|
| B1. Wagtail dance | B5. ETL and EIL |
| B2. Supercedure | B6. Roving survey and fixed plot survey |
| B3. Management of mosquitoes | B7. Delousing cattle and birds |
| B4. Key pest and potential pest | B8. Ripening of honey |

PART - C

Answer any five

5 x 2 = 10

- C1. Draw a flow chart to show economic classification of insects
- C2. List 5 major differences between rock bee (*Apis dorsata*) and Indian bee (*Apis cerana indica*)
- C3. Discuss the ways to reduce pesticidal poisoning to bees.
- C4. Write in brief the causes for pest outbreak
- C5. Discuss pollination in fig by fig wasp
- C6. Define IPM. Give a diagrammatic representation of various components of IPM
- C7. Define cultural method of pest control. Mention any eight farm level cultural practices with examples

WISH YOU ALL THE BEST

LEGAL CONTROL METHODS - DEFINITION - PEST INTRODUCTIONS - QUARANTINE - PHYTOSANITARY CERTIFICATE PEST LEGISLATION LEGAL CONTROL/LEGISLATIVE CONTROL/REGULATORY CONTROL

Definition: Preventing the entry and establishment of foreign plant and animal pest in a country or area and eradication or suppression of the pests established in a limited area through compulsory legislation or enactment

Pests Accidentally Introduced Into India

1. Pink bollworm - *Pectinophora gossypiella*
2. Cotton cushion scale - *Icerya purchasi*
3. Woolly aphid of apple - *Aphelinus mali*
4. SanJose scale - *Quadraspidiotus perniciosus*
5. Potato tuber moth - *Gnorimoschima operculella*
6. Cyst (Golden) nematode of potato - *Globodera* sp.
7. Giant african snail - *Acatina fullica*
8. Subabul psyllid - *Heteropsylla cubana*
9. Bunchytop disease of banana
10. Spinalling whitefly - *Aleyrodicus dispersus*

Foreign Pests From Which India Is Free

1. Mediterranean fruitfly - *Ceratitidis capitata*
2. Grapevine phylloxera
3. Cotton boll weevil - *Anthonomos grandis*
4. Codling moth of apple - *Lasperyssia pomonella*

Quarantine

Isolation to prevent spreading of infection

Plant Quarantine

Legal restriction of movement of plant materials between countries and between states within the country to prevent or limit introduction and spread of pests and diseases in areas where they do not exist.

PEST LEGISLATIONS

- 1905 - 'Federal Insect Pest Act' - first Quarantine act against SanJose scale
- 1912 - 'US Plant Quarantine Act'
- 1914 - 'Destructive Insects and Pests Act' of India (DIPA)
- 1919 - 'Madras Agricultural Pests and Diseases Act'
- 1968 - 'The Insecticides Act'

DIFFERENT CLASSES OF QUARANTINE

1. Foreign Quarantine (Legislation to prevent the introduction of new pests, diseases and weeds from foreign countries)

- a. Plant quarantine inspection and treatments at sea ports of Mumbai, Kolkata, Cochin, Chennai and Visakapattinam and airports of Amritsar, Mumbai, Kolkata, Chennai and New Delhi
- b. Import by post parcel prohibited except by scientists
- c. Import of plant materials prohibited or restricted
- d. Import permits required for importation of plant material
- e. Phytosanitary certificate from the country of origin is required

Phytosanitary certificate is issued by State Entomologist and Pathologists to the effect that the plant or seed material is free from any pest or disease

- a. Fumigation of imported plant material based on need
- b. Taking care of pests of quarantine concern in India

Restriction imposed on the importation of

- i. Sugarcane setts - to prevent West Indies sugar weevil
- ii. Coffee seeds - to prevent coffee berry borer
- iii. Cotton seeds - to prevent cotton boll weevil
- a. Export of pepper, cardamom and tamarind restricted
- b. In 1946, Directorate of Plant Protection, Quarantine and Storage, Government of India established - for inspection of export and import of agricultural commodities.

2. Domestic quarantine (within different parts of country)

- Fluted scale *Icerya puchasi* noticed in Nilgiris and Kodaikanal in 1943 in Wattle trees. Quarantine stations at Mettupalayam and Gudalur for Nilgiris and Shenbaganur for Kodaikanal to prevent spread of fluted scale in TN.
- Preventing movement of Banana from Palani hills to prevent Bunchy top spread

3. Legislation to take up effective measures to prevent spread of established pests Example: Cotton stem weevil, Groundnut RHC, Coffee stem borer, Coconut black headed caterpillar (BHC), Sugarcane top borer.

i. Stem weevil of cotton (Combodia cotton, 1913)

Previous crop to be removed before Aug.1

Next crop to be sown not before Sep. 1 to keep land free of cotton for sometime

ii. RHC of groundnut (1930)

- Collection of pupae in summer ploughing
- Putting light traps and bonfires
- Hand picking of egg and larvae
- Spread leaves in field, trench, collect and destroy

iii. Stem borer of coffee (1946)

This act is still in force in Salem, Coimbatore, Madurai and Nilgiris

- All infested plants to be removed and destroyed by 15th December every year
- Swabbing with wettable powder (Carbaryl) on stem and branch

4. Legislation to prevent the adulteration and misbranding of insecticides and to determine the permissible residues in food stuff.

5. Legislation to regulate the activities of men engaged in pest control

THE INSECTICIDES ACT, 1968

- Implemented in 1971 (Insecticides Rule, 1971)
- Safety oriented legislation
- Regulates import, manufacture, storage, transport, sale, distribution and use of insecticides with a view to prevent risk to human beings and animals
- Regulatory provision - compulsory registration, licensing, inspection, drawal and analysis of samples, detention, seizure and confiscation of stocks, suspension and cancellation of licences, etc.
- Enforcement of the act is joint responsibility of central and state governments.
- Statutory bodies
 - (i) Central Insecticides Board (CIB) (28 members)
Chairman (CIB) - Director General of Health Services
 - (ii) Registration Committee (RC) (5 members)
Chairman (RC) - Deputy Director General, Crop Sciences, ICAR

Salient features of the insecticides act (1968)

- Compulsory registration with CIB (Central level)
- Licence for manufacture, formulation and sale at state level
- Inter departmental/Ministerial/Organisational co-ordination achieved by high level Advisory Board "Central Insecticides Board" with 28 members from various fields
- RC to look after registration aspects of insecticides
- Enforcement by Insecticide inspectors at state/central level
- Power to prohibit the import, manufacture and sale of insecticides and also confiscate stocks. Guilty are punishable.

Role of Plant Quarantine in the Export of Agricultural Commodities

International Plant Protection Convention (1951) of FAO, UN.

Article V of the convention makes it mandatory for member countries to issue Phytosanitary certificate (PSC)

PSC should be in conformity with Plant Quarantine Regulations of importing country.

Agricultural commodities during export should be accompanied by PSC.

General requirement of PSC

- Inspected agrl. commodities should be free from pest/diseases
- Takes time for inspection - seek prior guidance from plant quarantine authorities in India

Special requirements of PSC

- Additional declarations required from importing country for freedom of commodities from specific pests/diseases
- Obtain complete details of requirements of importing country

Technical limitations

- Rules not relaxable. No compromise with principles of Plant Quarantine.

Procedure for getting PSC

- Application to be submitted to Plant Quarantine and Fumigation station
- Will be scrutinised, samples drawn and examined for pest, diseases, weeds
- If free PSC issued
- If found infested - rejected, PSC not issued
- Sometimes treatment (fumigation) given and PSC issued

Authority to issue PSC

Union Govt. of Agrl. has authorised officers in Central and State Govt. and UT
PPA to Govt. of India - Heads of Unit

Airports	Seaports	Land frontiers
Amristar	Bombay	Amristar Rail
Bombay	Tuticorin	Attari Rail
Calcutta	Bhavnagar	Attari Road
Hyderabad	Calcutta	Bongaon
Chennai	Cochin	Gede
New Delhi	Chennai	Kalimpong
Patna	Nagapattinam	Panitanki
Varanasi	Rameswaram	
Tiruchirapalli	Visakhapatnam	
Trivandrum		

HOST PLANT RESISTANCE - DEFINITION - TYPES AND MECHANISMS ECOLOGICAL AND GENETIC RESISTANCE

Host Plant Resistance (HPR)

Definition

“Those characters that enable a plant to avoid, tolerate or recover from attacks of insects under conditions that would cause greater injury to other plants of the same species” (Painter, R.H., 1951).

“Those heritable characteristics possessed by the plant which influence the ultimate degree of damage done by the insect” (Maxwell, F.G., 1972).

Types of Resistance

Ecological Resistance or Pseudo resistance

Apparent resistance resulting from transitory characters in potentially susceptible host plants due to environmental conditions.

Pseudoresistance may be classified into 3 categories

a. Host evasion

Host may pass through the most susceptible stage quickly or at a time when insects are less or evade injury by early maturing. This pertains to the whole population of host plant.

b. Induced Resistance

Increase in resistance temporarily as a result of some changed conditions of plants or environment such as change in the amount of water or nutrient status of soil

c. Escape

Absence of infestation or injury to host plant due to transitory process like incomplete infestation. This pertains to few individuals of host.

Genetic Resistance

A. Based on number of genes

- Monogenic resistance: Controlled by single gene
 - Easy to incorporate into plants by breeding
 - Easy to break also
- Oligogenic resistance: Controlled by few genes
- Polygenic resistance: Controlled by many genes
- Major gene resistance: Controlled by one or few major genes (vertical resistance)
- Minor gene resistance: Controlled by many minor genes. The cumulative effect of minor genes is called adult resistance or mature resistance or field resistance. Also called horizontal resistance

B. Based on biotype reaction

- Vertical resistance: Effective against specific biotypes (specific resistance)
- Horizontal resistance: Effective against all the known biotypes
(Non specific resistance)

C. Based on population/Line concept

- Pureline resistance: Exhibited by lines which are phenotypically and genetically similar
- Multiline resistance: Exhibited by lines which are phenotypically similar but genotypically dissimilar

D. Miscellaneous categories

- Cross resistance: Variety with resistance incorporated against a primary pest, confers resistance to another insect.
- Multiple resistance: Resistance incorporated in a variety against different environmental stresses like insects, diseases, nematodes, heat, drought, cold, etc.

E. Based on evolutionary concept

- Sympatric resistance: Acquired by coevolution of plant and insect (gene for gene)
Governed by major genes
- Allopatric resistance: Not by co-evolution of plant and insect.
Governed by many genes

Mechanisms of Resistance

The three important mechanisms of resistance are

- Antixenosis (Non preference)
- Antibiosis
- Tolerance

a. Antixenosis: Host plant characters responsible for non-preference of the insects for shelter, oviposition, feeding, etc. It denotes presence of morphological or chemical factor which alter insect behaviour resulting in poor establishment of the insect. e.g.

Trichomes in cotton - resistant to whitefly

Wax bloom on crucifer leaves - deter feeding by DBM

Plant shape and colour also play a role in non preference

Open panicle of sorghum - Supports less Helicoverpa

b. Antibiosis

Adverse effect of the host plant on the biology (survival, development and reproduction) of the insects and their progeny due to the biochemical and biophysical factors present in it.

Manifested by larval death, abnormal larval growth, etc.

Antibiosis may be due to

- Presence of toxic substances
- Absence of sufficient amount of essential nutrients
- Nutrient imbalance/improper utilization of nutrients

Chemical factors in Antibiosis - Examples

Chemicals present in plants	Imparts resistance against
1. DIMBOA (Dihydroxy methyl benzoxazin)	Against European corn borer, <i>Ostrinia nubilalis</i>
2. Gossypol (Polyphenol)	<i>Helicoverpa armigera</i> (American bollworm)
3. Sinigrin	Aphids, <i>Myzus persicae</i>
4. Cucurbitacin	Cucurbit fruit flies
5. Salicylic acid	Rice stem borer

Physical factors in antibiosis

Thick cuticle, glandular hairs, silica deposits, tight leaf sheath, etc.

c. Tolerance

Ability to grow and yield despite pest attack. It is generally attributable to plant vigour, regrowth of damaged tissue, to produce additional branches, compensation by growth of neighbouring plants.

Use of tolerance in IPM

- Tolerant varieties have high ETL - require less insecticide
- Apply less selection pressure on pests. Biotype development is less

HPR in IPM

- HPR is a very important component of IPM
- Selection and growing of a resistant variety minimise cost on all other pest management activities

Compatibility of HPR in IPM

a. Compatibility with chemical control

- HPR enhances efficacy of insecticides
- Higher mortality of leaf hoppers and plant hoppers in resistant variety compared to susceptible variety
- Lower concentration of insecticide is sufficient to control insects on resistant variety

b. Compatibility with biological control

- Resistant varieties reduce pest numbers - thus shifting pest: Predatory (or parasitoid) ratio favourable for biological control. e.g. Predatory activity of mirid bug *Cyrtorhinus lividipennis* on BPH was more on a resistant rice variety IR 36 than susceptible variety IR 8
- Insects feeding on resistant varieties are more susceptible to virus disease (NPV)

c. Compatibility with cultural method

- Cultural practices can help in better utilization of resistant varieties. e.g. Use of short duration, pest resistant plants effective against cotton boll weevil in USA.

Examples of resistant varieties in major crops

	Pest	Resistant varieties
Rice	Yellow stem borer	TKN 6, Paiyur 1
	Brown planthopper (BPH)	CO 42, IR 36, IR 64
	Green leaf hopper (GLH)	IR 50, Ptb 2, CO 46
Sugarcane	Early shoot borer (ESB)	CO 312, CO 421, CO 661,
	Internode borer	CO 975, CO 7304
	Top shoot borer	CO 745, CO 6515
Cotton	American bollworm	Abhadita
	Spotted bollworm	Deltapine
	Stem weevil	MCU 3, Supriya
	Leaf hopper	MCU 5, K 7, K 8
Sorghum	Earhead bug	K tall
Jasmine	Eriophyid mite	Pari Mullai

Advantages of HPR as a component in IPM

1. Specificity: Specific to the target pest. Natural enemies unaffected
2. Cumulative effect: Lasts for many successive generations
3. Eco-friendly: No pollution. No effect on man and animals
4. Easily adoptable: High yielding insect resistant variety easily accepted and adopted by farmers. Less cost.
5. Effectiveness: Res. variety increases efficacy of insecticides and natural enemies
6. Compatibility: HPR can be combined with all other components of IPM
7. Decreased pesticide application: Resistant varieties requires less frequent and low doses of insecticides
8. Persistence: Some varieties have durable resistance for long periods
9. Unique situations: HPR effective where other control measures are less effective
 - a. When timing of application is critical
 - b. Crop of low economic value
 - c. Pest is continuously present and is a single limiting factor

Disadvantages of HPR

1. Time consuming: Requires from 3-10 years by traditional breeding programmes to develop a res. variety.
2. Biotype development: A biotype is a new population capable of damaging and surviving on plants previously resistant to other population of same species.
3. Genetic limitation: Absence of resistance genes among available germination

BIOLOGICAL CONTROL - DEFINITION - HISTORY AND DEVELOPMENT - CLASSICAL EXAMPLES - FACTORS GOVERNING BIOLOGICAL CONTROL

Biological control

Definition

The study and utilization of parasitoids, predators and pathogens for the regulation of pest population densities.

Biological control can also be defined as the utilization of natural enemies to reduce the damage caused by noxious organisms to tolerable levels.

Biological control is often shortened to biocontrol.

History and development of biological control and classical examples of biological control

Antient times - In China Pharaoh's ant *Monomorium pharaonis* was used to control stored grain pest. Red ant *Oecophylla* spp. used to control foliage feeding caterpillar.

Year 1762 - 'Mynah' bird imported from India to Mauritius to control locust.

1770 - Bamboo runways between citrus trees for ants to control caterpillars.

1888 - **First well planned and successful biological control attempt made**

- During 1888 citrus industry in California (USA) seriously threatened by cottony cushion scale, *Icerya purdian*
- Chemical treatments not known at that time
- Mr. C.V. Riley, a prominent entomologist suggested that the scale insect originated from Australia and natural enemy for the scale from Australia should be introduced into USA
- Mr. Albert Koebele was sent to Australia
- He found a beetle called Vedalia (*Rodolia cardinalis*) attacking and feeding on seeds
- Vedalia beetle (*Rodolia cardinalis*) was imported in November 1888 into USA and allowed on scale infested trees
- Within a year spectacular control of scale insect achieved
- Even till date this beetle controls the scale insect
- After this successful attempt of biological control many such introduction of natural enemies were tried.

1898 - First introduction of natural enemy into India

- 1898 - A coccinellid beetle, *Cryptolaemus montrouzieri* was imported into India from Australia and released against coffee green scale, *Coccus viridis*. Even today it is effective against mealybugs in South India.
- 1920 - A parasitoid *Aphelinus mali* introduced from England into India to control Woolly aphid on Apple, *Eriosoma lanigerum*.
- 1929-31 - *Fodolia cardinalis* imported into India (from USA) to control cottony cushion scale *Icerya purchasi* on Wattle trees.
- 1958-60 - Parasitoid *Prospatella perniciosus* imported from China
- 1960 - Parasitoid *Aphytis diaspidis* imported from USA
Both parasitoids used to control Apple Sanjose scale *Quadraspidiotus perniciosus*
- 1964 - Egg parasitoid *Telenomus* sp. imported from New Guinea to control Castor semilooper *Achaea janata*
- 1965 - Predator *Platymeris laevicollis* introduced from Zanzibar to control coconut Rhinoceros beetle, *Oryctes rhinoceros*

History, development, classical examples of biocontrol

Till 1988

At global level 384 importations made against 416 species of insect pests. Out of them

- 164 species (39.4%) - Completely controlled
- 75 species - Substantially controlled
- 15 species - Partially controlled
- Regional Station of Commonwealth Institute of Biological Control (CIBC) established at Bangalore in 1957
- Presently Project Directorate of Biological Control (PDBC) Bangalore looks after Biocontrol in India.

Factors affecting biological control

1. Tolerance limit of crop to insect injury - Successful in crops with high tolerance limit
2. Crop value - Successful in crops with high economic value
3. Crop duration - Long duration crops highly suitable
4. Indigenous or Exotic pest - Imported NE more effective against introduced pest
5. If alternate host available for NE, control of target pest is less
6. If unfavourable season occurs, reintroduction of NE required
7. Presence of hyperparasites reduces effectiveness of biocontrol

8. Tritrophic interaction of Plant-Pest-Natural enemy affects success of biocontrol, e.g. *Helicoverpa* parasitization by *Trichogramma* more in tomato than corn
9. Use of pesticides affect natural enemies
10. Selective insecticides (less toxic to NE required)
11. Identical situation for successful control does not occur

Qualities of an effective natural enemy

1. Adaptable to the environmental condition
2. Host specific (or narrow host range)
3. Multiply faster than the host (with high fecundity)
4. Short life cycle and high female : male ratio
5. High host searching capacity
6. Amenable for easy culturing in laboratory
7. Dispersal capacity
8. Free from hyper parasites
9. Synchronise life cycle with host

Three major techniques of biological control

1. Conservation and encouragement of indigenous NE

Defined as actions that preserve and increase NE by environmental manipulation. e.g. Use of selective insecticides, provide alternate host and refugia for NE.

2. Importation or Introduction

Importing or introducing NE into a new locality (mainly to control introduced pests).

3. Augmentation

Propagation (mass culturing) and release of NE to increase its population. Two types,

- (i) **Inoculative release:** Control expected from the progeny and subsequent generations only.
- (ii) **Inundative release:** NE mass cultured and released to suppress pest directly e.g. *Trichogramma* sp. egg parasitoid, *Chrysoperla carnea* predator

ROLE OF PARASITOIDS AND PREDATORS IN IPM

- Parasitoids and predators may be used in Agriculture and IPM in three ways. They are
 - i) Conservation
 - ii) Introduction
 - iii) Augmentation - (a) Inoculative release, (b) Inundative release

- Since biological control is safe to environment, it should be adopted as an important component of IPM.
- Biological control method can be integrated well with other methods namely cultural, chemical methods and host plant resistance (except use of broad spectrum insecticides)
- Biological control is self propagating and self perpetuating
- Pest resistance to NE is not known
- No harmful effects on humans, livestock and other organisms
- Biological control is virtually permanent
- Biological agents search and kills the target pest

MICROBIAL CONTROL

- It is a branch of biological control
- Defined as control of pests by use of microorganisms like viruses, bacteria, protozoa, fungi, rickettsia and nematodes.

I. VIRUSES

Viruses coming under family *Baculoviridae* cause disease in lepidoptera larvae. Two types of viruses are common.

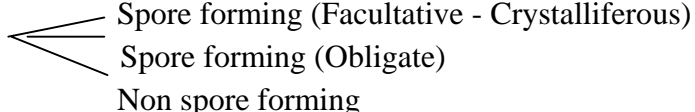
NPV (Nucleopolyhedro virus) e.g. HaNPV, SINPV

GV (Granulovirus) e.g. CiGV

Symptoms

Lepidopteran larva become sluggish, pinkish in colour, lose appetite, body becomes fragile and rupture to release polyhedra (virus occlusion bodies). Dead larva hang from top of plant with prolegs attached (Tree top disease or “Wipfelkrankheit”)

II. BACTERIA

2 types of bacteria 

- Spore forming (Facultative - Crystalliferous)
- Spore forming (Obligate)
- Non spore forming

i. Spore forming (Facultative, Crystalliferous)

The produce spores and also toxin (endotoxin). The endotoxin paralyses gut when ingested e.g. *Bacillus thuringiensis* effective against lepidopteran. Commercial products - Delfin, Dipel, Thuricide

ii. Spore-forming (Obligate)

e.g. *Bacillus popilliae* attacking beetles, produce ‘**milky disease**’

Commercial product - ‘Doom’ against ‘white grubs’

iii. Non-spore forming

e.g. *Serratia entomophila* on grubs

III. FUNGI

- Green muscardine fungus - *Metarhizium anisopliae* attack coconut rhinoceros beetle

- ii. White muscardine fungus - *Beauveria bassiana* against lepidopteran larvae
- iii. White halo fungus - *Verticillium lecanii* on coffee green scale.

Other Microbs: Protoza, Nematodes

Limitations of biocontrol technique

- Complete control not achieved - Slow process
- Subsequent pesticide use restricted
- Expensive to culture many NE
- Requires trained man power

CHEMICAL CONTROL - DEFINITION - HISTORY AND DEVELOPMENT - TOXICITY PARAMETERS - IDEAL QUALITIES OF AN INSECTICIDE

Chemical Control: Management of insect pests using chemical pesticides is termed as chemical control.

Pesticides: Chemicals which are used to kill pests

History of insecticide development

Year	<i>Chemicals</i>
900	- Arsenites in China (Inorganic compound)
1690	- Tobacco used in Europe (Plant/natural product)
1787	- Soaps used in Europe
1867	- Paris Green in US
1874	- DDT synthesized by Zeidler
1883	- Bordeaux in France
1925	- Dinitro compounds (First synthetic organic insecticide)
1932	- Thiocyanates
1939	- DDT insecticidal property discovered by Paul Muller of Switzerland . Paul Muller awarded Nobel Prize in 1948 for discovering insecticidal property of DDT
1941	- BHC in France and UK (in 1942) (BHC is presently called as HCH)
1944	- Parathion (Organo phosphate) discovered by Gerhard Schrader in Germany
1945	- Chlordane (Cyclodien compound) in Germany
1947	- Carbamate insecticides in Switzerland
1962	- Rachel Carson's Silent Spring appears (US) (This is not a chemical. The book 'Silent Spring' created awareness about ill effects of pesticides)
1967	- First JH mimic (Juvenile Hormone mimic) used in US (Insect growth regulator)
1970	- Development of synthetic pyrethroids (UK) (Fast degradation) (Effective at very low doses)
1980	- Discovery of avermectins (derived from bacteria). Effective at low dose. Fast degradation.
1990	- Discovery of newer groups like (1) Neonicotinoids (Imidacloprid), similar to natural nicotine, (2) Spinosyns (e.g. Spinosad) derived from actinomycetes

TOXICITY PARAMETERS

Toxicity of a given chemical to an organism can be measured using various parameters as listed below.

1) **LD₅₀ or Median lethal dose**

LD₅₀ is defined as the amount of insecticide per unit weight which will kill 50% of the particular organism or insect. LD₅₀ usually expressed as mg/kg body weight or µg/larva or adult insect.

2) **LC₅₀ or Median lethal concentration**

Defined as the concentration of insecticide required to kill 50% of the given organism or insect. This is used when the exact dose per insect is not known, but the concentration is known.

LC₅₀ is expressed in PPM (1/1,000,000) or Percentage (1/100)

3) **LT₅₀ (Median lethal time)**

LT₅₀ is defined as the time required to kill 50% of the population at a certain dose or concentration.

LT₅₀ expressed in hours or minutes. LT₅₀ is used in field studies and also for testing insect viruses (NPV).

4. **KD₅₀: Median knockdown dose** } Dose of insecticide or time required to
5. **KT₅₀: Median knockdown time** } knockdown 50% of the insects

KD₅₀ and KT₅₀ are used for evaluating synthetic pyrethroids against insects.

6. **ED₅₀: Median effect dose** } These terms are used to express the
7. **EC₅₀: Median effective concentration** } effectiveness of insect growth
regulators (IGR)

ED₅₀ and EC₅₀ are defined as the dose or concentration of the chemical (IGR) required to affect 50% of population and produce desired symptoms in them.

Toxicity terms used to express the effect on mammals

- | | | |
|------------------------|---|--------------------------------------------------------------------------------------------------------|
| 1. Acute toxicity | : | Toxic effect produced by a single dose of a toxicant |
| 2. Chronic toxicity | : | Toxic effects produced by the accumulation of small amounts of the toxicant over a long period of time |
| 3. Oral toxicity | : | Toxic effect produced by consumption of pesticide orally |
| 4. Dermal toxicity | : | Toxic effect produced when insecticide enters through skin |
| 5. Inhalation toxicity | : | Toxic effect produced when poisonous fumes of insecticide are inhaled (fumigants) |
| Other terms | : | Acute oral, Acute dermal, Acute inhalation toxicity, etc. |

Ideal Qualities of an Insecticide

An ideal insecticide should possess the following qualities

1. Kill the target insect effectively and quickly
2. Be less toxic to natural enemies
3. Be less toxic to honey bees, soil microorganisms
4. Be less toxic to fishes and mammals
5. Less hazardous and less toxic during handling or accidental consumption by human beings
6. Quickly degradable in environment and should be less persistent (Residues should be very less)
7. Should not cause resurgence of the target insect (i.e. Increase in population of target insect) e.g. Chlorpyrifos causes resurgence of BPH on rice.
8. Should not cause outbreak of secondary pest on a minor pest by killing the natural enemies
9. Should have a complex mode of action against which resistance development will take more time. e.g. Azadirachtin from neem tree has complex action
10. Should have a longer storage life or shelf life
11. It is advantageous to select an insecticide which can kill a relatively broad spectrum of target pests
12. It should be cost effective (High benefit/Cost ratio) and safe to use (High benefit/Risk ratio)

Various generations of insecticides

	Generation	Year	Compounds
1.	First generation insecticide	1939-1942	BHC and DDT
2.	Second generation insecticide	1944-1947	Organophosphates and Carbamate
3.	Third generation insecticide	1967	Hormonal insecticides, JH mimic insect growth regulators
4.	Fourth generation insecticide	1970s	Synthetic pyrethroids

PESTICIDES GROUPS

Groups of pesticides : The pesticides are generally classified into various groups based on pest organism against which the compounds are used, their chemical nature, mode of entry and mode of action.

1. Based on organisms

- a) Insecticides : Chemicals used to kill or control insects (eg.) endosulfan, malathion
- b) Rodenticides : Chemicals exclusively used to control rats (eg.) Zinc phosphide
- c) Acaricides : Chemicals used to control mites on crops / animals (eg.) Dicofol
- d) Avicides : Chemicals used to repel the birds (eg.) Anthraquinone
- e) Molluscicides : Chemicals used to kill the snails and slugs (eg.) Metaldehyde
- f) Nematicides : Chemicals used to control nematodes (eg.) Ethylene dibromide
- g) Fungicides : Chemicals used to control plant diseases caused by fungi (eg.) Copper oxy chloride
- h) Bactericide : Chemicals used to control the plant diseases caused by bacteria (eg.) Streptomycin sulphate
- i) Herbicide : Chemicals used to control weeds (eg.) 2,4, - D

2. Based on mode of entry

- a) Stomach poison : The insecticide applied in the leaves and other parts of the plant when ingested, act in the digestive system of the insect and bring about kill (eg.) Malathion.
- b) Contact Poison : The toxicant which brings about death of the pest species by means of contact (eg.) Fenvalerate.
- c) Fumigant : Toxicant enter in vapour form into the tracheal system (respiratory poison) through spiracles (eg.) Aluminium phosphide
- d) Systemic poison : Chemicals when applied to plant or soil are absorbed by foliage (or) roots and translocated through vascular system and cause death of insect feeding on plant. (eg.) Dimethoate.

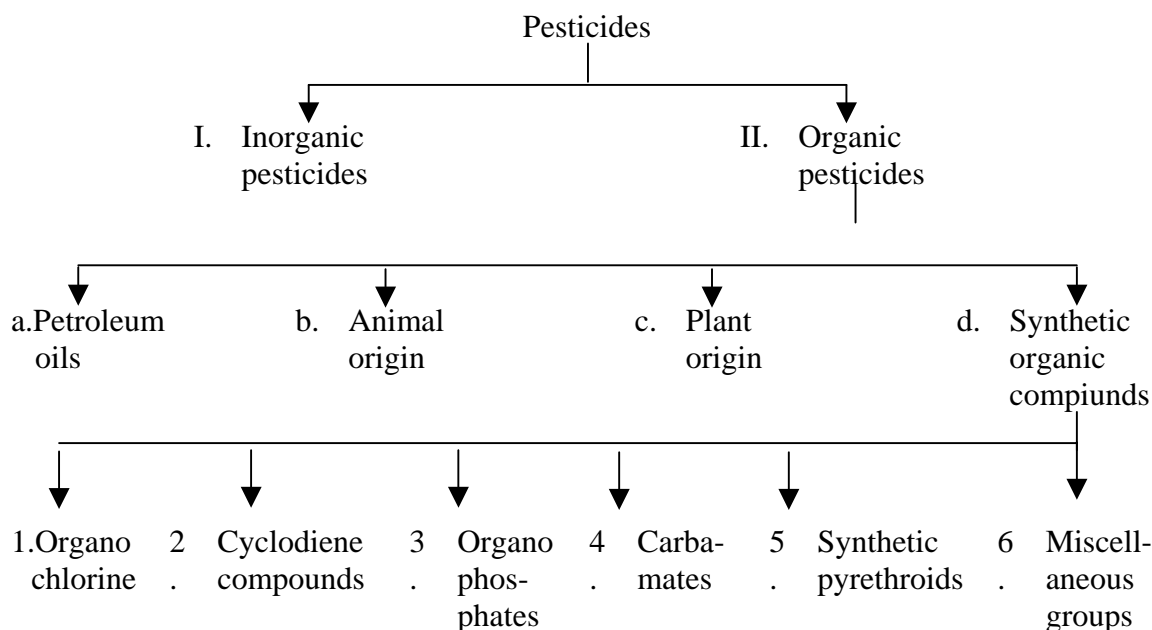
3. Based on mode of action

- a) Physical poison : Toxicant which brings about kill of one insect by exerting a physical effect (eg.) Activated clay.

- b) Protoplasmic poison : Toxicant responsible for precipitation of protein (eg.) Arsenicals.
- c) Respiratory poison : Chemicals which inactivate respiratory enzymes (eg.) hydrogen cyanide.
- d) Nerve poison : Chemicals inhibit impulse conduction (eg.) Malathion.
- e) Chitin inhibition : Chemicals inhibit chitin synthesis (eg.) Diflubenzuron.

4. Based on chemical nature

Classification based on chemical nature of insecticides



I. Inorganic pesticides

Inorganic chemicals used as insecticides

Eg. Arsenic, Fluorine, Sulphur, lime sulphur (Insecticides) zinc phosphide (Rodenticide)

II. Organic pesticides

Organic compounds (constituted by C, H, O and N mainly)

- a. Hydrocarbon oil (or) Petroleum oil – eg. Coal tar oil, kerosine etc.,
- b. Animal origin insecticides – eg. Nereistoxin extracted from marine annelids – commercially available as cartap, padan.
- c. Plant origin insecticides : Nicotine from tobacco plants, pyrethrum from *Chrysanthemum* flowers, Rotenoids from roots of *Derris* and *Lonchocarpus* Neem – *azadirachtin*, *Pongamia glabra*, Garlic etc.,
- d. Synthetic organic compounds : These organic chemicals are synthetically produced in laboratory.
 - i. Chlorinated hydrocarbon (or) organochlorines
Eg. DDT, HCH, Endosulfan, Lindane, Dicofol (DDT, HCH banned)
 - ii. Cyclodienes
Eg. Chlordane, Heptachlor (Banned chemicals)
 - iii. Organophosphates : (Esters of phosphoric acid)

- .
 - Eg. Dichlorvos, Monocrotophos, Phospanidon, Methyl parathion, Fenthion, Dimethoate, Malathion, Acephate, Chlorpyrifos
- iv. Carbamates: (Derivatives of carbamic acid)
 - Eg. Carbaryl, Carbofuran, Carbosulfan
- v. Synthetic pyrethroids ; (Synthetic analogues of pyrethrum)
 - Eg. Allethrin, Cypermethrin, Fenvalerate
- vi. Miscellaneous compounds
 - a. Neonicotinoids (Analogues of nicotine) eg. Imidacloprid
 - b. Spinosyns (Isolated from actinomycetes) eg. Spinosad
 - c. Avermectins (Isolated from bacteria) eg. Avermectin, Vertimec
 - d. Fumigants : Eg. Aluminium phosphide, Hydrogen cyanide, EDCT

The Insecticides Act, 1968

An act to regulate the import, manufacture, sale, transport, distribution and use of insecticides with a view to prevent risk to human beings on animals and for matters connected therewith.

Salient features of the Insecticides Act

1. **Compulsory registration** of the product at the Central level and licenses for manufacture, formulation and sale at state level.
2. Inter – departmental / ministerial / organizational co-ordination is achieved by a high level advisory board “**Central Insecticides Board**” with 24 members (to be raised to 29 by an amendment) drawn from various fields having expert knowledge of the subject.
3. “**Registration Committee**” to look after the registration aspects of all Insecticides.
4. Establishment of enforcement machinery like Insecticide Analysts and **Insecticide Inspectors** by the Central or State Government.
5. Establishment of **Central Laboratory**
6. **Power to prohibit** the import, manufacture, and sale of pesticides and also **confiscate** the stocks. The offences are punishable and size and other penalties are prescribed.
7. Both the Central and State Governments are empowered to make rules, prescribe forms and fees.

The Central Insecticides Board (CIB)

The Central Insecticides Board advises on matters relating to:

- a. The risk to human beings or animals involved in the use of insecticides and the safety measures necessary to prevent such risk.
- b. The manufacture, sale, storage, transport, distribution of insecticides with a view to ensure safety to human beings and animals.

Board members

1. The Director General Health Services ⇐ Chairman
2. The Drugs Controller, India
3. The Plant Protection Adviser to the Government of India
4. The Director General, ICAR
5. The Director General, ICMR

Totally 24 members – others from various other fields such as BIS, Animal husbandry, Pharmacology, Fisheries, Wild life etc.,

The Registration Committee (RC)

RC comprises a Chairman and five members. Among them are:

1. Deputy Director General, Crop Sciences, ICAR-Chairman
2. Drugs Controller, India
3. Plant Protection Adviser to the Government of India

Role of RC

To register insecticides after scrutinizing them with regard to efficacy and safety.

Registration of Insecticides

- a. When applied for registration, the RC allots a registration number within a period of 12 months.
- b. When pesticide registered for first time in India, provisional registration for two years given initially. After data generation full registration allowed.

The Central Insecticides Laboratory (CIL)

CIL carries out the analysis relating to insecticide registration and other matters.

Insecticide Inspectors

Central or State Government appoints person called Insecticide Inspector who is empowered.

- a. To enter and search premises
- b. To stop the distribution or sale or use of insecticide
- c. Take samples of insecticide and send for analysis

The Insecticides Rules, 1971

There are nine chapters in the insecticide rule, 1971 relating to the functions of CIB, RC, CIL, grant of licenses, packing, labelling, first aid, antidote protective clothings etc.,

Insecticide residues and waiting period

Residues

The toxicant that remains in the environment (like soil, water, plant harvested produce, etc.) after the application of insecticides. The duration of retention is called persistence.

- Only 1% of the pesticide applied to crop reaches the target. The remaining 99% contaminate soil, water, air, food, forage, etc.
- When surveyed in India 20% of market samples of food commodities were having residues above legal MRL (maximum residue limits).
- 37% of milk samples contaminated with DDT above MRL (0.05 mg/kg)
- Due to contamination the dietary intake of DDT and HCH are above ADI (acceptable daily intake) in India.
- Waiting period must be observed which is the minimum period allowed between time of application of pesticide and harvest of commodities in order to allow the toxicant residue level to come below MRL.

The following are some examples of waiting period of some chemicals in a few important crops

Crop	Insecticide and Dose	Waiting period (days)
1. Chillies	Dicofol 0.05%	1
	Quinalphos 0.05%	8

2.	Tomato	Phosalone 0.05%	3
		Quinalphos 0.05%	5
3.	Brinjal	Phosalone 0.05%	2
		Endosulfan 0.07%	3
		Aldicarb 1 kg a.i./ha	60

Role of pesticides in IPM

1. Pesticide should be applied only based on the need, i.e. if pest reaches ETL.
2. It should be judiciously combined with other components of IPM and pesticides should be used as last resort.
3. When pest population approaches ETL, insecticides are the only means of preventing economic damage.
4. Insecticides are available in easy and ready to use packings.
5. Easy to apply and large area can be covered.
6. A range of insecticides are available depending on crop, insect and nature of damage.
7. Pesticides which are cost effective (High benefit/cost ratio) and safe (High benefit/risk ratio) should be used in IPM.

PHEROMONES

Semiochemicals are chemical substances that mediate communication between organisms. Semiochemicals may be classified into Pheromones (intraspecific semiochemicals) and Allelochemicals (interspecific semiochemicals).

Pheromones are chemicals secreted into the external environment by an animal which elicit a specific reaction in a receiving individual of the same species. Pheromones are volatile in nature and they aid in communication among insects.

Pheromones are exocrine in origin (i.e. secreted outside the body). Hence they were earlier called as ectohormones. In 1959, German chemists Karlson and Butenandt isolated and identified the first pheromone, a sex attractant from silkworm moths. They coined the term pheromone. Since this first report, hundreds of pheromones have been identified in many organisms. The advancement made in analytical chemistry aided pheromone research.

Based on the responses elicited pheromones can be classified into 2 groups

a) **Primer pheromones:** They trigger off a chain of physiological changes in the recipient without any immediate change in the behaviour. They act through gustatory (taste) sensilla. (eg.) Caste determination and reproduction in social insects like ants, bees, wasps, and termites are mediated by primer pheromones. These pheromones are not of much practical value in IPM.

b) **Releaser pheromones:** These pheromones produce an immediate change in the behaviour of the recipient. Releaser pheromones may be further subdivided based on their biological activity into

- 1) Sex pheromones
- 2) Aggregation pheromones
- 3) Alarm pheromones
- 4) Trail pheromones

Releaser pheromones act through olfactory (smell) sensilla and directly act on the central nervous system of the recipient and modify their behaviour. They can be successfully used in pest management programmes.

1) **Sex pheromones** are released by one sex only and trigger behaviour patterns in the other sex that facilitate in mating. They are most commonly released by females but may be released by males also. In over 150 species of insects, females have been found to release sex pheromones and about 50 species males produce.

Aphrodisiacs are substances that aid in courtship of the insects after the two sexes are brought together. In many cases males produce aphrodisiacs.

Major differences between male and female produced pheromones are listed below.

Sl. No	Properties	Female sex pheromone	Male sex pheromone
1.	Range	Acts at a long range. Attracts males from long distance	Acts at a short distance
2	Role of other stimuli	Play less role	Visual and auditory stimuli play major role
3.	Action elicited in the other sex	Attracts and excites males to copulate	Lowers females resistance to mating
4.	Importance in IPM	More important	Less important

Insect orders producing sex pheromones

Lepidoptera, Orthoptera, Dictyoptera, Diptera, Coleoptera, Hymenoptera, Hemiptera, Neuroptera and mecoptera. In Lepidoptera, sex pheromonal system is highly evolved.

Pheromone producing glands:

In Lepidoptera they are produced by **eversible glands** at the tip of the abdomen of the females. The posture shown during pheromone release is called 'calling position'. Aphrodisiac glands of male insects are present as **scent brushes** (or hair pencils) at the tip of the abdomen (eg. Male butterfly of *Danaus sp.*). **Andraconia** are glandular scales on wings of male moths producing aphrodisiacs.

Pheromone reception:

Female sex pheromones are usually received by olfactory sensillae on male antennae and males search upwind, following the odour corridor of the females. In pheromone perceiving insects, the antennae of male moths are larger and greatly branched than female moths to accommodate numerous olfactory sensilla.

Chemical nature of sex pheromones

In general pheromones have a large number of carbon atoms (10-20) and high molecular weight (180 – 300 daltons). Narrow specificity and high potency are two

attributes which depend on long chain carbon atoms and high molecular weight. But since pheromones are volatile their molecular weights cannot be very high as they cannot be carried by wind.

Butenandt and his coworkers in 1959 isolated 12mg of pheromone from the abdomen of half a million virgin females of silkworm. They named the pheromone as Bombykol. The chemical name is 10,12 – hexadeca dienol. It is a primary alcohol.

The following are some of the female sex pheromones identified in insects

Sl. No.	Name of the Insect	Pheromone
1.	Silkworm, <i>Bombyx mori</i>	Bombykol
2.	Gypsy moth, <i>Porthesia dispar</i>	Gyplure, disparlure
3.	Pink bollworm, <i>Pectinophora gossypiella</i>	Gossyplure
4.	Cabbage looper, <i>Trichoplusia ni</i>	Loop lure
5.	Tobacco cutworm, <i>Spodoptera litura</i>	Spodolure, litlure
6.	Gram pod borer, <i>Helicoverpa armigera</i>	Helilure
7.	Honey bee queen, <i>Apis sp.</i>	Queen's substance

Examples of male sex pheromones

Cotton boll weevil, *Anthonomas grandis*, Coleoptera

Cabbage looper, *Trichoplusia ni*, Lepidoptera

Mediterranean fruitfly, *Ceratitidis capitata*, Diptera.

Multi-component pheromone system : If the pheromone of an insect is composed of only one chemical compound we call it monocomponent pheromone system. Pheromones of some insects contain more than one chemical compound. In this case we call it as multi-component pheromone system. The sex pheromone of two different species may contain same chemical compounds but the ratio of the compounds may vary. This brings about species specificity.

Pest Management With Sex Pheromones

Synthetic analogues of sex pheromones of quite large No. of pests are now available for use in Pest management. Sex pheromones are being used in pest management in three different ways.

- In sampling and detection (Monitoring)
- To attract and kill (Mass trapping)
- To disrupt mating (Confusion or Decoy method)

a) In sampling and detection (Monitoring) :

Pheromones can be used for monitoring pest incidence/ outbreak in the following ways.

STERILITY METHODS - DEFINITION - PRINCIPLES - METHODS - REQUIREMENTS AND LIMITATIONS

Sterility method - Definition

Control of pest population achieved by releasing large number of sterilised male insects, which will compete with the normal males and reduce the insect population in subsequent generation.

It is usually referred as SIT (Sterile insect technique) or SIRM (Sterile insect release method)

Sterile insect release method is a genetic control method. This is also called Autocidal control since insects are used against members of their own species.

E.F. Knipling in 1937 in South East USA used the SIRM technique to control the screw wormfly (*Cochliomyia nominivorax*) a serious livestock pest.

The sterile to fertile male ratio, called S:F ratio is important, as the reduction in reproductive potential of natural population depends on S:F ratio.

The mating with the sterile males will produce inviable or sterile eggs.

Trend of hypothetical population subjected to SIRM

Assumption

1. Female:Male ratio 1:1
2. 1 female produces 5 females as off spring in one generation

<i>Generation</i>	No.of females without releases	No.of sterile males released	No.of females releases(9:1)	Ratio sterile to normal males	No. of fertile females
1.	1,000,000	9,000,000	1,000,000	9:1	100,000
2.	5,000,000	9,000,000	500,000	18:1	26,316
3.	25,000,000	9,000,000	131,579	68:1	1,907
4.	125,000,000	9,000,000	9,535	944:1	10
5.	625,000,000	9,000,000	50	180,000:1	0

In suitable circumstances sterile male release method (SIRM) can be more effective, compared to insecticide application.

Comparison of SIRM with insecticide - Trend of hypothetical population

Generation	No. of females with no treatment	No. of females with sterile release (9:1)	No. of females with insecticide (90% kill)
1.	1,000,000	1,000,000	1,000,000
2.	5,000,000	500,000	500,000
3.	25,000,000	131,579	250,000
4.	125,000,000	9,535	125,000
5.	625,000,000	50	62,500
6.	3,125,000,000	0	31,250

SIRM technique can also be used after insecticide application which will be more effective.

Circumstances for using this method

1. Against well established pest when their population density is low
2. Against newly introduced pest
3. Against isolated population as in island
4. Combined with cultural and chemical methods

Methods of sterilization

- 1. Chemosterilants:** Any chemical which interfere with the reproductive capacity of an insect.

a. Alkylating agents

They inhibit nucleic acid synthesis
inhibit gonad development
produce mutagenic effect
(e.g.) TEPA, Chloro ethylamine

b. Antimetabolites

Chemicals having structural similarity to biologically active substances. They interfere with nucleic acid synthesis. e.g. 5-Fluorouracil, Amithopterin

Methods of sterilization - continued

II. Irradiation

Irradiation done by exposing insects to α , β , γ radiations, X rays and neutrons. Of these, γ -radiation by ^{60}Co (cobalt) with its half-life of 60 years is the most common method.

Irradiation causes following sterility effects in insects

- Infecundity
- Aspermia
- Inability to mate
- Dominant lethal mutation

Radiation dose required for different species and stages for sterilization (expressed as rads - radiation absorbed dose).

Insect	Stage	Dose
Housefly	2-3 day pupae	3000 rads
Screw worm	5 day pupae	2500 rads
	1 day adult	5000 rads

Sterilizing natural population

In this method, instead of releasing sterilised males into the field, a chemosterilant is sprayed in field like insecticide. The chemosterilant sterilizes both male and female. These do not produce offspring-equivalent to killing them.

Bonus effect: The bonus effect of this method is that the sterilized males mate with normal females and reduce their reproductive capacity.

Chemosterilants used are TEPA, HEMPA, BISULFAN, etc.

Requirements for SIRM

1. A method inducing sterility without impairing sexual behaviour of insects.
2. Mass rearing of the insects
3. Information on population density and its rate of increase
4. The released insects must not cause damage to the crops, livestock or human beings
5. Good intermingling of released and natural population
6. Releasing sterilized insects when the wild population is abundant
7. This method is effective against newly introduced pest or isolated insect population as in island.
8. There should be high sterile to fertile (S:F) ratio for quicker control.

Limitations of SIRM

1. Not effective against insects which are prolific breeders
2. Sterilizing and mutagenic effect of chemosterilants and irradiation cause problem in higher animals and man (Carcinogenic and mutagenic)

INSECT GROWTH REGULATORS

Insect Growth Regulators (IGRs) are compounds which interfere with the growth, development and metamorphosis of insects. IGRs include synthetic analogues of insect hormones such as ecdysoids and juvenoids and non-hormonal compounds such as precocenes (Anti JH) and chitin synthesis inhibitors.

Natural hormones of insects which play a role in growth and development are

1. **Brain hormone:** They are also called activation hormone (AH). AH is secreted by neuro secretory cells (NSC) which are neurons of central nervous system (CNS). Its role is to activate the corpora allata to produce juvenile hormone (JH).
2. **Juvenile hormone (JH):** Also called neotinin. It is secreted by corpora allata which are paired glands present behind insect brain. Their role is to keep the larva in juvenile condition. JH I, JH II, JH III and JH IV have been identified in different groups of insects. The concentration of JH decreases as the larva grows and reaches pupal stage. JH I, II and IV are found in larva while JH III is found in adult insects and are important for development of ovary in adult females.
3. **Ecdysone:** Also called Moulting hormone (MH). Ecdysone is a steroid and is secreted by Prothoracic Glands (PTG) present near prothoracic spiracles. Moulting in insects is brought about only in the presence of ecdysone. Ecdysone level decreases and is altogether absent in adult insects.

IGRs used in Pest management

- a) **Ecdysoids:** These compounds are synthetic analogues of natural ecdysone. When applied in insects, kill them by formation of defective cuticle. The development processes are accelerated by bypassing several normal events resulting in integument lacking scales or wax layer.
- b) **Juvenoids (JH mimics) :** They are synthetic analogues of Juvenile Hormone (JH). They are most promising as hormonal insecticides. JH mimics were first identified by **Williams and Slama** in the year 1966. They found that the paper towel kept in a glass jar used for rearing a *Pyrrhocoris* bug caused the bug to die before reaching adult stage. They named the factor from the paper as '**paper factor**' or '**juvabione**'. They found that the paper was manufactured from the wood pulp of **balsam fir tree** (*Abies balsamea*) which contained the JH mimic.

Juvenoids have **anti-metamorphic effect** on immature stages of insect. They retain *status quo* in insects (larva remains larva) and extra (super numerary)

moultings take place producing super larva, larval-pupal and pupal-adult intermediates which cause death of insects. Juvenoids are **larvicidal** and **ovicidal** in action and they **disrupt diapause** and **inhibit embryogenesis** in insects.

Methoprene is a JH mimic and is useful in the control of larva of hornfly, stored tobacco pests, green house homopterans, red ants, leaf mining flies of vegetables and flowers

- c) **Anti JH or Precocenes:** they act by destroying corpora allata and preventing JH synthesis. When treated on immature stages of insect, they skip one or two larval instars and turn into tiny precocious adults. They can neither mate, nor oviposit and die soon. Eg. EMD, FMev, and PB (Piperonyl Butoxide)
- d) **Chitin Synthesis inhibitors:** Benzoyl phenyl ureas have been found to have the ability of inhibiting chitin synthesis in vivo by blocking the activity of the enzyme chitin synthetase. Two important compounds in this category are Diflubenzuron (Dimilin) and Penfluron. The effects they produce on insects include
- Disruption of moulting
 - Displacement of mandibles and labrum
 - Adult fails to escape from pupal skin and dies
 - Ovicidal effect.

Chitin synthesis inhibitors have been registered for use in many countries and used successfully against pests of soybean, cotton, apple, fruits, vegetables, forest trees and mosquitoes and pests of stored grain

IGRS from Neem : Leaf and seed extracts of neem which contains azadirachtin as the active ingredient, when applied topically causes growth inhibition, malformation, mortality and reduced fecundity in insects.

Hormone mimics from other living organisms: Ecdysoids from plants (Phytoecdysones) have been reported from plants like mulberry, ferns and conifers. Juvenoids have been reported from yeast, fungi, bacteria, protozoans, higher animals and plants.

Advantages of Using IGRs

- Effective in minute quantities and so are economical
- Target specific and so safe to natural enemies
- Bio-degradable, non-persistent and non-polluting
- Non-toxic to humans, animals and plants

Disadvantages

- Kills only certain stages of pest
- Slow mode of action
- Since they are chemicals possibility of build-up of resistance
- Unstable in the environment

ANTIFEEDANTS

Antifeedants are chemicals that inhibit feeding in insects when applied on the foliage (food) without impairing their appetite and gustatory receptors or driving (repelling) them away from the food. They are also called gustatory repellents, feeding deterrents and rejectants. Since do not feed on treated surface they die due to starvation.

Groups of antifeedants

1. **Triazenes:** AC 24055 has been the most widely used triazene which is a odorless, tasteless, non-toxic chemical which inhibit feeding in chewing insects like caterpillars, cockroaches and beetles.
2. **Organotins.** They are compounds containing tin. Triphenyl tin acetate is an important antifeedants in this group effective against cotton leaf worm, Colorado potato beetle, caterpillars and grass hoppers
3. **Carbamates:** At sublethal doses thiocarbamates and phenyl carbamates act as antifeedants of leaf feeding insects like caterpillars and Colorado potato beetle. Baygon is a systemic antifeedants against cotton boll weevil.
4. **Botanicals:** Antifeedants from non-host plants of the pest can be used for their control The following antifeedants are produced from plants.
 - a) **Pyrethrum:** Extracted from flowers of *Chrysanthemum cinerarifolium* acts as antifeedants at low doses against biting fly, Glossina sp.
 - b) **Neem:** Extracted from leaves and fruits of neem (*Azadirachta indica*) is an antifeedant against many chewing pests and desert locust in particular
 - c) **Apple factor:** Phlorizin is extracted from apple which is effective against non-apple feeding aphids.
 - d) **Solanum alkaloids:** Leptine, tomatine and solanine are alkaloids extracted from Solanum plants and are antifeedants to leaf hoppers.

5. **Miscellaneous compounds:** Compounds like copper stearate, copper resinate, mercuric chloride and Phosphon are good antifeedants.

Mode of action: Antifeedants inhibit the gustatory (taste) receptors of the mouth region. Lacking the right gustatory stimulus the insect fails to recognize the treated leaf as food. The insect slowly dies due to starvation.

Advantages:

- Affect plant feeders, but safe to natural enemies
- Pest not immediately killed, so natural enemies can feed on them
- No phytotoxicity or pollution

Disadvantages

- Only chewing insects killed and not sucking insects
- Not effective as sole control measure, can be included in IPM

INSECT ATTRACTANTS

Chemicals that cause insects to make oriented movements towards their source are called insect attractants. They influence both gustatory (taste) and olfactory (smell) receptors.

Types of Attractants:

1. **Pheromones:** Pheromones are chemicals secreted into the external environment by an animal which elicit a specific reaction in a receiving individual of the same species.
2. **Food lures :** Chemical present in plants that attract insect for feeding. They stimulate olfactory receptors.

List of natural and synthetic food lures

Insects	Lure
	Natural
Pests of cruciferae	Isothiocyanates from seeds of cruciferae
Onion fly (<i>Hylemya antiqua</i>)	Propylmercaptan from onions
Bark beetle	Terpenes from barks
Housefly	Sugar and molasses
	Synthetic
Oriental fruitfly (<i>Dacus dorsalis</i>)	Methyl eugenol
Melon fruitfly (<i>Dacus cucurbitae</i>)	Cuelure
Mediterranean fruitfly (<i>Ceratitis capitata</i>)	Trimedlure

3. **Oviposition lures:** These are chemicals that govern the selection of suitable sites for oviposition by insects. For example extracts of corn attracts *Helicoverpa armigera* for egg laying on any treated surface.

Use of Attractants in IPM

Insect attractants are used in 3 ways in pest management

- a) Sampling and monitoring pest population
- b) Luring pests to insecticide coated traps or poison baits

Examples of poison baits

- For biting insects: Moistened Bran + molasses) + insecticides
- For sucking insects : Sugar solution + insecticide
- For fruitflies: Trimedlure/ Cuelure/ Methyl eugenol + insecticides
- For cockroaches: Sweet syrup + white or yellow phosphorus
- For sweet-loving ants : Thallous sulphate + sugar + honey + glycerine + water
- For meat loving ants : Thallous sulphate + peanut butter

- c) in distracting insects from normal mating, aggregation, feeding or oviposition
The female insects if lured to wrong plants for egg laying, the emerging larva will starve to death

Advantage of using attractants is that they are specific to target insects and NE not affected. But they cannot be relied as the sole method of control and can only be included in IPM as a component.

INSECT REPELLENTS

Chemicals that induce avoiding (oriented) movements in insects away from their source are called repellents. They prevent insect damage to plants or animals by rendering them unattractive, unpalatable or offensive.

Types of repellents

1. Physical repellents : Produce repellence by physical means

- a) Contact stimuli repellents: Substances like wax or oil when applied on leaf surface changes physical texture of leaf which are disagreeable to insects
- b) Auditory repellents: Amplified sound is helpful in repelling mosquitoes.
- c) Barrier repellents: Tar bands on trees and mosquito nets are examples.
- d) Visual repellents: Yellow light acts as visual repellents to some insects.
- e) Feeding repellents: Antifeedants are feeding repellents. They inhibit feeding.

2. Chemical repellents:

- a) **Repellents of Plant origin:** Essentials oils of Citronella, Camphor and cedarwood act as repellents. Commercial mosquito repellent 'Odomos' uses citronella oil extracted from lemongrass, *Andropogon pardu* as repellent.

Pyrethrum extracted from *Chrysanthemum* is a good repellent and has been used against tsetse fly, *Glossina morsitans*.

- b) Synthetic repellents: **Repellents synthetically produced.**

List of important synthetic repellents

Insects	Repellents
Mosquito, blood suckers	Dimethyl phthalate
Mites (chiggers)	Benzyl benzoate
Crawling insects	Trichlorobenzene
Phytophagous insects	Bordeaux mixture
Wood feeders	Pentachlorophenol
Fabric eaters	Naphthalene or mothballs
Bees	Smoke

Uses of repellents:

- They can be applied on body to ward off insects
- Used as fumigants in enclosed area.
- Used as sprays on domestic animals
- To drive away insects from their breeding place.

BIORATIONAL CONTROL

Controlling insects using chemicals that affect insect behaviour, growth or reproduction, is called biorational control.

Insect Growth Regulator,
Chitin synthesis inhibitor,
JH analogues, Anti JH,
Moulting hormone,
Pheromones
Allelochemicals
Attractant, Repellent,
Antifeedant,
Chemosterilant,
Sterile male release

All these methods are included in
Biorational method of control

They are called biorational agents in pest control, because of their selective nature in killing only the target insects without affecting non target organisms.

PESTICIDE APPLICATION METHODS

The desired effect of a pesticide can be obtained only if it is applied by an appropriate method in appropriate time. The method of application depends on nature of pesticide, formulation, pests to be managed, site of application, availability of water etc.

- 1. Dusting :** Dusting is carried out in the morning hours and during very light air stream. It can be done manually or by using dusters. Some times dust can be applied in soil for the control of soil insects. Dusting is cheaper and suited for dry land crop pest control.
- 2. Spraying :** Spraying is normally carried out by mixing EC (or) WP formulations in water. There are three types of spraying.

	Spray fluid (litre per acre)	Droplet size	Area covered per day	Equipment used
a) High volume spraying	200-400	150	2.5 ac	Knapsack, Rocker sprayers
b) Low volume spraying	40-60	70-150	5.6 ac	Power sprayer, Mist blower
c) Ultra low volume spraying	2-4 lit.	20-70	20 ac	ULV sprayer, Electrodyn sprayer

- 3. Granular application :** Highly toxic pesticides are handled safely in the form of granules. Granules can be applied directly on the soil or in the plant parts. The methods of application are
 - a) Broadcasting :** Granules are mixed with equal quantity of sand and broadcasted directly on the soil or in thin film of standing water. (eg.) Carbofuran 3G applied @ 1.45 kg/8 cent rice nursery in a thin film of water and impound water for 3 days.
 - b) Infurrow application :** Granules are applied at the time of sowing in furrows in beds and covered with soil before irrigation. (eg.) Carbofuran 3G applied @ 3 g per meter row for the control of sorghum shootfly.
 - c) Side dressing :** After the establishment of the plants, the granules are applied a little away from the plant (10-15 cm) in a furrow.

- d) **Spot application** : Granules are applied @ 5 cm away and 5 cm deep on the sides of plant. This reduces the quantity of insecticide required.
 - e) **Ring application** : Granules are applied in a ring form around the trees.
 - f) **Root zone application** : Granules are encapsulated and placed in the root zone of the plant. (eg.) Carbofuran in rice.
 - g) **Leaf whorl application** : Granules are applied by mixing it with equal quantity of sand in the central whorl of crops like sorghum, maize, sugarcane to control internal borers.
 - h) **Pralinage** : The surface of banana sucker intended for planting is trimmed. The sucker is dipped in wet clay slurry and carbofuran 3G is sprinkled (20-40 g/sucker) to control burrowing nematode.
4. **Seed pelleting/seed dressing** : The insecticide mixed with seed before sowing (eg.) sorghum seeds are treated with chlorpyrifos 4 ml/kg in 20 ml of water and shade dried to control shootfly. The carbofuran 50 SP is directly used as dry seed dressing insecticide against sorghum shootfly.
 5. **Seedling root dip** : It is followed to control early stage pests (eg.) in rice to control sucking pests and stem borer in early transplanted crop, a shallow pit lined with polythene sheet is prepared in the field. To this 0.5 kg urea in 2.5 litre of water and 100 ml chlorpyrifos in 2.5 litre of water prepared separately are poured. The solution is made upto 50 ml with water and the roots of seedlings in bundles are dipped for 20 min before transplanting.
 6. **Sett treatment** : Treat the sugarcane setts in 0.05% malathion for 15 minutes to protect them from scales. Treat the sugarcane setts in 0.05% Imidacloprid 70 WS @ 175 g/ha or 7 g/l dipped for 16 minutes to protect them from termites.
 7. **Trunk/stem injection** : This method is used for the control of coconut pests like black headed caterpillar, mite etc. Drill a downward slanting hole of 1.25 cm diameter to a depth of 5 cm at a height of about 1.5 m above ground level and inject 5 ml of monocrotophos 36 WSC into the stem and plug the hole with cement (or) clay mixed with a fungicide. Pseudo stem injection of banana, an injecting gun or hypodermic syringe is used for the control of banana aphid, vector of bunchy top disease.

8. **Padding :** Stem borers of mango, silk cotton and cashew can be controlled by this method. Bark of infested tree (5 x 5 cm) is removed on three sides leaving bottom as a flap. Small quantity of absorbant cotton is placed in the exposed area and 5-10 ml of Monocrotophos 36 WSP is added using ink filler. Close the flap and cover with clay mixed with fungicide.
9. **Swabbing :** Coffee white borer is controlled by swabbing the trunk and branches with HCH (BHC) 1 per cent suspension.
10. **Root feeding :** Trunk injection in coconut results in wounding of trees and root feeding is an alternate and safe chemical method to control black headed caterpillar, eriophyid mite, red palm weevil. Monocrotophos 10 ml and equal quantity of water are taken in a polythene bag and cut the end (slant cut at 45) of a growing root tip (dull white root) is placed inside the insecticide solution and the bag is tied with root. The insecticide absorbed by root, enter the plant system and control the insect.
11. **Soil drenching :** Chemical is diluted with water and the solution is used to drench the soil to control certain subterranean pests. (eg.) BHC 50 WP is mixed with water @ 1 kg in 65 litres of water and drench the soil for the control of cotton/stem weevil and brinjal ash weevil grubs.
12. **Capsule placement :** The systemic poison could be applied in capsules to get toxic effect for a long period. (eg.) In banana to control bunchy top vector (aphid) the insecticide is filled in gelatin capsules and placed in the crown region.
13. **Baiting :** The toxicant is mixed with a bait material so as to attract the insects towards the toxicant.
 - a) **Spodoptera :** A bait prepared with 0.5 kg molasses, 0.5 kg carbaryl 50 WP and 5 kg of rice bran with required water (3 litres) is made into small pellets and dropped in the field in the evening hours.
 - b) **Rats :** Zinc phosphide is mixed at 1:49 ratio with food like popped rice or maize or cholam or coconut pieces (or) warfarin can be mixed at 1:19 ratio with food. Ready to use cake formulation (Bromodiolone) is also available.
 - c) **Coconut rhinoceros beetle :** Castor rotten cake 5 kg is mixed with insecticide.
14. **Fumigation :** Fumigants are available in solid and liquid forms. They can be applied in the following way.
 - a) **Soil :** To control the nematode in soil, the liquid fumigants are injected by using injecting gun.

- b) **Storage :** Liquid fumigants like Ethylene dibromide (EDB), Methyl bromide (MB), carbon tetrachloride etc. and solid fumigant like Aluminium phosphide are recommended in godowns to control stored product pest.
- c) **Trunk :** Aluminium phosphide $\frac{1}{2}$ to 1 tablet is inserted into the affected portion of coconut tree and plugged with cement or mud for the control of red palm weevil

PESTICIDE COMPATIBILITY

- In pest control treatment, two or more pesticides, fungicides or even fertilizers are sprayed or applied in the same operation to minimize cost of labour.
- Before mixing two different chemicals, their physical and chemical properties should be well understood.
- Incompatible pesticides should not be mixed. Only compatible pesticides can be mixed.

Incompatibility of pesticides may be of following types

a. Chemical incompatibility

Chemical compounds in the two pesticides react with the another producing a different compound, reducing the pesticidal activity of the pesticides (Degradation of active ingredient).

b. Biological incompatibility (Phytotoxic incompatibility)

The mixed product exhibit phytotoxic action, which independantly is not phytotoxic.

c. Physical incompatibility

The physical form of the pesticides change, and one of them become unstable or hazardous for application (agglomeration, phase separation, explosive reaction, etc.).

HAZARDS CAUSED BY PESTICIDES

The adverse effect caused by pesticides to human beings during manufacture, formulation, application and also consumption of treated products is termed as the hazard.

Pesticide hazard occurs at the time of

- a. Manufacturing and formulation
- b. Application of pesticides
- c. Consumption of treated products

Examples of hazards caused by pesticides

1. In Kerala, in 1953, 108 people died due to parathion poisoning
2. 'Bhopal Gas Tragedy' in 1984 at Bhopal where the gas called Methyl isocyanate (MIC) (an intermediate involved in manufacture of carbaryl) leaked killing 5000 people and disabling 50,000 people. Totally 2,00,000 persons were affected. Long term effects like mutagenic and carcinogenic effects are felt by survivors.
3. Cases of Blindness, Cancer, Liver and Nervous system diseases in cotton growing areas of Maharashtra where pesticides are used in high quantity.
4. Psychological symptoms like anxiety, sleep disturbance, depression, severe head ache in workers involved in spraying DDT, malathion regularly.

5. Endosulfan - causing problem due to aerial spraying in cashew in Kerala - recent controversy - yet to be studied in detail.

Safe handling of pesticides

1. Storage of pesticides :

- a) Store house should be away from population areas, wells, domestic water storage, tanks.
- b) All pesticides should be stored in their original labeled containers in tightly sealed condition.
- c) Store away from the reach of children, away from flames and keep them under lock and key.

2. Personal protective equipment

- a) Protective clothing that covers arms, legs, nose and head to protect the skin.
- b) Gloves and boots to protect hands and feet.
- c) Helmets, goggles and facemask to protect hair, eyes and nose.
- d) Respirator to avoid breathing dusts, mists and vapour.

3. Safety in application of pesticides

Safe handling of pesticides (Fig.68) involves proper selection and careful handling during mixing and application.

- a) **Pesticide selection :** Selection of a pesticide depend on the type of pest, damage, losses caused, cost etc.
- b) **Safety before application :**
 - i. Read the label and leaflet carefully.
 - ii. Calculate the required quantity of pesticides.
 - iii. Wear protective clothing and equipment before handling.
 - iv. Avoid spillage and prepare spray fluid in well ventilated area.
 - v. Stand in the direction of the wind on back when mixing pesticides.
 - vi. Do not eat, drink or smoke during mixing.
 - vii. Dispose off the containers immediately after use.
- c) **Safety during application**
 - i. Wear protective clothing and equipment.
 - ii. Spray should be done in windward direction.
 - iii. Apply correct coverage.
 - iv. Do not blow, suck or apply mouth to any spray nozzle.
 - v. Check the spray equipment before use for any leakage.
- d) **Safety after application**
 - i. Empty the spray tank completely after spraying.

- ii. Avoid the draining the contaminated solution in ponds, well or on the grass where cattle graze.
- iii. Clean the spray equipment immediately after use.
- iv. Decontaminate protective clothing and foot wear.
- v. Wash the hands thoroughly with soap water, preferably have a bath.
- vi. Dispose off the containers by putting into a pit.
- vii. Sprayed field must be marked and unauthorized entry should be prevented.

First aid : In case of suspected poisoning; call on the physician immediately. Before calling on a doctor, first aid treatments can be done by any person.

Swallowed poison

- i. During vomiting, head should be faced downwards.
- ii. Stomach content should be removed within 4 h of poisoning.
- iii. To give a soothing effect, give either egg mixed with water, gelatin, butter, cream, milk, mashed potato.
- iv. In case of nicotine poisoning, give coffee or strong tea.

Skin contamination

- i. Contaminated clothes should be removed.
- ii. Thoroughly wash with soap and water.

Inhaled poison

- i. Person should be moved to a ventilated place after loosening the tight cloths.
- ii. Avoid applying frequent pressure on the chest.

III. Antidotes and other medicine for treatment in pesticide poisoning

S.No.	Antidote / Medicine	Used in poisoning due to
1.	Common salt (Sodium chloride)	Stomach poison in general
2.	Activated charcoal (7g) in warm Magnesium oxide (3.5g) water Tannic acid (3.5g)	Stomach poison in general
3.	Gelatin (18 g in water) or Flour or milk power (or) Sodium thiosulphate	Stomach poison in general
4.	Calcium gluconate	Chlorinated insecticide, Carbon tetrachloride, ethylene dichloride, Mercurial compound

5.	Phenobarbital (or) Pentobarbital intravenous administration	Stomach poison of chlorinated hydrocarbon insecticides
6.	Sodium bicarbonate	Stomach poison of organophosphate compounds
7.	Atropine sulphate (2-4 mg intramuscular / intravenous administration) or PAM (Pyridine-Z aldoxime-N-methliodide)	Organophosphate Compounds
8.	Atropine sulphate (2-4 mg intramuscular / intravenous administration)	Carbamates
9.	Phenobarbital	Synthetic pyrethoid
10.	Potassium permanganate	Nicotine, Zinc phosphide
11.	Vitamin K1 and K2	Warfarin, Zinc phosphide
13.	epinephrine	Methyl bromide
14.	Methyl nitrite ampule	Cyanides

Impact of Pesticides in Agroecosystem

The following are some problems caused by pesticides in agro-eco system

1. Pesticide residues
2. Insecticide resistance
3. Insect resurgence and secondary pest outbreak
4. Toxicity to non target organism

1. Pesticide residues

The pesticide that remains in the environment after application causes problems to humans and non-target organisms (Already dealt in theory - Read) e.g. Residues of DDT, HCH in milk, vegetable above MRL.

2. Insecticide resistance

Insecticide resistance is the development of an ability to tolerate a dose of insecticide, which would prove lethal (kill) to majority of the individuals of the same species.

This ability is due to the genetic change in pest population in response to pesticide application.

Insecticide resistance in insect pests in India

	Name of pest	Common name	Insecticides to which resistant
1.	<i>Aphis craccivora</i>	Aphid	Carbamates, OP, Cypermethrin,
2.	<i>Bemisia tabaci</i>	Whitefly	Endosulfan, Monocrotophos
3.	<i>Helicoverpa armigera</i>	Cotton boll worm	OP, Synthetic pyrethroid, <i>Bacillus thuringiensis</i>
4.	<i>Plutella xylostella</i>	Diamond back moth on cabbage, cauliflower	Abamectin, Bt, OP compounds

Simple resistance : Insect develops resistance only against the insecticide to which

it is exposed

Cross resistance : Insect develops resistance not only to exposed insecticide but also to other related insecticides to which it is not exposed.

Pest Resurgence

Tremendous increase in pest population brought about by insecticides despite good initial reduction in pest population at the time of treatment.

Insecticides lead to pest resurgence in two ways.

- i. After initial decline, resistant population increase in large numbers
- ii. Killing of natural enemies of pest, cause pest increase
e.g. Quinalphos, phorate - Cause resurgence of BPH in rice
Carbofuran - Leaf folder in rice

Secondary pest outbreak

Application of a pesticide against a major pest, kills the natural enemies of minor or secondary pest. This causes the outbreak of a secondary pest.

e.g. Use of synthetic pyrethroids against bollworms in cotton killed natural enemies of whitefly causing an outbreak of whitefly which was a minor pest till then.

Toxicity of non-target organisms

- i. Natural enemies : Predators and parasitoids are killed leading to pest outbreak
- ii. Bee toxicity : Bees are important pollinators. Killing bees reduce crop productivity
- iii. Soil organisms : Soil organisms like microbes, arthropods, earthworm,

etc. are required for maintaining soil fertility. These are killed by some pesticides e.g. DDT, HCH

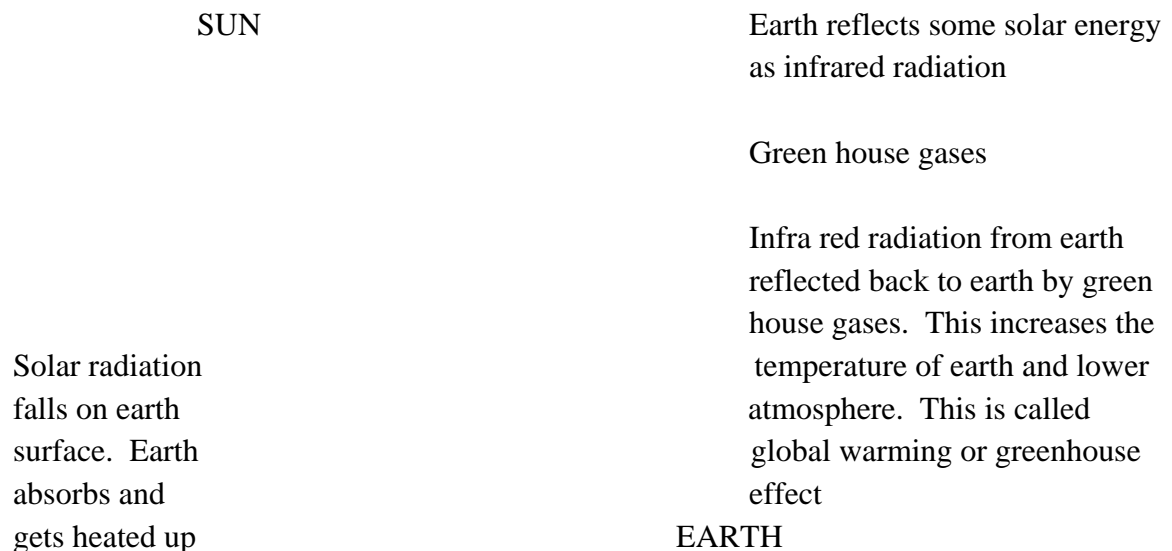
- iv. Fishes : Pesticides from treated surface run off to nearby lakes and kill the fishes

Hence while choosing an insecticide it should be safe (causing less harm) to these organisms.

Specific IPM practices for rice and cotton. Biotechnology in pest management.

IMPACT OF GLOBAL WARMING ON PESTS

What is global warming?



- Warmth from sun heats the surface of the earth
 - Earth absorbs most of the energy but reflects back some energy in the form of infra red radiation
 - Greenhouse gases (e.g. CO₂, Methane, CFC (Chloro Fluoro Carbon), Nitrous oxide) present in atmosphere trans the infrared radiation and reflects back to earth
 - This reflected energy falls on earth and also lower atmosphere and keeps it warmer (Heats the earth's surface)
- This is called global warming or green house effect.

Effect of global warming on world and agriculture

- Increase in overall temperature on earth (e.g.) Earth's surface temperature has increased 1.4°F in 1st one century (Forecast: 5°F rise in next century)
- Change in climate tremendously
- Melting of ice in Polar region
- Increase in sea level and submerging of coastal areas
- Flooding and intense down pours
- Drought in warmer regions

Impact of global warming on pest status

1. Due to change in climate, temperature and water availability, the farmers may change the type of crops grown.
2. Due to increase in temperature, there can be outbreak of certain insect pests and diseases.
3. In forest areas there will be a shift in tree species and also pest species.
4. In agriculture lands since cropping pattern is changed new crops to suit the climate is introduced and new pests are also introduced.
5. When water availability is less, crops will be raised as rainfed. It will be difficult to take up control measures without water.

Sources of green house gases

Developed countries : Emission from Automobiles and factories contain CFCs

Developing countries : Deforestation causes rise in CO₂ level

Methane gas from paddy fields and livestock

Nitrous oxide from 'N' based fertilizer

INTEGRATED PEST MANAGEMENT - HISTORY, PRINCIPLES AND STRATEGIES RELATIONSHIP BETWEEN DIFFERENT COMPONENTS AND ECONOMICS

History of Integrated Pest Management

- Michelbacher and Bacon (1952) coined the term “integrated control”
- Stern *et al.* (1959) defined integrated control as “applied pest control which combines and integrates biological and chemical control”
- Geier (1966) coined the term “pest management”
- Council on Environmental Quality (CEQ, 1972) gave the term “Integrated Pest Management”
- Food and Agricultural Organization (FAO, 1967) defined IPM as “a pest management system, that, in the context of associated environment and population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains pest populations at levels below those causing economic injury”
- In 1989, IPM Task Force was established and in 1990. IPM Working Group (IPMWG) was constituted to strengthen implementation of IPM at international level.
- In 1997, Smith and Adkisson were awarded the World Food Prize for pioneering work on implementation of IPM.

Principles and strategies of Integrated Pest Management

I. Monitoring insect pests and natural enemies

Pest surveillance and forecasting are essential tools in IPM which help in making management decision.

II. Concepts of injury levels

ETL (Economic threshold level) and EIL (Economic injury level) concepts are followed to reduce the use of insecticide and their impact on environment.

III. Integration of pest control tactics

Proper choice of compatible tactics and blending them so that each component complements the other.

The strategy of applying pest management tactics is similar to that of human medicine.

i.e. Preventive practice

Curative practice

Preventive methods of IPM include the following

- a. Natural enemies
- b. Host plant resistance
- c. Cultural control
- d. Legal control (Plant Quarantine)

Curative methods of IPM include the following

- a. Physical and mechanical methods
 - b. Inundative method releasing biocontrol agents
 - c. Chemical insecticides, IGR
- Preventive methods can be used, irrespective of the level of pest incidence. It can be followed as a routine, even if the pest is at a low level.
 - Curative methods have to be followed only when the pest attains economic threshold level (ETL).

Integration of different components of IPM

There are two steps involved

- i. Selection of appropriate method
- ii. Integration of pest control method

i. Selection method: It could be preventive (prophylactic) or curative.

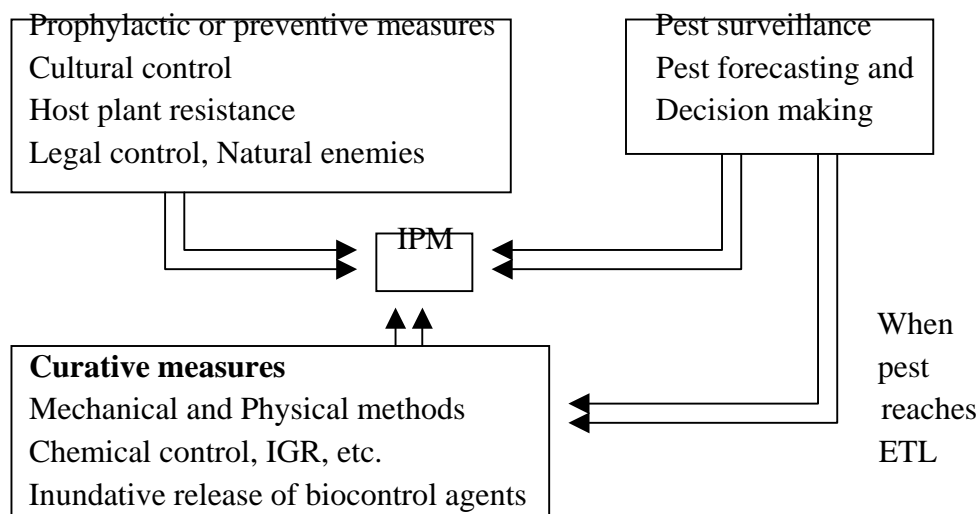
While selecting the method, it should possess following features:

- a. It should be ecofriendly and cause minimum adverse effect on agro-eco system
- a. There should not be any conflict between the methods
- b. The methods should be least expensive

Integration of tactics

- Integrating management tactics is not simply adding a number of these tactics to form a program.
- Actual integration involves proper choice of compatible tactics and blending them so that each complements the other.
 - e.g. (1) Host plant resistance can be easily blended with crop sanitation
 - (2) Insecticide control is compatible with other preventive methods
 - (3) It is difficult to blend natural enemy release with others like pesticides
- Integration of tactics, requires interdisciplinary approach.
- A knowledge of other subjects like, nematology, plant pathology, microbiology, crop and farm management also required when we go upward in level of integration.

Relationship among different components of IPM



ECONOMICS OF INTEGRATED PEST MANAGEMENT

An Integrated Pest Management (IPM) programme can be successful only if reduces cost on control measures, or increases crop yield (or both) and also reduce environmental pollution and health hazards.

The following are some examples of successful IPM programmes worldwide

1. In Philippines, in 1993, IPM farmers obtained 4.7 to 62% higher rice yield and reduced pesticide use by 15% compared to non-IPM.
2. In India in 1995, IPM farmers obtained 6.2 to 42.1% increased rice yield, and reduced pesticide use by 50% compared to non-IPM farmers.
3. In India on cotton crop, adoption of IPM technology resulted in 73.7 and 12.4% reduction in the number of insecticide sprays against sucking pests and bollworms. In spite of reduction in pesticide sprays 21-27% increase in seed cotton yield was obtained in IPM areas compared to non-IPM. Natural enemy population also increased 3 folds.
4. In Thailand in 1993 adoption of IPM technology resulted in 145% increase in net profit in IPM fields over non-IPM fields in cruciferous vegetables.
5. IPM is useful and economical in high value, plantation crops like Coconut, Coffee, Tea, Cashewnut and Arecanut.

Institutional support for IPM

International: IPMWG, FAO, CABI, ICIPE

Global IPM facility (1992) - Sponsored by FAO, UNDP, UNEP and World Bank

National : NCIPM: National Centre for Integrated Pest Management at Faridabad (Near Delhi) (1988) - Supports IPM in India

INTEGRATED PEST MANAGEMENT - ISSUES AND OPTIONS

ECOFRIENDLY IPM-INDIGENOUS/TRADITIONAL TECHNOLOGIES IN IPM

Constraints in IPM have been listed by IPM task force as follows:

i. Institutional constraint

IPM requires interdisciplinary approach to solve pest problem. Lack of coordination among different institution is a constraint. Research programme based on farmer's need - is lacking.

ii. Informational constraint

Lack of information on IPM among farmers and extension worker. Lack of training on IPM.

iii. Sociological constraint

Some farmers feel it is risky to adopt IPM compared to use of pesticides alone. Our farmers are habituated to using more pesticides.

iv. Economic constraint

Lack of funds for training farmers and extension workers on the use of IPM.

v. Political constraint

- Vested interest associated with pesticide trade
- Pesticide subsidy by Government

These are the constraints for the implementation of IPM.

Options/strategies in IPM implementation

Acceleration of IPM implementation requires the following

i. Farmer's participation

Farmers must be encouraged to participate in IPM and give their views.

ii. Government support

Government can remove subsidies on pesticides and allot more fund for IPM implementation.

iii. Legislative measures

Suitable legislation (law) may be passed for adopting IPM by all farmers (IPM will be successful only if adopted on community basis).

iv. Improved institutional infrastructure

National level institution for implementation of IPM is a must. Data base on role of biotic and abiotic factors on pest population, crop yield are required.

v. Improved awareness

Awareness should be created at all levels on IPM i.e. Policy makers, farmers, consumers and general public. NGOs (Non Governmental Organisation) should be made aware of the advantages of IPM.

Ecofriendly IPM

- IPM which lays more importance on environmental safety. All methods except the use of chemical insecticides are encouraged.
- 'Organic farming' is a new concept where no chemical pesticide or fertilizer is used in agriculture.
- Ecofriendly IPM may be followed in organic farming
- Ecofriendly IPM uses methods like biological control, behavioural method, physical, cultural and mechanical methods.
- Here more stress is given to environmentally sustainable pest management.

Indigenous/Traditional technologies in IPM

The following are some examples of traditional technologies in IPM

i. Cultural methods: (a) Farm level (b) Community level

- which were originally practiced by farmers.

Examples: Already covered in previous classes.

ii. Physical and mechanical methods originally followed by farmers

e.g. (a) Use of storage bins, treatment of stored grain with vegetable oil etc., to ward off storage pest.

(b) Tanjore bow trap for rats

Other examples can also be quoted.

iii. Farmers' wisdom on pest control tactics as follows

e.g. (a) Use of **scare crows** to ward off bird pests

(b) Use of '*Kavankal*' to ward off birds

(c) Use of '*Pachakavya*' a mixture of cowdung, with other ingredients has been tried as a pest control agent - Research is ongoing.

(d) Use of chilli mash and garlic juice spray against rice earhead bug

Many other similar techniques are followed by farmers. Research has to be done to prove their usefulness in IPM.

IPM (Integrated Pest Management) for Rice

1. Avoid use of excess nitrogenous fertilizer which induces BPH and leaf folder
2. Remove/destroy stubbles after harvest
3. Trim field bunds and keep field free from weeds
4. Control irrigation by intermittent draining to manage BPH (Alternate wetting and drying of field)
5. Avoid close planting, especially in BPH and leaf folder prone areas/seasons
6. Provide rogue spacing of 30 cm at every 2.5 m interval to take up plant protection operation
7. Use light traps to monitor incidence of pests
8. Avoid resurgence inducing chemicals against BPH like Methyl parathion and quinalphos
9. Remove stem borer egg masses by dipping off tip of rice seedling during transplanting
10. Select and use resistant varieties against major pests
11. Manage caseworm by passing rope on crop and draining water
12. Release egg parasitoid *Trichogramma japonicum* on 30 and 37th day after planting against stem borer
13. Release egg parasitoid *T. chilonis* and bacteria *Bacillus thuringiensis* against leaf folder
14. Use of Neem Seed Kernel Extract 5% (NSKE 5%) or Neem oil 2% against Earhead bug
15. Use insecticides as need based application if pest reaches ETL

S.No.	Pest (on rice)	ETL
1.	Thrips	25/5 passes of wet palm
2.	Stem borer	10% Dead heart or 2% white ear
3.	Gall midge	10% Silver shoot
4.	Leaf folder	10% leaf damage (at vegetative stage) 5% leaf damage (at Bootleaf stage)
5.	GLH	5/hill at vegetative stage, 10/hill flowering stage, 2/hill in RTV endemic areas
6.	BPH (Brown Plant Hopper)	1/tiller; 2/tiller when spider present at 1/hill
7.	Earhead bug	5 bugs/100 panicle - Flowering stage 16 bugs/100 panicle - Milky stage

IPM FOR COTTON

1. Selection and use of resistant/tolerant varieties against major pests

2. Use of light trap to monitor hoppers, bollworms, cutworm
3. Use of pheromone traps for monitoring/mass trapping bollworms
4. Collection and destruction of infested plant parts, squares and bolls
5. Growing trap crop (e.g.) Castor for *Spodoptera litura*
6. Manual collection and removal of egg masses of *S. litura*
7. Hand picking of bollworm larvae
8. Use of insect viruses SINPV and HaNPV against *Spodoptera litura* and *Helicoverpa armigera* respectively
9. Avoid ratoon and double cotton crop
10. Avoid staking of stalks in the field
11. Synchronise sowing time at village level
12. Follow crop rotation with unrelated crops
13. Removal of alternate hosts
14. Judicious use of nitrogen and water to manage hoppers and white flies
15. Use of yellow sticky traps for whiteflies
16. Observe IRM (Insecticide Resistance Management) practices like
 - a. Treat seeds with Imidacloprid 7.5 g/kg seed of cotton to manage early stage sucking pests
 - b. Use of predators like *Chrysoperla carnea*
 - c. Use of egg parasitoid *Trichogramma* sp. against bollworms
17. Apply insecticides only based on need, when pest population/damage reaches ETL

S.No.	Cotton pest	ETL
1.	Leaf hopper/thrips	50 nos./50 leaves (or 1/leaf)
2.	Whitefly	5 nymphs/leaf
3.	Bollworms	10% damage of reproductive parts
4.	Stem weevil	10% infested plants
5.	<i>Spodoptera litura</i>	8 egg masses/100 m row

BIOTECHNOLOGY IN PEST MANAGEMENT

Use of molecular biology techniques for the management of insect pests. The following are some strategies.

1. **Wide hybridization:** This technique involves transfer of genes from one species to other by conventional breeding. The genes for resistance are transferred from a different species. e.g. WBPH resistant gene has been transferred to *Oryza sativa* from *O. officinalis*.
2. **Somaclonal variability:** The variation observed in tissue culture derived progeny. e.g. Somaclonal variants of sorghum resistant to *Spodoptera litura* has been evolved.

3. **Transgenic plants:** Transgenic plants are plants which possess one or more additional genes. This is achieved by cloning additional genes into the plant genome by genetic engineering techniques. The added genes impart resistance to pests.

Transgenic plants have been produced by addition of one or more following genes.

- a. Bt endotoxin from *Bacillus thuringiensis*
- b. Protease inhibitors
- c. α -Amylase inhibitors
- d. Lectins
- e. Enzymes

- c. **Bt endotoxin gene:** The gram positive bacteria *Bacillus thuringiensis* produces a crystal toxin called δ (delta) endotoxin.

The δ endotoxin is a stomach poison and kills the lepidopteran insects if consumed.

The gene (DNA fragment) responsible for producing δ endotoxin is isolated from Bt and cloned into plants like cotton, potato, maize, etc. to produce Transgenic cotton, etc.

Transgenic Bt plants

1. Cotton
2. Maize
3. Rice
4. Tobacco, Tomato
5. Potato, Egg plant

Target insect pests

- Bollworms, *S. litura*
European corn borer
Leaf folder, stem borer
Cut worms
Colorado potato beetle

b. Protease inhibitors (PI) gene

Insects have proteases in their gut which are enzymes helping in digestion of protein. Protease inhibitors are substances inhibit the proteases and affect digestion in insects. The protease inhibitor gene are isolated from one plant and cloned into another to produce transgenic plants.

e.g. Transgenic apple, rice, tobacco containing PI. e

e.g. Cowpea trypsin inhibitor (CpTI) is a PI isolated from cowpea and cloned into tobacco. This transgenic tobacco is resistant to *Heliothis virescens*.

c. α -Amylase inhibitor gene

α -Amylase is a digestive enzyme present in insects for digestion of carbohydrate. α -Amylase inhibitor, affect digestion in insects.

Transgenic tobacco and tomato expressing α -amylase inhibitor have been produced which are resistant to Lepidopteran pests.

d. Lectins genes

Lectins are proteins that bind to carbohydrates. When insect feed on lectins, it binds to chitin in peritrophic membrane of midgut and prevents uptake of nutrients. e.g. Transgenic tobacco containing pea lectin gene is resistant to *H. virescens*

e. Enzyme genes

Chitinase enzyme gene, and cholesterol oxidase gene have been cloned into plants and these show insecticidal properties.

PYRAMIDING GENES

Engineering transgenic crops with more than one gene to get multi-mechanistic resistance is called pyramiding of genes. e.g.

1. The CpTi gene and pea lectin gene were cloned to produce a transgenic tobacco.
2. Transgenic potato which express lectin and bean chitinase have been produced.

Potentials/Advantages of Biotechnology in IPM

1. Slow development of resistance against transgenic Bt, PI, lectins
2. All plant parts express toxin and so no need for insecticide spray
3. No need for continuous monitoring
4. No environmental pollution, safe to NE, non-target organism

***** GOOD LUCK*****

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1. IDENTIFICATION OF DIFFERENT BEE SPECIES, MORPHOLOGY, LIFE HISTORY AND STRUCTURAL ADAPTATIONS

Honey bees belong to the family **Apidae**, suborder **Apocrita**, of the order **Hymenoptera**. Five species of honey bees are found in India.

1.	Giant or Rock bee	<i>Apis dorsata</i>
2.	Indian bee	<i>Apis cerana indica</i>
3.	Italian bee	<i>Apis mellifera ligustica</i>
4.	Little bee or Dwarf bee	<i>Apis florea</i>
5.	Dammer bee or mosquito bee	<i>Melipona iridipennis</i> (or) <i>Trigona iridipennis</i>

Rock bees and little bees are not fully domesticated while Indian bees and Italian bees are fully domesticated. The above four are true honey bees. Stingless bees are different from true honey bees. Dammer bees belong to stingless bee group and can be domesticated.

A. NON - DOMESTICATED HONEY BEES

i) Similarities

- * Nest in open air
- * Construct single comb
- * Queen brood cells are found in the lower edge of comb
- * Light reflection by iridescent wings helps in thermoregulation
- * Curtains of bees insulate the brood

ii) Differences

	Character	Rock bee, Apis dorsata	Little bee Apis florea
1.	Nesting site	Thick limbs of a tree (or) rock cliffs (or) caves of a building	Thin branch of bush (or) small tree
2.	Comb attachment	Fixed underneath a broad support	Comb top encircles the branch completely
3.	Brood cells	Drone and worker brood cells are similar	Drone cells are larger than worker
4.	Site of honey storage	Honey is stored in the upper most comb corner	Stored in cylindrical cell structures around the branch

5.	Body size	Largest	Smallest
6.	Differences between sexuals and workers	Not well marked	Marked
7.	Length of lapping tongue	Long	Small
8.	Temperament	Most ferocious	Not ferocious
9.	Honey yield/colony/year	20 to 40 kg	0.5 to 1 kg
10.	Wax	Deserted comb is a major source of wax	Not a major source of wax

B. DOMESTICATED HONEY BEES

i) Similarities

- * Nests are constructed in dark cavities
- * Construct multiple combs
- * Combs are parallel with uniform bee space
- * Brood cells are similar
- * Honey is stored in the upper part of the comb and in outer combs adjacent to the hive walls

ii) Differences

	Character	Indian bee <i>Apis cerana indica</i>	Italian bee <i>Apis mellifera ligustica</i>
1.	Body size	Smaller	Larger
2.	Tongue length	Short	Long
3.	Fecundity (Eggs laid/queen /day)	300 - 500	1000 - 1500
4.	Worker layer problems	Starts early	Starts late
5.	Drone brood cell	Cell cap with a central pore	No pore in the cell cap
6.	Pollen carrying capacity	Less	More
7.	Nectar carrying capacity	Less	More
8.	Propolis collection	Not done	Done
9.	Activity at low temperature	More	Less
10.	House keeping	Poor	Good
11.	Aggressiveness in common feeding location	Less	More
12.	Docility	Less docile	More docile
13.	Stinging tendency	Less	More
14.	Sting autotomy	Less common	More common

15.	Defence behaviour	Very good	Poor
16.	Wax moth infestation	More	Less
17.	Bird predation	Less	More
18.	Mite infestation	Less	More
19.	Thai sac brood virus infection	More	Absent
20.	Swarming Tendency	More	Less
21.	Absconding behaviour	More	Less
22.	Robbing tendency	More	Less
23.	Sugar feeding during dearth period	Needed	Must
24.	Economic forage range	1 Km	2 Kms
25.	Honey yeild/box/year	3 -5 kgs	25 - 30 kgs

C. DAMMMER BEES, *Trigona iridipennis*

- * Construct nests in tree hollows (or) cracks in walls
- * Use a mixture of wax and resin/propolis for comb construction
- * Nest entrance projects as an external tube
- * Brood cells are surrounded by a sheath of involucrum
- * Brood cells are spherical with an opening at the top
- * Mass provisioning is given for the developing grub
- * A mixutre of glandular secretions of the workers, honey and pollen is given as larval food
- * Honey is stored in spherical pots
- * Pollen is stored in waxen tubes
- * Sting is vestigeal
- * They bite their enemies (or) intruders
- * Can be domesticated
- * Honey yield / hive / year is 100 grams

MORPHOLOGY OF WORKER HONEY BEE

Systematic Position

Order : Hymenoptera
Suborder : Apocrita
Family : Apidae

A. GENERAL CHARACTERISTICS

1. GENERAL CHARACTERISTICS OF HYMENOPTERA

- * Wings membranous with reduced venation
- * Hind wings smaller than forewings
- * Hamulate wing coupling

2. GENERAL CHARACTERISTICS OF APOCRITA

- * First abdominal segment is fused with the metathorax and called as *propodeum*
- * Second abdominal segment is slender and called *pedicel* or *petiole (waist)*
- * The portion of the abdomen beyond the pedicel is called *gaster*
- * Ovipositor is modified as sting
- * Larvae apodous, eucephalous

3. CHARACTERISTICS OF APIDAE

- * Basitarsus is flattened

B. MORPHOLOGY OF WORKER BEE

- 1. Head :** Head is Triangular sensory centre consisting of eyes, antennae and mouth parts.

a) Eyes :

- * One pair of compound eyes and 3 ocelli
- * Compound eyes holoptic (or) dichoptic
- * Perceive form, colour and movement
- * Perceive blue, yellow, green and ultraviolet
- * Cannot distinguish red, gray and black colours
- * Dorsal ocelli three, perceive light intensity

b) Antenna :

- * Genuiculate type with long scape, short pedicel and flagellum (10 or 11 segmented)
- * Perceives smell, taste, water vapour, air pressure and temperature

c) Mouth parts :

- * Chewing and lapping type of mouth parts

Chewing Unit :

- * Consists of plate like labrum & blunt mandibles
- * Mandibles not toothed, stumpy and protrude near the base of the lapping tongue
- * Mandibles are helpful in pollen ingestion, wax moulding, carrying things and supporting the lapping unit while feeding and maintaining the flexed lapping tongue in position when not in use

Lapping Unit :

- * Consists of 2 galeae of maxillae 2 labial palpi and glossa of labium
- * Galea is large, blade like and tapering towards the apex with concave inner surface
- * Labial palp is four segmented
- * Glossa is greatly elongated, flexible extensible with a spoon shaped tip called **flabellum** (or) **bouton** useful to lick the nectar

2. Thorax

Consists of locomotory organs, wings and legs

i) Wings :

- * Forewings are larger and hind wings smaller, wing venation reduced with hamulate type of wing coupling
- * 15 - 25 hamuli present in the anterior margin of hindwing lock with anal fold present in the posterior margin of forewing

ii) Legs :

3 pairs of foraging legs

Foreleg

Foreleg consists of

- a) **Eyebrush** - hairs on tibia
- b) **Antenna cleaner** (Velum + antennal comb)
Velum - clasp at distal end of tibia

Antennal comb :

Notch lined with spines at the basal end of basitarsus

- c) **Pollen brush** : Bristles on basitarsus useful to collect pollen from anterior part of body

ii) Middle leg:

Consists of a) Pollen brush and B) spur

- a) **Pollen brush** : Bristles on basitarsus. Pollen collection from the middle part of the body and from anterior leg
- b) **Spur** : Present at the distal end of tibia, used to clean spiracles and wings and to loosen pollen packets from the pollen basket

iii) Hind leg

Consists of a) Pollen basket b) Pollen packer and c) Pollen comb

a) Pollen basket (corbiculum)

Concavity on the outer surface of tibia lined with curved hairs

b) Pollen packer (Pollen press)

- * Consists of pecten and auricle
- * Pecten is a row of stout bristles present at the distal end of the tibia
- * Auricle is a small plate fringed with hairs along the margin
- * Pack pollen inside the pollen packet

c) Pollen comb

- * Ten transverse rows of stiff spines on the innerside of basitarsus
- * Used in pollen collection from middle leg, removal of wax flakes from wax mirror

Pretarsus :

- * The structures beyond the last tarsal segments
- * Consists of a pair of noched claws and a fleshy glandular pulvillus
- * Claws give hold in rough surface
- * Pulvillus helps to cling to smooth objects

3) ABDOMEN

- * Six segments are visible
- * First abdominal segment is fused with metathorax
- * Consists of wax glands and sting

a) Wax glands

- * Four pairs of wax glands are present in the ventral side of 4 - 7th abdominal segments
- * Below each gland is a large oval shaped polished area called wax plate or wax mirror
- * Wax is secreted as a liquid which hardens later to form flakes

b) Sting

- * Modified ovipositor present in last abdominal segment
- * Consists of two barbed lancets and one stylet
- * Bee venom is secreted from a pair of acid glands
- * Three plates helpful in driving the sting into victims body are quadrate plate, triangular plate (or) oblong plate

2. BEE FAMILY

A. COMPARISON OF 3 CASTES OF HONEY BEES

Character	Queen	Worker	Drone
MORPHOLOGICAL DIFFERENCES:			
1. Size	Bigger	Smaller	Biggest
2. Head	Smaller	Smaller	Larger
3. Colour	Not dark	Pale	Darker
4. Compound eye			
i. Type	Dichoptic	Dichopitc	Holoptic
ii. No. of eye ommatidia	4000	5000	8000
iii. Vision power	Good	Better	Best
5. No. of divisions in flagellum	10	10	11
6. Length of lapping tongue	Short (3 mm)	Long (6 mm)	Short (4 mm)
7. Wings	Not extending upto the tip of abdomen	Extend upto the tip of abdomen	Largest Not extending upto the tip of abdomen
8. Wing flexing	Flexed neatly over the abdomen	Not neatly flexed	Not neatly flexed
9. Corbicula	Absent	Present	Absent
10. Pollen press	Absent	Present	Absent
11. Abdomen	Elongated bulged	& Posteriorly Pointed	Broad & blunt
i. Shape	Triangular	Triangular	Rectangular
ii. No. of gaster segment	6	6	7
iii. Sting	Slightly curved	Straight	Absent
iv. Barbs in lancet	Few, very small	Many, well developed	Absent
INTERNAL DIFFERENCES :			
	Queen	Worker	Drone
1. Gonads	Ovaries well	Ovaries poorly	Testes present

		developed	developed	
2.	Spermatheca	Large	Rudimentary	Absent
3.	Mandibular glands	Very large, secrete queen substance	Large, soften wax	Absent
4.	Pharyngeal glands	Not developed secrete bees's milk	Well developed,	Not developed
5.	Wax glands	Absent	Present	Absent

DEVELOPMENTAL VARIATIONS :

1.	Development	Develops from fertilized egg	Fertilized egg	Unfertilized egg
2.	Sex and fertility status	Fertile female	Sterile female	Fertile male
3.	Brood cell			
i.	Location	Bottom edge	Surface of the hive	Surface of the hive
ii.	Shape	Irregular	Hexagonal	Hexagonal
iii	Size	Largest	Smaller	Larger
.				
iv.	Capping	Present	Flat cap	Covex with central hole (bullet nose cap)
v.	No/hive	Few	Several hundreds	Several thousands
4.	Larval duration	5 days	4 days	7 days
5.	Larval food	Royal jelly	Royal jelly -2 days Bee bread -2 days	Royal jelly-3 days Royal jelly + Bee bread 4 days
6.	Feeding	Fed by workers	Self	Feed by workers & feed on honey too
7.	Duties	Egg laying, lead the swarm	Many duties	Fertilize queens
8.	Longevity	2-2 1/2 years	3 months	60 days

B. BIOLOGY/LIFE HISTORY OF HONEY BEE

1. Queen :

- * Reared in special cup shaped cells located on the lower edges of comb
- * Egg period : 3 days
- * Larval period : 5 days - larvae fed with royal jelly
- * Pupal period : 7 days
- * After emerging, virgin queen destroys any other queen cells
- * Six weeks after emergence, the queen takes a nuptial flight (or) mating flight and mates with upto 10 (or) more drones in succession. Returns to the hive with spermatheca filled with sperm
- * Three days after mating, eggs are laid. A good queen lays 2000 eggs/day. Lays upto 6 lakh eggs during the entire life period of 2-3 years. She can lay either fertilized (or) unfertilized eggs.
- * Queen substance containing ectohormone influences the production of new queen

Duties

- * Egg laying
- * Maintaining the colony strong

2. DRONE

- * Egg period : 3 days
- * Larval period : 7 days. Fed with royal jelly for three days and with a mixture of royal jelly & bee bread for 4 days
- * Pupal period : 13 days. Cells capped with dome shaped wax cap with a central hole
- * Adult longevity : 60 days

Duties

- * Mating with queen
- * Enjoy the sunshine and food gathered
- * Regulating hive temperature

3. WORKER

- * Egg period : 3 days
- * Larval period : 4 days. Fed with royal jelly for two days and with bee bread for remaining two days
- * Pupal period : 12 days. Cell cap flat
- * Longevity : 3 months

Duties

- * First 3 weeks confined to the hive called house bees (or) nurse bees

First week

First three days : Cleaning and incubating (33-36⁰C)

Next four days : Foster mother. Produces mother's milk. At the end of first week it makes an orientation flight for 5 minutes

* **Second week :**

Secretes royal jelly and wax

* **Third week :**

Receives honey, ripen and store it. Pollen digestion, cleaning & defence

* **After three weeks :** Foraging bees Collects honey dew, pollen, nectar, water and propolis

2. BEE KEEPING APPLIANCES

BEE HIVES

Bee hives were designed after the discovery of "Bee Space" (or) "Bee Passage" by L.L.Langstroth. It is the optimum distance to be left in between two adjacent comb surfaces in a bee hive which is essential for normal movement and functioning of bees. It is too small for comb construction and is too large for propolis deposition. It varies with honey bee species.

Eg. Indian bees	-	7 - 9 mm
Italian bees	-	10 mm

Bee keeping in movable frames

- * It is the noblest innovation in bee keeping which has several advantages
- * Hive volume can be increased (or) decreased based on need
- * Easy to assess food store position
- * Bees can be fed artificially
- * Brood development can be effectively monitored
- * Artificial queen rearing can be done
- * Old and damaged combs can be removed
- * Bees can be easily observed with least disturbance
- * Honey can be extracted without damaging the comb
- * More honey can be extracted by giving more honey supers

Hive bodies painted externally will last longer. The colour of the paint shall be white, blue, yellow or green. White is generally preferred for hive construction. It offers durability, flexibility easy handling and improves the colony efficiency in regulating hive interior temperature and humidity.

Materials

Bee hives are constructed mainly with seasonal timber such as teak, kail (or) toon. The timber should be free from insect holes, dead knots, shakes, splits and cracks. The thickness of the wooden walls should be 20 mm.

Types

Newton's hives, BIS hives and Marthandam hives are suited for rearing Indian bees. Langstroth hives are suited for rearing Italian bees.

Latest BIS Specifications for bee hives

Type	Bee space in mm	No. of frames	Bee species
A	7 or 8	10 or 8 or 4	<i>cerana</i>
B	9	10 or 8 or 4	<i>cerana</i>
C	10	10 or 6	<i>mellifera</i>

Parts of hive

The bee hive consists of the following parts

i) Bottom board (or) Floor board :

It forms the floor of the hive made up of a single piece of wood (or) two pieces of wood joined together. Wooden beadings are fixed on to the lateral sides and back side. There is a removable entrance rod in the front side with two entrance slits to alter the size of the hive entrance based on need. The board is extended by 10 cm in front of the hive body which provides a landing platform for bees. (Alighting board).
Size: 40x28 cm
(BIS hive).

ii) Brood Chamber

It is a four sided rectangular wooden box of cross section without a top and bottom. It is kept on the floor board. A rabbet is cut in the front and back walls of the brood chamber. The brood frames rest on the rabbetted walls. Notches on the outersurface of the side walls are useful for lifting. The four sides of the chamber are joined by special joints. In brood frames, bees develop comb to rear brood. Size (outer dimensions) : 29x29x17 cm. There will be 8 frames length and height of frame is 20.5x14.0 cm (BIS hive).

iii) Super Chamber

It is kept over the brood chamber and its construction is similar to that of brood chamber. Super frames are hung inside. The length and width of this chamber is similar to that of brood chamber. The height may be also similar if it is full depth super as in Langstroth hive. But the height will be only half if it is a shallow super as in Newton's hive. Surplus honey is stored in super chamber. The height of the chamber is 9.5 cm. The inner height of the frame is 6.0 cm (BIS hive).

iv) Hive Cover

It insulates the interior of the hive. In Newton's hive it has sloping planks on either side. On the inner ceiling plank there is a square ventilation hole fitted with a wire gauge. Two holes present in the front and rear also help in air circulation.

In Langstroth hive and BIS hive, the hive cover consists of a crown board (or) inner cover and an outer cover. The inner cover is provided with a central ventilation hole covered with wire gauze. The outer cover is covered over with a metallic sheet to make it impervious to rain water. Circular ventilation holes covered by wire gauze help in air circulation. It protects the hive against rain and sun.

v) Frames

The frames are so constructed that a series of them may be placed in a vertical position in the brood chamber (or) the super chamber so as to leave space in between them for bees to move. Each frame consists of a top bar, two side bars and a bottom bar nailed together. Both the ends of the top-bar protrudes so that the frame can rest on the rabbet.

The depth of the super frame is less than that of the brood frame in Newton's hive and ISI hive. But in Langstroth hive it is same as that of brood frame. A groove present underneath the top bar is useful to fix the comb foundation sheet. Holes present on the side bars are useful for wire reinforcement. Joined wire of 28 gauge is used for wiring frames. The height of the side bar reflects the depth of the super.

OTHER ACCESSORIES

1. Comb Foundation Sheet

It is a thin sheet of bee wax embossed with a pattern of hexagons of size equal to the base of natural brood cells on both sides. The size of the hexagon varies with bee species. The sheet is fixed to the frames on fine wires threaded through holes in the side bars and stretched tight. A spur embedder or an electrical heating device is used to embed wires into the comb foundation sheets which are prepared in a comb foundation mill.

Advantages

- * Bees have to add cell walls only
- * Combs will be vertical
- * Cell size will be uniform
- * Combs are strong and sturdy
- * Better and more honey harvest is made possible

2. Embedder

It is a small tool with a spur or round wheel on the top. It is used to fix the comb foundation sheet on the wires of the frame. Electric wire embedder is also used for this purpose which is useful to reinforce the comb and give extra strength to the comb.

3. Synthetic Combs

It is made up of high density polythene (plastic). It can be used in both super and brood chamber. Since the comb is fully moulded, bees only put wax caps on the cells.

Advantages

- * More honey can be extracted
- * Combs can be easily sterilized
- * Resist wax moth attack
- * Combs are not damaged during honey extraction

4. Dummy Division Board / Movable Wall

It is a wooden board slightly larger than the brood frame. It is placed inside the brood chamber. It prevents the bees from going beyond it. It can be used as a movable wall there by limiting the volume of brood chamber which will help the bees to maintain the hive temperature and to protect them from enemies. It is useful in managing small colonies.

5. Bee escape board or super clearer

It is a device which allows the bees to go through a self closing exit. eg. Spring bee escape or wire gauze cone. A board having one way passage in the centre can also be used. It is kept in between honey super and brood chamber. It is used for clearing the bees from super for extracting honey.

6. Queen Excluder

It is made up of perforated zinc sheet. The slots are large enough to allow the workers to pass through but too narrow for the queen. A wire grid/dividing grid with parallel wire mounts can also be used as a queen excluder. It is inserted in between the brood frames in single storey hive.

Uses

It is useful to confine the queen to brood chamber. But it allows the workers to have access to super. It prevents the queen from laying eggs in honey combs. It is also used in producing royal jelly in queen-rearing and in forming multi-queen colonies.

7. Drone Trap

It is a rectangular box with one side open. The other side is fitted with queen excluder sheet. At the bottom of the box there is a space for movement of worker bees. There are two hollow cones at the bottom wall of the box. Drones entering through the cones into the box get trapped. The narrow end of the cone is wide enough to let the bees pass out but not large enough to attract their attention or reentry. This device is used at the entrance to reduce the drone population inside the hive.

8. Queen Gate

It is a piece of queen excluder sheet. It is fitted on the slot of entrance gate. It confines the queen inside the hive. It is useful to prevent swarming and absconding. It also prevents the entry of bee enemies like wasps into the hive.

9. Queen Cage

It is a cage made up of wire gauze. It is useful for queen introduction.

10. Queen Cell Protector

It is a cone shaped structure made of a piece of wire wound spirally. It fits around a queen cell. It is used to protect the queen cell, given from a queen right to a queenless colony until its acceptance by bees.

11. Swarm Trap

It is a rectangular box used to trap and carry the swarm. It is fixed near the hive entrance with one (or) two combs inside during the swarming period. This box traps and retains the queen only. But the swarm coming out from the hive reenter the hive and settles on the comb, since the queen is trapped.

12. Pollen trap

Pollen trapping screen inside this trap scrapes pellets from the legs of the returning foragers. It is set at the hive entrance. The collected pollen pellets fall into a drawer type of receiving tray.

13 Division Board / Sugar Feeder

It can be hung along with the frames. A wooden strip (or) cut bits of leaves kept inside serve as float which prevents the drowning of bees in the sugar syrup.

14. Hive tool

It is a piece of flattened iron with flattened down edge at one end. It is useful to separate hive parts and frames glued together with propolis. It is also useful in scraping excess propolis or wax and superfluous combs (or) wax from various parts of the hive.

15. Protective dress

i) Bee veil

It is worn over face for protection against stings. It should be made up of black nylon netting screen (12-mesh). Screen wire (or) fabric are the preferred materials. Veils should be made to fit snugly around the hat and to fit tightly to the shoulder leaving enough space between veil and face.

ii) Overalls

White overalls are occasionally worn. Light coloured cotton materials are preferable since they are cooler and create less risk for antagonizing bees.

iii) Gloves

Bee gloves are made of tightly-knit cloth (or) soft leather. They cover the fore arms. To gloves are useful for the beginners to develop confidence in handling bees. But handlings of frames will be cumbersome if gloves are worn.

iv) High boots

A pair of gum boots will protect the ankles and prevent bees from climbing up under trousers.

17. Bee brush

A soft-camel-hair brush is used to brush the bees off the honey comb before it is taken for extraction.

18. Smoker

The smoker is used to calm bees and drive away bees from super. It consists of a metal fire pot with a funnel shaped cover and a bellow. A smoke releasing fuel (wood shavings, old rag) is burnt in the fire pot. Air is injected into the pot by operating the bellow and the smoke is directed to the desired spot.

19. Decapping knife

Single (or) double edged steel knife is used for removing wax cappings from the honey comb.

20. Honey extractor

It consists of a cylindrical drum. A rack is fixed inside the drum to hold the super frames. The rack is rotated by a set of gear wheels. The decapped honey frames are kept in the slots of the rack. The rack is rotated by operating the handle. Honey flow out from the combs by centrifugal force. The extracted honey comes out through the spout present at the bottom of the container. The honey comb is not damaged. So it can be reused. By using the extractor, pure honey can be obtained.

3. PESTS AND DISEASES OF HONEY BEES, THEIR MANAGEMENT AND ECONOMICS OF BEE KEEPING

1. PESTS OF HONEY BEES

1. WAX MOTHS

a) Greater wax, moth, *Galleria mellonella*

(Galleriidae : Lepidoptera)

- * Adults brown in colour
- * Female moth enters the hive during night and lays creamy white eggs in groups in the cracks and crevices of the hive and combs and in the gap between super and brood chamber
- * Caterpillar is dirty white in colour
- * Egg, larval and pupal periods are 8-10, 30 and 8 days respectively
- * Caterpillars tunnel into the combs and feed on the pollen, wax, propolis and royal jelly and make silken galleries in the tunnels
- * Complete damage of comb with numerous black faecal pellets, when the damage is heavy
- * Usually uncovered or partially covered combs and weaker colonies are damaged
- * In case of severe infestation, bees may abandon the colony

b) Lesser wax moth, *Achroia grisella*

- * Seen comparatively at higher altitudes
- * Caterpillars feed mainly on the debris of the combs

c) *Achroia innotatalankella*

- * Occurs both inside the combs and on the floor boards of working colonies

These wax moths at times decap the sealed cells exposing the pupae and this condition is referred to as bald brood.

2. ANTS (Formicidae : Hymenoptera)

- * Black ant, *Camponotus compressus*
- * Household red ant, *Dorylus labiatus*
- * *Monomorium spp.*
- * Attack weak colonies and carry away the honey, pollen and the brood, leading to destruction and end of the colony

3. WASPS

a) Yellow banded hornet, *Vespa cincta* (Vesipdae : Hymenoptera)

- * Large wasp with a broad transverse yellow band on the abdomen
- * A social insect constructing papery nests in hollows spaces

- * It waits near the entrance (alighting board) of the hive, catches bees as they come out, macerates them for feeding the juice to its young ones
- * It captures the bees in the field also

b) Bee hunter wasp, *Palarus orientalis*

- * Black colored with transverse yellow lines on the abdomen
- * It catches bees while on flight
- * A wasp can collect 80 bees a day, stings and carries them to its underground nests and places one in each of the compartments of the nest before laying an egg on the back of each bee. The grub on hatching feeds on the bee

c) Bee hunter wasp, *Philanthus ramakrishnae*

- * Found in hilly regions
- * Attacks and carries away bees

4. WAX BEETLES

- * *Platylolium alvearum* (Tenebrionidae : Coleoptera)
- * Found in hives under unhygienic conditions
- * Feed on the debris and on old combs in weak colonies

5. BIRDS

- * King crow, *Dicrurus* sp.
- * Bee eater, *Merops orientalis*
- * They capture bees and devour them

6. OTHER ENEMIES

1. The sphinx, *Acherontia styx* enters the hive and consumes honey
2. Cockroaches enter weak colonies and impart a foul smell to the hive
3. Robber flies
4. Leaf cutter bees
5. Dragon flies
6. Preying mantids
7. Lizards
8. Frogs and toads
9. Bears dismantle the hives and eat upon the honey, pollen, brood and the bees
10. Termites damage wooden parts of the hive

KEY POINTS TO PREVENT ENEMIES

1. Maintain vigorous colonies with adequate food store
2. Regularly observe and clean the hive
3. Destroy the infested comb

4. Remove excess comb from the hive and store them in closed containers

II DISEASES OF HONEY BEES

i. Brood diseases

Honey bee broods suffer from variety of diseases. Loss of brood affects the colony strength. Adult bees are not affected by brood diseases but they can spread the causal organisms.

Brood diseases are more serious than adult diseases. Brood disease are

1. American Foul Brood (*Bacillus larvae*)
2. European Foul Brood (*Melissococcus pluton*)
3. Thai Sac brood
4. Sac brood
5. Fungal diseases

ii) ECONOMICS OF BEE KEEPING

The economics of bee keeping for *Apis mellifera ligustica* at a basic unit of 10 bee colonies is given below.

1. Equipment and capital cost

Item	Number required	Rate/pc.	Cost Rs.
Double chamber bee boxes	10	650	6500
Hive stands	10	50	500
Propolis screens	10	30	300
Queen excluders	10	60	600
Feeders	10	100	1000
Pollen traps	10	120	1200
Supers	10	165	1650
Sets of accessories	1	400	400
Smokers	1	100	100
Comb foundation sheets	250	7	1750
Nucleus bee colonies	10	300	3000
Colonies training and followup for	10 (colonies)	100	1000
10 bee colonies total cost			18000
Add sales tax @ 8% on capital items			1120

So cost of 10 bee colonies and equipment along with tax = Rs. 19,120/-

2. Investment on a bee keeping unit of 10 bee colonies

The breakup of the investment is as follows:

Items	Capital (Rs.)
Capital invested	19120.00
State Govt. subsidy @ 250/bee colony	2500.00
Capital invested less subsidy	16620.00
Margin of bee keeper taken at 25.00 %	4155.00
Loan from institutions	2465.000
Instalment yearly (required in 4 years)	3116.25
Interest (1st year) 12.00%	1495.80

3. Details of income from the unit of 10 colonies

The items produced by the bees are assumed to be honey pollen and propolis, where propolis is produced in large quantities in areas where many trees are available.

Item	Yield/hive (kg)	Total produced (kg)	Rate/kg (Rs.)	Value (Rs.)
Honey	25	250	25	6250
Pollen	4	40	30	1200
Propolis	0.3	3	500	1500
Total Income				8950

4. Recurring expenses

The expenses on 10 bee colonies for their maintenance during the year are

Items	Units	Rate/Unit	Value (Rs.)
Sugar used	100 (kg)	9	900
Medicines	10	5	50
Total			950

5. Term loan repayment schedule, instalments and interests

The analysis of repayment of term loan over a period of 4 years is as follows

	Year 1	Year 2	Year 3	Year 4
Yearly instalment	3117	3117	3117	3117
Term loan balance	12465	9349	6233	3117
Interest on term loan	1496	1122	748	374

6. Profitability of a bee keeping unit of 10 bee hives

At the above investment and instalments for the loan, the breakup of the profitability and cash flow for 5 years is:

Items	Years					
	1st	2nd	3rd	4th	5th	6th
A. Income (assuming 50% in first year)	4475	8950	8950	8950	8950	8950
B. Expenses Running costs	950	950	950	950	950	950
Interest on loan	1496	1122	748	374		
Total expenses	2446	2072	1698	1324		
C. Net profit	2029	6878	7252	7626	8000	8000
Less instalment		3116	3116	3116	3116	
Net cash accrual	2029	3762	4136	4510	4884	8000
D. Cumulative Cash accrual	2029	5791	9927	14437	19321	27321
Return on investment (ROI=Net profit/capital investment)	11%	36%	38%	40%	42%	
E. Monthly income after repayment of term loan and interests is	169	313	345	376	407	667

4. LAC INSECT : LIFE HISTORY, NATURAL ENEMIES AND LAC PRODUCTS

Lac Insect	:	<i>Kerria lacca (or) Laccifer lacca</i>
Family	:	Kerridae (or) Lacciferidae
Super family	:	Coccoidea
Sub order	:	Homoptera
Order	:	Hemiptera

1. LAC

- * All scale insects secrete a hard encrustation over the body as a protective covering
- * Lac insects secrete brownish substance (lac) and live in the encrustations
- * The commercial product, shellac is manufactured from true lac

2. HOST PLANTS

- | | | | |
|----|-------|---|---------------------------|
| 1. | Palas | - | <i>Butea monosperma</i> |
| 2. | Ber | - | <i>Zizyphus jujuba</i> |
| 3. | Kusum | - | <i>Schleichera oleosa</i> |
| 4. | Khair | - | <i>Acacia catechu</i> |

3. STRAINS

- | | | | |
|----|-----------------|---|--------------------------|
| 1. | Kusumi strain | - | Lives on Kusum |
| 2. | Rangeeni strain | - | Lives on all other hosts |

4. LIFE CYCLE

- * Eggs laid inside the encrustations
- * Eggs hatch immediately; First instar nymphs emerge out from the cell through the opening near the anal region of the female
 - Emergence = *swarming*
 - First instar nymphs = *crawlers*
- * Nymphs: Minute boat shaped, deep red in colour, 0.6 mm long, soft bodied with black eyes and 3 pairs of legs and a pair of antennae
- * Crawlers search for tender branches and settle on them
- * Feeding by piercing the shoot with their long styles
- * Once the proboscis is thrust into the host, nymphs get settled and work / move afterwards
- * One or two days after settling they secrete lac or resin. Resinous covering = cell
- * Secretion is produced by resin glands present all over the cuticle except mouth parts, anus and breathing pores
- * As insects grow, secretion also increases and completely covers the insect forming a globular cell

- * Secretion is continuous hence the coating around one insect meets and coalesces with that from another
- * Thus continuous / semi continuous covering on the twig or shoot is formed
- * Males walk over the lac encrustations; fertilize the females present inside cell through anal tubercular opening
- * Females after mating grow very fast, secrete lack abundantly. Size of the female cell is several times larger than male cell

5. MANUFACTURE OF SHELLAC

It involves three steps

i) Production of crushed lac

- * Remove lac encrustations from the branches either by twisting them or scrapping by knife
- * Scrapped material is called as *raw lac* or *scrapped lac* or *stick lac*
- * Powder the stick lac (powdered lac is called crushed lac)

ii) Production of seed lac or grain lac

- * Keep the crushed lac immersed in water in cement tubs for 3 days
- * Stir the contents
- * Drain off the supernatant coloured liquid
- * Transfer the material that settle at the bottom to large vats
- * Add water and lime at 1 kg/160 kg of uat
- * Collect the lac dye which settles down
- * Remove the bits of twigs, fibrous material and parts of insect body that floats in the vat

iii) Production of shellac - Hot melting method

- * Mix grain lac with arsenic sulphide to colour the lac (yellow orpiment)
- * Put the blended material in a cloth bag of 9 m long and 0.6 m dia and heat over an open fire rotating the bag continuously
- * Lac melts and oozes out of the bag and sticks to outer surface
- * Twist the bag, when sufficient quantity of molten lac is collected outside the bag
- * Coat the lac coming out of the bag uniformly over a cylindrical container containing hot water and cool it
- * Remove the sheet, again heat and stretch by hand into a size of a metre square
- * Break up this sheet into flakes
- * SHELLAC : Orange to pale yellow in colour

Button Lac

- * Pour the molten lac into dies made of zinc sheet - instead of stretching
- * Cool in which will result in very hard buttons of lac

6. OTHER BY - PRODUCTS

1. Molemma : Finely divided dust like material separated from seed lac. Contains 70% shellac

2. Kiri : The dirt and left over material in the cloth bag after recovering molted lac. Contains 50% shellac
3. Passewa : It is the material that is collected from the cloth bag by boiling them after removing kiri.

7. USES OF SHELLAC

- * Sted lac and shellac is used in french polish, floor polish, gramophone records, bangles, flots, sticks and straw hats, printing ink, electric insulators, sealing wax, shellac varnishes, adhesives, etc.
- * To paint wooden toys
- * To paint sides of ships to prevent leakage
- * Used in Ayurvedic Medicine for preparing medicine to cure chronic fever and rheumatism. Lac also has germicidal, febrifuge (fever curing) and astringent properties (substance which induces contractions)
- * Lac dye contains nitrogen and hence used as manure
- * Lac dye is used for dyeing eri-silk which gives beautiful red colours

8. NATURAL ENEMIES OF LAC INSECTS

a) Predators

- i) The larger white lac moth, *Eublemma amabilis* (Noctuidae; lepidoptera)
 - * Larvae dirty-white in colour
 - * More destructive on the trees
- ii) The smaller black lac moth, *Holcocera pulverea* (Gelechiidae: Lepidoptera)
 - * Larvae chocolate coloured
 - * More serious on stored lac
 - * The above two moths lay their eggs on or near lac encrusted branches. The larvae on hatching bite their way inside the lac encrustation and feed on lac insects as well as the lac encrustations
- iii) lace-wing fly, *Chrysopa* sp. (Neuroptera)
 - * Maggots feed on the body content of lac insects

b) Parasitoids

- * Small winged insects of order, Hymenoptera and family, Chalcididae
- * Lay eggs in the lac cells and the grubs feed on lac insects

c) Non-insect enemies

- i) Rats ii) Squirrels iii) Monkeys

5. IDENTIFICATION OF PREDATORY INSECTS

An insect predator is large in size, active in habits and has structural adaptations for catching the prey with well developed sense organs and capacity for swift movements. They feed upon a large number of small insects every day. The important groups are as follows :

1. **Order : ODONATA**
 Sub order : ANISOPTERA Eg. Dragon fly
 Sub order : ZYGOPTERA Eg. Damsel fly
 - * Relatively larger sized insects
 - * Immature stages (Naiads) are aquatic feeding on aquatic insects
 - * In naiads, labium is modified into a prehensile organ called mask for catching the prey
 - * Adults feed on midges, mosquitoes, flies and small moths
 - * Adults are capable of catching prey during flight with the help of basket shaped legs

2. **Order : DICTYOPTERA**
 Family : MANTIDAE
 - * Preying mantids are large elongate insects
 - * Nymphs and adults are cryptically coloured with long prehensile raptorial forelegs
 - * Highly predaceous feeding on variety of insects like flies, grasshopper and many caterpillars Eg. *Mantis religiosa*

3. **Order : HEMIPTERA**
 - i) **Family : REDUVIIDAE**
 - * Assassin bugs or cone nose bugs or kissing bugs
 - * Usually blackish or brownish in colour
 - * The beak or proboscis is short and three segmented
 - * Most are predaceous and some are blood sucking
 - * Both nymphs and adults are predaceous
 - * Eg. *Harpactor costalis* on the red cotton bug *Dysdercus cingulatus*

 - ii) **Family : PENTATOMIDAE**
 - * Stink bugs
 - * Bugs are shield shaped with 5 segmented antennae
 - * Some of the species are predaceous on lepidopterous larvae
 - * Both nymphs and adults are predaceous
 - * Eg. *Eucanthecona furcellata* on the larvae of red hairy caterpillar, *Amsacta albistriga* and gram caterpillar, *Helicoverpa armigera*

 - iii) **Family : BELOSTOMATIDAE**
 - * Giant water bug
 - * Elongate oval and somewhat flattened with raptorial forelegs

- * Feed on variety of aquatic insects

iv) Family : MIRIDAE

- * Elongated soft bodied insects
- * A few species are predaceous
- * Eg. Green mirid bug, *Cyrotorhinus lividipennis* feeds mainly on the eggs and early stage nymphs of green leaf hopper (GLH), brown plant hopper (BPH) and white backed plant hopper (WBPH) in rice

v) Family : VELIIDAE

- * Ripple bugs
- * Aquatic insects living on the surface of water
- * Brown or black in colour
- * Eg. *Microvelia atrolineata* feeding on the first instar caterpillar of lepidopteran pests and GLH, BPH and WBPH in rice ecosystem

4. Order : NEUROPTERA

i) Family : MYRMELEONTIDAE

- * Antlions
- * Larvae construct pit falls and remain buried in the soil
- * Feed on the ants and other insects that fall into the pits
- * Feed by inserting the mandibulo - suctorial mouth parts into the prey and sucking the internal contents

ii) Family : CHRYSOPIDAE

- * Aphid wolves or green lace wings
- * Adults are green in colour with golden or copper coloured eyes
- * Feed on more than 18 families of insects
- * The larvae are predaceous mainly on aphids and also on eggs of lepidopteran insects, psyllids, coccids, thrips and mites
- * Larvae have sharp mandibles
- * The eggs of aphid lions are stalked (pedicellate)

5. Order : DIPTERA

i) Family : ASILIDAE

- * Robberflies
- * Adults are mostly elongate with tapering abdomen
- * Body is covered with dense hairs
- * Legs are long, strong and well developed
- * Adults are predaceous and attack a variety of insects like wasps, bees, grasshoppers, flies etc.
- * Mouth parts are piercing type. They feed by sucking the body fluid of the prey

ii) Family : SYRPHIDAE

- * Hover fly adults are brightly coloured and resemble various bees and wasps
- * Good pollinators
- * Maggots are green in colour and feed on aphids by sucking their body fluids

6. Order : COLEOPTERA

i) Family : COCCINELLIDAE

- * Lady bird beetles
- * Beetles are small, oval, convex and often brightly coloured
- * Grubs are elongate, somewhat flattened and covered with minute tubercles or spines
- * Adults and grubs feed on aphids, coccids, mealy bugs, whiteflies and other soft bodied insects
- * Except one or two species in the family all are predaceous
- * Eg. *Rodolia cardinalis* on cottony cushion scale, *Icerya purchasi*

ii) Family : CARABIDAE

- * Ground beetles
- * Dark in colour and shiny and some what flattened
- * Most of them feed on caterpillars
- * Eg. *Inthia sexguttata*, *Ophionea indica*

iii) Family : CICINDELIDAE

- * Tiger beetles
- * Beetles are very active and brightly coloured
- * They run and fly rapidly
- * Both adults and grubs are predaceous
- * Adults capture the prey with sickle shaped mandibles
- * Eg. *Cicindela* spp.

iv) Family : STAPHYLINIDAE

- * Rove beetles
- * Eg.: *Paederus fuscipes* feeds on rice leaf folder

7. Order : HYMENOPTERA

i) Family : VESPIDAE

- * Wasps collect various insects and feed their larvae with them
- * Mudwasps construct nests made of mud and provide caterpillars for the young ones in the nest

ii) Family : SPHECIDAE

- * Digger wasps construct nests made of mud and feed its young ones with insect caterpillars

iii) Family : FORMICIDAE

- * About half the members of the family are predaceous upon insects

6. IDENTIFICATION OF INSECT PARASITIDS

A parasitoid is an insect living on or in the body of another insect, called the host from which it gets protection and food during its immature stage and the adults are free living. In a typical case, eggs are laid on or in the body of the host, the larvae feed on the body contents of the host, pupate either inside or on the host body and emerge as adults. The hosts are not killed immediately. Most of the parasitoids belong to Hymenoptera (90%) and Diptera (10%).

1. Order : HYMENOPTERA

The ovipositor originates and protrudes ventrally from the abdomen and is used to insert eggs into their hosts. There are three super families.

a) Super Family : ICHNEUMONOIDEA

- * Possess long and filiform antennae
- * Wings are veined

i) Family : ICHNEUMONIDAE

- * Eg. *Eriborus trochanteratus*, a larval parasitoid on coconut black headed caterpillar, *Opisina arenosella*
- * Antennae longer with more than 16 segments
- * Trochanter two segmented
- * Possesses two recurrent veins and rarely one
- * Abdomen three times as long as the rest of the body
- * Ovipositor longer than the body
- * Large slender black, yellow or reddish yellow insects
- * Larvae are endo or ecto parasitic on many groups of insects and spiders

ii) Family : BRACONIDAE

- * Eg. *Bracon brevicornis*, a larval parasitoid on *O. arenosella*, *Chelonus blackburni*, egg larval parasitoid on cotton spotted bollworms, *Earias* spp.
- * Adults are relatively small, more stout bodied than ichneumonids
- * Abdomen is about as long as the head and thorax combined
- * Not more than one recurrent vein
- * Adults not as bright as ichneumonids
- * Mostly endoparasitic on lepidopteran larvae

b) Super Family : CHALCIDOIDEA

- * Mostly smallest parasitoids and gregarious
- * Antennae geniculate

- * Abdomen very short or globular with very slender propodeum
- * Wings without veins

i) Family : CHALCIDIDAE

- * Eg. *Brachymeria nepantidis* a larval parasitoid on *O. arenosella*
- * Minute insects
- * Abdomen humped
- * Hind femur enlarged and toothed
- * Wings are not folded longitudinally when at rest
- * Ovipositor straight and short
- * Parasitic on Lepidoptera, Diptera and Coleoptera

ii) Family : TRICHOGRAMMATIDAE

- * Eg. *Trichogramma chilonis*, an egg parasitoid on many lepidopterous pests
- * Mostly egg parasitoids
- * Minute insects (0.3 to 1.0 mm long) with three segmented tarsi and broad and elongated fore wings with rows of microscopic hairs on them
- * Hind wings reduced with hairs

iii) Family : EULOPHIDAE

- * Eg. *Trichospilus pupivora* and *Tetrastichus israeli*, pupal parasitoids on *O. arenosella*
- * Adults have four segmented tarsi
- * Many have brilliant metallic colouring
- * Males of many species have pectinate antennae
- * Mostly parasitic on aphids and scales and some are on pupae of Lepidoptera

c) Super family : BETHYLOIDEA

- * Smaller than Ichneumonidea and larger than Chalcidoidea

i) Family : BETHYLIDAE

- * Eg. *Parasierola* (= *Goniozus*) *nepantidis*, a larval parasitoid on *O. arenosella*
- * Small to medium sized, usually dark coloured wasps
- * Females of many species are wingless and antlike in appearance
- * In a few species, both winged and wingless forms occur in each sex
- * Parasitic on Lepidoptera and Coleoptera

2) **Order : DIPTERA**

Family : TACHINIDAE

- * Eg. *Sturmiopsis inferens*, a larval parasitoid on sugarcane shoot borer, *Chilo infuscatellus*
- * Large bristle flies
- * Eggs may be macrotype or microtype
- * Macrotype eggs are laid directly on the host's body usually attached to the neck region by a glutinous secretion
- * Eg. *Spoggosia bezziana* on *O. arenosella*
- * Microtype eggs are laid on the host plant and the host larvae feeding on the plant tissue ingest them

3) **Order : LEPIDOPTERA**

Famil : EPIRICANIDAE

- * Eg. *Epiricania melanoleuca*
- * Parasitic on nymphs and adults of sugarcane leafhopper, *Pyrilla perpusilla*

KINDS OF PARASITISM

a) **Simple parasitism**

- * Single attack of the parasitoid on the host irrespective of the number of eggs laid
- * Eg. *Parasierola nephantidis* on *O. arenosella*

b) **Super parasitism**

- * Many individuals of the same species of the parasitoid attack a single host
- * Eg. *Trichospilus pupivora* on the pupae of *O. arenosella*

c) **Multiparasitism**

- * Parasitism by different species of parasitoids on the same host at a time
- * Eg. Bethylids and braconids on *O. arenosella*

d) **Hyperparasitism**

- * Parasitoid of a parasitoid
- *

Eg. Host	-	Parasitoid	-	Hyperparasite
Aphid	-	<i>Aphidius</i>	-	<i>Asaphes</i>
Diamond back moth	-	<i>Apanteles</i>	-	<i>Hemiteles</i>

7. MASS PRODUCTION METHODS OF BIOCONTROL AGENTS

A. Mass culturing of parasitoids

Rice moth, *Corcyra cephalonica* (Fig. 23) is a potential host/prey insect for rearing number of parasitoids and predators.

1. Rearing of *C. cephalonica*

The larvae of *C. cephalonica* can be reared on cumbu grain. Heat sterilised broken cumbu grain @ 2.5 kg along with 100 g of groundnut powder and 5 g of powdered yeast tablet are taken in a wooden or plastic tray (45 cm x 30 cm x 10 cm) (Fig.24). Steptomycin sulphate 0.05 per cent spray is given @ 5 g per tray to prevent storage mite infection. *Corcyra* eggs @ 0.5 cc (8000 - 9000 eggs)/tray are uniformly mixed in cumbu medium and the trays are covered with kada cloth, secured by rubber band. The hatching larvae feed on the grain by webbing and larval period lasts for 30-35 days. The pupation takes place inside the web itself. Pupal period lasts for 5-7 days and adult moths emerge after 30-45 days from the date of egg inoculation.

The emerging *Corcyra* adults are collected (Fig.17) every morning and transferred to a specially designed mating drum made of G.I. with wire mesh bottom (Fig.25) where they are provided with honey solution as food. The eggs are collected at the bottom on a blotting paper kept in a tray. The eggs are cleaned with sieves or egg separator (Fig.26). One cc of eggs will contain approximately 16,000 to 18,000 eggs. About 100 pairs of *Corcyra* moth will produce 1.5 cc of eggs during the four days of egg laying period. From each culture tray a maximum of 2500 moths can be obtained. A tray can be kept for about 90 days for collection of adult moths due to staggered development.

2. Mass culturing of egg parasitoid, *Trichogramma spp.*

The eggs of *Corcyra* are sterilized by exposing to UV light (15 W for half an hour) to kill embryo and are sprinkled uniformly on large egg cards (30 cm x 20 cm divided into 30 rectangles (7 cm x 2 cm) (Fig.28) by drawing lines containing a thin layer of gum @ 6 cc/card. These cards are taken in large polythene bags (45 cm x 30 cm) are kept for another 2 days at room temperature and on fourth day parasitised eggs turn black in colour. At this stage, the egg card can be used for field release or stored at 10°C for a fortnight.

Field release : The parasitoids emerge 7 days after parasitisation under room temperature. When cold stored, the cards are taken out and kept in room temperature for a day before field release. The egg card's cut into smaller cards along the lines and stapled on the plant.

Pest	Dose
i. Sugarcane internode borer	1 cc of parasitised eggs / release / ac; six releases at 15 days interval from fourth month onwards
ii. Cotton bollworm	6 cc of parasitised eggs / release / ac 3 to 4 releases based on pest intensity
iii. <i>H. armigera</i> on tomato	3 cc of parasitised eggs / release / ac, coinciding with flowering based on ETL or 6 moths / sex pheromone traps
iv. Rice stem borer	<i>T. japonicum</i> - 2 cc / release / ac; 3-4 releases after planting (l.c)
v. Rice leaf folder	<i>T. chilonis</i> - 7 cc / release / ac; 5 releases at weekly intervals from 30 days after transplanting

3. Mass culturing of egg-larval parasitoid, *Chelonus blackburni*

C. blackburni parasitises the egg stage but life cycle is completed in larval stage. *Corcyra* eggs are sparsely sprinkled on white cards on a thin layer of diluted gum. After drying the parasitoid adults are allowed at one per 100 eggs into a plastic container (Fig.29) and covered with muslin cloth. After exposing for 24 hr. the cards are transferred to another plastic container containing 250 g of broken cumbu grain. The parasitoids develop inside *Corcyra* larvae and spin small white cocoons. The adult emerge in 15-20 days.

Field release : The emerged parasitoids are collected daily and taken to cotton fields for release @ 1/plant (or) 8000 parasitoids/ac larval parasitoid.

4. Mass culturing of *Bracon* sp. (Sandwich method)

Bracon can be mass reared on *Corcyra* larva. The broader end of chimney is covered with muslin cloth by using a rubber band. Two mated female *Bracon* adults are released to each *Corcyra* larva through the narrow end of the chimney which is closed with another muslin cloth. After 3-4 hours the parasitised caterpillar are transferred to containers having folded papers (Fig.30). The female *Bracon* lays about 8 - 12 eggs on the ventral side of the caterpillar and egg hatches in about 28-30 hours. The larval period lasts for 3-4 days and the pupal period 2-3 days. Life cycle is completed in 7-9 days.

Field release : *B. hebetor* is released @ 8000 adults/ac for cotton bollworm and *B. brevicornis* released @ 10 adults/tree for coconut black headed caterpillar.

5. Mass culturing of larval parasitoid, *Eriborus trochanteratus*

E. trochanteratus can be reared on *Corcyra* larvae under laboratory condition. The adult parasitoids (1:1, male : female) are released into mating cage (30 x 30 x 30 cm) with adult food kept in a sponge. Next morning the females are separated and transferred to glass or plastic containers. *Corcyra* larvae @ 10/female parasitoid are allowed for parasitisation. The container is kept upside down on a sheet of paper for 3

hr. The parasitoids inject their eggs into host larval body. After 3 hr. the parasitised larvae are transferred into a container with broken cumbu grains for further development. The parasitised cocoons are collected after 10 days from the rearing containers and kept separately for adult emergence.

Field release : Release 800 adults/acre.

6. Mass culturing of larval parasitoid, *Goniozus nephantidis*

This can be mass cultured on the natural host, coconut black headed caterpillar. Adult parasitoids are released in specimen tube for 1-2 days for mating with 30% sugar solution as food. One female parasitoid is taken in a 7.5 cm specimen tube with medium sized black headed caterpillar for parasitisation. The parasitoid lays 10-15 eggs on host larval body surface. The grubs feed on larval contents from outside and kill them. The grubs are collected and transferred to setting paper strips in which they construct silken cocoons.

Field release : The emerging adults are released in coconut garden @ 10 adults/tree.

7. Mass rearing of pupal parasitoids, *Trichospilus pupivora* and *Tetrastichus israeli*

T. pupivora and *T. israeli* are parasitic on the pupae of coconut black headed caterpillar, *H. armigera*, *Spodoptera* and castor spiny caterpillar, *Ergolis* etc. They can be mass cultured on the pupae of the above host insects. Fresh pupae of the host insect are transferred @ 5/tube of 15 x 2.5 cm size and 30 mated female parasitoids are released into each tube with 50 per cent honey as adult food. After 2 days, the parasitised pupae are transferred in test tubes for parasitoid emergence. It is a gregarious parasitoid which completes the life cycle inside the pupa of the host. Larval and pupal period lasts for 6 days and 8-10 days, respectively.

Field release : Release @ 20 adults/tree for coconut black headed caterpillar.

INSECT PREDATORS

A predator is a free living organism throughout its life, it kills the prey, usually larger than the prey and requires more than one prey to complete its development.

I. Insect predators of agricultural importance

a) Insects

Order and Family	Name	Prey Insect
Coleoptera		
i) Coccinellidae - (Lady bird beetle)	<i>Coccinella septumpunctata</i> <i>C. rependa</i> (Fig.31) <i>Scymnus coccivora</i> <i>Menochilus sexmaculata</i> (Fig.32) <i>Rodolia cardinalis</i> <i>Chilocorus nigritus</i> <i>Cryptolaemus montrouzieri</i>	Aphids Aphids Grape vine mealy bug Mealy bugs and scales Cottony cushion scale Tapioca scales Grape vine mealy bug
ii) Carabidae (ground beetle)	<i>Parena laticincta</i> <i>Ophionea sp.</i> (Fig.33) <i>Paederus fuscipes</i> (Fig.34)	Coconut black headed caterpillars Rice BPH and leaf folder
iii) Cicindellidae (Tiger beetle)	(Fig.35)	
2. Hemiptera		
i) Reduviidae (Reduviid bug) (Fig.36)	<i>Rhinocoris fuscipes</i> <i>Platyeris laevicollis</i>	H. armigera Coconut rhinoceros beetle
ii) Miridae (Mirid bug)	<i>Cyrtorhinus lividipennis</i> (Fig.37)	Rice hoppers
iii) Veliidae (Riffle bug)	<i>Microvelia atrolineata</i> (Fig.38)	Rice leaf and plant hopper
3. Neuroptera		
i. Chrysopidae (Lace wing fly)	<i>Chrysoperla carnea</i>	Aphids, scales bollworms, mealy bugs
ii. Myrmeleonidae (Antlion Fig.31)		
4. General predators		
i. Dragon flies	Naiads and adults (Fig.40)	On small insect, butterflies
ii. Damselflies	Naiads and adults (Fig.41)	On small insects, caterpillars
iii. Preying mantids	Naiads and adults (Fig.42)	Grasshoppers, caterpillars, butterflies
iv. Giant water bug	Adults	Small aquatic insects
v. Robber flies	Adult (Fig.43)	Small insects
vi. Hover flies (Syrphids)	Larva (Fig.44)	Aphids
vii. Wasps	Adult (Fig.45)	Caterpillars
Others		

i. Arachinds	Spiders (Fig.46), scorpions and mites,	On insects and mites
ii. Fishes	<i>Gambusia affinis</i> (Fig.47), <i>Fundulus</i>	On mosquito larvae
iii. Amphibians	Frogs (Fig.48) and toads	On small insects
iv) Birds	Ducks (Fig.50), Owls (Fig.51) King crow (Fig.52), Mynah (Fig.53), Wood pecker (Fig.54).	Rice BPH On rats Caterpillar
v. Reptiles	Lizards, Snakes	Small insects, Rats

B. Mass culturing of Predators

1. *Cryptolaemus montrouzieri* (Fig.55) is a promising predator on mealybugs, scale insects and aphids. This exotic predator is used in large scale to control grapevine mealy bugs, *Maconellicoccus hirsutus*. Red pumpkin is used for the multiplication of grapevine mealy bug in the laboratory. Select the well ripened pumpkin having a small stalk and sterilise the outer surface with 0.1 per cent fungicide (Dithane M45) and air dried. Release the crawlers of (New born) mealy bug on the pumpkin and allow them to multiply on the pumpkin in a dark place.

A fully infested pumpkin with mealy bug is placed in a cage (30 x 30 x 30 cm) covered with cloth on all sides having a glass door in front (Fig.56). Expose the fruits to adult beetle for oviposition and remove the fruit after 48 hours. The hatching larvae feed and develop on the mealybug. The fully grown larvae, pupate on the folded paper placed on the floor of cage. Collect the pupae in a separate cage for emergence of adults.

Field release : For citrus mealy bug and grape vine mealy bug, release 10 beetles/tree (or) vine. Before releasing the predators, the ant movement should be arrested.

2. *Chrysoperla carnea* The green lace wing, *Chrysoperla* also called as aphidlion (Fig.57), is predatory during the larval stage on a variety of insects viz., aphids, mealy bugs, white flies, thrips, eggs and larvae of *H. armigera*, Spodoptera, Pink bollworm etc. The mass rearing technique of this predator involves two steps viz., larval rearing and adult rearing.

a) Larval rearing: Larval rearing can be done in round plastic basins at 250 larvae/ basin covered with kada cloth (Fig.58). The eggs of *Corcyra* are given as food to the larvae of aphidlion. For rearing 500 larvae 25 cc of *Corcyra* eggs are required @ 5 cc/feeding on alternatedays. The *Chrysoperla* larvae pupate (white silken cocoons) in 10 days and green coloured adults with transarent lace like wings emergence in 9-10 days. The cocoons are transferred with fine brush to one litre plastic containers with wire mesh window for adult emergence (Fig.59).

- b) **Adult rearing :** The adults are transferred to pneumatic glass trough or G.I. round trough (30 x 12 cm) wrapped with brown sheet acting as oviposition substratum. About 250 adults (60% female) are allowed into each trough and covered with white nylon cloth. Three bits of moist foam sponge and protein rich diet in semi solid form are placed over the nylon cover as food for the adults (Fig.60). The stalked eggs are laid on the brown sheet. The egg sheets can be stored at 10°C for 21 days. When the eggs are required for field release, the egg sheet is kept at room temperature and the eggs turn brown and hatch on third day. The eggs are destalked by brushing with a sponge piece on second day. The first instar larvae are either taken for culture (or) field release.

Field release : The first instar larvae of *Chrysoperla* are released in cotton fields at 20,000 to 40,000/acre for 3-5 times at 10 days interval to control aphids, whitefly, Spodoptera, Heliothis, pink bollworm, thrips and mites. The larvae are taken in plastic containers with 1-2 cc of corcyra eggs and loose paper strips. The paper strips along with larvae sticking on them are dropped in the field at random while walking across the field.

C. Mass production of insect viruses

Microorganisms which cause diseases in host insects are known as insect pathogens. Utilisation of insect pathogens and their products in the suppression of insect pests is known as microbial control (eg.) virus, bacteria, fungi, protozoa, rickettsiae and nematodes.

I. Insect viruses

The important family among the viruses is Baculoviridae which include nuclear polyhedrosis viruses (NPV) and granulosis viruses (GV). They are obligate pathogens requiring the living host insects for development and multiplication. Disease caused by the virus is called as virosis. They are highly specific and do not attack beneficial insects besides being safe to other animals including man.

a) Nuclear polyhedrosis virus (NPV)

The virus consists of proteinaceous polyhedral occlusion bodies inside which the virions or virus rods are embedded.

Mode of entry : The virus should be ingested to produce the disease (Per os). Due to alkaline gut juice, the virions are liberated from the polyhedral coat which attack nuclei of cells of tissues viz., fat body tracheal matrix, haemocytes, sarcolemma of muscles, neurilemma and nerve cells of ganglion and brain.

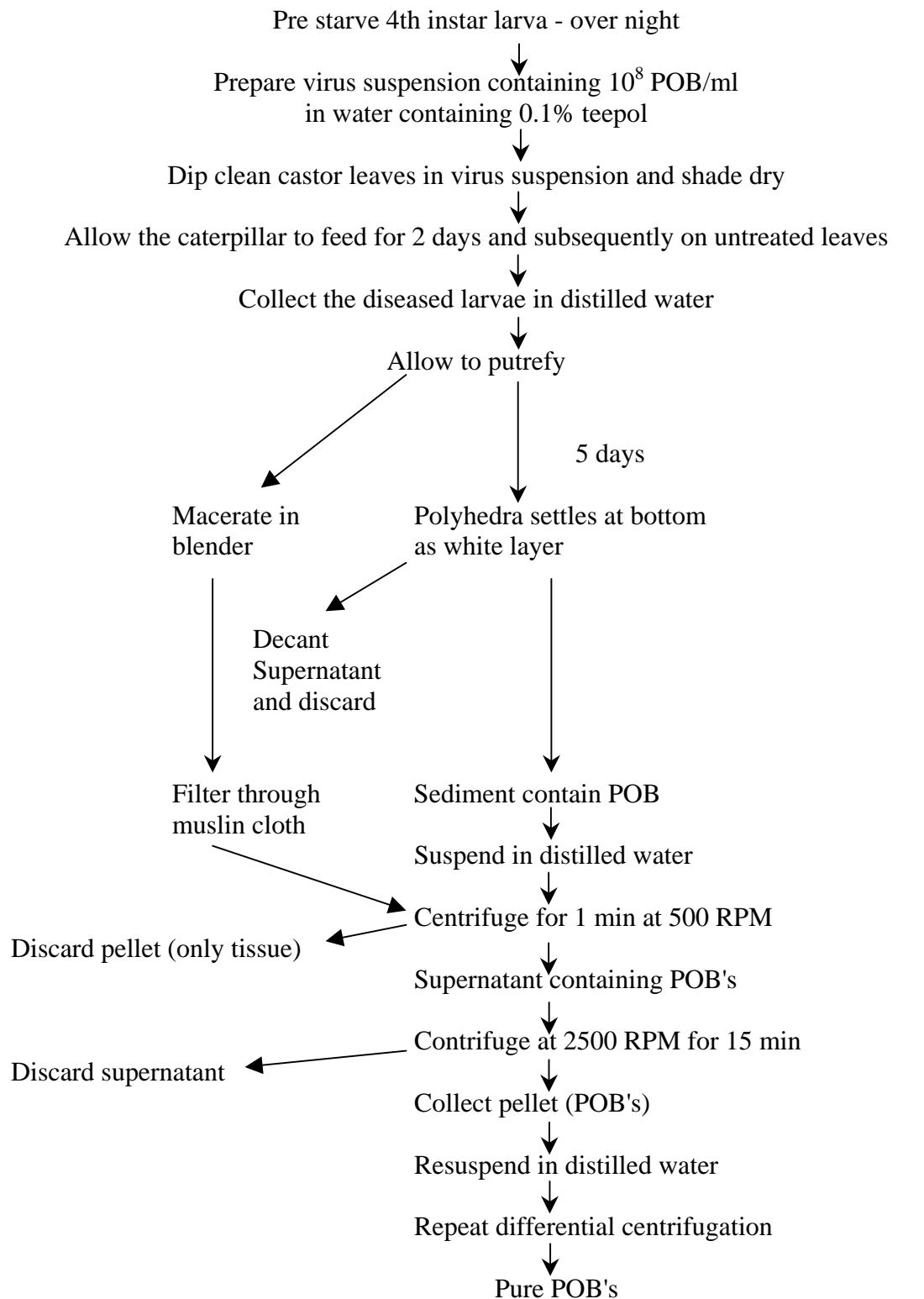
Symptoms : Insects become dull in colour, feeding rate is reduced and larvae become pinkish white especially in the ventral side due to accumulation of polyhedra. In advanced stage larvae become flaccid, the skin becomes very fragile and eventually

rupture. Diseased larvae hang upside down from the plants. This is called tree top disease (or) Wipfelkrankheit (Fig.66).

Incubation period : 4-6 days depending upon the stage of the infection, weather conditions and dose of virus. Early instars are most susceptible to the virus.

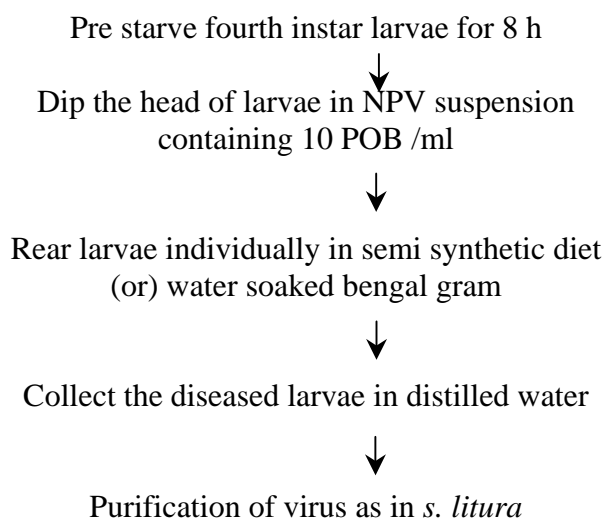
i) Mass production of NPV of *Spodoptera litura*

S. litura (Fig.61) can be mass cultured using the natural diet, viz., castor leaves under laboratory condition in plastic buckets (Fig.62 & 63). The steps involved in the production on NPV are :



The dose of virus is expressed as larval equivalent (LE) and one LE is 6×10 POB. One LE can be had from three fully grown up and virus infected larvae.

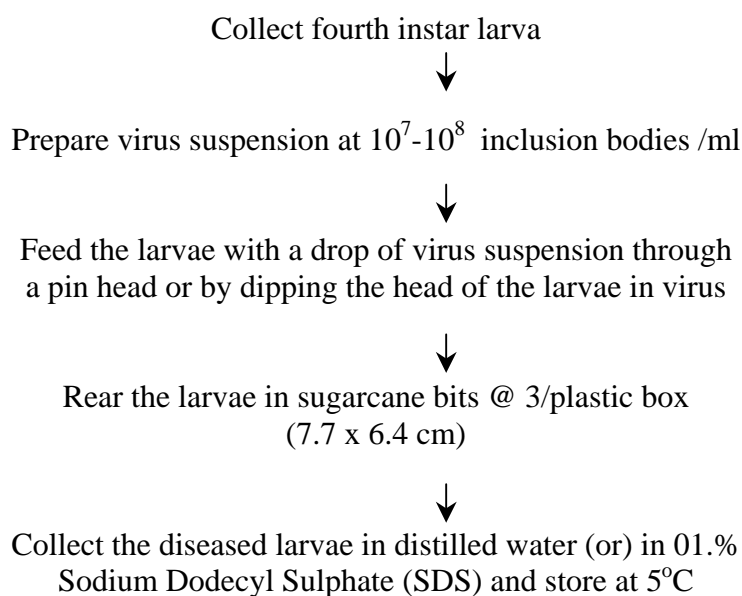
ii) **Mass production of *Helicoverpa armigera*** (Fig.64 & 65)



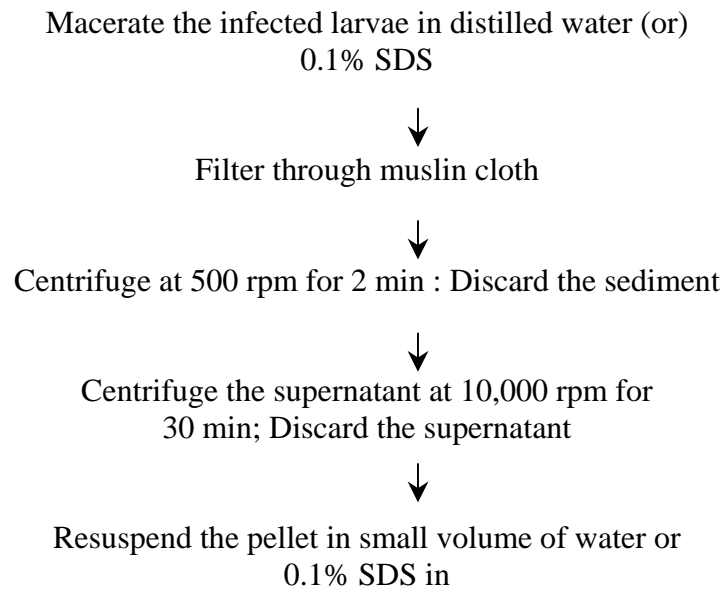
b) **Granulosis virus (GV) of Sugarcane shoot borer**

The GV of early shoot borer of sugarcane is virulent and pathogenic to all larval stages of the host insect. The virus is also transmitted to offsprings through diseased adults. The capsules are found as inclusion bodies in granulosis virus.

Symptoms : Loss of appetite, sluggishness and appearance of milky white colour especially on the ventral surface.

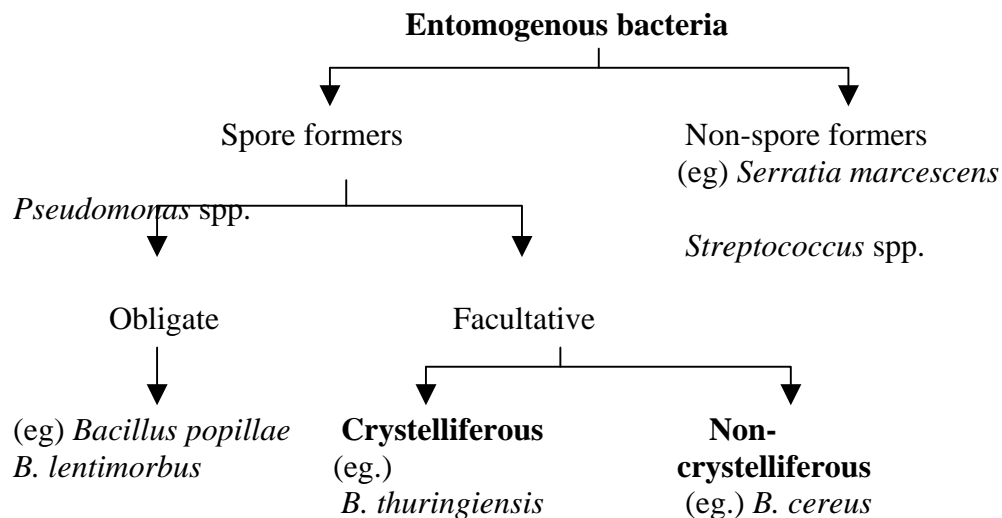


Purification



The virus can be stored by suspending in distilled water in amber coloured bottle in a cool dark place.

II. Bacteria



Symptoms : The infected larvae cease to feed, become sluggish in movement, may exhibit diarrhoea or vomiting or both, gradually become flaccid and die usually within 24-72 hours. The cadavers turn dark brown to black in colour and filled with the causative bacterium and eventually dry down to a hard black scale.

Commerical formulation of *B. thuringiensis* : Dipel, Thuricide, Bactospein, Delfin, Spicturin, Biobit, Bilep. These are used to control diamondback moth, rice leaf folder, *Spodoptera*.

Mass production : Through culture medium and fermentation technique

C. Fungi :

Disease cuased by fingi is known as 'Mycosis'.

- i) **White halo fungus**, *Cephalosporium lecanii* infecting coffee green scale, *Coccus viridis*.

Symptoms : Body of scale insect is mummified and becomes hard. Body covered with filamentous white hyphae. Infected scale is found struck ot leaf veins with spores on the surface.

Mass production

Take 65 g of sorghum grain in 250 ml conical flask
with 25-30 ml of distilled water



Autoclave at 20 Psi for 30 min



Cool and inoculate with fungus



Fungal culture can be used after 3 weeks of growth

- ii) **Green muscardine fungus** *Metarhizium anisopliae* infecting coconut rhinoceros beetle / grub.

Symptom : Body is mummified and shrunk from original 'C' shape and becomes dried to hard structure. Body is covered with dark olive green powdery mass viz., spores.

Mass production : By Carrot broth method

Take 40 g of carrot bits in 250 ml conical flask with
65 ml of water



Autoclave at 20 Psi for 30 min



Cool and inoculate with the fungus



Fungus can be applied to manure pit after a fortnight

iii) **White muscardine fungus**, *Beauveria bassiana* attacks, silkworm, castor semilooper.

D. Protozoa : *Farinocystis tribolii* infecting red flour beetle, *Tribolium castaneum*.

Symptoms : Body becomes soft and breakable. Body gets dried giving a milky liquid in water, Malformed pupae and adults can be seen.

E. Rickettsiae

Rickettsiae are micro organisms intermediate between viruses and bacteria. These are obligatory pathogen attacking cytoplasm of midgut epithelium and cause rickettsiosis.

Eg. *Rickettsiella melolanthae* attacking Lamellicorn beetle.

8. BIOLOGICAL CONTROL - BY USING PARASITOIDS AND PREDATORS

A parasitoid is an insect parasite of an arthropod which is parasitic on immature stages and adults are free living. In the process of development it may slowly weaken and kill the host insect. Most of the parasitoids belong to the order Hymenoptera (90%) and Diptera (10%).

A. Parasitoids of agricultural importance : order : Hymenoptera

I. Egg parasitoid

1. *Trichogramma chilonis* (Fig.15) : Trichogrammatidae - Eggs of sugarcane internode borer, cotton bollworm, rice leaf folder etc.
2. *T. japonicum* (Fig.16) : Trichogrammatidae - Eggs of rice stem borer
3. *Tenonomus rowani* : Scelionidae - Eggs of rice stem borer
4. *T. remus* : Scelionidae - Eggs of tobacco caterpillar

II. Egg - larval parasitoid

1. *Chelonus blackburni* : Braconidae - Eggs of cotton spotted bollworm.

III. Larval parasitoid

1. *Bracon hebetor* (Fig.17) : Braconidae - Larvae of coconut black headed caterpillar
2. *B. brevicornis* : Braconidae - Larvae of coconut black headed caterpillar
3. *Campoletis chloridae* : Ichneumonidae - Larvae of *H. armigera*
4. *Cotesia plutella* : Braconidae - Larvae of diamondback moth
5. *Eriborus trochanteratus* : Ichneumonidae - Larvae of coconut black headed caterpillar
6. *Goniozus nephantidis* : Bethyidae - Larvae of coconut black headed caterpillar
7. *Platygaster oryzae* (Fig.18) : Platygasteridae - Larvae of rice gall midge

IV. Larval - Pupal parasitoid

1. *Isotima javensis* : Ichneumonidae - Pre pupal parasite of top shoot borer of sugarcane

V. Pupal parasitoid

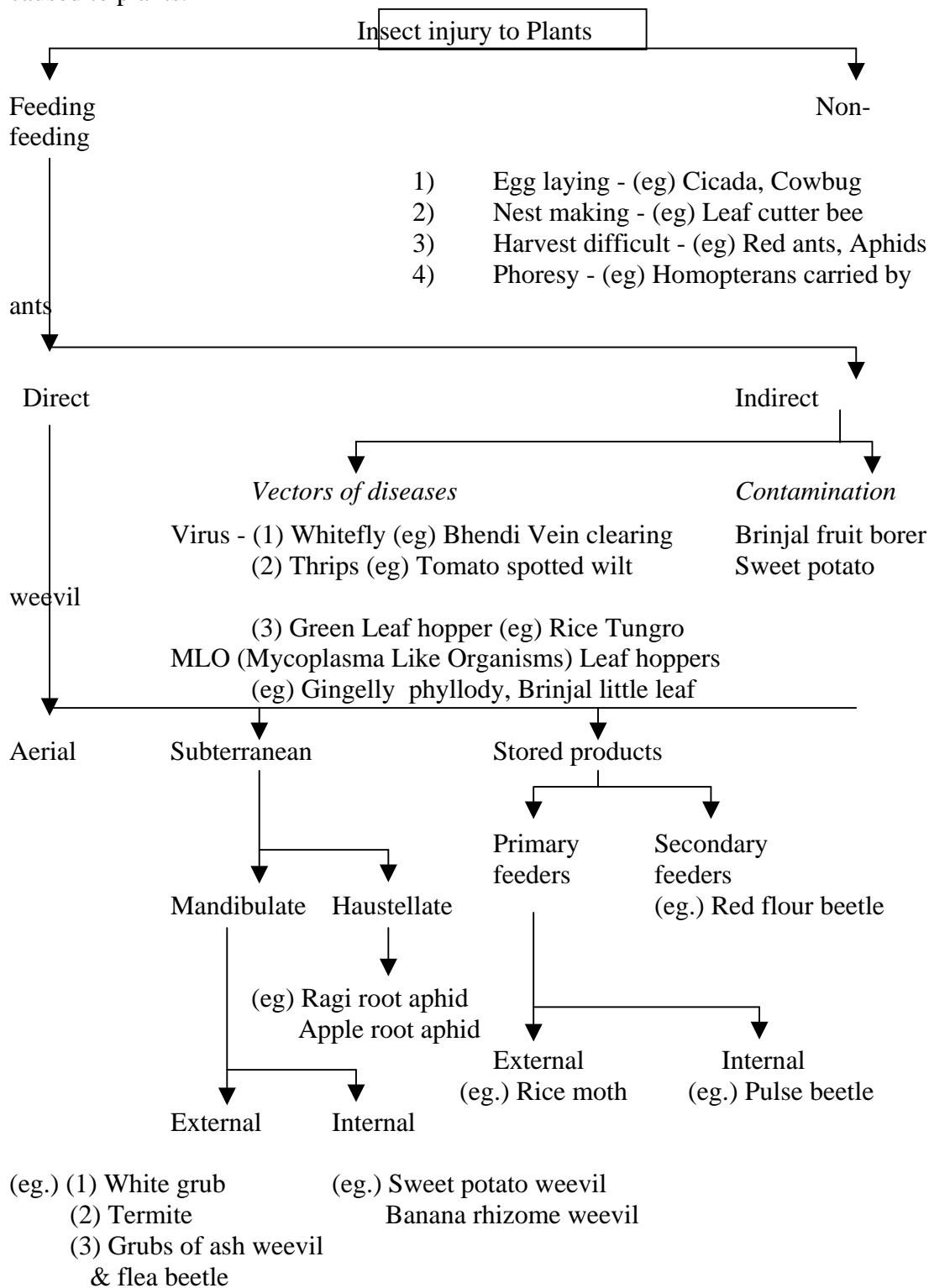
1. *Brachymeria nephantidis* (Fig.19): Chalcidae - Pupae of coconut black headed caterpillar
2. *Tetrastichus israeli* (Fig.20) : Eulophidae - Pupae of coconut black headed caterpillar
3. *Trichospilus pupivora* : Eulophidae - Pupae of coconut black headed caterpillar
4. *Xanthopimpla punctata* (Fig.21) : Ichneumonidae

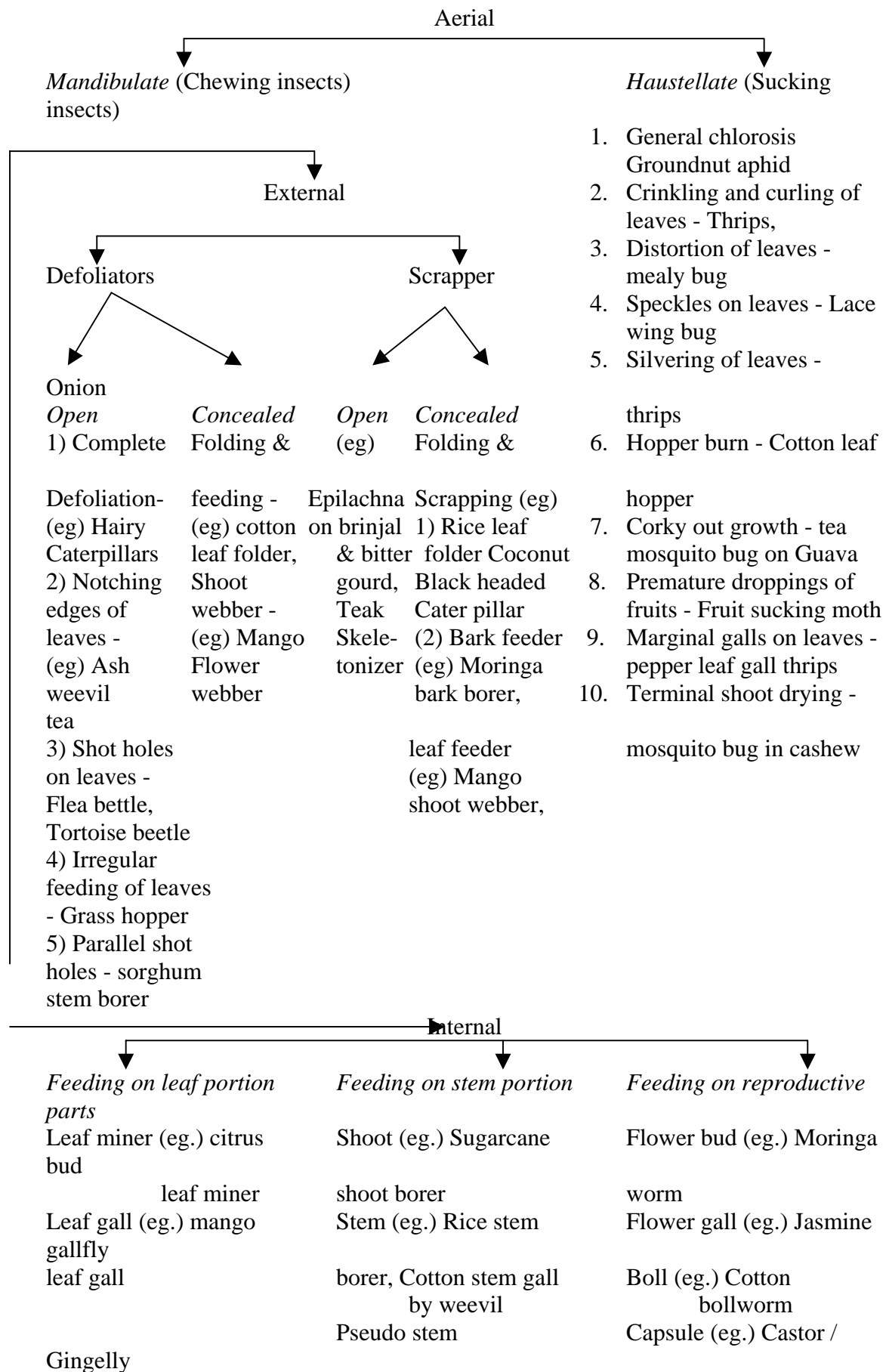
VI. Nymphal and adult parasitoid

- a. *Aphelinus mali* : Aphelinidae - Aphids
- b. *Encarsia formosa* : Aphelinidae - Cotton whitefly

9. TYPES OF INJURY BY INSECTS TO PLANTS

Any insect that feeds on any part of a plant is potentially a pest. The feeding habits and mouth parts of insects are related to the type and symptoms of damage caused to plants.





	(eg.) Banana pseudo stem	Capsule borer, Fruitfly
weevil	by weevil	Nut (eg.) Mango nut

10. ASSESSMENT OF INSECT POPULATION AND DAMAGE

Need

- a. To know the extent of pest load and their damage
- b. To workout economic injury level (EIL) and economic threshold level (ETL)
- c. To estimate yield loss
- d. To decide the timing of control measures in order to avoid indiscriminate use of insecticide.

EIL: Cost of control measures = Loss by insect

ETL: Level at which, control measures to be taken to avoid the insect population / damage reaching EIL.

A. RICE SUCKING INSECTS

1. Thrips : Feeding results in longitudinal curling and yellowing with pointed leaf tips mostly in the nursery. Leaves may dry in due course. Pass wet palm or table tennis bat over the seedling in 5 places and count the number (ETL : 25/5 passes or 10% of affected seedlings).
2. Green leafhopper (GLH) : Feeding on leaves results in yellowing. Vector for rice tungro virus disease (RTV). Count the number of insects per seedling in the nursery (ETL: 50/100 seedling) (or) number per hill in the field (ETL : 5/hill at vegetative stage, 10/hill at reproductive stage (or) 2/hill in RTV endemic area). Sweep net can also be used for sampling.(ETL : 60/25 sweeping).
3. Brown planthopper (BPH) : Feeding on stem just above water level results in hopper burn. Count the total number of insects in 10 hills selected at random in one square metre area (ETL : 1/tiller (or) 2/tiller if predatory spider is present).
4. Earhead bug : Black spot at feeding point on the grain and individual chaffy grains. Insects emit stinky odour. Count the number of bugs in 100 earheads selected at random (ETL : 5 (flowering stage) or 16 bugs (milky stage) / 100 panicles).

CHEWING INSECTS

1. Rice stem borer : Based on eggs and larval damage: Presence of yellowish brown egg mass near the leaf tip/presence of dead heart (vegetative stage) or white ear (reproductive stage).
 - a. Eggs in the nursery : Number of egg masses/m² (ETL : 2)
 - b. Larval damage : Count the total tillers and affected tillers in a unit area and arrive at a percentage

$$\% \text{ dead heart} = \frac{\text{Number of dead hearts}}{\text{Total number of tillers}} \times 100 \text{ (ETL : 10\%)}$$

$$\% \text{ white ears} = \frac{\text{Number of white ears}}{\text{Total productive tillers}} \times 100 \text{ (ETL : 2\%)}$$

2. Gall midge : Based on damage - Silver /onion shoot

$$\% \text{ Silver shoot} = \frac{\text{Number of silver shoot}}{\text{Total number of tillers}} \times 100 \text{ (ETL 10\%)}$$

3. Leaf folders : Based on damage - folded and scrapped leaves

$$\% \text{ leaf damage} = \frac{\text{Number of damaged leaves}}{\text{Total number of leaves (in 10 randomly selected)}} \times 100$$

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

4. Whorl maggot : Based on damage - marginal blotching and yellow patches on the leaves

$$\% \text{ leaf damage} = \frac{\text{Number of damaged leaves}}{\text{Total number of leaves (in 10 randomly selected plants)}} \times 100$$

B. COTTON

SUCKING INSECTS

1. Leafhopper : Leaf hopper causes marginal yellowing, downward cupping of leaves and hopper burn. Count number of hoppers in first two terminal leaves on 25 plants in the early stage and expressing as number per leaf (ETL 1/leaf).
2. Aphid : Desapping by aphid colonies results in curling and crinkling of leaves. Honey dew secreted by aphids attracts ants and invites sooty mould. Count the number of infested plants in 100 randomly selected plants and arrive at a percentage (ETL - 20%).

3. Thrips : Thrips causes leaf crinkling, ragged margin and silvery white spots on the under surface. Count the number of insects in the top unopened leaves on 25 plants and express as number per leaf (ETL : 1/leaf).
4. Whitefly : Sedentary oval shaped nymphs and pupae and small white moth like adult insect desap the leaves resulting in yellowing, honey dew secretion and sooty mould infection. Count the number of nymphs and pupae on three leaves one at bottom, one at middle and at the top during vegetative and maturity phase (ETL : 10/m²).

CHEWING INSECTS

1. Stem weevil : Based on damage : gall on the collar region of stem.

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

2. Bollworms :

- a) Spotted bollworm : Symptoms are wilting of shoots, presence of bore hole at base of the boll plugged with excreta.
- b) American bollworm : Bollworm infestation in the square results in flaring and shedding. Circular clear bore hole in the developing boll.
- c) Pink bollworm : Rosetted flower, no holes at the entry point (boll tip) bore hole disappears as the boll matures, bore hole in locule, discoloured lint and empty seeds.

Assessment is based on shoot damage in pre-square stage, flared square at squaring stage and boll damage at boll stage. Count the number of squares, flowers, bolls and number damaged squares, flowers and bolls including shedding due to bollworms (ETL - 10%).

3. Tobacco cutworm : Based on number of egg masses in 100 m length row (walking crisscross at 20 m in 5 places) (ETL : 8/100 m row).

C. VEGETABLES

a) Brinjal

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

Fruit : Number basis : Count the infested as well as healthy fruits and arrive at a percentage. **Weight basis :** Weigh the damaged and healthy fruits and workout the percentage at harvest.

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

3. **Defoliators**

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

Method II : (a) Dividing each leaf into 4 squaters, (b) Counting affected squaters and (c) Working out the damage

$$\% \text{ damage} = \frac{\text{Number of damaged quarters}}{\text{Number of leaves} \times 4} \times 100$$

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

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

4. **Mite :** Count the number of mites in two leaves at two places in each leaf using 1 cm² window card and express as number/cm².
5. **Epilachna beetle :** Based on the number of grubs and adults in affected leaves, expressing them as number per leaf. Based on leaf damage, work out per cent infested leaves in the sampled plants.

b) **Bhendi**

1. **Fruit borer :** Count the total number and number of fruits damaged in a plot and arrive at a percentage.
2. **Leafhopper :**
 - a) Based on number of insects in three fully opened leaves, express as number/leaf.
 - b) Grading the damage visually by observing the leaves in sample plants.

Grade I : Free from hopper burn

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

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

Grade IV : Extreme crinkling and curling hopper burn, leaf shedding and stunted growth.

11. TRADITIONAL METHODS OF PEST CONTROL

CULTURAL CONTROL

Definition : Manipulation of cultural practices to the disadvantage of pests.

I. Farm level practices

S.No.	Cropping Techniques	Pest Checked
1.	Ploughing	Red hairy caterpillar
2.	Puddling	Rice mealy bug
3.	Trimmming and plastering	Rice grass hopper
4.	Pest free seed material	Potato tuber moth
5.	High seed rate	Sorghum shootfly
6.	Rogue space planting	Rice brown palthopper
7.	Plant density	Rice brown plathopper
8.	Earthing up	Sugarcane whitefly
9.	Detrashing	Sugarcane whitefly
10.	Destruction of weed hosts	Citrus fruit sucking moth
11.	Destruction of alternate host	Cotton whitefly
12.	Flooding	Rice armyworm
13.	Trash mulching	Sugarcane early shoot borer
14.	Pruning / topping	Rice stem borer
15.	Intercropping	Sorghum stem borer
16.	Trap cropping	Diamond back moth
17.	Water management	Brown palthopper
18.	Judicious application of fertilisers	Rice leaf folder
19.	Timely harvesting	Sweet potato weevil

II. Community level practices

1. Synchronised sowing : Dilution of pest infestation (eg) Rice, Cotton
2. Crop rotation : Breaks insect life cycle
3. Crop sanitation
 - a) Destruction of insect infested parts (eg.) Mealy bug in brinjal
 - b) Removal of fallen plant parts (eg.) Cotton squares
 - c) Crop residue destruction (eg.) Cotton stem weevil

Advantages

1. No extra skill
2. No costly inputs

Disadvantages

1. No complete control
2. Prophylactic nature

- | | | | |
|----|-----------------------|----|------------------------|
| 3. | No special equipments | 3. | Timing decides success |
| 4. | Minimal cost | | |
| 5. | Good component in IPM | | |
| 6. | Ecologically sound | | |

PHYSICAL CONTROL

Modification of physical factors in the environment to minimise (or) prevent pest problems. Use of physical forces like temperature, moisture, etc. in managing the insect pests.

A. Manipulation of temperature

1. Sun drying the seeds to kill the eggs of stored product pests.
2. Hot water treatment (50 - 55°C for 15 min) against rice white tip nematode.
3. Flame throwers against locusts.
4. Burning torch against hairy caterpillars.
5. Cold storage of fruits and vegetables to kill fruitflies (1 - 2°C for 12 - 20 days).

B. Manipulation of moisture

1. Alternate drying and wetting rice fields against BPH.
2. Drying seeds (below 10% moisture level) affects insect development.
3. Flooding the field for the control of cutworms.

C. Manipulation of light

1. Treating the grains for storage using IR light to kill all stages of insects (eg.) Infra-red seed treatment unit (Fig.1).
2. Providing light in storage godowns as the lighting reduces the fertility of Indian meal moth, *Plodia*.
3. Light trapping.

D. Manipulation of air

1. Increasing the CO₂ concentration in controlled atmosphere of stored grains to cause asphyxiation in stored product pests.

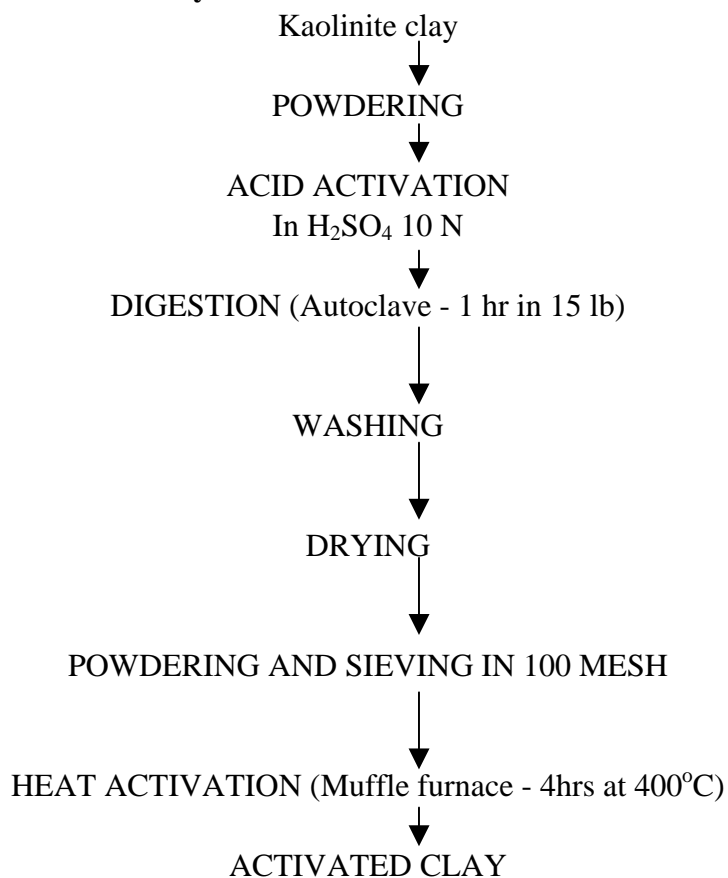
E. Use of irradiation

Gamma irradiation from Co⁶⁰ is used to sterilise the insects in laboratory which compete with the fertile males for mating when released in natural condition. (eg.) cattle screw worm fly, *Cochliomyia hominivorax* control in Curacao Island by E.F.Knipling.

F. Use of Abrasive dusts

1. Red earth treatment to redgram : Injury to the insect wax layer.
2. Activated clay : Injury to the wax layer resulting in loss of moisture leading to death. It is used against stored product pests.
3. Drie-Die : This is a porous finely divided silicagel used against storage insects.

Preparation of activated clay :



G. Use of greasing material

Treating the stored grains particularly pulses with vegetable oils to prevent the oviposition and the egg hatching. eg., bruchid adults.

H. Use of visible radiation : Yellow colour preferred by aphids, cotton whitefly : yellow sticky traps.

MECHANICAL CONTROL

Use of mechanical devices or manual forces for destruction or exclusion of pests.

A. Mechanical destruction : Life stages are killed by manual (or) mechanical force.

Manual Force

1. Hand picking the caterpillars
2. Beating : Swatting housefly and mosquito
3. Sieving and winnowing : Red flour beetle (sieving) rice weevil (winnowing)
4. Shaking the plants : Passing rope across rice field to dislodge caseworm and shaking neem tree to dislodge June beetles
5. Hooking : Iron hook is used against adult rhinoceros beetle
6. Crushing : Bed bugs and lice
7. Combing : Delousing method for Head louse
8. Brushing : Woolen fabrics for clothes moth, carper beetle.

Mechanical force

1. **Entoletter** : Centrifugal force - breaks infested kernels - kill insect stages - whole grains unaffected - storage pests.
2. Hopper dozer : Kill nymphs of locusts by hording into trenches and filled with soil.
3. Tillage implements : Soil borne insects, red hairy caterpillar.
4. Mechanical traps : Rat traps of various shapes like box trap, back break trap, wonder trap, Tanjore bow trap.

B. Mechanical exclusion

Mechanical barriers prevent access of pests to hosts.

1. Wrapping the fruits : Covering with polythene bag against pomegrante fruit borer.
2. Banding : Banding with grease or polythene sheets - Mango mealybug.
3. Netting : Mosquitoes, vector control in green house.
4. Trenching : Trapping marching larvae of red hairy catepillar.
5. Sand barrier : Protecting stored grains with a layer of sand on the top.
6. Water barrier : Ant pans for ant control.
7. Tin barrier : Coconut trees protected with tin band to prevent rat damage.
8. Electric fencing : Low voltage electric fences against rats.

Advantage of mechancial control

1. Home labour utilization
2. Low equipment cost
3. Ecologically safe
4. High technical skill not required in adopting.

Disadvantages

1. Limited application
2. Rarely highly effective
3. Labour intensive

Appliances in controlling the pests

1. Light traps : Most adult insects are attracted towards light in night. This principle is used to attract the insect and trapped in a mechanical device.
 - a) Incandescent light trap : They produce radiation by heating a tungsten filament. The spectrum of lamp include a small amount of ultraviolet, considerable visible especially rich in yellow and red. (eg.) Simple

incandescent light trap (Fig. 2), portable incandescent electric (Fig.3). Place a pan of kerosenated water below the light source.

- b) Mercury vapour lamp light trap : They produce primarily ultraviolet, blue and green radiation with little red. (eg.) Robinson trap (Fig.4). This trap is the basic model designed by Robnson in 1952. This is currently used towards a wide range of Noctuids and other nocturnal flying insects. A mercury lamp (125 W) is fixed at the top of a funnel shaped (or) trapezoid galvanized iron cone terminating in a collection jar containing dichlorvos soaked in cotton as insecticide to kill the insect.
 - c) Black light trap : Black light (Fig.5) is popular name for ultraviolet radiant energy with the range of wavelengths from 320-380 nm. Some commercial type like Pest-O-Flash, Keet-O-Flash are available in market. Flying insects are usually attracted and when they come in contact with electric grids, they become elctrocuted and killed.
2. Pheromone trap : Synthetic sex pheromones are placed in traps to attract males. The rubberised septa, containing the pheromone lure are kept in traps designed specially for this purpose and used in insect monitoring / mass trapping programmes. Sticky trap (Fig.6), waterpan trap (Fig.7) and funnel type (Fig.8) models are available for use in pheromone based insect control programmes.
 3. Yellow sticky trap : Cotton whitefly, aphids, thrips prefer yellow colour. Yellow colour is painted on tin boxes and sticky material like castor oil / vaseline is smeared on the surface (Fig.9). These insects are attracted to yellow colour and trapped on the sticky material.
 4. Bait trap : Attractants placed in traps are used to attract the insect and kill them. (eg.) Fishmeal trap: This trap is used against sorghum shootfly. Moistened fish meal is kept in polythene bag or plastic container inside the tin along with cotton soaked with insecticide (DDVP) to kill the attracted flies (Fig.10&11).
 5. Pitfall trap helps to trap insects moving about on the soil surface, such as ground beetles, collembola, spiders. These can be made by sinking glass jars (or) metal cans into the soil. It consists of a plastic funnel, opening into a plastic beaker containing kerosene suppoed inside a plastic jar (Fig. 12).
 6. Probe trap : Probe trap is used by keeping them under grain surface to trap stored product insect (Fig.13).
 7. Emergence trap : The adults of many insects which pupate in the soil can be trapped by using suitable covers over the ground. A wooden frame covered with wire mesh covering and shaped like a house roof is placed on soil

surface. Emerging insects are collected in a plastic beaker fixed at the top of the frame (Fig.14).

8. Indicator device for pulse beetle detection : A new cup shaped indicator device has been recently designed to predict timely occurrence of pulse beetle *Callosodorus* spp. This will help the farmers to know the correct time of emergence of pulse beetle. This will help them in timely sundrying which can kill all the eggs.

B. HOST PLANT RESISTANCE

Plant resistance to insects is a quality that enables a plant to avoid, tolerate or recover from the effects of oviposition or feeding that would cause greater damage to other genotypes of the same species under similar environmental conditions.

I. Types of resistance

1. Ecological resistance (or) Pseudo resistance

- i) Host evasion (Phenological asynchrony)
- ii) Escape
- iii) Induced resistance

2. Genetic resistance (or) True resistance

- * Monogenic : Controlled by a single gene. Easily incorporated into breeding programme and easily broken.
- * Oligogenic : A group of genes control resistance
- * Polygenic : Many genes control resistance
- * Vertical resistance : Specific to given biotypes (less stable)
- * Horizontal resistance : Expressed equally to all biotypes of a pest
- * Multiple resistance : Ability of a variety to resist more than one insect species.

II. Mechanism of resistance

1. **Non-preference (Antixenosis)** : Plant character(s) (morphological) that keep away an insect species from oviposition or feeding on a variety.
2. **Tolerance** : Ability to grow and yield economically despite pest attack.
3. **Antibiosis** : Adverse effect of host plant on the biology of the insect, death, reduced development and reproduction influenced by biochemical factors. (Biochemicals : Toxic, distasteful chemicals, absence of stimulant).

III. Advantages : Selective, cumulative, persistence, easy to adopt by farmers, can be compatible with other methods of pest management, no danger to environment, useful for low value crop.

IV. Disadvantages : Time consuming (5 to 10 years is required to develop a variety), high initial cost, biotype selection and conflicting resistance factors.

V. Methods of developing resistant variety

1. Screening of available germplasm

Available germplasm collections are sown in a single row in a location at a time and evaluated where there is a moderate to heavy incidence and the incidence may be compared by growing a susceptible variety.

2. **Selective screening under natural infestation**

Select promising lines from general screening and screen under natural condition in a single row or 2-3 rows in replicated trials.

3. **Selective screening under artificial condition**

To test true resistance, the selected varieties are screened under artificial condition in which insects are bombarded over the plant. Results are compared with a resistant and susceptible check.

Breeders start screening it from F₂ - F₆ stages for yield and resistance. If found suitable they will be forwarded to multilocation trial (MLT) and for Adaptive Research Trials (ART). If a line/cultivar succeeds in all stages, it will be released as a variety.

Examples of resistant variety

Rice

Yellow stem borer	:	TKM6, Paiyur-1, Vikas, Ratna, Sasyasree
Brown plathopper	:	Co 42, PY 3 Ptb 33, IR 64, IR 36
Green leafhopper	:	IR 50, Ptb 2, 18, Co 46, CR 1009
Gall midge	:	MDU 3, Udaya, Shakti, Vikram

Sugarcane

Early stem borer	:	Co 312, Co 421, Co 661, Co 917, Co 853
Internode borer	:	Co 975, Co 7304, CoJ 46
Top shoot borer	:	Co 745, Co 6515
Mealy bug	:	Co 439, Co 443, Co 720, Co 730
Scale	:	Co 439, Co 443, Co 671, Co 691, Co 692

Cotton

Bollworm	:	Abhadita
Spotted bollworm	:	Hopi, Detapine
Stem weevil	:	MCU 3, Supriya
Leaf hopper	:	Pk 719, Pk 688, Pk 1717, MCU 5, SRT 1, K 7, K 8
Whitefly	:	Kanchana

Sorghum

Shootfly	:	Co
Ear head bug	:	K tall

Jasmine

Eriphyid mite	:	Pari Mullai
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Brinjal

Aphids	:	Annamalai
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13. PESTICIDES: GROUPS, FORMULATION AND LABEL INFORMATION

Pesticides: Chemicals used to kill or control pests.

I. Groups of pesticides : The pesticides are generally classified into various groups based on pest organism against which the compounds are used, their chemical nature, mode of entry and mode of action.

1. Based on organisms

- a) Insecticides : Chemicals used to kill or control insects (eg.) endosulfan, malathion
- b) Rodenticides : Chemicals exclusively used to control rats (eg.) Zinc phosphide
- c) Acaricides : Chemicals used to control mites on crops / animals (eg.) Dicofol
- d) Avicides : Chemicals used to repel the birds (eg.) Anthraquinone
- e) Molluscicides : Chemicals used to kill the snails and slugs (eg.) Metaldehyde
- f) Nematicides : Chemicals used to control nematodes (eg.) Ethylene dibromide
- g) Fungicides : Chemicals used to control plant diseases caused by fungi (eg.) Copper oxychloride
- h) Bactericide : Chemicals used to control the plant diseases caused by bacteria (eg.) Streptomycin sulphate
- i) Herbicide : Chemicals used to control weeds (eg.) 2,4, - D

2. Based on mode of entry

- a) Stomach poison : The insecticide applied in the leaves and other parts of the plant when ingested, act in the digestive system of the insect and bring about kill (eg.) Malathion.
- b) Contact Poison : The toxicant which brings about death of the pest species by means of contact (eg.) Fenvalerate.
- c) Fumigant : Toxicant enter in vapour form into the tracheal system (respiratory poison) through spiracles (eg.) Aluminium phosphide
- d) Systemic poison : Chemicals when applied to plant or soil are absorbed by foliage (or) roots and translocated through vascular system and cause death of insect feeding on plant. (eg.) Dimethoate.

3. Based on mode of action

- a) Physical poison : Toxicant which brings about kill of one insect by exerting a physical effect (eg.) Activated clay.

- b) Protoplasmic poison : Toxicant responsible for precipitation of protein (eg.) Arsenicals.
- c) Respiratory poison : Chemicals which inactivate respiratory enzymes (eg.) hydrogen cyanide.
- d) Nerve poison : Chemicals inhibit impulse conduction (eg.) Malathion.
- e) Chitin inhibition : Chemicals inhibit chitin synthesis (eg.) Diflubenzuron.

4. Based on chemical nature

A. Inorganic compounds

Compounds of mineral origin (eg.) Sulphur, Zinc phosphide, Arsenic compounds, Fluorine compounds

- a) Chlorinated hydrocarbon : Compounds containing chlorine bonded to carbon atoms (eg.) DDT, HCH, aldrin, endosulfan
- b) Organophosphorus (OP) compounds : Esters of phosphonic, phosphoric, thiophosphoric (or) dithiophosphoric acid. (eg.) Malthion, fenthion, quinolphos.
- c) Carbamates : They are esters of carbamic acid. (eg.) aCarbaryl, carbofuran, aldicarb.
- d) Synthetic pyrethroids : Synthetic compounds showing structural resemblance to natural pyrethrins synthesised from petroleum based chemicals (eg.) Fenvalerate, cypermethrin, permethrin.

Pesticide formulations

Pesticides are not usually applied in pure form (active ingredient) since they are highly toxic and quantity available for application is low and hence they are diluted with inert materials like talc (or) with water combining with other materials such as solvents, wetting agents, stickers etc. The final product is the formulated pesticide and it is ready for use.

According to the mode of application, the types of formulation are as follows:

For dry application directly from container

1. **Dusts (D)** : The technical material (active ingredient) is mixed with a carrier such as clay (attapulgate, Kaolin, ash), organic flour (wood bark), pulverised minerals (sulphur, talc, lime, gypsum). Particle size will be less than 100 and it should pass through 200 mesh sieve. Dusts are cheaper and easy to use. However, they are least effective and cause wind drift leading to poor deposit on surface; they are highly toxic to beneficial insects.
2. **Granules (G)** : Granules are prepared by applying liquid insecticides to coarse particle of porous material like clay, corn cobs (or) walnut shells. The amount of active ingredient ranges from 2-10 per cent. They are much safer to apply than dusts.

For spraying after mixing with water

1. **Wettable powders (WP)** : It consists of active ingredient mixed with inert dust and a surfactant that mixes readily with water and forms a short - term suspension. WOs are much more concentrated than dusts, containing 15 to 95 per cent active ingredient. Frequent agitation is required to keep the insecticides in suspension. WPs usually cause less phytotoxicity than ECs. WPs should never be used without dilution.
2. **Emulsifiable concentrates (EC)** : It consists of a toxicant, a solvent and an emulsifier with a stabilizing agent. When EC is mixed in water gives emulsion - droplets of oil containing the insecticide dispersed in water. Emulsifier makes the water insoluble toxicant to water soluble and it yields a stable milky solution when diluted with water. When applied, the solvent evaporates quickly leaving the toxicant from which water also evaporates.
3. **Soluble powders (SP)** : Soluble powder consists of finely ground solid material which dissolves in water or some other liquid forming true solution.
4. **Flowable (F)** : Flowable is a pesticide formulation in which the active ingredient is wet milled with a clay diluent and water. Flowables must be constantly agitated to prevent the insecticide from coming out of suspension and settling.
5. **Ultra low volume concentrates (ULV)** : They are a special kind of high concentrate solutions and are applied without dilution with special aerial or ground equipment to produce extremely fine spray.

For application as gas or vapour

1. **Fumigants** : Fumigants are pesticides in the form of poisonous gases that kill when absorbed or inhaled. Most of the fumigants are liquid and are mixtures of two or more gases.
2. **Smoke generators** : They are used in the form of coil like strips containing pyrethrum, oxidant and wood dust for the control of mosquitoes. When ignited, these coils release vapours.
3. **Aerosols** : Aerosol contains a small amount of pesticide that is driven through a fine opening by a chemically inactive gas under pressure when the nozzle is triggered (or) by burning toxicant or vapourizing it with that. The toxicant is suspended as minute particles (0.1 - 50 w/w) in air as a fog or mist. It consists of toxicant (2%), solvent (10%), knockdown agent (2%) and propellant (86%).

Other formulations

1. **Poison bait** : These mixtures of an insecticide with food attractive to the target pests.
2. **Seed dressers** : This consist of an active ingredient in carrier material with an adhesive for better coating of the chemical on the seeds.
3. **Tablets** : It consist toxicant, a carrier to prevent the flamability.
4. **Insecticide paints and polishes** : Toxicant is produced in the form of pant/polish and can be applied as such by using a brush.
5. **Encapsuled fumigants** : The fumigant is impregnated in some inert material and sealed in plastic containers. Cut open the plastic container before use.

III. Label information

Every pesticide container has a lable affixed on it with a leaflet. The label gives information of the pesticide in the container. The leaflet contains information on directions to use warmings, disposal and sotrage.

Both the lable and leaflet are statutorily required under the Insecticide Act, 1968. The following information must be furnished on the lable.

1. Name of the pesticide (Brand name, Trade name, Common name).
2. Name of the manufacturer and address
3. Registration number
4. Kind and name of active ingredient and their percentage
5. Types of formulation
6. Net content by weight
7. Batch number (assigned by manufacturer)
8. Date of manufacture
9. Expiry date
10. Antidote statement
11. Warming symbols and signal (warming symbol is of diamond shaped consisting of two triangles with a colour in the lower triangle and a signal in the upper triangle).

Category	Classification of the Insecticides	Symbol and Word to be Printed on the upper portion of triangle	Warning Statement to be printed out side the triangle	Colour of the Identification band on the lower portion of the triangle	Acute toxicity I.D mg/kg body weight	
					Oral route	Dermal route
I.	Extremely toxic	Skull and Cross bone 'POISON'	a) Keep out of the reach of children b) If swallowed or if symptoms of poisoning occur, call physician immediately	Bright red	1-50	1-200
II.	Highly toxic	Poison	Keep out of the reach of children	Bright yellow	51-500	201-2000
III.	Moderately toxic	Danger	Keep out of the reach of children	Bright blue	501-5000	2001-20,000
IV.	Sightly toxic	Cauton		Bright green	5000	20,000

The leaflet must furnish the following

1. Name of the pests, weeds and diseases against the chemical may be used
2. Direction for use.
3. Warning and cautioning statement, symptoms of poisoning, antidotes and first aid.
4. Direction for storage, careful handling and method of disposal.

14. PESTICIDE APPLICATION METHODS

The desired effect of a pesticide can be obtained only if it is applied by an appropriate method in appropriate time. The method of application depends on nature of pesticide, formulation, pests to be managed, site of application, availability of water etc.

1. **Dusting** : Dusting is carried out in the morning hours and during very light air stream. It can be done manually or by using dusters. Sometimes dust can be applied in soil for the control of soil insects. Dusting is cheaper and suited for dry land crop pest control.
2. **Spraying** : Spraying is normally carried out by mixing EC (or) WP formulations in water. There are three types of spraying.

	Spray fluid (litre per acre)	Droplet size	Area covered per day	Equipment used
a) High volume spraying	200-400	150	2.5 ac	Knapsack, Rocker sprayers
b) Low volume spraying	40-60	70-150	5.6 ac	Power sprayer, Mist blower
c) Ultra low volume spraying	2-4 lit.	20-70	20 ac	ULV sprayer, Electrodyne sprayer

3. **Granular application** : Highly toxic pesticides are handled safely in the form of granules. Granules can be applied directly on the soil or in the plant parts. The methods of application are
 - a) **Broadcasting** : Granules are mixed with equal quantity of sand and broadcasted directly on the soil or in thin film of standing water. (eg.) Carbofuran 3G applied @ 1.45 kg/8 cent rice nursery in a thin film of water and impound water for 3 days.
 - b) **Infurrow application** : Granules are applied at the time of sowing in furrows in beds and covered with soil before irrigation. (eg.) Carbofuran 3G applied @ 3 g per meter row for the control of sorghum shootfly.
 - c) **Side dressing** : After the establishment of the plants, the granules are applied a little away from the plant (10-15 cm) in a furrow.
 - d) **Spot application** : Granules are applied @ 5 cm away and 5 cm deep on the sides of plant. This reduces the quantity of insecticide required.

- e) **Ring application** : Granules are applied in a ring form around the trees.
 - f) **Root zone application** : Granules are encapsulated and placed in the root zone of the plant. (eg.) Carbofuran in rice.
 - g) **Leaf whorl application** : Granules are applied by mixing it with equal quantity of sand in the central whorl of crops like sorghum, maize, sugarcane to control internal borers.
 - h) **Pralinage** : The surface of banana sucker intended for planting is trimmed. The sucker is dipped in wet clay slurry and carbofuran 3G is sprinkled (20-40 g/sucker) to control burrowing nematode.
4. **Seed pelleting/seed dressing** : The insecticide mixed with seed before sowing (eg.) sorghum seeds are treated with chlorpyrifos 4 ml/kg in 20 ml of water and shade dried to control shootfly. The carbofuran 50 SP is directly used as dry seed dressing insecticide against sorghum shootfly.
 5. **Seedling root dip** : It is followed to control early stage pests (eg.) in rice to control sucking pests and stem borer in early transplanted crop, a shallow pit lined with polythene sheet is prepared in the field. To this 0.5 kg urea in 2.5 litre of water and 100 ml chlorpyrifos in 2.5 litre of water prepared separately are poured. The solution is made upto 50 ml with water and the roots of seedlings in bundles are dipped for 20 min before transplanting.
 6. **Sett treatment** : Treat the sugarcane setts in 0.05% malathion for 15 minutes to protect them from scales. Treat the sugarcane setts in 0.05% Imidacloprid 70 WS @ 175 g/ha or 7 g/l dipped for 16 minutes to protect them from termites.
 7. **Trunk/stem injection** : This method is used for the control of coconut pests like black headed caterpillar, mite etc. Drill a downward slanting hole of 1.25 cm diameter to a depth of 5 cm at a height of about 1.5 m above ground level and inject 5 ml of monocrotophos 36 WSc into the stem and plug the hole with cement (or) clay mixed with a fungicide. Pseudo stem injection of banana, an injecting gun or hypodermic syringe is used for the control of banana aphid, vector of bunchy top disease.
 8. **Padding** : Stem borers of mango, silk cotton and cashew can be controlled by this method. Bark of infested tree (5 x 5 cm) is removed on three sides leaving bottom as a flap. Small quantity of absorbant cotton is placed in the exposed area and 5-10 ml of Monocrotophos 36 WSP is added using an ink filler. Close the flap and cover with clay mixed with fungicide.
 9. **Swabbing** : Coffee white borer is controlled by swabbing the trunk and branches with HCH (BHC) 1 per cent suspension.

- 10. Root feeding :** Trunk injection in coconut results in wounding of trees and root feeding is an alternate and safe chemical method to control black headed caterpillar, eriophyid mite, red palm weevil. Monocrotophos 10 ml and equal quantity of water are taken in a polythene bag and cut the end (slant cut at 45°) of a growing root tip (dull white root) is placed inside the insecticide solution and the bag is tied with root. The insecticide absorbed by root, enter the plant system and control the insect.
- 11. Soil drenching :** Chemical is diluted with water and the solution is used to drench the soil to control certain subterranean pests. (eg.) BHC 50 WP is mixed with water @ 1 kg in 65 litres of water and drench the soil for the control of cotton/stem weevil and brinjal ash weevil grubs.
- 12. Capsul placement :** The systemic poison could be applied in capsules to get toxic effect for a long period. (eg.) In banana to control bunchy top vector (aphid) the insecticide is filled in gelatin capsules and placed in the crown region.
- 13. Baiting :** The toxicant is mixed with a bait material so as to attract the insects towards the toxicant.
- a) **Spodoptera :** A bait prepared with 0.5 kg molasses, 0.5 kg carbaryl 50 WP and 5 kg of rice bran with required water (3 litres) is made into small pellets and dropped in the field in the evening hours.
- b) **Rats :** Zinc phosphide is mixed at 1:49 ratio with food like popped rice or maize or chola or coconut pieces (or) warfarin can be mixed at 1:19 ratio with food. Ready to use cake formulation (Bromodiolone) is also available.
- c) **Coconut rhinoceros beetle :** Castor rotten cake 5 kg is mixed with insecticide.
- 14. Fumigation :** Fumigants are available in solid and liquid forms. They can be applied in the following way.
- a) **Soil :** To control the nematode in soil, the liquid fumigants are injected by using injecting gun.
- b) **Storage :** Liquid fumigants like Ethylene dibromide (EDB), Methyl bromide (MB), carbon tetrachloride etc. and solid fumigant like Aluminium phosphide are recommended in godowns to control stored product pest.
- c) **Trunk :** Aluminium phosphide ½ to 1 tablet is inserted into the affected portion of coconut tree and plugged with cement or mud for the control of red palm weevil.

15. PREPARATION OF SPRAY SOLUTION AND SAFE HANDLING OF PESTICIDES

I. Preparation of spray solution

1. Quantity of insecticide required

The requirement of quantity of commercial formulation of the insecticide can be calculated by the formula.

$$= \frac{\text{Volume of spray fluid} \times \text{Strength of the spray solution desired (\%)}}{\text{Strength of commercial formulation (\%)}}$$

2. Strength of the finished spray solution

To calculate the strength of a finished spray solution when a known quantity of chemical is added to known quantity of water, the following formulate may be adopted.

$$= \frac{\text{Quantity of the insecticide used} \times \text{Strength of the insecticide (\%)}}{\text{Quantity of finished spray solution required}}$$

3. In case of granules

$$\text{Quantity of chemical needed} = \frac{\text{Recommended dose a.i/ha} \times 100}{\text{Area} \times \% \text{ a.i. of insecticide}}$$

Points to be considered in spray fluid preparation / spraying

- i. Use good quality water to prepare spray fluid.
- ii. Prepare spray fluid in clean drum or plastic buckets .
- iii. For missing pesticide, use long handled stirr
- iv. Always prepare spray fluid just before use
- v. Spraying should be done under ideal weather conditions
- vi. The walking speed of the operator should be uniform to ensure even coverage of spray chemicals in the target area.

Botanicals

Among the plant derivatives, neem oil 0.5 to 3 per cent and neem seed kernel extract 5 per cent with teepol 0.05 per cent are quite effective against major pests of rice, pulses, sucking pests of cotton, vegetables etc.

Neem oil (NO) : To get a 3 per cent solution first mix 30 ml of neem oil with 5 ml of sticking agent teepol until white emulsion is formed. Then add one litre of water and mix thoroughly for use of spray fluid.

Neem seed kernel extract (NSKE)

Further preparation of 5 per cent NSKE, take 50 gm of powdered seed kernel and soak it in a small quantity of water, overnight. Filter through muslin cloth and make up the volume to one litre. Add one ml of teepol per litre before spraying with high volume sprayer.

II. Safe handling of pesticides

1. Storage of pesticides :

- a) Store house should be away from population areas, wells, domestic water storage, tanks.
- b) All pesticides should be stored in their original labelled containers in tightly sealed condition.
- c) Store away from the reach of children, away from flames and keep them under lock and key.

2. Personal protective equipment (Fig. 67)

- a) Protective clothing that covers arms, legs, nose and head to protect the skin.
- b) Gloves and boots to protect hands and feet.
- c) Helmets, goggles and facemask to protect hair, eyes and nose.
- d) Respirator to avoid breathing dusts, mists and vapour.

3. Safety in application of pesticides

Safe handling of pesticides (Fig.68) involves proper selection and careful handling during mixing and application.

- a) **Pesticide selection :** Selection of a pesticide depends on the type of pest, damage, losses caused, cost etc.
- b) **Safety before application :**
 - i. Read the label and leaflet carefully.
 - ii. Calculate the required quantity of pesticides.
 - iii. Wear protective clothing and equipment before handling.
 - iv. Avoid spillage and prepare spray fluid in well ventilated area.
 - v. Stand in the direction of the wind on back when mixing pesticides.
 - vi. Do not eat, drink or smoke during mixing.
 - vii. Dispose of the containers immediately after use.
- c) **Safety during application**
 - i. Wear protective clothing and equipment.
 - ii. Spray should be done in windward direction.
 - iii. Apply correct coverage.
 - iv. Do not blow, suck or apply mouth to any spray nozzle.
 - v. Check the spray equipment before use for any leakage.

d) Safety after application

- i. Empty the spray tank completely after spraying.
- ii. Avoid the draining the contaminated solution in ponds, well or on the grass where cattle graze.
- iii. Clean the spray equipment immediately after use.
- iv. Decontaminate protective clothing and foot wear.
- v. Wash the hands thoroughly with soap water, preferably have a bath.
- vi. Dispose off the containers by putting into a pit.
- vii. Sprayed field must be marked and unauthorized entry should be prevented.

First aid : In case of suspected poisoning; call on the physician immediately. Before calling on a doctor, first aid treatments can be done by any person.

Swallowed poison

- i. During vomiting, head should be faced downwards.
- ii. Stomach content should be removed within 4th of poisoning.
- iii. To give a soothing effect, give either egg mixed with water, gelatine, butter, cream, milk, smashed potato.
- iv. In case of nicotine poisoning, give coffee or strong tea.

Skin contamination

- i. Contaminated clothes should be removed.
- ii. Thoroughly wash with soap and water.

Inhaled poison

- i. Person should be moved to a ventilated place after loosening the tight clothes.
- ii. Avoid applying frequent pressure on the chest.

III. Antidotes and other medicine for treatment in pesticide poisoning

S.No.	Antidote / Medicine	Used in poisoning due to
1.	Common salt (Sodium chloride)	Stomach poison in general
2.	Activated charcoal (7g) in warm Magnesium oxide (3.5g) water Tannic acid (3.5g)	Stomach poison in general
3.	Gelatin (18 g in water) or Flour or milk power (or) Sodium thiosulphate	Stomach poison in general
4.	Calcium gluconate	Chlorinated insecticide, Carbon tetrachloride, ethylene dichloride, Mercurial compound
5.	Phenobarbital (or) Pentobarbital or axapam (5-10 mg) intravenous administration	Stomach poison of chlorinated hydrocarbon insecticides
6.	Sodium bicarbonate	Stomach poison of organophosphate compounds
7.	Atropine sulphate (2-4 mg intramuscular / intravenous administration) or PAM (Pyridine-Z aldoxime-N-methiodide)	Organophosphate Compounds
8.	Atropine sulphate (2-4 mg intramuscular / intravenous administration)	Carbamates
9.	Enobarbital, Diphenylhydantoin	Synthetic pyrethroid
10.	Potassium permanganate	Nicotine, Zinc phosphide
11.	Vitamin K1 and K2	Warfarin, Zinc phosphide
12.	Afferine sodium benzonate	Carbon disulphide, methyl bromide
13.	Ineprine	Methyl bromide
14.	Methyl nitrite ampule	Cyanides
15.	Etachlopramide (10 mg) intravenous	Cyclodiene compounds

16. PLANT PROTECTION APPLIANCES

A. Dusters

Appliances that are used for applying dry dust formulations of pesticides are called as dusters. They make use of an air stream to carry the chemicals in finely divided and dry form to the plants. The dusters consists essentially of a hopper which contains an agitator, an adjustable orifice or metering mechanism and delivery tube. A rotary fan or a belooow provide the conveying air. They may be operated either manually or by power.

1. **Rotary dusters :** They are also known as crank dusters and fan type dusters. They vary in design and may be soulder mounted, back mounted or belly mounted. a rotary duster consists of a blower with gear box and a hopper with a capacity to hold 4-5 kg dust. The duster is operated by rotating a crank and the motion is transmitted through the gear to the blower. Generally an agitator is connected to one of the gears. the air current produced by the blower draws the dust from the hopper and discharges out through a delivery tube which may have one or two nozzles (Fig.69). They are used for dusting field crops, vegetables and small trees and bushes in orchards. The efficiency is 1 to 1.5 per day.
2. **Knapsack dusters :** It consists of dust container of 2 to 5 kg of capacity through which air current is blown by menas of bellows which are worked by hand liner attached to one side of the container. The air blast takes the dust into delivery pipe and discharges out in an intermittent manner. They are used for low crops and for spot application.
3. **Power operated dusters :** This may be from Knapsack types with engine motive power to powerful row crop or trees dusters pulled by tractor. These dusterss are useful for covering larger area and tall trees.
4. **Plunger duster :** This is a simple pump to which a dust chamber is connected. The pump generates an air balst that is passed on to the dust chamber causing the dust to blow out through delivery tube (Fig.70). It is used kitchen garden.
5. **Bellow duster :** This type of duster works on compressing bellow to produce an air blast for ejecting the dust out in small clouds (Fig.71).

B. Sprayers

Principle : The function of a sprayer is to atomize the spray fluid into small droplets and eject it with some force.

The important parts are tank, pump, agitator, pressure gauge, valves, filters, pressure chamber, hose, spray lance, cut of device, boom and nozzle.

1. **Tank :** To hold the spray fluid during spraying, a sprayer should have a built in or separate container. In case of knapsack and power sprayers the capacity of the tank varies from 9 to 13 litres.
2. **Pump :** The pump is necessary for creating the energy required for atomization of spray fluid. It is most vital part of a sprayer. A sprayer may be equipped with one of the following types of pumps.
 - a) **Air pump : (Pneumatic) :** Mostly used in compression sprayers. In this the force created by pump acts, over the spray fluid and the pump does not act directly over the spray fluid.
 - b) **Positive displacement pumps (Plunger, rotary and centrifugal pump) :** This pump takes a definite volume of liquid inlet and transfer it without any escape to outlet.
3. **Agitator :** Most of the sprayers are provided with an agitator for dispersing the pesticide uniformly. It may be hydraulic or mechanical agitation.
4. **Pressure gauge :** It is connected to the pipe line near the nozzle usually.
5. **Valves :** They govern the direction of the flow of the spray fluid.
6. **Filter :** Usually this is provided between tank and the pump unit, pump and spray lance and within the lance. This is provided mainly to protect the pump from abrasion, to avoid interference with the function of valves and to prevent blocking of nozzles.
7. **Pressure chamber :** It is present in sprayers working with hydraulic pumps. It prevents fluctuation in the pressure and effects uniformly in spraying.
8. **Hose:** It is attached to the sprayer on one end and the spray lance on the other. Mainly plastic and nylon materials are used since they are cheap and light.
9. **Spray lance :** The nozzle of sprayer is usually attached to a brass rod of variable design. Known as the spray lance the length varies from 35 to 90 cm. It is usually detachable. In certain cases, it has a 120° bend to form a goose neck which is useful for spraying under surface of leaf (Fig.72).
10. **Cut-off valve :** It is used to shut off the liquid (fig.73). This may be operated by a knob or spring activated (trigger cut-off). Three types are used (a) Wheel cut-off valve with strainer. (b) Trigger cut-off valve with strainer. (c) Trigger cut off valve without strainer.
11. **Spray boom :** Spray bars carrying more than one nozzle is known as spray booms.
12. **Nozzle :** It breaks the liquid into droplets and spread them into spray droplets. It consists of (Fig.74).

- a) Body - piece of brass, one end has internal threads and if the threads are inside they will be called as female nozzles and it present outside as male nozzles. One the other end these threads are always on out side.
- b) Cap : It is a nut screwed on the body which holds the strainer, orifice plate, washer and swirl plate in position.
- c) Swirl plate : Nozzle has a specially drilled swirl plate to give a definite characteristic spray pattern.
- d) Washer (sealer) : They are of various thickness to allow variation in depth of the swirl chamber and it also prevents the leakage of spray fluid.
- e) Stainer : The nozzle is equipped with a strainer. Openings in the strainer are small to prevent the entry to bigger size particle.

Types of nozzles (Fig.75)

1. **Fan spray nozzles** : In this nozzle, the orifice plate has an oblong orifice. When the spray fluid is forced through this orifice, it produces a characterisitc fan type spray swath. Droplet size will be smaller in the centre of fan. Uniform pattern of spray is obtained when more than one nozzle is used. It is recommended for spraying flat surface such as soil.
2. **Cone spray nozzles** : These are commonly used. It may be either hollow or solid cone,
 - a) **Hollow cone** : There the liquid is forced through a slot in the swirl plate to impart a swirl to the spray fluid to produce a hollow cone shape. This is used for insecticide and fungicide spraying.
 - b) **Solid cone** : Here one more slot is present at the centre of swirl plate. This type is used for herbicide spraying.
 - c) **Adjustable nozzle** : Sprays in a cone pattern of various angles and also in a solid or borken form.
- 3) **Flood jet nozzle** : This type throw out the spray in the form of a jet of coarser droplet. Since the jet falls at right angle to the surface, drifting of the chemical is minimised. This is used for herbicide spray.

Types of sprayers : manually operated hydraulic sprayers

In this type, the hydraulic pump directly acts on the spray fluid and dischrgees it.

1. **Hand syringe** : It is single acting pump working on the principle of cycle pump. It consist of a culinder into which the spray fluid is drawn during the suction storke and delivered during the pressure stroke and discharge through nozzle (Fig.76). It is useful to operate only a small area.
2. **Hand sprayer** : It consists of a built in pump. The tank capacity is 0.5 to 1.0 litre. The delivery tube is directly attached to the piston which discharges the

spray fluid during the pressure stroke. It is also used for spraying small kitchen garden.

3. **Bucket pump sprayer :** It consists of a brass pump, a foot rest (stirrup), a hose, a lance and a nozzle. There is no built in tank and mostly buckets are used as containers for holding spray fluid at time of spraying. It consists of a double acting pump with 2 cylinders or a single pump with one cylinder. In the single acting pump the spray discharge is discontinuous since the fluid is ejected only during the downward compression stroke while in double pump discharge is continuous (Fig.77). This is suited for small scale spraying.
4. **Knapsack sprayer :** It is similar to bucket type and fits comfortably on the back of the operator. So it consists of a piston pump, a lever to operate, a built in the tank (10 to 14 litre capacity), hose, lance and a nozzle. The pressure is developed with help of level handle (Fig.78).
5. **Rocker sprayer :** It consists of pump assembly, platform, operating lever, pressure chamber, suction hose with strainer, delivery hose and an extension rod with spray nozzle. By rocking movement of the lever, pressure can be built in the tank (Fig.79). With the high pressure developed and also with long hose, this is used for spraying fruit trees and tall crops.
6. **Foot sprayer (pedal pump) :** It consists of a plunger assembly a stand a suction hose, a delivery hose, an extension rod with a spray nozzle (Fig.80). Principle is same as in case of rocker sprayer but it is operated by foot instead of hand.
7. **Manually operated compression sprayers :** These are also known as penmatic sprayers because air pressure is employed for forcing the liquid through the nozzle for atomization. The containers of these sprayers should not be filled completely with the spray fluid. a part of the container is kept empty so that adequate air pressure can be developed over the spray fluid in the tank.
 - a) **Pneumatic hand sprayer :** The container for the spray fluid also acts as pressure chamber. An air pump is attached to the chamber. The inner end of the discharge pipe runs down to the bottom of the container and its outlet ends in a nozzle. The tank is filled to $\frac{3}{4}$ capacity and the pump is worked to build sufficient pressure upon spray fluid. The spray is forced out of the nozzle through trigger cut off valve under the pressure of air above the spray fluid to emerge in form of a continuous spray (Fig.81). This is mostly used in glass houses and kitchen garden.
 - b) **Pneumatic knapsack sprayer :** These sprayers are similar to compression hand sprayers but are adapted for spraying large quantities of liquid (9-10 litres). It comprises of a tank for holding the spray fluid with compressed air, a vertical air pump with a handle, a filler hole, a spray lance with a nozzle and cut off device. Before

starting the sprayer, air is compressed into the empty space in the tank. As the spray continues the pressure drops continuously.

8. Power sprayer (Mist blower cum duster) (motorised knapsack sprayer) :

Here the spray fluid is blown out by an air current produced in the machine (Fig.82). It consists of the following parts :

- | | |
|----------------------------|--------------------|
| 1. Chemical tank (12 lit.) | 6. Blower assembly |
| 2. Fuel tank (2.5 lit.) | 7. Delivery system |
| 3. Engine (1 - 2 hp) | 8. Nozzle system |
| 4. Carburettor | 9. Starter pulley |
| 5. Spark plug | |

Two types of nozzles are available

- i) **Jet nozzle :** It contains the dosage sleeves with 4 marks viz., I, II, III and IV indicating the size of the hole. No.1 is for the lowest rate of discharge (0.5 lit/ha) where No.IV is for highest rate of discharge.
- ii) **Adjustable micronizer nozzle :** It is designed to give one fixed rate discharge at a time with a help of discharge control disc.

Operation : Before filling the tank with fuel, ascertain that the petrol cock at the bottom of the tank is closed. Then fill the tank with 3/4th capacity and also ensure that the cut-off device is closed at that time. Before mounting the machine, start the engine and keep it on idle speed. The power operated spraying unit can be converted into a dusting unit by changing certain components.

9. Ultra low volume sprayer (ULV) (Hand carried, battery operated spinning dis-sprayer): Here the pesticides are applied as such or with less than 5 litres spray fluid produces fine droplets (80 μ m). These are light weight sprayers (less than 3 kg) have a rotary atomiser (spinning disc) powered by an enclosed DC motor with a plastic spray head, a liquid reservoir, a handle and a power supply unit. Liquid is gravity fed from polythene container screwed into the spray head moulding and the liquid is flung off by centrifugal force.

10. Electrodyn sprayer (EDS) : Electrodyn sprayer is completely a new system of spraying for the controlled droplet application of chemicals (CDA). It makes use of electrical energy for droplet formation and propulsion towards target crops. The EDS consist of a spray stick and an unique combination of bottle plus nozzle the bozzle. The spray stick consists of the batteries and a solid state high voltage generator (Fig.83). The bozzle contains ready formulated chemical for immediate application to crops. This type is more advantageous than other system because

1. Charged droplets attracted to target crop.
2. Coverage on under surface of leaves also.
3. Minimal drift to non-target areas.
4. Very simple in operation.
5. No water is needed for spraying.

6. Spray is independent of wind and temperature.

7. Minimum labour and energy.

Limitations are the cost is high and suitable formulations is not available.

C. Other appliances

1. Soil injecting gun

It is used for fumigating the soil at different depths to control the nematodes and soil insects. It consists of a tank, a pump barrel, plunger assembly, injector nozzle, thrust handle and an injection handle. By holding with thrust handle, the equipment is thrust into the soil till the nozzle rod gets into the soil completely and the injection needle is pressed to release the calculated quantity of liquid fumigant (Fig.84).

2. It is produced loud noise at regular interval and used to scare away the birds. It consists of a big chamber to hold calcium carbide, a small chamber inside the former to generate when water comes into contact with calcium carbide in slow trickles. The frequency of sound production can be adjusted by regulating the flow of water. One unit is sufficient to scare away the birds from an area of 3-6 ac.

3. Flame thrower

It is used to destroy locust swarm, hairy caterpillars. It is ordinary pneumatic sprayer filled with kerosene for producing flame but the lance and nozzle are replaced with metal burner.

4. Granular applicator

The essential components are a hopper to hold the granules, a regulating mechanism to ensure constant flow of granules to the point of distribution and a means of operating the regulating mechanism.