TAMIL NADU AGRICULTURAL UNIVERSITY

AEN 201 APPLIED ENTOMOLOGY (2+1)

(2003 Syllabus)

Lecture notes

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AEN.201 APPLIED ENTOMOLOGY 2+1

2003 SYLLABUS

THEORY

Economic entomology – applied entomology – principles – classification of insects based on economic importance – study of Indian bees and Italian bees – comparison. Apiary management practices, bee pasturage, foraging. Bee products, properties and uses.

Pest management- insect ecology- balance of life in nature – population dynamics – role of abiotic and biotic factors. Bioresources in ecosystem. Life table – interspecific and intraspecific relationships – pests – definition and categories – pest outbreak – factors governing pest outbreak – need for pest control – pest monitoring, surveillance and forecasting. Economic Threshold Level – Economic Injury Level. Principles of Pest Management- Cultural, Physical, Mechanical methods Resistant varieties in pest management - parasitoids, predators and microbial agents in pest and weed management.

Pesticides – insecticides – history, classification.

Semiochemicals – allomones – kairomones – pheromones- semiochemicals in pest management. Sterile male technique – chemosterilants, insect growth regulators – moult inhibitors – Juvenile Hormone mimics – antifeedants and repellents - utility in pest management.

Pesticide application technology. Impact of pesticides in agro-ecosystem, compatibility, safety and hazards in the use of pesticides – pesticide poisoning. Impact of global warming on pests. Natural pesticides. Integrated Pest Management – Issues and options – Ecofriendly Integrated Pest Management – Indigenous/Traditional technologies. Integrated Pest Management practices for rice and cotton – economics of Integrated Pest Management. Pests of stored commodities and their management – Rodents and their management – Birds as pest and their management. Biotechnology in pest management.

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APPLIED ENTOMOLOGY-ECONOMIC CLASSIFICATION OF INSECTS

Insects are the only animals giving challenge to man for his supremacy. They occupy more than 2/3 of the known species of animals. They have been upon earth for 300 million years. Insects have great potential for rapid rise in population through a variety of ways. Insects affect man's interests in many ways. Insects become 'pests', when their existence conflicts with man's profit, convenience and welfare. Insects feed on crop plants raised by man, feed on food and other materials stored by man. Some insects act as vectors of some diseases and some also attack wood workings, stationary articles and museum specimens. Some other insects affects man's health. Mosquitoes, housefly and rat flea are some insects transmit diseases to man. However, many insects are harmless and beneficial to human beings. They are productive insects like honey bees, silk worm and lac insects, predators, parasites, weed killers, pollinators, scavengers etc.,

A study of insect, which affects the interests of man in various ways is referred to as " **Economic Entomology**".

Economic Classification of Insects

Insects

Insects possessing economic Importance (Economic entomology)

Insects of no economic importance (Harmless insects)

Harmful insects (Injurious)

Beneficial insects

A. Insect pests

a. Pests of crop and plants
(**Agricultural entomology**)
Pests of forest trees
(**Forest entomology**)

Damage by feeding.
Direct
(Borers, leaf feeders)
Indirect

A Productive insects

a. Secretion of insects.
Silk by silk worm
Lac by lac insects
Wax by honey bees

a. Bodies useful or contain
Dye (Cochneal insect)
Cantharidin (Blister loeetle)
Fish bait (stone fly nymphs)

(vectors, whitefly, leaf hoppers)

Damage by Non feeding

By Egg laying

(cow bugs)

Using plant parts for Constructing nests

(red ants, leaf cutter bee)

b. Pests of stored products (**Storage Entomology**)

House hold pests (**Medical Entomology**)

Damage by feeding

(pulse beetle, furniture beetle)

Contamination by excretion

(cockroach)

Seeking protection / building nests/tunnels

(termites, wasps, meal moth)

c. Insects inimical to man (**Medical entomology**)

Causing annoyance

(head louse, bed bugs, eye fly, ants, etc.)

Causing irritations on body

(ants, wasps, mosquito)

Disseminating diseases

(mosquito- malaria, rat flea- plaque, housefly- cholera, typhoid, dysentery, diarrhea)

Sucking blood

(mosquito, horsefly, flea)

b. Collect elaborate and store plant product.

Honey (nectar collected by honey bees)

c. Products from plant galls caused by insects- Tannic acid, inks, dyes.

d. Insects as food for animals and human beings

(Termites, white grubs, silk worms, pupae, grasshoppers)

B**. Helpful insects**

a. Aids in pollination

(Honey bees, butterflies, fig wasp)

b. Predators and parasitoids

(Dragon fly, preying mantis, ***Chrysoperla*, *Trichogramma sp*,** ***Bracon*** sp)

c. Destroy weeds

(Mexican beetle, ***Zygogramma bicolorata*** feeding on ***Parthenium***.

d. Improve soil fertility

(Ants, crickets, ground beetles, termites)

e. As scavengers

(Dung rollers, maggots, beetles)

f. Ideal material for scientific investigations.

(***Drosphila melanogaster)***

g. Aesthetic value

(Butterflies, Jewel beetle, clear wing moth)

Applied entomology is nothing but manipulation of insects (both harmful and beneficial) to man's advantage. Successful manipulation of any organism depends on adequate understanding of biology and ecology of insects.

Principles in applied entomology

The following are the principles in the applied entomology

1. Knowledge on Insect classification and life history
2. Knowledge on ecology of insects (Habitat, spread, influencing factors)

3. Survey and detection (monitoring and surveillance on distribution and abundance of the insect species)
4. Consumer demands (market value, consumer preference)
5. Preventive approaches in pest management
6. Community level approaches in pest management
7. New methods and materialin pest management
8. Combining chemical control with botanicals, biological, cultural, physical and mechanical methods- IPM.
9. Extension service, an important approach in all pest control programme.

HONEY BEES – SPECIES CASTES, BEHAVIOUR

APICULTURE

The act of rearing of bees is called 'Apiculture' or ' Bee keeping'. The location where the honey bees are reared is called 'Apiary'. Honey bees are reared in artificial hives for the products they give viz., honey, wax and help rendered by them in pollination of the crop.

BEE SPECIES

Sub family : Apinae (*Apis spp*), Meliponiae (*Melipona iridipennis*)
Family : Apidae
Super family : Apoidea
Sub order : Apocrita
Order : Hymenoptera

Domesticated

1. Dammer bee : *Melipona, iridipennis* (*=Trigona irridipennis*)
2. Indian bee : *Apis cerana indica*
3. Italian bee : *Apis mellifera lingustica*

' Hive bees'

Non domesticated

4. Rock bee : *Apis dorsata*
5. Little bee : *Apis florea*

'Single comb bees'

COMPARISON OF BEE SPECIES

Character	Rock bee	Indian bee	Italian bee	Little bee	Dammer bee
Size	Biggest	Medium	Medium	Smaller	Smallest

Honey yield/year	35 kg	3-5 kg	100 kg	1 kg	100 g
Comb construction	Single wax comb in open space (1m dia)	Several parallel wax combs in concealed place		Single wax Comb in open space (5 cm dia)	Cerumen combs in cracks and crevices
Domestication	Not possible	Possible	Possible	Not possible	Possible
Migratory behaviour	Present	Present	Absent	Absent	Present
Population /colony	25,000	20,000-30,000	20,000-30,000	5,000	500-1000
Nature	Ferocious	Tamable	Tamable	Not ferocious	Biting

CASTES OF BEES

A honey bee colony comprises three castes; the drone (male-normally in 100 s), the queen (functional female-normally one) and the workers (sterile female –remaining 90%).

The queen is the mother of the colony, the centre of all activities and the binding force. The queen on 5-10 days after emergence takes one or more **nuptial flights** (**marriage flights**) which will be followed by several drones. Only one drone succeeds in mating and usually the queen mates with 6-8 males before starting egg laying. Once she sits for egg laying she does not take up any mopre nuptial flights. The drone that had been successful in mating with queen dies soon due to abdominal rupture while bringing back the copulatory organ. All other drones will return to the hive to take part in any further fight or to remain idle just by enjoying the sunshine and the food gathered by the workers. During mating, queen is able to store about 2 crores of spermatozoa in her spermatheca where they can survive for over 2 years. With single copulation, queen can lay eggs for 3 years. A good queen can lay 2000 eggs per day (Fecundity 300-2000/day). The sex is determined by fertilization. Fertilized eggs produce females and the unfertilized ones males. Caste is also determined by nutrition. Larvae of queen bees are fed only with royal jelly, but other castes are fed with royal jelly for first 2 or 3 days.

COMPARISON OF BEE CASTES

Characters	**Queen**	**Worker**	**Drone**
Development	FertileE	ImperfectE	FertileΓ
Feeding	Fed by workers	By themselves	Fed by workers
Compound eye	Dicoptic	Dicoptic	Holoptic
Ommatiadia /eye	4000	5000	8000
Antenna	Flagellum with 10 segments	Flagellum with 10 segments	Flagellum with 11 segments
wing	Not extended upto tip of abdomen and flexed neatly over abdomen	Extended upto tip of abdomen – Flexing not so as in queen	Extended upto tip of abdomen – Flexing not so as in queen
Leg modification	Absent	Present	Absent
Abdomen shape	Elongate and bulged	Pointed posteriorly	Broad and blunt
Gaster segments	6	6	7
Sting	Curved slightly	Straight	Absent
Mandibular gland	Well developed (Secrete queen substance)	Well developed (secrete alarm pheromones ?)	Absent
Pharyngeal gland	Not developed	Developed (Secrete royal jelly /bee milk)	Not developed
Pheromone gland	Well developed (secrete queen odour)	Poorly developed	Absent
Scent gland	Poorly developed	Well developed and present in 5th	Absent

		and 6^{th} abdominal tergites (secrete scent)	
Wax glands	Absent	Present on 4-7^{th} abdominal sternites (secrete wax)	Absent
Brood cells	Largest, irregular, hanging vertically	Smallest, hexagonal	Intermediate, hexagonal
Cell cap	-	Flat	Convex with a central hole
Location of cells	Lower side of the (bottom) hive	Surface of the hive	Surface of the hive
No/colony	Only one; rarely few	In thousands	In hundreds
Biology Egg period Larval period Pupal period Adult longevity Larval feed	 3 days 5 " 8 " 3 years Royal jelly throughout	 3 days 4 " 13 " 3 months Royal jelly - 2 days Bee breed - 2 days	 3 days 7 " 14 " 2 months Royal jelly–3 days Royal jelly + Bee bread – 4 days
Bee breed : It is a mixture of honey and partially digested pollen			

DUTIES OF CASTES(Age Polyethism)

- Queen - Egg laying and leading out the swarm
- Drones – Fertilizing the queen
- Workers

I week : 1-3 days – Cleaning and incubating the brood cells
4-7 days – Feeding the larvae (Feeder bees)
II week - Royal jelly and wax secretions
III week - Role of house bees

Day 22 – old age -Foragers (field bees)

Duties of house bees

- Close the brood cells with wax before pupation
- Remove the cell cap during adult emergence
- Comb building with wax
- Repair hive with propolis (a gummy exudate from plants)
- Insulate the brood against cold
- Regulate hive temperature (33^o –36^oC)
- Receive nectar from foragers and store in comb cells after ripening
- Receive and pack pollen in cells (also add some honey over pollen as a preservative)
- Defence the invading enemies

Duties of forages

The searchers or scout bees get activated in the early morning and go out for finding out new sources of bee pasturage. They return to beehive and communicate the message to young foraging bees by dancing. Forages collect pollen, nectar, water, propolis and juice of damaged fruits. Pollen is the major food for grubs in combination with honey. Nectar is the raw material for honey and the honey is the reserve food for the colony. Propolis is used for comb repair and water proof the hive. Water is used in hive temperature maintenance and to dilute the honey before eating it.

BEE BEHAVIOUR

Swarming

It is a behaviouristic phenomenon of the bee colony wherein the reigning queen along with 1/3 or ½ of workers and drones come out to form a new colony. It occurs during maximum honey flow period i.e. November-December, when the population is increased / crowded. It may also occur due to inconvenient location, congestion, want of breeding space and bad ventilation etc. The swarming can be minimised by adding supers to avoid overcrowding, providing shades and improving ventilation by widening the entrance.

Presence of more drone brood cells in two sides of comb, two queen cells constructed along the lower side of the brood comb and clusters of bees on the outside of the hive are the signs of swarming.

The first swarm from the parent colony is called '**primary swarm'** and subsequent swarms are known as '**after swarm'** or **'cast swarm**'. There may be three or four swarming from a colony depending upon its strength.

Chemical control of hive behaviour

Pheromone glands of queen bee produce queen odour. This is the specific odour of the hive. Queen secretes queen substance by mandibular gland, which is licked by workers. Queen substance inhibits ovary production in workers and thereby any additional queen.

Queen supersedure

When the queen egg laying ability diminishes to a low level, she may be replaced by the workers with new queen. This process is called **supersedure**. Construction of three or four queen cells on the face of the comb is the sign of supersedure. This may be due to opening of the hive more than once in a week.

Foraging behaviour of bees

The **field bees** or **forages** get activated in the morning by about 7-8 Am and go out for foraging (collection of pollen, nectar, propolis, water etc.). The honey bees usually forage within 100m distance from the hive, but they can go upto 1.5 km. The bees are capable of flying at a speed of 23-30 km/hr and active in foraging within a temperature range of 25-27^{o}C. Honey bees collect the following materials

Pollen is collected from flowers. The bees load the pollen in both the pollen baskets fully. A bee carriers pollen upto 35% of its body weight one trip. The workers make about 6000 trips to collect 500-1000 g of pollen.

Nectar is also collected from flowers and stored in crop where it is mixed with saliva. The invertase contained in saliva acts upon sucrose of nectar and converts into dextrose and levulose. The bees return to hive and regurgitate the contents of the stomach into pellets. Which are ripened (eliminating moisture), put into cells and covered with flat and airtight capping. A forager makes about 19,000 trips a day to collect the nectar.

Propolis is the resinous substance exuded by buds, leaves and other parts of various trees and shrubs. The bees collect the propolis in the pollen basket and use it for cementing the crevices of comb.

Water is collected from stream and channels and also from plants. The hives should be kept near the water source.

BEE DANCE

The bees that go out first to find out new sources of food materials are called **searchers** or **scout bees**. They return to the hive and communicate the message to young foraging bees by means of definite patterns of dancing. This is called ‘**bee dance’.** The scientist Karl Von Frisch, who won Nobel prize in 1946, accomplished the decoding of the dance language of the honey bees.

Honey bees perform round or wag tail dance to indicate the distance and direction of food source. If the foraging source is rich the scout bees open the scent glands situated in 5^{th} and 6^{th} abdominal tergites and the odour emitted attracts the other forages to the vicinity.

Round dance

When a scout bee finds a plant with flowers within 50 m of the hive, the round dance is performed. The scout bee runs one to two circles clockwise and then anti clockwise. Round dance tells the other bees the distance alone, but does not indicate direction in which the food source is located. First few bees go out to locate the plant and then after finding emit powerful scents from the scent glands situated at 5^{th} and 6^{th} abdominal tergites to help the other workers arrive at the source. The richness of flower source is indicated by more frequency/ vigour the dance.

Wagtail dance

If the food source is far away from the colony about 100 meters or more, this dance is performed. Here the bees make a half circle on one side and then run in a straight line to starting point and make a half circle in the opposite direction, thus completing a full circle. This dance informs the companions both the distance and direction of the food plant. The number of dances completed in unit time gives the distance. That is faster the dance the closer is the food plant

Distance between the hive and food source (in m)	Dances per quarter minute
10,000	1
5,000	2
1,000	5
500	6
100	10

The direction of the food source is communicated by various ways.

If the food source is directly towards the direction of the sun, the straight run is upward

If the food source is in the opposite direction from the sun, the straight run is downward

If the food source is either to the left or right of the sun direction, the dance is performed with identical angular deviations. Depending upon the position of food to the sun, the straight run is either downward or upward.

Sickle dance

If the food source is between 50 and 100 m this dance is performed. It is a halfway between the round and wagging dance.

Stinging behaviour of bees

When the brood or adult bees are accidentally injured or crushed, other bees rush and sting the operator. When one is stung, the smell of sting attracts other bees. When a bee stings, the sting apparatus is left inside the victim's body and a massive abdominal rupture occurs to the bee. This will lead to dehydration, which causes death. This 'sting autonomy' is not common in Indian bees. Because Indian bees in general try to take back the sting after stinging by rotating the abdomen.

APIARY MANAGEMENT PRACTICES

1. Location of an Apiary

a. An apiary should be located in an orchard or near bee pasturage within the radius of 1-2 km.
b. The hives should not face the wind direction. Trees and bushes form a good wind barrier.
c. The site should be flat with good drainage.
d. Clean and fresh running water should be available
e. A young orchard without thick groves is an ideal choice.
f. A young orchard without thick groves is an ideal choice.
g. In the shadeless area, an artificial shed may be provided.
h. An apiary should not be located too near a high way.
i. A good barbed wire fence or a live thorny hedge may be provided to keep out intruders.
j. The site should be free from termite and black ant.
k. The hives should be placed 2-3 meters apart in rows at a spacing of 3-7 metres apart based on availability of space.
l. Landmarks such as trees, bushes etc., may be planted at suitable intervals to help the bees to recognize their hives.

2. Swarm control

The strength of the colonies gets depleted as a result of swarming. The methods of swarm control are:

- Clipping off specially constructed queen cells.
- Primary swarm is allowed to take place, but trapped in a swarm trap and hived as a separate colony. Destroying the remaining open brood cells prevents the after swarms.

- ♦ Take out 1 or 2 brood combs with the reigning queen and few workers from strong colonies and put in a separate hive thus the colony is divided.
- ♦ Interchange the positions between a strong and weak colony.
- ♦ 1 or 2 brood combs of strong colonies are removed and given to week colonies.
- ♦ Add supers for ventilation
- ♦ Provide shade

3. Improving the strength and vigour of the colony

The strength and vigour of the colony can be improved by uniting the colonies into one. The reasons for uniting are;

a. When one of the colonies is weak
b. When one of the colonies is queenless
c. When the queen is having bad traits

Methods of uniting

a. **Direct uniting**: The hives to be united are brought near gradually and kept side by side. Next day morning, when the bees are busy, the combs of weaker colony should be placed inside the strong colony after destroying the queen with bad traits. The success of this method depends on the skill of the labour.

b. **Newspaper method**: This is safer than the former. Two hives are brought closely. From the weaker colony, the queen is removed. After the dusk (sunset) the brood chamber of strong colony is covered with a newspaper with number of holes and over which the dequeened brood chamber is placed. The entrance of both the chambers is closed with a gauge. The bees slowly mingle together and accept the hive odour of the other and unite into a single colony. Next morning the wire gauge is taken out and the frames can be put into a single hive.

4. Queen rearing

Reasons: a. To obtain good pedigree queen
b. When there is necessity for spare queen.

Method of queen rearing

1. By distributing brood combs from a colony of good traits to two or three small hives.
2. A few cells in each of the combs with just hatched larvae are enlarged by cutting adjacent cells and from this queens are reared.

5. Care of queenless colonies

a. A brood comb with one or two sealed queen cells can be put in the hive.

b. The quickest way of rectifying a queenless colony is to supply another queen. This should be done after driving away all the workers. She can be caged in a glass tube. Plugged with a muslin cloth and put in an empty super. In course of a few hours, workers cluster around the cage indicating that the queen has become acceptable and now the new queen can be released.
c. Another method is ti dip the queen in honey and leaves it straight away in the hive. The workers lick the honey and the hive odour of the queen and the workers mingle with new queen.
d. When above methods fail the queenless colony can be united by newspaper method.

6. Care during lean season

When availability of pasturage is less during lean season / dearth period, a dummy division board is to be kept to confine the bees to a limited area. The bees are artificially fed with honey or sugar syrup. This is the time when the enemies of bees gain entrance to the hive. (In Tamil Nadu, July-October is the lean season).

Artificial feeding

Honey: Artificial feeding of sugar syrup increases bee strength, brood area and food reserves. Provision of 3 kg sugar solution (10%) in split doses per month at weekly intervals is preferable. The food is given only in the evening hours in containers with floats.

Pollen: Pollen deficiency may be supplemented by feeding cakes containing trapped pollen (1 part), soybean flour (3 parts) and sugar syrup (2 parts) (sugar and water at 2:1). During lean season, the occurrence of wax moth is common and black ants may be attracted to sugar syrup. These enemies should be checked. Feeding is to be stopped when the cells are full with the liquid.

7. Management during honey flow period

- Provide enough space for honey storage
- Use queen excluder to keep the super free from brood if needed.
- Make the bees to draw new combs by giving empty frames fixed with comb foundation sheet.
- Check the super and remove the super frames when they are fully sealed for honey extraction.

8. Shifting bee colonies

It should be done with care after dusk, moving about a half or one metre a day. Before packing for transport the brood combs should be well secured with banana fibres. One or two combs with honey should be hung in brood chamber to provide food while transit. An additional empty super is kept over the existing one to provide good ventilation. The hive entrance is closed with wire gauge. Then the floor board, brood chamber, supers and the roof are all fixed together by nailing a few reapers.

9. Inspection of a colony

Periodical inspection should be done to know the swarming, activity of queen and general behaviour. A record of each colony should be maintained to know the yield of honey swarms that went out etc.

- Gently smoke the entrance and wait for a while
- Remove the roof and lay it on the ground with the bottom upward just behind the hive
- Check for the presence of spider, cockroach and lizard inside the roof.
- Remove the super and keep it diagonally on the upturned roof.
- Smoke between the brood frames if the bees are defensive.
- Gently lift the end frame without rolling the bees, using the hive tool as a lever initially. Examine the first frame and keep it slanting against the hive on the ground.
- Remove other frames one after another and place inside the box.
- Frame with queen be placed back with least delay.
- Keep the brood box over the super after nest inspection
- Check for the presence of wax moth larvae or dead bees on floor board and clean thoroughly.
- Replace the brood box, then super box
- Inspect the super frames in a similar fashion

Do's and Don'ts in hive inspection

Don'ts

- Don't inspect during cold rainy days or at night
- Don't stand in front of the hive entrance
- Avoid jerks or crushing of bees
- Never make any sudden movements when bees are buzzing around us.
- Don't use smoke excessively which will alarm the bees
- Avoid using scent or strong smelling shampoos and lotions
- If a bee stings, place back the frame calmly and then pull out he sting with a sharp blade or with the fingernail. Don't crush it. Wash the spot with water.

- Honey bees are less prone to light coloured smooth finished cloths e.g. Khaki clothing. Rough materials such as leather, suede, felt appear to irritate bees and they sting these materials more readily. Hence avoid these materials while handling bees.

Do's

- Inspect the colony in good weather
- Use veil until you gain confidence in handling bees
- Use smoke judiciously to calm the bees
- Stand by the side of the hive
- Replace the frames in the same order in the brood box
- If the bees are aggressive even after smoking, close the hive and postpone hive inspection.
- Record your observations in a note book to know about the hive history and works to be done to the inspected colony.
- Frames should be carefully handled to avoid the risk of getting stings.

10. **Supering**

- Remove and cut the honeycomb in the end frame of the brood chamber into two halves.
- Fit the cut honey comb in the super frame
- Fill the empty space in the brood chamber with empty frames
- Do supering when the brood chamber is full with brood and bees

11. Honey extraction

- Use bee escape board the previous day to clear off the bees in the super.
- Use the bee brush to remove any bees remaining on the frame
- Do honey extraction in a bee proof room
- Decap the wax seal of the honey comb using a decapping knife
- Keep the decapped honey frames (2 or 4) inside the rack of the honey extractor
- Gently rotate the handle of the extractor to spin off the honey from the cells by centrifugal force.
- Decap the other side and repeat the extraction process.
- Filter the honey using a muslin cloth.
- Ripen the honey by heating it in a water bath at $60^{o}C$ for 30 minutes.
- Store the cooled honey in clear glass / plastic jars and closes the lid tightly.
- Keep back the honey extracted frames in the hive for the bees to clean by licking.
- Remove the super after the honey flow is over
- Leave enough honey for bees to tide over the dearth period.

BEE PASTURAGE

Bees collect nectar and pollen from plants. The wild and cultivated flora which are source of pollen and nectar to the honey bees are collectively called as '**bee pasturage'** or **'bee forage'**. Nectar is a sweet secretion from floral and extra floral nectaries of flowers, and it is the raw material for honey. Pollen is a protein rich food for the bees. The period when a good number of plants have nectar is called a **honey flow period** or **bloom season**. The season when there is a no honey flow is called **dearth period** or **lean season**.

A. Vegetable sources

Nectar yielding plants: Tamarind, neem, soapnut tree, ***Eucalyptus*** sp., Pungam, ***Prosopis***, ***Quisqualis***, ***Morinda***, ***Tribulus***, ***Glyricidia***, etc. Of these, tamarind provides a rich supply of nectar.

Pollen yielding plants : Sorghum, maize, roses, millets like bajra, finger millet, varagu, and tenai, pomegranate, sweet potato, zinniae, tobacco, castor, palmyra, tea (when the bush is allowed to blossom) etc. Of these, sorghum is a rich supplier of pollen.

Nectar and pollen yielding plants: Banana, citrus, apple, pear, plum, peach, guava, mango, coconut, sesamum, safflower, mustard, crucifers, cucurbits, bhendi, onion (when left for seeds), lucerne, clover, cosmos, hollycock, *Acacica*, ***Cassia***, ***Polygonum*** sp., ***Antigonon*** creeper and cotton. Of these, cotton is a very rich source.

B. Animal Source

Bees also collect honey from insects like aphids, coccids, shoot bugs, mango hoppers, etc., which have the habit of secreting a sweet sticky liquid faeces called the honey dew. Bees collect this liquid during the time of scarcity.

Honey bees show considerable preference to a particular source only by the availability of the food materials. The period of collection of food is limited to the opening flowers. For nectar, bees visit cotton throughout the day and tamarind during mornings. Collection of pollen from millets is limited to the mornings upto 9.00 am.

Seasonal variations

Honey flow season begins from November and extends to March and again from May-July. During honey flow season, the colony will have a maximum population at 50,000. Rapid multiplication depends on the availability of pollen and nectar. During this season, queen lays more eggs and the house bees construct fresh combs. The queen generally restricts her egg laying to the central combs as the side combs are reserved for honey and pollen.

If the central combs are full of broods, they may be removed and placed in weaker hives. Empty combs or comb foundation sheet may be replaced. Remove the combs which are completely sealed or two thirds capped may be taken out for honey extraction and placed to the supers after extraction. Two or three extractions are possible during honey flow period. Swarming is a behaviouristic phenomenon during maximum honey flow period. Control measures should be taken against swarming.

Once the honey flow period is over, the adverse conditions set in. Provisions of dummy divisions board, artificial feeding and taking control measures against was moth and black ants are the practices to be followed during the dearth period.

Foraging of bees : Refer previous chapter.

ROLE OF BEES IN CROSS POLLINATION

Cross-pollination is the transfer of pollen from the anthers of one plant to the stigma of another plant with different genetic makeup. Pollinators are necessary for distributing pollen because some pollen are moist and heavy. Deciduous fruit pollen are gummy and must be transferred by insects.

Honeybees are the most valuable pollinators of commercial crops. Honeybees accomplish >80% of the pollination by insects. It is estimated that bee visits in field crops can enhance about 30% of total agricultural productivity, but they are not fully exploited. Pollination by honeybees in cotton, results in increased yield of 23-53%. The value of honeybees in pollination of crops is fifteen to twenty times higher than that of honey or wax it produces. A bee visits 10 times a day and one colony would visit 3 lakh flowers a day.

Desirable qualities of honey bees

- Bodies covered with branched hairs.
- Both adults and immature stages depend on nectar and pollen for food and they are not injurious to plants
- Honey bees also capable of foraging at lower temperature
- Honeybee body size and proboscis length suits them to forage varied types of flowers than other insect pollinators.

Exploitation of bees in cross pollination

1. Optimum number of colonies per unit area is 5 per 2 hectares of crop. It depends upon the concentration of flowers, their attractiveness and the presence and number of other pollinating insects

2. Colony should be appropriately strong, as the efficiency of pollination depends upon the vigour and foraging behaviour of the colony and climatic conditions.
3. Colony should be kept near the orchard with sufficient number of flowers to avoid the time and energy wastage in bees.
4. Colony should be moved well before the flower looses their receptivity to fertilization.
5. The colonies should be kept at intervals of 180 m since the bee activity is concentrated within the radius of 90 m from the colony.
6. When many crops are grown at a time, the bees can be directed to particular crop by feeding them on syrup flavoured with flow extract from target crop.
7. Pollen from appropriate source can be collected by hand and dispersed over the bodies of field bees when they go out for attaining the cross pollination.

Case studies in selected crops

Fruits and nuts

- Apples are self-incompatible and inter planting of pollinizers is required. Insects mediate cross-pollination in apple. Two bee colonies per ha are recommended. Bees tend to forage near hive and thus the fruit set is increased with decreasing distance from the hive.
- In Pear, higher fruit set is obtained by bee pollination than under selfing.
- Plums are mostly self-compatible but honeybees greatly contribute in fruit set.
- In Litchi, the flowers panicles have only male flowers for first few days, male and female flowers for next few days and only male flowers again in the last few days. In this case, fruit set is higher by honeybee pollination and no fruit set is obtained under selfing.
- In Papaya, best fruit set is obtained by cross-pollination by honeybee.
- Among nuts, almond is dependent on insects for fruit set. Moving bees colonies to almond orchard for pollination is main practice in many countries. 5-7 colonies per ha are recommended for cross-pollination in India.
- In cashew, no fruit set is obtained by selfing and the cross-pollination is obtained by bee pollination.

Vegetable crops

- Flowers of many vegetable crops are good forage for bees.
- Cole crops are cross-pollinated to an extent of 95%. The bee visits produce more number of seeds per pod and weight of seed is greater as compared to selfing.
- Bees visit flowers of coriander and carrot.

- ❖ The weight of seed produced is more in plants visited by bees and low when exclude them.
- ❖ Onion is cross-pollinated crop, because of protandry and sticky pollen.
- ❖ In cucurbits, the male and female flowers are separate on the same plant. The pollen grains are heavy and large sized. Bees and wasps are primary pollinators.

Pulses

- ❖ Most of pulse crops are self-pollinated but bees visit the flowers and increase yield..

Oil seed crops

- ❖ In mustard, the stigma of the flower projects from the bud before opening and it is receptive. Wind is an important cross-pollinating agent, but insect especially bees also play an important role. Value of yields parameters such as pod, set, number of seeds/pod and weight of seeds were higher in insect/ bee pollinated than wind or self-pollinated crop. Application of ***Apis mellifera lingustica*** for hybrid seed production of mustard is followed in India.
- ❖ Niger is a good bee plant and 20-75% cross-pollination is done by bees. Plants caged with honeybees recorded 40 seeds / head as against 15 /head in plants caged without bees.
- ❖ Sunflower provides high quality nectar and pollen and bee pollination gives more yields. Bees increased seed setting by 27% and also oil contents.
- ❖ Safflower is also a good source of nectar and pollen. It yields more when pollinated by bees.

Fibre crops

- ❖ Cotton is main source of pollen and nectar. Plants caged with Indian and little bees gave 17% more cotton seed than in plants without insects. Bolls per plant, weight and number of seeds per boll and weight of lint also increased.
- ❖ Honeybees are ineffective in bringing about pollination in sunhemp, because they robbed flower nectar through a hole cut in the lateral portion of the keel, but rockbees exert more pressure on the keel and expose genital column of the flowers for pollination in sunhemp and thus they are important pollinators.

BEE PRODUCTS, THEIR PROPERTIES AND USES

Bee products are honey, bees wax, royal jelly, and propolis and bee venom. Of these, bees wax royal jelly and bee venom are synthesized by the bees and so can be called as real bee products; honey and propolis are only collected from plants.

Honey

Honey is defined as an aromatic viscid sweet product modified by the honey bees from the nectar of plants. Nectar is secreted by the nectar glands (nectaries). Bees also collect fruit juices, cane juices and insects honeydew secretions for honey preparation.

Honey processing

The bees draw nectar by their proboscis and hold it in their honey stomach (crop) where it is converted into honey (sucrose in nectar is converted / split into dextrose and levulose by the invertase in the salivary secretions). The honey thus converted is regurgitated, ripened and stored in the honey cells. The honey is get rid of moisture by wing beet. The whole process of eliminating the moisture by the fanning of bees themselves is called **honey ripening** and the cells containing ripe honey are then sealed with wax. The honey in the unsealed cells is called as **unripe** or **green honey**.

A pure sample of honey should granulate homogeneously and should weight not less than 1.4 kg per litre.

When about 75% of the cells are sealed, the frames are ready for extraction. The frames can be taken out, and the cells are and then a honey is extracted using the extractor. The honey is then ripened in water bath at 60^oC for 30 minutes and the impurities, which float as a scum, are removed before stored in glass or enamel vessels.

Properties of honey

Chemical : It contains 41% levulose, 35% dextrose, 1.9 % sucrose, 1.5% dextrins, 2% minerals, 17% water and 3.4% others like enzymes, vitamin A, B and C, acids, pigments etc.

Physical : Hygroscopic (viscous liquid) with specific gravity 1.35-1.44 g / cc / Kelvin. Viscosity determines flow ability. If the temperature is below 24^oC, dextrose in honey crystallizes and then the honey is said to have granulated. After granulation, dextrose settles down while levulose and water remains above increasing the danger of fermentation. Heating at 64^oC can prevent this.

Uses of honey

1. **Honey as food**: Honey is a rich, readily assimilable energy giving food and with milk forms a perfect and complete food. It is so nutritious that 1 kg of honey is estimated to be equivalent to 5 kg of milk., 1.5 kg of meat, 40 oranges or 50 eggs. Honey is useful to regain the energy by sports persons and used

in baking bread, cake and biscuits. Honey helps to build hemoglobin of blood.

2. **Honey as medicine**: Honey is used as a carrier in Ayurvedic, Homeopathic and Unani medicines. It is by itself used as a laxative and a blood purifier etc. Regular use of honey is advocated for cold, cough, fever, sores, eye ailments, ulcers on tongue and intestine. Being potentially alkaline in nature, it does not produce acidosis.
3. **Other uses** : Honey is used in many religious poojas. It is used for making alcoholic drinks, feeding race horses, as ingredient in cigar and chewing tobacco for flavour and taste an in manufacturing chewing gum. Honey is said to induce rooting in cuttings.

BEESWAX

Beeswax is obtained from the combs of wild hives, frame hives and capping. ***Apis dorsata*** is the main source of wax in India. Wax is secreted from 4^{th} to 7^{th} abdominal sterna of worker bees aged 14-18 days. To produce wax, bees fill themselves with honey and then hang quietly in a cluster. After 24 hours, the wax glands begin to secrete wax. The wax is hardened as flakes over the wax mirrors or wax plates (a pair of plates just below each wax gland). The bees digest about 7-15 kg of honey to synthesize 1 kg of wax. A set of 10 combs of ***A. dorsata*** will yield about 2.5 pounds of bees wax. The wax of ***A. dorsata*** is called **ghedda wax**. Solar wax extractor or hot water press can be used for melting bits of combs and capping and obtained bees wax.

Properties of wax

Chemical : It contains 72% of alkyl esters of fat and wax acids, 13-13.5 % of free wax acids, 12-12.5 % of hydrocarbons, 1-2% of moisture, 0.8% of fatty acids and 0.6% of lactone. It is insoluble in water.

Physical : Specific gravity 0.95% -0.97 melting point 62-65^{o}C.

Uses of bees wax

Bees wax is used in the manufacture of cosmetics (creams, lotions, lipsticks, eyebrow pencils), grease and paints, shoe polish, floor and furniture polish, links, electrical insulating apparatus and candles. Also used for preparing comb foundation sheets in bee industry.

PROPOLIS

It is resinous substance of plants collected by bees for ceiling cracks and crevices. It is usually admixed with bee's wax and is difficult to recognize. Propolis is obtained by scrapping it from the frames. It contains 55% resins and balsams, 10% ethanol and scented oils, 5% pollen etc.

Uses of propolis

It is a natural antibiotic with medicinal qualities. Used for preparing ointments and Vaseline.

ROYAL JELLY

Royal jelly is a glandular secretion of worker, fed to the queen and larvae. The royal jelly is secured from freshly started queen cells and harvested 2 or 3 days after the grafted larvae are introduced into the cell building colonies. From ***A. mellifera*** about 100 mg royal jelly is obtained from a queen cell. The royal jelly is collected from the cell by a standard jelly spoon or commercial vacuum pump. Royal jelly is capable of turning a sexless short lived into fully matured female capable of living 20 times longer period.

Uses of royal jelly

It increases vitality, potency and delays ageing in human beings.

BEE VENOM

Workers while stinging inject it. The poison glands of bees are modified accessory glands of two types ***viz***., the acid and alkaline glands. Combination of both secretions results in death of prey or causes extreme pain in man. Bee venom is collected by the use of electric shock. The bees get shock and release venom by inserting the sting into a thin nylon cloth below the copper wires. Venom is deposited on a glass plate placed below the nylon sheet. Another crude method is to place the bees in wide mouth glass jar, which is then covered with filter paper. Some ether is poured on the filter paper, the vapours of which irritate bees and they deposit venom on the walls of glass jar.

The chief components of the bee venom are a protein (**mellitin**) that has a powerful haemolytic (blood cell breaking) action and allergic reactions in sensitive persons and enzymes lecithinase and hyaluronidase. Lecithinase inhibits lactic dehydrogenase in citric acid cycle, which is the cause of intense pain in the victim. Hyaluronidase helps the spored of other components to the tissues.

Uses of bee venom

It cures rheumatism and nervous disorders. It reduces cholesterol and keeps away heart problems.

EFFECT OF AGRICULTURAL INPUTS ON BEE ACTIVITY

In modern agriculture, there is increasing use of pesticides for the control of insects, mites, rodents, nematodes and diseases of crop plants. The insect pollinators are killed by pesticidal usage on crop protection and results in direct loss of honey production and indirect inadequate pollination of crops resulting in reduced productivity. Weedicides are used to control the weeds and hence lead to starvation of pollination insects.

Pesticidal hazards

Many of the Indian crop plants need cross-pollination and about one third of the cropped area is under entomophilous crops. The pesticides sprayed on crops pose threat to pollinators and foraging bees visiting. The bees come in contact with pesticidal deposits while foraging on treated crops / weeds and thus get killed. The nectar and pollen can also be contaminated with pesticides and resulted in stomach toxicity to bees and also to brood when fed with contaminated pollen. Some pesticides may even cause hazards by fumigant action.

Cotton: Is the very good source of nectar and pollen, but is the most dangerous crop for bees, because more insecticides are sprayed during flowering period to control aphids, boll worms, bugs, etc., which will also kill bees by the sprays. Coordinated application of insecticides minimizes the bee kill. Flowering in cotton continues for about 2 months but flowers that set fruit appear within 3-4 weeks. Therefore use of insecticides during this period should be reduced so that bees can be moved to the crop. Nectar in flowers and extra floral nectaries is exhausted by mid-day and very few bees are foraging in the afternoon, during when insecticides can be applied with reduced hazardous to bees.

Oil seeds and vegetables : Flowering is greatly extended lasting for one to one and half months. The crops like ground nut, castor, cauliflower, cabbage, radish, turnip, carrot, fennel and coriander need insecticide application during flowering periods against aphids, caterpillars, bugs, etc., which causes bee poisoning. Pesticides can be sprayed well before or after foraging activity. In sunflower, bees forage in the forenoon and therefore evening or late in the afternoon is appropriate time for chemical control operations.

Symptoms of pesticide poisoning

- An excessive number of dead bees in front of the hive, on the floor board or on the top of the frames.
- An unusual number of dead colonies at one time, particularly if they contain honey.
- Bees carrying dead bees from the entrance.
- Bees crawling from the entrance to die nearby
- A depleted population of strong colony even during honey flow season.
- Dead or deserted brood with honey in the hive.
- A severe break in the brood rearing cycles.

- Incoming nectar or pollen laden bees attacked at the hive entrance by other bees.
- A cessation in flower visitation and food storage
- The absence of the usual hum of workers in the air
- Bees become paralytic, lose the power of orientation of legs and wings, digestive tract stops functioning, show uncoordinated movement, abdomen become distended, irritated and aggressive.
- Not all of the symptoms are likely to bee seen at any one time.

Relative toxicity of pesticides

Based on the degree of toxicity to the honeybees pesticides can be classified into four categories.

Extremely toxic

Direct application kills all bees. Treated plants remain toxic even after few days. These pesticides should not be sprayed during blooming. Eg. Acephate, aldicarb G, carbaryl ULV (over 0.5 kg / ha), chlorpyriphos, cypermethrin (over 0.025 kg/ha), deltamethrin, fenvalerate, malathion D, monocrotophos, parathion, phosphamidon and quinalphos.

Highly toxic

Direct application kills all bees. Treated plants remain toxic for few hours (8 Hours). These should be sprayed only late evening. Eg. carbaryl WP, endosulfan (over 0.5kg/ha), fenvalerate (0.1 kg or less), malathion EC and phorate EC.

Less toxic

These pesticides should be sprayed only during late evening or early morning. The treated plants remain toxic for 1-3 hours. Eg. carbaryl ULV (0.5 kg/ha or less), chlropyriphos ULV, cypermethrin (0.25 kg /ha or less), demeton, endosulfan (0.05 kg/ha or less), phorate G and phosalone.

Least toxic

These pesticides can be safely used around bees at any time. Eg. ***Bacillus thuringiensis***, carbaryl G, carbofuran G, Malathion G, dicofol, diflubenzuron, pyrethrum, baits, sulphur and weedicides. Deltamethrin at 0.02% and fenvalerate at 0.1% were found to be least toxic to ***A. indica***.

Measures to reduce pesticidal poisoning

1. Apply insecticides only when the crop is infested and the treatment is worthwhile.
2. Avoid spraying at blooming

3. Use non chemical methods for control of pests especially organic pesticides
4. Colonies should not be moved in and around field applied with toxic insecticides
5. Use sprays, which are safer than dust formulations because of drift problem.
6. Use emulsified insecticides than wettable or dispersible powders, which have longer residual effect than emulsions. Avoid oil emulsions, which are more dangerous to bees.
7. Granular formulations applied in soils are the safest for bees.
8. Choose safer insecticides for application during blooming.

Care of poisoned colonies

1. Provide pollen and sugar syrup to the depleted population
2. Move away the colonies to safer places, if the treatment remains residual for long time.
3. Uniting can increase the strength of poisoned colonies.
4. The combs with poisoned pollen can be soaked in water for few hours and washed by slight shaking.

INSECT ECOLOGY –BALANCE OF LIFE IN NATURE – REPRODUCTTIVE POTENTIAL AND ENVIRONMENTAL RESISTANCE

Ecology : It refers to **"**The science of relationships of organisms to their environment"
Ecology is derived from the Greek word 'Oikos' – means 'a house or a place to live'

INSECT ECOLOGY

"The science of relationships of insects to their environment"

Importance of insect Ecology

To understand insect number is to understand their inherited traits and the particular environment of their life cycles. The interaction between these two aspects, inherited traits and environment, results in given number of individuals and because these aspects are dynamic (constantly changing), insect number also are dynamic. It is a major objective of insect ecology to explain the dynamics of insect number in time and space. For this explanation, insect ecology relies on an understanding of physiology and behaviour of insects as affected by their environment. By providing explanations of how environment affects abundance, timing and diversity of insects, ecology forms the very basis of pest management.

With the ecological basis, the occurrence and severity of potential problems can be predicted and appropriate management activities formulated.

Terminologies

Population: Groups of individuals of any kind of organisms of the same species occupying a particular area at a specific time.

Community : Groups of species of organisms found at given place at particular point of time.

Insect community : Insects of different species found in a particular place at particular point of time.

Ecosystem : An assemblage of interacting plant and animal communities and non living environmental components.

Life system : The part of an ecosystem that determines the existence, abundance and evolution of a particular population.

Agro-ecosystem : An ecosystem largely created and maintained to satisfy a human want or need.

Effective environment : An environment / ecosystem composed of elements that have a direct influence on reproduction, survival and movements of the subject species.

BALANCE OF LIFE IN NATURE

The basic requirement of an ecosystem is a continuous supply of energy. This energy is derived from the food they are taking in. Individuals not only interact among themselves for mating, feeding and other purposes, but also interact with individuals of other animals and plant populations. The herbivores feed on plants, which are fed by other predators / animals. These predators /animals are fed by large birds/ animals/human beings, which give oxygen and nutrients to plants. Thus they form food chains and food webs. The process of repeated eating and being eaten is known as **food chain** and a network of inter related food chains forms a **food web**.

Common examples of natural ecosystems are ponds, lakes, forests and prairies. Just as ecosystems are the basic unit of study to ecology, agroecosystems are the basic unit of study for pest management, a branch of applied entomology.

In an agro-ecosystem, crop plant population, weed communities, animal communities (including insects), microbiotic communities and physical environment in which they interact are inter-linked.

In unmanaged ecosystems, a state of balance exists or will be reached. That is, species interact with each other and with their physical environment and the 'balance of nature' is maintained. When human beings begin to manage the system or create a new system in the area (i.e establishment of an agro-ecosystem where a natural ecosystem existed) the balance is altered.

Biotic balance is the condition of equilibrium in the population of animals. It is not a static one, but oscillating. Population level is determined by

1. Reproductive potential and
2. Environmental resistance.

1. Reproductive potential

'It is the ability of the insects to multiply in a given time in the absence of all environmental resistance'. It is often expressed as '**potential natality**'. It is defined as 'the reproductive rate of individuals in an optimal environment'. It is usually represented by number of insects or eggs / female.

It is also referred as '**biotic potential**' ('Innate ability of the population to reproduce and survive')

Initial population, fecundity, length of development period and sex ratio ar4e the factors controlling the reproductive potential..

2. Environmental resistance

't is the some total of physical and biological restraints in an environment that prevents a species from realizing its biotic potential'.

It is expressed in the form of an equation

$M=ad+b$ where m = death rate

a = density dependent component (biotic factors)

b = density independent factors (abiotic factors)

d = density of the population.

Thus, the actual abundance = Biotic potential –Environmental resistance.

INSECT POPULATION AND POPULATION DYNAMICS

Characteristics of a population

1. **Density**: Number of individuals per unit area or space occupied.
2. **Natality**: Refers to the number of new individuals produced per unit of time. Fecundity, fertility and sex ratio determine it.
3. **Mortality**: Refers to the number of individuals dying in a given population in a given period of time. It is governed by biotic and abiotic factors. The causes of mortality are aging, low vitality, accidents, physiochemical conditions, natural enemies, food shortage and lack of shelter.

4. **Population dispersal**: The movement of individuals into or out of the population. It may occur in three ways.
   a. **Immigration**: One way inward movement from one place to another
   b. **Emigration** : One way inward movement from one place to another
   c. **Migration** : Mass movement of entire population, where some insects return again to the moved area.
5. **Dispersion**: The distribution or physical location of individuals within a population at a particular time. It is decided by predation, competition and mutualism.

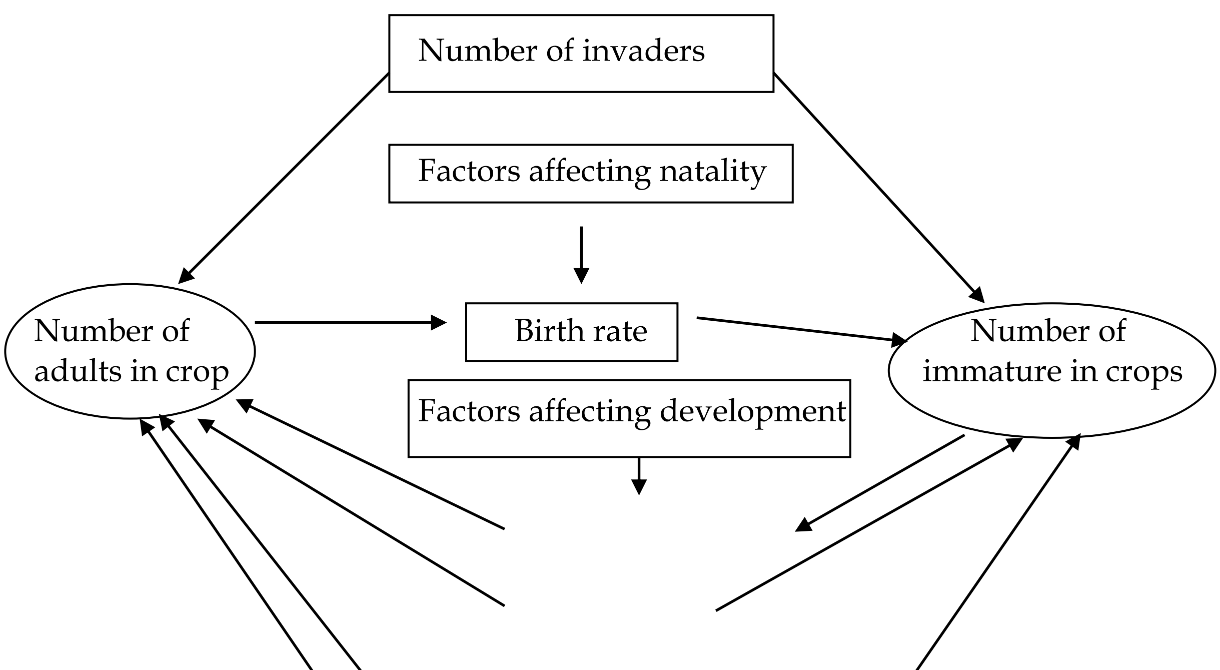
Population dynamics refers to 'the study of changing density of insects pests both in time and space parameters and understanding the process which cause their change'.

The existence and abundance of the population in the area determined by the physical and biotic influences of the environment as well as the genetic makeup of the species. This leads to fluctuations in numbers within certain lower and upper limits. The widely used expression with the primary factors of this change is as follows:

$$Nt = Noe^{(b-d)t} - Et + It$$

Where,	Nt	-	Number at the end of a short time period
	No	-	Number at the beginning of the time period
	e	-	base of natural logarithms = 2.7183
	b	-	birth rate
	d	-	death rate
	t	-	time period
	E	-	Emigration – movement of an area
	I	-	Immigration =movement into an area.

Diagrammatic representation of factors governing population dynamics



Development rate

Death rate

Factors affection mortality

Numbers of emigrants

Life table

Numbers of insects dying over a period of time are often represented in life tables, a tabular form of accounting for deaths. Life table is an numerical aid used in the study of insect population to record in a systematic fashion. There are two types of life table.

1. **Age specific (horizontal) life table** – Life table is based on observations made on single generation in different regions.
2. **Time specific (vertical) life table** - Life table is based on observations on overlapping / multiple generations.

Indices of life table

X	= Age interval (age of cohort)
Lx	= Number of alive (l) insects at the beginning of the age intervals noted in column x.
Dx	= Number dying (d) within the age interval x
Dxf	= The factors (f) responsible for death of individuals (dx) within each age interval.
100 qx	= mortality rate (dx as percentage of lx)
100 dx / N1	= generation mortality (dx as percentage of N1)
N1	= number of eggs observed in the present generation.
N2	= number of eggs observed in the next generation
Sx	= survival rate within the age interval x.

Life table of American boll worm

Age interval (x)	Lx	Dxf	dx	100 qx	100 dx/N1
Egg (N1)	100	Parasites	10	10.0	
		others	20	20.0	
				30.0	30.0
Larval	70	Dispersal	10	14.3	
I instar		Parasite	4	5.7	

		Disease	3	4.3 24.3	47.0
II instar	53	Disease Others	4 3	7.5 5.7 13.2	54.0
III instar	46	Parasite Disease	2 1	4.3 2.2 7.5	57.0
Pupae	43	Parasite	4	9.3 9.3	61.0
Adult	39	Others	2	5.1 5.1	63.0
			-63.0		

Use of life tables

- Ages of different life stages can be known
- Key mortality factors, stages affected can be known
- Population models can be developed from life table
- Pest surveillance, forecasting and prediction of pest can be possible
- It is possible to regulate beneficial processes like parasitism, predation, inter and intraspecific competitions etc.

REGULATION OF INSECT POPULATION – ROLE OF BIOTIC AND ABIOTIC FACTORS.

The natural phenomenon of numbers being arrested short of extinction is called **regulation**. The insect populations have a tendency to fluctuate as a result of influences by the environmental factors. The degree of influence of various **environmental factors** determines the magnitude of increase or decrease in numbers of pest population. The factors regulating insect populations are generally classified into **biotic** and **abiotic factors**.

BIOTIC FACTORS

Under natural conditions, organisms live together influencing each others life directly. The vital processes such as growth, nutrition and reproduction depend upon the interaction between the individuals of the same species (**intraspecific**) or between those of different species (**interspecific**).

A. Interspecific biotic factors

a. **Natural enemies**: The natural enemies such as predators, parasitoids and disease causing microorganism such as fungi, bacteria, viruses, protozoa, nematodes, viruses and rickettsia regulate the insect populations. The abundance of predators influences the abundance of pests in the field conditions. Predators respond to an increase in prey population density through numerical response (increase in the density of predators in a given area) and functional response (increase in consumption by individual predators). Predation and parasitism occur between primary and secondary consumer trophic levels. That is the insect (pests) feeding on plants (primary consumers) are attacked by predators and parasitoids (secondary consumers) thus the population is regulated.

b. **Food** : Insect depend or indirectly on plants for food. The quantity and quality of food play an important role in insects' survival, longevity, distribution, reproduction, speed of development etc. The availability of food to a particular population is influenced by number of individuals of the same species per unit quantity of food, individuals of other species and environmental factors.

c. **Human population trend**: The rapidly growing human population also decides the insect population and natural resources.

d. **Competition**: It refers to 'the type of interaction in which two individuals or species for a limited amount of food, water, nesting space, mates or other resources'. Usually two closely related species do not occupy the same niche, i.e. they cannot coexist with similar requirements for food and habit. If they do occur in the same habitat, they exploit different resources and remain active at different times and frequently displace one another. This is called '**Gause's hypothesis/ principle'** or **'competitive exclusion principle**' after the Russian biologist G.F. Gause who observed first such separation in 1932.

Types of competition

Intraspecific competition : There may be large number of the same individuals per unit quantity of food.

Interspecific competition : There may be more than one species consuming the same food materials. Eg. *Trichogramma* and *Chrosperla* compete for *Helicoverpa* eggs in cotton.

B. **Intra specific biotic factors**

In nature, the density of population is not always optimum. The phenomenon of under population or over crowding may influence the rate of increase or decrease in populations.

a. Colonization: Grouping of free living individuals to form colonies to have better protection from predators or environmental conditions and for improved utilization of food.

b. Aggregation: Tendency of congregating in large numbers than normal distribution for mating food etc.

c. Cannibalism: When crowding, the insects feed on the individuals of the same species. Eg. *Helicoverpa armigera, Tribolium confusem* (Large larvae and adults feeds on egg and small larvae)

ABIOTIC FACTORS

Among the abiotic factors, primarily the physical factors such as temperature, moisture and light have a direct influence on the development, longevity, reproduction, distribution and fecundity of insect pests. These factors also influence the pest populations indirectly by modifying the biotic factors.

A. Physical factors

a. **Temperature**: It influences the rate of development and level of distribution. The insects are all ' **poikilothermic'** i.e. they have no precise mechanism for regulating the temperature of their bodies. Insects require optimum range of temperature for development and survival. Exposure to lethal low or high temperature may result in instant killing and even the survivors may fail to grow reproduce normally. Some insects may become dormant i.e. undergo hibernation or aestivation.
b. **Moisture**: Moisture is essential for metabolic reactions in an insect's body. The moisture influences distribution and development. Excess moisture adversely affects the normal development and feeding activity of insects and encourages disease-causing microorganisms.
c. **Light**: Light is an essential factor for many biological processes such as orientation and periodicities of occurrence. The photoperiodicity is response of certain life stages to light. Photopeiodism influences the motor activity of rhythms of insects such as locomotion, feeding, adult emergence, mating and oviposition and also moulting and growth in some insects.
d. **O_2 & CO_2**: Available O_2 and CO_2 in an ecosystem decide the survival of insects.
e. **Air and water currents**: Both air and water currents are of great value to insects displacement and there by the numbers into or out of an area.
f. **Edaphic factors**: Several properties of soil like texture, moisture, drainage, chemical composition and topography affect the distribution and abundance of insects.

B. Nutritional factors

a. Availability of food regulates population abundance.
b. Kind and quality of food influences life cycle.
c. Host selection – The chemical factors within the plant decide the host selection. The preference of the plants decides the monophagous or polyphagous nature of the pests.

C. Physiological factors

Rapidity of growth, foliage characteristics, and taste factors etc., influence the development of insects.

INSECT PESTS-CATEGORIES AND CAUSES FOR OUTBREAK

Pest

"Any organism that is detrimental to man and his properties"

" Any organism that cause significant and economic damage to crops, stored produced and animals".

INSECT PESTS

" Insects that cause economic loss to plant and plant produces and attack livestock or man".

CATEGORIES OF PESTS

I. Insect pests are classified as follows based on season and locality

a. **Regular pests**: Pests that occur more frequently on a crop having close association. Eg. Rice stem borer.
b. **Occasional pests**: Pests that occur rather infrequently and have no close association with a particular crop. Eg. Caseworm of rice, Castor slug caterpillar.
c. **Seasonal pests**: Pests that occur on a crop during a particular part of the year. Eg. Red hairy caterpillar in groundnut.
d. **Persistent pests**: Pests, which occur on a crop almost throughout the year. Eg. Thrips on chillies.
e. **Sporadic pests**: Pests, which occur in a few isolated localities Eg. Rice ear head bug.

II. Insects pests are also classified as follows based on intensity of infestations

a. **Epidemic pests**: Pests, which occur in severe form in a region or locality at a particular season. Eg. RHC in groundnut in Bhavani, Prambalur, Kulathur, Gingee and Melur taluks.

b. **Endemic pests**: Pests, which occur regularly and confined to a particular area of locality. Eg. Rice Gall midge in Madurai district and rice stem borer cauvery delta.

III. Pests are classified as follows based on damage potential

a. **Key pests**: These are the most severely damaging pests. The damage is always above the EIL. Human intervention may bring the population temporarily below the EIL, but it rises back rapidly and repeated interventions (sprays) may be required to minimize damage.
b. **Major pests**: These are pests with the population crosses EIL quite frequently and require repeated control measures to avoid economic damage. (Damage >10%).
c. **Minor pests**: These are pests with population rarely crosses EIL and fluctuates around ETL. But these pests are easily amenable to available control measures and a single application of insecticides is usually enough to prevent economic damage (5-10% damage).
d. **Potential pests**: These pests normally do not cause any economic damage. Any change in the ecosystem may make them to cause economic damage (Damage > 5%).

CAUSES FOR OUTBREAK OF PESTS

1. **Destruction of forest or bringing forest area under cultivation**
   This will affect the weather conditions in that locality and thus set favourable conditions for some insects to assume pest status. There is always a chance for forest tree pests become field crop pests.
2. **Destruction of natural enemies**
   The natural enemies keep the pests under check. Destruction of these natural enemies by man by indiscriminate use of pesticides or other agencies tends to increase the population of insects in an area.
3. **Intensive and extensive cultivation**
   When one ore more related crops are raised over extensive area, limitations of food is nullified. Even if the same crop is grown for more than one season or crops of closely related each other are grown in rotation will also favour for the increase in insect population.
4. **Introduction of new crops and improved strains**
   Introduction of new crops in a new area may serve as new hosts for some of the insect pests. Most of the improved strains of crops are susceptible to pests. Sometimes, the minor pests become major with the introduction of new varieties or strains.
5. **Improved agronomic practices**
   Good tilth, higher 'N', closer spacing, weed control etc, improve crop growth and reduce competition for food.
6. **Introduction of new pest in a new area**

A pest becomes more abundant when it is introduced into a new area without its natural enemies. Eg. Apple woolly aphid, *Eriosoma lanigera* become a serious pest in Nilgiris as there was no natural enemy of the pest. It was brought under control, when its specific parasite ***Aphelinus mali*** was introduced from Punjab.

7. **Introduction of foreign pests**

   Several insect pests were introduced into India through imported materials. The important are diamond backmoth, ***Plutella xylostella***, San Jose scale, ***Quadraspidiotus perniciosus***, coffee green scale, ***Coccus viridis***, Potato tuber moth, ***Pthorimaea operculella*** etc.

8. **Large-scale storage of food grains**

   It enhances the stored product pest problems.

9. **Resurgence of sucking pests:**

   Insecticides applied for the control of one pest may tend to offer physiological conditions favourable for rapid multiplication of some sucking insects (called resurgence)

10. **Climatic factors of a particular locality**

    The environmental factors, when they are favourable, cause pest out break.

LOSSES CAUSED BY PESTS

Attainable yield: Maximum yield that can be obtained with best production techniques.

Actual yield : Specific yield obtained with current cultivation and plant protection practices at the farm level.

Crop loss : A crop loss is any reduction in quantity and or quality of yield. Crop loss is measured is the difference between actual yield and attainable yield due to the effects of one ore more pests.

Yield loss : The reduction in yield caused by a single pest.

Direct loss : It refers to the decrease in productivity (quantitative) or value or acceptability of the produce (qualitative).

Indirect loss : Decreased in purchasing power of farmers due to reduced production.

Methods of assessing yield loss

1. Mechanical protection - Using enclosures
2. Chemical protection - Using pesticides
3. Comparison of yield in different fields with different degrees of infestation.

d. Comparison of yield of individual plants.

Extent of losses

Pests cause 69.8% yield loss without plant protection and 42.0% with plant protection. Among pests, insects cause 15.6%, pathogen cause 13.3% and weeds cause 13.2% yield loss.

Insects cause 25, 18, 15 and 10% yield loss respectively in fruits, cotton, rice and sugarcane. Minimum yield loss due to insect pests is noticed in wheat (3%). Monetary value of estimated annual crop losses due to insect pests in 2,92,400 million rupees (US $ 8600 million).

PEST SURVEILLANCE AND FORECASTING

Pest surveillance is nothing but 'periodical assessment of pests populations and their damage' or 'watch kept on a pest for the purpose of decision making in pest management'.

Pest surveillance can provide the necessary information to determine the feasibility of a pest control programme.

Pest surveillance comprises of three basic components

i. Determination of the level of incidence of pest species
ii. Determination of what loss the incidence will cause and
iii. Determination of economic benefits the control will provide.

Objectivesof pest surveillance

a. To monitor the presence of a pest and
b. To determine the population density, dispersion, damage caused etc.

Survey : Regular survey activity is necessary for successful surveillance programmes. An insect pest survey is 'a detailed collection of insect population information at a particular time in a given area'. These surveys are both qualitative and quantitative. The **qualitative surveys** aim at the pest detection, employed with newly introduced pests and often precedes quantitative survey. The **quantitative surveys** attempt to define numerically the abundance of an insect population in time and space. It is useful to predict future population trends and to assess damage potentials.

Sampling : It is 'a representative part of the total population and base our estimate on that part'.

Sampling techniques: Surveillance requires suitable sampling techniques. A sampling technique is 'the method used to collect information for a single sample'. The sampling techniques include direct counts (*insitu* counts), knock down, netting, trapping, (use of light trap, pheromone trap, sticky trap), extraction from soil etc

Sampling programme : It is 'the procedure for employing the sampling techniques in time and space'. Sampling programme describes when sampling is to begin, location of samples, number of samples and how often samples should be taken.

Scientific surveillance methodologies

For rice, cotton and groundnut, a scientific surveillance methodology has been worked out. The methodology consists of fixed plot surveys, roving surveys and monitoring through light pheromone and sticky traps.

Fixed plot survey : In an acre plot, five micro plots of m^2 area are marked one each in four corners (1 m away from bund) and fifth in the centre of the chosen field. Periodical assessment is done in these micro plots. These plots are to be kept free from chemical sprays till the ETL is reached.

Roving survey : This is conducted every week in randomly selected field plots along the prescribed route of the survey. Observations are recorded from the west corner by a diagonal walk to 100 m.

Decision-making: is the key stone in insect pest management programmes. It indicates the course of action to be taken in any pest situation.

Identification of pest, Life history and behaviour of the pests, natural regulating factors, need for control measures, timing of control measures and selection of suitable control measures are critical factors in IPTA decision making.

Indices in pest surveillance

Economic damage: is 'the amount of injury, which justify the cost of artificial control measures'.

Economic injury level: is defined, as the lowest number of insects that will cause economic damage 'or' the cost of control measures is equal yield loss by insects'.

Economic thresh hold level: It is 'the level at which management action should be taken to prevent population reaching EIL'.

Factors affecting the ETL:

1. Crop value / market value
2. Management costs
3. Degree of injury per insect
4. Crop susceptibility to injury

The relationship between ETL and market value is inverse. The crop market value is always under fluctuations. Management costs tend to be more stable than crop market value. The degree of injury by various type of feeding is also important. The relationship between injury and the crop yield is the most important factor of the ETL.

$$\text{Gain thresh hold} = \frac{\text{Management cost (Rs./acre)}}{\text{Market value (Rs./kg)/acre}} = \text{kg/ac}$$

$$\text{EIL} = \frac{\text{Gain thresh hold}}{\text{Loss per insect}}$$

FORECASTING

It is 'an advance knowledge of probable pest infestations (out breaks) in a crop for planning the cropping pattern in such a way as to minimize the damage but also to get the best advantage of the pest control measures' or 'forewarning of the forthcoming infestations of pests'.

Forecasts are being done based on population's studies, studies on the pest's life history and field studies of the effect of climatic factors on the pest and its environment.

Forecasting service serves (I) to predict the forthcoming infestation level of the pest, which knowledge in essential in justifying the use of control measures and (ii) to find out the critical stage at which the applications of insecticides would afford maximum protection.

The forecasts may be of two types viz.,

(I) **Short term forecasting** (covers a particular season or two successive seasons and it is based on simple sampling).

(II) **Long term forecasting** (covers large areas and it is based on possible effects of weather on the insect abundance or by extrapolating from the present population density into the future).

PEST MANAGEMEN AND ITS COMPONENTS

Pest management is defined as 'the application of technology to achieve a satisfactory reduction of pest numbers or effects (pest control)'.

Natural control: The nature insect population is kept in check by many factors such as abiotic and biotic environmental factors. The operation of the natural factors is not dependent upon man and not influenced by him. This is called 'natural control'.

Applied or artificial control: It is planned and organized by man to eliminate or reduce the number of insects and the damage.

The control measures are generally termed as (1) **prophylactic or preventive** and (2) **curative or direct** methods.

(1) **Prophylactic or preventive methods**: These are 'measures taken as a preventive step before the actual occurrence of the pest'. effective against seasonal or persistent pests. Field sanitation, summer ploughing, crop rotation, resistant varieties, trap cropping, mixed cropping, crop residue destruction, pest free healthy seeds, seed treatment, swabbing tree trunks with insecticides or tar, drying of grains, adjusting of sowing time etc. are some of the preventive methods.

(2) Curative or direct methods: These are 'measures taken as a curative step to eliminate the insects after they have gained a foothold in the crops'. The following are some of the curative methods.

a. Cultural methods : Good tillage, racking and hoeing, pruning, fertilization, water management, mulching, detrashing, timely harvest etc.
b. Resistant varieties : Some varieties are inharently less damaged than the other by insects
c. Mechanical methods : Hand destruction, exclusion and trapping.
d. Physical methods : Heat, cold, humidity, light and sound energy.
e. Chemical method : Attractants, repellents, insecticides, growth inhibitors, sterilants etc.,
f. Biological methods : Parasites, pathogens and predators.
g. Genetic method : Male sterile techniques.
h. Regulatory methods : Quarantines, legislation.
i. Integrated pest management : Integration of possible components.

Objectives of pest control

- To prevent feeding, multiplication and dispersal of insects and
- To kill, repel, sterilize them and ultimately to prevent the loss to the crops.

Components of pest control

- Cultural methods
- Physical control
- Mechanical control
- Legal control
- Varietal resistance
- Biological control
- Chemical control

Requirement of successful pest management

- Farmers participation - involvement - implementation
- Government support in making plant protection policies
- Improved awareness about pests, pest management practices.
- More training before implementation on pest, natural enemy, method of pest management.
- Selection of suitable pest management method of a pest
- Proper adoption of pest management methods.
- Coordination by farmers for adopting pest management in larger areas.
- Feed back and rectification of defects
- Stringent legislative measures on substandard insecticides.

CULTURAL CONTROL

Definition

'Manipulation of cultural practices for reducing or avoiding pest damage to crops' is called cultural control. It is also defined as 'control of insect pests through adoption of ordinary farm practices in appropriate time in such a way that insects are either eliminated or reduced in population'

Impact of cultural control

The cultural practices may lead to the control of insect pest either by directly affecting their growth and multiplication or by minimizing the chance of their attack on plants. The main purpose of cultural control is to make the environment less favourable for the pest and more favourable for its natural enemies.

Characteristics of cultural control

- Use of cropping techniques
- Behaviour pattern transfer
- Independence from outside resources
- Reapplication of resources not meant for insect control.

Requisites for cultural control

- Sound knowledge on pest ecology
- Large scale adoption.

Cultural practices in pest management

A. Farm level practices

Sl. No.	Cropping techniques	Pests checked
1	Ploughing	Red hairy caterpillar, white grubs, cut worms
2	Racking and hoeing	Fruit flies, pumpkin beetles
3	Puddling	Rice mealy bug
4	Pest free seed materials	Potato tuber moth, sweet potato weevil, banana rhizome weevil
5	High seed rate (25% extra)	Sorghum shoot fly
6	Plant density/rogue spacing	Brown plant hopper
7	Earthing up on 30 DAP	Early shoot borer of sugarcane
8	Detrashing on 5th and 7th month after planting	Scale, white fly of Sugarcane
9	Destruction of weed hosts (***Tinospora cardifolia***)	Citrus fruit sucking moth
10	Destruction of alternate hosts (***Abutilon indicum***)	Cotton white fly
11	Inter-cropping *Lab lab/cowpea in sorghum at 1:4 ratio *Cumbu in groundnut at 1:4 ratio	 Sorghum stem borer Groundnut leaf miner
12	Trap cropping *Mustard in cabbage (1:25) *Caster as border crop *Marigold and bhendi on channel bunds	 DBM in cabbage ***Spodoptera litura*** in cotton American boll worm and spotted boll worm, respectively
13	Mixed cropping of red gram, sunflower, maize, onion, coriander, cowpea, marigold in cotton	Sucking pests and bollworms
14	Water management	Caseworm, BPH in rice
15	Judicious application of fertilizers	BPH, leaf folder in rice
16	Clipping off top in seedlings	Rice stem borer
17	Mulching-trash mulching to a thickness of 10cm on 3 and 21 days after planting	Early shoot borer of sugarcane
14	Timely harvesting	Sweet potato weevil, pulse beetle

B. Community level practices

- ❖ Synchronised sowing - Dilution of pest infestation
- ❖ Crop rotation - Breaks insect life style
- ❖ Crop sanitation - Destruction of insect infested parts, Removal of fallen plant parts and crop residue destruction

Merits and demerits of mechanical control

Advantages	Disadvantages
♦ No extra cost ♦ No costly inputs ♦ No special equipments ♦ Minimum cost of labour, if required ♦ Minimum chance for biotype selection ♦ No health hazards -Ecologically sound ♦ No harmful effects on non target organisms ♦ Good component in IPM.	♦ Prophylactic in nature ♦ Timing decides success ♦ No complete control ♦ It requires long term planning.

PHYSICAL CONTROL

Definition

" Modification of physical factors in the environment to minimize or prevent pest problems" is called physical control.

Impact of physical control

Insects require definite ranges of physical conditions and any departure from such ranges are lethal to the survival and other life activities of insects.

Physical methods in pest management

I. Temperature manipulation

Insect activity and metabolic rate are influenced by environmental temperature. Optimum range of temperature is vital for normal insect activity.

- ♦ High lethal temperature

  Sun drying of grains - rice weevil

  Hot water treatment of rice seeds at 52-54^{o}C for 15 minutes-white tip nematode

  Flaming (flame thrower)-Locusts and moringa hairy caterpillar.

  Steaming (Steam sterilization of soil)- Nematodes in green house.
- ♦ Low lethal temperature: Cold storage of potatoes - potato tuber moth

II. Moisture manipulation

In well-dried grains (moisture content <10%), the survival of stored grain pests becomes impossible. Eg. Rice weevil, pulse beetle. Alternate wetting and drying in rice fields reduces the brown plant hopper damage

III. Light manipulation

Behavioural orientation is influenced by light. Provision of light causes

1. Mating frequency reduction - RHC
2. Reduced fertility -Indian meal moth and
3. Diapause disruption - All diapausing insects.

Light trapping: It Serves many purposes like monitoring initial infestation, seasonal incidence, pest / weather relationship, pest intensity, pest survey, trapping and killing.

IV. Use of electromagnetic energy

- Use of radio frequency (RF) (wave length range is 10^{2}-10^{10}µ) affects thoracic ganglion and causes synaptic blocking, alteration of amino compounds of nerve cells and dissolution of nerve cells Eg. Rice weevil
- Use of infra red radiation (wave length range 0.78-10^{2}µ) - rice weevil
- Use of visible (0.38-0.78µ) and UV radiation (2×10^{-2} - 0.38µ). Yellow colour attracts aphids and black colour attracts Angumois grain moth.
- Ionizing radiation-X rays (10^{-5}-10^{-2}µ), gamma rays (10^{-8} -10^{-4}µ) kill sterilize insects at lethal dose.

V. Use of sound energy

- Acoustical device (Bird scarer/acetylene exploders) produces sudden loud sound which frighten birds.
- Fire crackers also used to make loud sound to scatter away squirrel, foxes, rats, mice, deer, etc.

Disadvantage: Habituation to the sound

MECHANICAL CONTROL

Definition

"Use of mechanical force of manual labour either for destruction or exclusion of pests".

Mechanical methods in pest management

Life stages of the pests are killed by mechanical force or manual labour.

I. Mechanical destruction

A. By manual labour

- Hand picking - Red hairy caterpillar, American boll worm, egg masses of *Spodoptera and RHC*
- Hooking - Rhinoceros beetle
- Brushing -Woolen fabrics for cloth moth
- Combing - Delousing for head louse
- Crushing - Bed bugs and lice
- Swatting - Hit by severe blow against mosquitoes
- Sifting - Sieving for red flour beetle
- Shaking plants - White grub adults, case worm of rice.

B. By mechanical force

- Entoleter -Centrifugal force is applied to kill insect stages of stored grain pests
- Hopper dozer -Kills nymphs of locusts by herding into trenches and filling with soil
- Tillage implements -Soil borne insects, pupae of many insects.

II. Mechanical exclusion

Mechanical barriers prevent access of pests to hosts.

- Banding -Banding with grease or polythene sheets to control mango mealy bugs
- Wrapping -Covering the fruits with perforated polybags to control pomegranate fruit borer and cloth bag to control fruit pests of grapevine
- Covering materials - Red earth coating on red gram grains to control pulse beetle
- Netting -Mosquito control in house, vector control in green house.
- Trenching -Trapping marching larvae of RHC
- Water barrier - Ant pans for ant control.
- Tin barrier -Metallic sheets fixed around tree trunks in coconut for rat control
- Trapping - Box trap, back break trap, wonder trap for rats.
- Electric fencing - Electrocution checks rat and wild animals.
- Insect proof packing - Stored pests.

Merits and demerits of mechanical control

Merits	**Demerits**
♦ Home labour utilization	♦ Limited application

♦ Low equipment cost ♦ Ecologically safe ♦ Good component of IPM	♦ Require continuous use ♦ Rarely highly effective ♦ Labour intensive

LEGAL CONTROL

Definition

"Preventing the entry and establishment of foreign plant and animal pests in a country or area and eradication or suppression of pests established in a limited area".

Foreign pests introduced into India

In olden days, there were no restrictions on the transport of plants from one country to another, because the danger involved was not either realized or appreciated. This has resulted in introduction of many insect pests, mites and nematodes to countries where they were not known to occur. The following are the pests introduced into India.

Cottony cushion scale	- ***I****cerya purchasi*
Wooly aphid	- *Erisoma lanigera*
Potato tuber moth	- *Pthorimaea operculella*
Golden nematode of potato	- ***Globodera rostrochinensis***
Serperntive leaf miner	- *Liriomyza trifolii*
Coffee berry borer	- *Hypothenemus hampei*

Foreign pests which have not gained entry into India (pests of quarantine concern)

Grapevine phylloxera, cotton boll weevil, Mediterranean fruit fly, Wheat stem sawfly, alfalfa aphid.

Pest Legislations

First quarantine Act in USA came into operation in 1905. Government of India passed an Act entitled "**Destructive Insects and Pest Act in 1914"** to prevent introduction into our country of any insect fungus or other pests destructive to crops.

Then Madras State enacted " **Madras Agricultural Pests and Diseases Act 1919**" , which was the first state Act in India.

Plant Quarantine

Legal restriction of movements of plants and plant materials between countries and between states within the country to prevent introduction and spread of pests and diseases where they do not exist.

Categories of Legislation

1. **Foreign quarantine**

It is the 'legislation to prevent the introduction of new pests from other countries' as per **"Destructive Insects and Pest Act 1914"**

- Prevents introduction of pests from foreign countries
- Takes care of pests of quarantine concern in India and
- Restricts or prohibits import of plant materials Eg. Sugarcane setts from Philippines, rubber seed from South America.

Restrictions on import of plant materials

- Scientists can obtain the seeds with permission from National Bureau of Plant Genetic Resources, New Delhi.
- Plant materials should be imported only with import permits.
- The consignments should be accompanied by phytosanitary certificate from the country of origin.
- Quarantine inspection of materials is made at notified sea and Airports. The Central Directorate of Plant Protection and Quarantine established in 1946 monitors the quarantine stations at ports.
- Fumigation of imported plant materials is also done based on need.

2. Domestic quarantine

It is the 'legislation to prevent of spread of already established pests from one part of the country to another'.

The state Acts empower to prevent the spread of dangerous pests within their jurisdiction. Quarantine stations at Mettupalayam, Shenbaganur and Top hill monitor and prevent the spread of fluted scale (*Icerya purchasi)* in Tamil Nadu.

3. Enforcement of Pest control measures

It is the legislation to prevent damages and spread of already established pests. The state Act is enforced on cultivators to take control measures for the following pests.

Cottony cushion scale	- ***I****cerya purchasi*
Coffee berry borer	- *Hypothenemus hampei*
Sugarcane top borer	- *Scirpophaga nivella*
Cattle fly	-*Stomaxys calcitrans*
Red hairy caterpillar	- *Amsacta albistriga*
Coffee stem borer	-*Xylotrechus quadripes*

4. Quality control

It is the 'legislation to prevent the adultration and misbranding of insecticides'.

The Government of India enforced " **The Insecticide Act 1968**",which empowers to regulate the import, manufacture, sale, transport, distribution and use of insecticides. The pesticide firms should register themselves stating the name and address of manufacturer, the brand and trade name of the insecticide, the active ingredient, net content in an unit pack, details of antidote. The container should carry a poison label with skull and cross bones and a warning or caution statement.

Central Insecticide Board was set up to advise Centre and States on technical matters of insecticide usage.

5. Legislation to regulate activities of personnel engaged in pest control

It ensures safety to workers engaged in plant protection operations and to public (Governed by Insecticide Act 1968).

HOST PLANT RESISTANCE

Plant species, which are fed upon by an insect are called ' host plants'. The inability of insect to attack a non-host plant is termed 'immunity'. A host plant, which shows lesser damage, is called 'resistant' and a host plant showing more damage is called 'susceptible'.

Definition

"Pest resistance is any inherited characteristic of a host that lessens the effect of attack".

Snelling (1941) Plant resistance to insects is "a quality that enables a plant to avoid, tolerate or recover from the effect of oviposition or feeding that would cause damage to other genotypes of the same species under similar environmental conditions".

Painter (157) defined plant resistance as "relative amount of heritable qualities possessed by the plant which influence the ultimate degree of damage done by the insects".

Kogan (1994) Resistance to insects is "the inheritable property that enables a plant to restrain the growth of insect populations or to recover from injury caused by populations'.

Characters of resistance

Resistance in heritable, relative, measurable and variable.

History of host plant resistance

1782 –'Underhill' variety of wheat was found to be resistant to Hessian fly *Mayetiola destructor*

1831 -'Winter Majetin" apples were reported resistant to the woolly aphid *Erisoma langigerum*.

1890 - Grapevine phylloxera, *Viteus vitifoliae* was controlled in French vine yards by using resistant rootstocks of America for grafting by Dr. C.V. Riley. This method was named as 'Riley method'.

Only after 1920, extensive studies were started on plant resistance by the pioneer of resistance R.H. Painter (Kansas State University, USA). He published a book 'Insect Resistance in Crop Plants' in 1951.

Types of resistance

1. Ecological or Pseudo resistance
2. Genetic or true resistance

1. Ecological resistance: No heritable trait is involved

- **i. Host evasion** : A host may pass through the most susceptible stage quickly or at a time when number of insects is less (early maturing varieties).
- **ii. Host escape**: Absence of infestation or injury to the host plant because of transitory circumstances such as incomplete infestation.
- **iii. 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 the soil or plant (low N, high K, etc.).

2. Genetic resistance or true resistance

A. Based on number of genes

- **i. Manogenic resistance** - resistance is controlled by a single gene
- **ii. Oligogenic resistance** - resistance is controlled by few genes
- **iii. Polygenic resistance** - resistance is controlled by many genes (also called as **horizontal resistance**)

B. Based on biotype reaction

- i. **Vertical resistance** - Resistance is specific to a given biotype (less stable).
- ii. **Horizontal resistance** - Resistant against all the known biotypes of the insect also called **'non-specific resistance'**.

C. Miscellaneous categories

- i. **Cross resistance** - When a variety with resistance to a particular pest, may confer resistance to another pest
- ii. **Multiple resistance**- Ability of a variety to resist variety of environmental stresses like insect, diseases, nematodes, etc.,

Mechanisms of resistance

Painter (1951) grouped mechanisms of resistance into three main categories viz., **non-preference**, **antibiosis** and **tolerance**.

Non-preference or Antixenosis

The term antixenosis was coined by Kogan and Ortman in 1978. Xenosis means 'guests' in Greek. Antixenosis refers to 'the resistance mechanisms employed by host plant to deter or reduce colonization of insects'. Antixenosis may result from certain morphological characteristics or the presence of allelochemicals in the host plant, which adversely affect the oviposition, rate of development, death and reproduction.

Antibiosis

It refers to 'the adverse effect of the host plant on the biology (survival, development and reproduction) of the insects and their progeny infesting it'. The adverse effect may be due to presence of toxic substances, absence or insufficient amount of essential nutrients, presence of antimetabolites and enzymes, which adversely affect food digestion, and utilization of nutrients.

The symptoms of insects affected by antibiosis are death of immature stages, reduced growth rate, disruption in conversion of ingested food, decline in size and weight of larvae, prolongation of larval period, failure to pupate, death in pupal stage, abnormal adults, reduced fecundity, restlessness and abnormal behaviour.

Tolerance

It refers to 'the ability of the host plant to withstand an insect population sufficient to damage severely the susceptible plants'. It is generally attributed to plant vigour, regrowth of damaged tissues, resistance to lodging, ability to produce additional branches and compensation by neighboring plants.

Bases of resistance

1. Biophysical bases

The morphological and anatomical characteristics of a plant like colour, shape, size, thick cuticle, trichomes, surface waxes, silica deposits, glandular hairs, tight leaf sheath, compact panicle and tightness of husk influence insects' preference. The resistance mechanisms related to morphological or structural plant features all together called **'Phenetic resistance'**. Phenetic resistance causes reduced or impaired feeding or oviposition and contribute to the action of other mortality factors.

Eg. 1. Tightly wrapped leaf sheath, closely packed vascular bundles and high silica content- rice stem borer.

2. Red pericarp and surface wax- Brown plant hopper

3. Pubescent varieties of soybean variety, cotton and bhendi - Leaf hopper
4. Frego bract cotton varieties - Boll weevil

5. Biochemical bases

Several inorganic chemicals in plants impart resistance to a wide variety of insect pests. E.g

Eg. Nutirents : **Asparagine** in Mudgo rice variety - Brown plant hopper
Low **carbohydrates**- Mexican bean beetle *Epilachna varivestis*
Low **aminoacids**- Pea aphid, *Acyrthosiphon pisum*

Allelochemicals: **DIMBOA** (2,4, dihydroxyl -7 methyl-1,4 benozoxaxine-3-one) - European corn borer, *Ostrinia nubilalis*.
Cucurbitacins - Many cucurbit pests especially ***Epilachna***
Gossypol in cotton - *Helicoverpa zea*
Pentadecanal in TKM 6 rice - stem borer.

HOST PLANT RESISTANCE IN PEST MANAGEMENT

Until 1960, the host plant resistance as a method of insect control received little attention except in few cases. However, the growing awareness of the limitations of pesticides in recent years has caused an upsurge of interest in this approach in insect control though developing a resistant variety involves faculties of different department and requires several years.

Methods of developing resistance varieties

1. Screening of available germplasm sown in lines under natural field conditions
2. Selective screening of elite entries under natural infestation through replicated trials
3. Selective screening of elite entries under bombarded condition in cages.

Resistant varieties

Crop	**Pest**	**Resistant varieties**
Rice	Stem borer	TKM 6, IR 20, Paiyur1
	BPH	CO42, P43, Ptb33, IR 36, IR 64
	GLH	CR 1009, IR 20, IR 50, TKM 6
	Gall midge	MDU3, Shakti, Vikram
Sugarcane	ESB	CO 312, CO 421, CO 661, CO 917, CO 853
	Internode borer	CO 975, CO 7304
	Top shoot borer	CO 745, CO 6515
	Mealy bug	CO 439, CO 443, CO 720, CO 730
Cotton	Boll worm	Abhadita
	Stem weevil	MCU3, Supriya
	White fly	Kanchana, LPS 141

	Leaf hopper	MCU 5, SRT 1, Gujarat 67, K7, K8
Sorghum	Earhead bug	K tall
Jasmine	Eriophyid mite	Pari mullai
Brinjal	Aphids	Annamalai

Integration with other tactics

1. **Chemical control**: High mortality of plant and leafhoppers was observed on resistant than on susceptible rice varieties when sprayed with insecticides. In many cases, the plant resistance enhances the efficacy of insecticides. Also it reduces the amount of insecticides required. For example, the amount of malathion required to kill aphid *Myzus persicae* on Brussels sprouts is reduced by 45% on partially resistant varieties.
2. **Biological control**: Though compatible, indirectly affect the natural enemies by reducing pest numbers. But it weakens the pest populations, which will make the pests more susceptible to natural enemies. For example, the predatory potential of spider *Lycosa pseudoannulata* on BPH is increased on resistant varieties.
3. **Cultural control**: Cultural practices (N and K management) cause specific physiological changes that reduce the suitability of host plants for phytophagous insects for example

Advantages of Host Plant Resistance

- **Selective** - against a particular pest thus no adverse effects on other insects or non-target organisms.
- **Cumulative** - effect continuous against successive generations
- **Persistence** - durable for long period.
- **Eco friendly**- no pollution or deleterious effects.
- **Easily adaptable**- it does not require additional cost and easy to adopt by farmers.
- **Effective** under all conditions
- **Compatible**- compatible with other pest control practices. Activity of insecticides and natural enemies is more on resistant varieties.
- Reduces pesticide application - lessens frequent pesticide applications
- **Useful** for low value crop.

Disadvantages of Host Plant Resistance

- Time consuming
- High initial cost
- Biotype selection *
- Conflicting resistance factors. **

* **Biotype selection**: Biotypes are discrete populations capable of utilizing and damaging the plant genotypes resistant to other populations of the same species. The biotypes are developed due to the selection pressure when resistant cultivars are grown widely. These biotypes can be over come by polygenic resistance.

** **Conflicting resistance factor**: Some plant traits confer resistance to one pest but enhance susceptibility to others. Eg. Pubescent cotton varieties resistant to leaf hopper are susceptible to bollworms. Frego bract in cotton mediates resistance to American boll weevil, but magnifies susceptibility to plant bugs.

BIOLOGICAL CONTROL

Definition

'The pest management tactic involving purposeful natural enemy manipulation to obtain a reduction in a pest's status' is called biological control or bio-control.

The naturally available enemies of insect pests are utilized for their control. They include parasitoids, predators and pathogens.

History and development

In ancient times, Chinese used nests of Pharoah's ant, *Monomorium spp*. to combat stored grain pests and *Oecophylla spp*. to control foliage feeding insects.

In 1762, Mynah was imported from India to combat locusts in Mauritius.

The first well planned and successful biological control attempt was made during 1887-88, when the developing citrus industry in California was seriously threatened by the fluted scale ***I****cerya purchasi*. Dr.C.V. Rilly suggested that, the original home of the scale was Australia or New Zealand and that natural enemies of the scale should be introduced into USA from these countries. Then Albert Koebele was sent to Australia and he found a small beetle known as Vedalia beetle ***Rodolia cardinalis*** attacking the scale in the Adelaide area. In November 1888, the beetles were brought and released into California. Within a year, a spectacular and highly effective control of the scale had been obtained.

In India, the coccinellid *Cryptolaemus montrouzieri* was introduced from Australia in 1898 and released against coffee green scale ***C****occus viridis*. Though it established, failed to control the scale, but it is now a common predator for mealy bugs in South India. In 1957, Regional Station of Common Wealth Institute of Biological control was established at Bangalore, to boost the bio-control works. In 1977, All India Coordinated Research Project on Biological Control of Crop Pests and Weeds (AICRPBC) was started by Indian Council of Agricultural Research. Further it was upgraded to Project Directorate of Biological Control at Bangalore in 1993 to coordinate all bio-control works.

SUCCESSFUL / CLASSICAL EXAMPLES OF BIOLOGICAL CONTROL

1. 1929-1930 - ***Rodolia cardinalis*** was obtained from California and Egypt and used for successful control of ***Jcerya purchasi*** at Nilgris
2. 1940- Specific parasite ***Aphelinus mali*** was obtained from Punjab and used effectively against *Erisoma lanigerum*.
3. 1960 - Parasites ***Bracon brevicornis, Parasierola nephantidis*** , ***Trichospilus pupivora*** were used at 10:10:20adults/tree against coconut black head caterpillar.
4. Egg parasitoid ***Trichogramma australicum*** against early shoot borer of sugarcane.
5. ***Cryptolaemus montrouzieri*** against grapevine mealy bug
6. ***Chrysoperla carnea*** against aphids
7. ***Gambusia*** fish against mosquitoes
8. Ichneumonid parasitoid ***Isotima javensis*** against top shoot borer of sugarcane.
9. Ducks against army worm and striped bug in rice

Merits and demerits of mechanical control

Merits	Demerits
• Selective and specific • Long lasting • Self perpetuation • Highly compatible with cultural control and host plant resistance • Highly economical • No chance for resistance • No harmful effects on humans, livestock etc.	• High initial cost • Slow in action • Require special skill • Effect is influenced by insecticides, hyperparasites and alternate hosts. • Do not work under pest complex, pest out break and unfavourable conditions.

Natural enemies of agricultural importance and their role

The biocontrol involves 3 techniques

1. **Inoculation**- Seasonal release of the control agent
2. **Inundation**- Mass release of control agent to control a particular pest at a particular time (using of and viruses)
3. **Augmentation**- Addition of control agents to supplement natural control agents for pest control.

Parasitoids

Parasitoid is an organism that mostly attacks another organism of the same taxonomic class, kills its host, requires only one host for development and parasitic during immature stage and free living in adult stage. Parasitoids belong to the order Hymenoptera (90%) and Dipter (10%).

Hymenoptera

Type of parasitoid	Name of the parasitoid	Family	Target pest	Dose for field application
Egg parasitoids	***Trichogramma chilonis***	Trichogrammatidae	Rice leaf folder Sugarcane internode borer	1 lakh/ha/release - thrice from 37 DAT at 7 days intervals 40,000/ha/release - 6 times from 4^{th} month at 15 days intervals
	T. japonicum	Trichogrammatidae	Rice stem borer	1lakh/ha/ release - 2 releases on 30 & 37 DAT.
Egg Larval parasitoids	***Chelonus blackburnii***	Braconidae	Cotton boll worms	
Larval parasitoids	***Bracon hebetor*** ***Bracon brevicornis***	Braconidae	BHC of coconut	
	Apanteles plutellae	Braconidae	Diamond back moth	
	Eriborus trochanteratus	Ichneumonidae	BHC of coconut	
	Parasierola nephantidis	Bethylidae	″	
	Platygaster oryzae	Platygasteridae	Paddy gall midge	1 parasitised gall/$10m^2$
Larval pupal paratiloids	***Isotima javensis***	Ichneumonidae	Top borer of sugarcane	
Pupal parasitoids	***Trichospilus pupivora***	Eulophidae	BHC of coconut	

	Tetrastichus israeli			
	Brachymeria nephantidis	Chalcidae	,,	
Nymphal adult parasitoids	***Aphelinus mali***	Aphelinidae	Apple woolly aphid	
	Encarsia formosa	,,	Cotton white fly	

Diptera

Type of parasitoid	Name of the parasitoid	Family	Target pest	Dose for field application
Larval parasitoid	***Sturmiopsis inferens***	Tachnidae	ESB of Sugarcane	125 gravid females/ha
	Spoggossia bassiana	,,	BHC of coconut	
Larval Pupal parasitoid	***Eucelatoria bryani***	,,	ESB of sugarcane	

Lepidopterta

Type of parasitoid	Name of the parasitoid	Family	Target pest	Dose for field application
Nymphal adult parasitoids	***Epiricania melanoleuca***	Epiricanidae	Sugarcane leaf hopper ***Pyrilla perpusilla***	

Predators

Predators are bigger in size, kill the prey, free living throughout their life, and require more than one prey to complete development and adults and larvae feed upon similar insects.

Non-insect predators

Arachnids - Spiders, Scorpions, mites
Fishes - ***Gambusia affinis*** on mosquito larvae
Amphibians - Frogs and toads (insectivorous)
Birds - Ducks, owls (on rats), king crow, mynah (on larvae of ***Helicoverpa***)

Reptiles - Lizards, snakes (rats)

Insect predators

Coleoptera : Cocinellidae -***Coccinella septumpunctata, C. rependa*** on aphids
Menochilus sexmaulata on mealy bugs, scales.
Rodolia cardinalis on cottony cushion scale
Cryptolaemus montrouzieri on grapevine mealy bug (10 beetles / vine)

Carabidae - ***Paederus fuscipes*** on rice BPH, leaf folder

Hemiptera : Reduvidae - ***Rhinocoris fuscipes*** on ***H. armigera***
- ***Platymeris laevicollis*** on Rhinoceros beetle

Miridae - ***Cyrtorhinus lividipennis*** on rice hoppers
Velidae - ***Microvelia altrolineata*** on rice hoppers

Neuroptera : Chrysopidae - ***Chrysoperla carnea*** on aphids, scales, bollworms in cotton (50,000- I lakh / ha)

Other predators: Dragonflies, damselflies, preying mantis, robber flies, houseflies, giant water bug, ant lions, owl flies etc. are the other insect predators.

Microbials / Insect pathogens

I. Virus

A. Nuclear Polyhedrosis virus (NPV): it is an obligate pathogen. The virus consists of a proteinaceous polyhedral occlusion body inside which the virions or virus rods are embedded. Due to alkaline gut juice, the virus are liberated, which attack nuclei of cell tissues, fat bodies, tracheal matrix, haemocytes, ganglia and brain. The infected insects become dull in colour, less active and larvae become pinkish white on ventral side. In advanced stages, larvae become flaccid, the skin becomes very fragile and eventually ruptures. Diseased larvae hang upside down from the plants. This is called tree top diseases or '**wipfel krankeit'**

NPV is specific and available for ***H. armigera*** (HaNPV), ***Spodoptera litura*** (SlNPV) and ***Amsacta albistriga*** (AaNPV). The recommended dose for field application is 250-500 LE /ha (1LE=$6x10^9$POBs/ml) with sticking agent teepol and adjuvant jaggery.

B. Granulosis virus (GV) : Virions are occluded singly in small inclusion bodies called capsules. It attacks cytoplasm or nucleus of epidermis, trachea and fat bodies. Infested larvae lose appetite, become sluggish and show milky white colour on ventral surface. GV is also specific and available for sugarcane early shoot borer. The recommended dose for field application is 750 diseased larvae/ha twice at 35 and 50 DAP.

II. Bacteria

It causes septicemia and the infected larvae become less active, loss appetite, may exhibit diarrhea or vomiting or both, body darken to brown or black.

Spore forming bacteria	Non spore forming bacteria
Obligate – ***Bacillus popillae***	***Pseudomonas spp.***
Facultative – ***B. thuringiensis***	***Serratia spp.***

Several commercial formulations of ***Bt*** like Dipel, Thuricide, Bactospein, Delfin, Spicthurin, Biobit, etc. are available against many lepidopteran pests.

III. Fungi: They are facultative parasites, cause mycosis in insects. There are three species of entomophagous fungi available.

Green muscardine fungus, ***Metarhizium anisopliae*** against rhinoceros beetle
White muscardine fungus, ***Beauveria bassiana*** on silk worm
White muscardine fungus, ***Cephalosporium lecanii*** against coffee green scale

IV. Protozoa : ***Farinocystis tribolii*** is effective against red flour beetle

V. Biological control of weeds

Quite many insects feed upon unwanted weeds (weed killers) just the same manner they do with cultivated crops. Because they damage the noxious and menacing weeds, they are helpful or friendly to man.

Desirable attributes of a weed killer

- It should not itself be a pest of cultivated plants
- Should be effective in damaging and controlling the weed
- Should preferably be a borer or internal feeder of the weed and
- Should be able to multiply in good numbers without being affected very much by predators and parasites.

Classical examples of biological control of weeds with insects

1. The prickly pear, ***Opuntia dillenii*** is a very serious weed occupying millions of cultivated area. In India, ***Opuntia dillenii*** was wrongly introduced in 1780 in place of ***O. coccinellifera*** for the cultivation of the commercial cochineal insect ***Dactylopius cocci,*** valued for its dye. The cactus got established and spread rapidly assuming a serous proportion as a noxious weed. It has been practically eradicated by the cochineal insect, ***Dactylopius tomentosus*** (Dactylopiidae : Hemiptera). It resembles the mealy bugs in appearance and habits. It was introduced in South India from Sri Lanka in 1925.

2. ***Parthenium hysterophorus*** (Congress grass, carrot weed, white top) has been successfully controlled in Karnataka by a Mexican beetle ***Zygogramma bicolorata*** (Chrysomelidae : Coleoptera). Grubs (creamy white) and adults (cream coloured with brown mottles) feed on leaves and flowers and active during June to October. One to two beetles destroy a single plant within 45 days.
3. ***Lantana***, a troublesome weed in hill plantations, is kept in moderate check by the coccid ***Orthezia insignis***. But this scale insect has been found to attack a number of cultivated crops also.
4. Caterpillars of Calotropis butterfly, ***Danaus chrysippus*** (Nymphalidae : Lepidoptera) and AK grasshopper, ***Poecilocerus pictus***, (Acrididae : Orthoptera) feed and defoliate completely the Calotropis.
5. Water hyacinth (***Eichhornia crassipes***) was successfully controlled with a weevil, ***Neochetina eichorniae*** (Curculionidae : Coleoplera) in Kerala and Karnataka. The larvae tunnel and feed inside the petioles and crown of the plant. Adults are grey with brown mottles.

CHEMICAL CONTROL

Pesticides : Chemicals used to kill or control pests

Toxicity parameters of a pesticide

LD 50: The dose or amount of pesticide which would kill 50% of the test animals if infested or absorbed through skin.

LC 50: The concentration of a single pesticide which is lethal to 50% of the test animals if infested or absorbed through skin.

LT 50: The time required to kill 50% of the test populations by the desired strength of the pesticides.

Ideal qualities of a pesticide

- It should be highly toxic
- It should have less residual toxicity but with quick knock down effect
- It should be toxic to several life stages
- It should have selective toxicity
- It should not be phytotoxic
- It should be non corrosive
- It should not cause biomagnifications
- It should be compatible
- It should be available in many formulations
- It should be available in good quality

The pesticides are termed as follows based on the target organisms

a. **Rodenticides**– Chemicals used to kill rats. Eg. Zinc phosphide
b. **Insecticides** - Chemicals used to kill insects. Eg. Malathion
c. **Acaricides** - Chemicals used to kill mites. Eg. Dicofol
d. **Avicides** - Chemicals used to kill birds. Eg. Anthraquinone
e. **Molluscicides**- Chemicals used to kill snails and slugs. Eg. Metaldehyde
f. **Nematicides** - Chemicals used to kill nematodes. Eg. Ethylene di bromide
g. **Fungicides** - Chemicals used to kill plant diseases. Eg. Thiram
h. Herbicides - Chemicals used to kill weeds. Eg. 2,4 - D

i. Classification of insecticides

j. 1. Based on mode of entry

a.**Stomach poison** -When ingested through digestive system, brings about kill,. Eg. Malathion
b.**Contact poison** -When contacted, brings about death. Eg. Fenvalerate
c. **Fumigant** - Toxicant enters into tracheal system as vapour and brings about death. Eg. Aluminium phosphide.
d.**Systemic poison** -Chemicals penetrate into plant tissues and translocated through vascular system and cause death of insect feeding on plant. Eg. Dimethoate.

2. Based on mode of action

a. **Physical poison** - Exerts physical effect. Eg. Activated clay
b. **Protoplasmic poison** - Precipitates proteins. Eg. Arsenicals
c. **Respiratory poison** -Inactivates respiratory enzymes. Eg. Phosphine
d. **Nerve poison** - Inhibits impulse conduction. Eg. Organo - phosphorous compounds
e. **Chitin inhibition** - Inhibits chitin synthesis. Eg. Diflubenzuron

4. Based on chemical nature

A. Inorganic compounds: These are compounds of mineral origin. Eg. Sulphur, Zinc phosphide, Arsenicals, Fluorine compounds.

B. Organic compounds

i. **Animal origin :** Eg. Nereistoxin is isolated from marine annelids, *Lumbricorneris heteropoda*. Available as Cartap.

ii. **Plant origin** : Eg. Nicotine, Pyrethrum, Rotenone and Azadirachtin

iii. **Synthetic organic compounds**

Synthetic organic compounds

a. **Chlorinated hydrocarbon** (**Organo chlorine compounds**): These are compounds with chlorine bonded to carbon atoms. These compounds attack central nervous system, ion permeability of nerve membranes and there by axonic transmission. Hyper sensitivity, violent agitation, paralysis followed by death are the symptoms of poisoning.

Important compounds

a. DDT (Dichloro Diphenyl Trichloro Ethene) : It was discovered by Paul Muller. It is an efficient contact poison, but phytotoxic to cucurbits.
b. BHC (Benzene Hexa chloride / Hexa chloro cyclo hexane): It is a very good contact insecticide.
c. Aldrin: It is persistent and effective against soil insects.
d. Chlodane: It is toxic to bees, but effective against soil insects.
e. Heptachlor: It is effective against soil insects.
f. Endosulfan: It is safer to bees, but effective contact poison. Available in several trade names as 35 EC or 4 D.

b. Organo phosphorous compounds

They are esters of phosphoric, phosphonic, thiophosphoric or di thiophosphoric acids. They have quick known down effect, ovicidal, nematicidal and systemic properties, but toxic to human beings. These compounds interfere with impulse conduction along the synapse. They destroy the acetyl choline esterase (AchE) and cause accumulation of acetyl choline (Ach), a chemical transmitter of impulse, in synapse. Increased excitation, tremor, convulsion, paralysis and death are symptoms of poisoning.

Important compounds
Contact and stomach toxicity
Fenthion: Highly persistent having ovicidal action. Available as Lebacid 100 EC.
Malathion: Highly safer. Available in several trade names as 50 EC or 4D.
Quinalphos: Available in several trade names as 25EC or Ekalux 25 AF.

Systemic insecticides
Dimethoate: Available in several trade names as 30 EC.
Methyl demeton: Available in several trade names as 25 EC.
Monocrotophos: Available in several trade names as 36 WSC.

Phosphomidon: Available in several trade names as 85 EC.
Phorate: Available as Thimet 10 G.

DDVP Dichlorvos: Available in several trade names as 76SL.
Chlorpyriphos: Available in several trade names as 20 EC.

c. Carbanates

They are derivatives of carbamic and dithiocarbamic acids. The mode of action is similar to organo phosphorous compounds.

Important compounds
Carbaryl: Broad spectrum insecticide, available as Sevin 50 WP

Cabofuran: Systemic insecticide cum nematicide. Available as Furadon 3G
Aprocarb: Quick knock down insecticide, available as Baygon spray
Aldicarb: Systemic nematicide, acaricide and insecticide. Available as Temik10 G

d. Synthetic pyrethroids

They are synthetic compounds showing structural resemblance of natural pyrethrums synthesized from petroleum based chemicals. They have quick knock down and low mammalian toxicity. They are biodegradable and safe. They affect axonic impulse conduction.

Important compounds
Cypermethrin: Available as Cymbush 50EC and Ripcord 10 EC
Fenvelarate: Available as Sumicidin 20 EC
Permethrin: Available as Permasect 25 EC
Allethrin: Available as Mosquito mats/coils 1 or 1.5%
Prallethrin: Available as Mosquito mats/coils 1 or 1.5%
Cyclothrin: Available as Mosquito mats 1 or 1.5%

e. Rodenticides: These are chemicals used to kill rats.
Acute poison- Zinc phosphide: Used as bait with popped rice or corn at 1:49

Chronic poison- Warfarin: Used as bait with popped rice or corn at 1:19
Bromodialone: It is an anticoagulant, available as ready cakes (moosh-moosh, Rat kill, etc.)

PESTICIDE APPLICATION TECHNIQUES

1. Dusting

1. Dusting is carried out iin morning hours and during very light air stream to improve better deposition. Dusting is cheaper and suited for dryland crop pest control. The normal dose is 25-50 kg per hectare.

2. Spraying

EC or WP formulations are mixed in water and than sprayed.

High Volume spraying 500 – 1000 lit / ha

Low Volume spraying 150 – 200 lit / ha

Ultra low volume spraying 2-4 lit / ha.

3. Granular application

The highly toxic pesticides are handled safety in the form of granules.

a. In furrow application: The granules are applied at the time of sowing in furrows in beds as well as on the sides of ridges.
b. Side dressing: After the establishment of the plants, the granules are applied a little away from the plant (10 – 15 cm) in a furrow. For fruit trees side dressing is done in a ring form around the tree.
c. Water surface application: Granules are broadcast on water surface in rice field.
d. Leaf whorl application: Granules are applied in the central whorl of crops like sorghum, maize, sugarcane etc. to control internal borers.
e. Pralinage: The surface of banana sucker intended for planting is trimmed with a knife. The sucker is dipped in wet clay slurry and carbofuran 3 G is sprinkled at 15-40 g / sucker to control burrowing nematode and rhizome weevil.

4. Seed Pelleting / Seed dressing

Seeds are mixed with insecticide (sorghum seeds with chlorpyriphos @ 4ml / kg in 20 ml of water) or dressed with insecticide (Sorghum seeds directly dressed with Carbosulfan 25SD)

5. Seedling root dip

To control sucking pests and stem borer, rice seedlings are dipped in solution prepared in a shallow pit lined with polythene sheet for 20 minutes (0.5 kg urea in 2.5 lit. of water and 100ml chlorpyriphos in 2.5 lit. of water prepared separately and the volume made up to 50 lit.)

6. Trunk / Stem injection

Insecticide (monocrotophos 5ml) is injected into a slanting hole (5cm depth) made on trunk at 1.5m above ground level. The hole is then plugged with cement or clay to control coconut BHC.

7. Padding

Stem borers of mango, silk cotton and cashew are controlled by this method. Bark (5x5cm) is removed on three sides leaving bottom as a flap. Small quantity of absorbent cotton is placed in the exposed area and 5-10ml of monocrotophos 36WSC is poured using ink filler. Close the flap and cover with clay mixed with fungicide.

8. Swabbing

Swabbing the trunk and branches with Lindane 20 EC controls coffee white borer (@1300 ml in 200 lit. of water along with 100 ml of sandovit or vettoplant).

9. Root feeding

It is the safe method to control coconut pests without wounds to trunk. Monocrotophos 36WSC 10ml is mixed with 10ml water and then taken in a polythene bag. An absorbing tender root of pencil thickness is identified and a slanting cut (at 45º) is made at root tip. The cut end of root tip is placed inside the insecticide solution in the bag and the bag is tied with root. The insecticide enters plant system through roots and controls the pests by systematic action.

10. Capsule placement

The systemic poisons could be applied in capsules to get toxic effect for a longer period. Eg. In banana to control bunchy top vector the insecticide is filled in gelatin capsules and placed in the crown region.

11. Soil drenching

Drenching of soil is advocated for certain subterranean pests. Eg. Cotton stem weevil could be controlled by soil drenching with HCH 0.1 percent.

12. Baiting

Baiting is done for the control of grasshoppers, caterpillars, cutworms, rats etc.,

a. Cutworm: A bait prepared with 0.5 kg molasses, 0.5 kg carbaryl 50WP and 5 kg of rice bran with required water is made into small pellets and dropped in the field in the evening hours. A pelleting device is available to pelletise the bait material.
b. Rats: Two groups of rodenticides are used for bait preparation

c. Acute poison: A single dose is enough for zinc phosphide. Prebaiting without poison is necessary for three days. On fourth day zinc phosphide is mixed at 1:49 ratio with food like popped rice or maize or cholam of coconut pieces or dried fish or wheat flour. Addition of few drops of oil and a pinch of salt increase the palatability of this bait.
d. Chronic poison: These compounds are to be applied for 4-5 days repeatedly. Probaiting is not necessary. Eg. Warfarin or Fumarin.

A ready to use cake formulation of a rodenticide i.e. Bromodiolone is also currently used for rat control. The cake pieces can be directly in required area.

13. Fumigation

Fumigants are available in solid and liquid forms recommended mainly in godowns to control stored pests. Liquid fumigants are injected into soils for nematodes control, or used for cover / shed fumigation in storage. Solid fumigants (Aluminium phosphide) are inserted into affected portions in trunk of coconut @ 1 tablet/tree for the control of red palm weevil or into live burrows @ 2 tablets each of 0.5-0.6 g / burrow to control rats. The holes are then plugged with cement or mud.

PLANT PROTECTION APPLIANCES

A. Dusters

1. Rotary duster

It consists of a blower with gearbox and a hopper with a capacity to hold 4-5kg dusts. The duster is operated by rotating a crank and the motion is transmitted through the gear to the blower. The air current produced by the blower draws the dust from the hopper and discharges out through a delivery tube. The efficiency is 1-1.5 ha / day.

2. Knapsack duster

It consists of dust container of 2-5kg capacity through which air current is blown by means 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 dusting low crops and spot application.

3. Power operated Dusters

They work by means of apetrol engine generally 1 to 3 HP. Larger dusters may have engines of 15 to 75 HP and are mounted to tractors. These dusters are useful for covering larger and tall trees and suitable in locust control also. A power duster with a single outlet can cover 2 ha per day.

B. Sprayers

Principle: The function of a sprayer is to atomize the spray fluid into small droplets and eject it with some force.

Parts of a sprayer: Tank, agitator, pressure gauge, valves, filters, pressure chamber, hose, spray lance, cut off device, boom and nozzle

I. Hydraulic sprayers : Hydraulic pressure is utilized for atomizing the spray fluid

1. Bucket 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 the spray fluid. It consists of a double acting pump with two cylinders or a single pump with one cylinder. The discharge is continuous only in double pump. This is suited for small scale spraying.

2. Knapsack sprayer

It is similar to bucket type and fits comfortably on the back of the operator. It consists of a piston pump, a lever to operate, a built in tank (10-14 litre capacity), hose, lance and a nozzle. A lever handle at the top or side is used for developing pressure inside the tank.

3. Rocker sprayer

It consists of pump assembly, platform, operating lever, pressure chamber, suction hose, delivery hose and an extension rod with spray nozzle. By rocking movement of the lever, pressure can be built in the tank. With the high pressure developed and also with long hose, this is used for spraying fruit trees and tall crops.

4. Pedal / Foot sprayer

It consists of a plunger assembly, a stand, a suction hose, delivery hose and extension rod with a spray nozzle. The principle is same as in rocker sprayer, but it is operated by foot instead of hand.

II. Pneumatic sprayers (Air compression sprayers)

1. Pneumatic hand sprayer

The container for the spray fluid also acts as pressure chamber. An air pump is attached to the chamber. The tank is filled to ¾ capacity and the pump is worked to build sufficient pressure upon spray fluid. This sprayer is used for spraying glass house and kitchen garden plants.

2. Pneumatic knapsack sprayer

This is used for spraying large quantity of liquid. It is similar to pneumatic sprayer in workings. It comprises of a tank for holding the spray fluid with compressed air, a vertical air pump with a handle, a filter hole, a spray lance with nozzle and a cut off device. Before starting the sprayer, air is compressed into the empty space in the tank.

III. Power operated sprayers

a. Mist blower cum duster

The spray fluid is blown out from the primary unit by means of intensive air current produced at high velocity by the engine. The sprayer consists of chemical tank, fuel tank, carburetor, spark plug, engine, blower assembly, delivery system, nozzle system and starter pulley. The power operated spraying system can be converted into a dusting unit by changing certain components.

b. Hand carried, battery operated spinning disc sprayer:

These light weight sprayers have a plastic spray head with small dc motor which drives a rotating disc, a liquid reservoir, a handle and a power supply unit. They are used on crops like rice , cotton, groundnut, tomato, maize etc. in places where farmers have difficulty in collecting water for conventional spraying systems.

c. **Electodyn sprayer**

The invention of "Electrodynamic spraying" (EDS) is a revolutionary breakthrough in the field of Controlled Droplet Application (CDA) which stresses need for a uniform and narrow droplet size range to achive effective control. This spraying target crops and appears extremely simple in operation.

EDS puts more of active chemical on the target than any other spraying system because

i. Charged droplets are attracted to target to target crop.
ii. Coverage on undersides of leaves, where many pests feed (Wraparound) spray and
iii. Minimal drift to non-target areas.

The EDS consists 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. The bozzle contains ready formulated chemical for immediate application to crop. It required less energy i.e. with four standard batteries an area of upto 40 hectares can be covered.

C. Other appliances

1. Bird scarer

It produces loud noise at regular interval and used to scare away the birds. It consists of a big chamber to hold calcium carbide and a small chamber inside the former to hold water. Water is released into the big chamber in slow trickles. Calcium carbide and water react to produce acetylene gas. The gas accumulates against a pressure valve. When sufficient pressure develops, the valve opens and the gas explodes resulting in loud noise, which scares away birds. The valve closes once the pressure is relieved. Frequency of blasts can be regulated by regulating the water flow.

2. Flame thrower

It is ordinary pneumatic sprayer but the lance and nozzle are replaced with metal burner. Kerosene is taken in the tank. It is used to destroy locust swarm and congregating hairy caterpillars

3. Soil injector or gun

It is used for fumigating the soil at different depths to control the nematodes and the soil insects. It has a mechanism to regulate the quantity of nematicide applied and the depth at which the nematicide is to be applied in the soil. It consists of a tank, a pump barrel, plunger assembly, injector, nozzle, thrust handle and an injection handle. By holding the thrust handle, the equipment is thrust into the soil till the nozzle rod gets into the soil completely and the injection needle pressed to release the calculated quantity of liquid fumigant.

PESTICIDES AND THE ENVIRONMENT

Insecticide residues

The toxicant retained for sometime in the environment after application is called **insecticide residues** and the duration of retention is known as its **persistence**. Residue tolerances are permissible residues in terms of ppm of actual chemical in the products used by man and animals. The **EPA** (Environmental Protection Agency) of USA established tolerance level for various pesticides. For example for Malathion, it is 2 ppm in cotton and 8 ppm in vegetable; for carbaryl it is 5 ppm in cotton and 100 ppm in other crops.

Maximum Residue Level (MRL)

Maximum concentration of pesticide residue in a produce resulting from pesticide usage accepted legally.

Acceptable Daily Intake (ADI)

Daily Intake of a chemical, which, during entire life time, appears to be without appreciable risk, on the basis of all the facts known at the time. It is expressed in milligrams of the chemical per kilogram of body weight.

ADIs and MRLs are not permanently fixed values. In India the MRL values for pesticides are prescribed under the **Prevention of Food Adulteration Act, 1954.**

Good Agricultural Practice:

GAP (in the use of pesticides) is the officially recommended or authorized use of pesticides, under practical conditions.

Waiting periods

The time interval between the spray and harvest of the produces to avoid pesticide toxicity. It varies with insecticides. Normally it is 3 day for Malathion, 7 days for carbaryl and endosulfan and 15 days and above for Monocrotophos.

Environmental pollution

Improper use of pesticides causes environmental pollution in different ways. The contamination may be due to drift, leaching, and persistence in soil. **The causes are;**

1. Use of non selective insecticide
2. Non-adoption of application details and guidelines

3. Not following ETL and indiscriminate use of insecticides.
4. Choice of wrong dispersing aids.

Systemic poisons are the least contaminants of the environment as they are degraded quickly into harmless compounds. However, persistent *Chlorinated hydrocarbons* (OC) are mostly responsible for pollution.

Impact of Pesticides on Agroecosystem:

I. **Abiotic Environment**: Include soil, air and water.

1. Soil: Source of contamination: Direct application; Fallout from plants; Rain
   Reason for persistence: Resist biochemical and microbial degradation
   Effect: Affect soil flora and fauna. Get into plants.
2. Air: Source of contamination: Drift during conventional and aerial application; Volatilization; Thermal decomposition; Evaporation with water vapour.
   Effect: Inhalation toxicity; Enter into soil and water.
3. Water: Source of contamination: Direct treatment; Surface run off; Aerial spraying; Precipitation.
   Effect: Biomagnification; Reduction of O_2 content; Toxic to fishes.

II. Plants

1. Presence of residual amount – health hazard.
2. Damage because of phytotoxicity
3. Changes in the vegetative development – Etiolation by herbicide

III. **Animals:**

1. Domestic Animals; Source: Forage treatment; Direct application
   Effect: Chronic poisoning; Storage in fat reserves
2. Wild Life: Trophic transfer of pesticides through food chain kill wild life eg. Egg shell thinning led non-vitality of bird eggs through D.D.T poisoning.
3. Natural Enemies: Elimination of parasitoid and predators upset the biotic balance.

   Effect:

   i) Pest resurgence: Recovery of pest population following the application of insecticides to levels higher than before treatment. eg. BPH resurgence after quinalphos application.
   ii) Secondary pest outbreak: Increase in the population of non-target insect to damaging levels followed by the application of pesticides due to the elimination of natural enemies of minor pests or potential pests eg. Red spider mite outbreak in apple followed by the application of organo chlorines.

4. Pollinators: Pesticide application during blooming kill honey bees.

IV. Man

1. Operational hazards: Manufacture – Distribution – Application – Post application.
2. Accidental and intentional poisoning.
3. Indirect hazards through food chain – Handigodu syndrome
4. Diseases: Carcinogenic, Mutagenic and Teratogenic effects

V. Food:

Residues in human food – reason: Use of persistent chemicals; Spraying crops nearing harvest; Excessive use of pesticides.

VI. Target Insect:

Development of resistance to insecticides. Excessive use exert a high selection pressure in selecting resistant strains. eg. Mosquito resistance in DDT; Synthetic pyrethroid resistance in bollworms.

How to avoid pollution?

- Choose a selective insecticide
- Use only adequate dose
- Apply insecticides at a time when drift would be very minimum or nil
- Use non persistent soil insecticide whenever necessary
- Use sticker or spreader with insecticides
- Use correct spraying device
- Use an insecticide only when it is absolutely necessary
- Do not indulge in dipping the produce in a solution of pesticides
- Don't spray before harvest
- Don't wash spray equipments, cloths in pods, rivers, irrigation channels etc.,

PESTICIDE HANDLING AND USAGE

Compatibility

Compatibility is combination of insecticides to get higher protection without any adverse effect. As for as possible insecticides should not be mixed, because the mixtures may cause various reactions.

The incompatibility may be;

1. Chemical incompatibility (different compounds are formed due to combination).
2. Phytotoxic incompatibility (mixtures cause injury to plants) and
3. Physical incompatibility (Physical from chemicals is changed)

Always we should have the compatibility charts.

Handling of pesticides and precautions

Before spraying

- Use pesticides if pest has exceeded to ETL
- Read instructions manual of pesticide and equipment
- Ascertain that all components are clean and perfect
- Test the sprayer for pumping, discharge etc.,
- Calibrate the sprayer with proper nozzle.
- Make sure that appropriate protective clothing is available
- Ensure that soap. Towel, and plenty of water is available
- Never work alone when holding highly hazardous pesticides
- Mix chemicals outside or in a well ventilated area
- Persons engaged in mixing, handling, or applying pesticides should not smoke, eat, or drink while working.
- Don't use mouth to siphon a pesticide from a container
- Clean up spilled pesticides immediately from skin clothing
- Always use gloves while mixing pesticides

During spraying

- Take only sufficient pesticide for the day's application from the store
- Recheck the use instructions of pesticide and equipment
- Mix the pesticide thoroughly in correct quantities
- Wear appropriate clothing
- Avoid contamination of the skin especially eyes and mouth'
- Don't spray in high wind, high temperature and rain
- Spray along the wind, not against the wind
- Never blow out clogged nozzles with mouth
- Never allow children during mixing
- Never leave pesticides un attended in the field
- Newer allow cattle's near by and never spray if the wind is blowing towards grazing livestock or pastures regularly used.
- Follow correct spray technique and spray crop throughly.

After spraying

- Dispose the pesticide containers in pits in waste lands.
- Never empty the tank into irrigation canals or pods
- Never leave unused pesticides in sprayer
- After spraying clean the sprayer and oil it.
- Don't use empty containers for any purpose
- Clean buckets, sticks, measuring jars etc.,

- Wash protective clothing and take bath well and put on clean clothing.
- Mark the sprayed plots with a flag
- Keep a accurate record of pesticide usage

Pesticide poisoning and first aid

Pesticide poisoning can happen in

- Deliberate consumption for suicidal purposes
- Working in pesticide manufacturing units
- Using pesticides in farm activities

Clinical features

OC compounds – Muscle twitching, fits, unconsciousness coma
OP compounds – Watering eyes, running nose, cough, breathlessness, vomiting, diarrhea, abdominal pain.
Pyrethroids - Muscle twitching fits.

First aid

- Remove the victim from the site to fresh air
- Look for the adequacy of breathing. If breathing is is inadequate take steps to restore normal breathing.
- Remove all contaminated cloths and wash the body
- Induce vomiting if swallowed
- Don't give alcohol in any form
- Give strong tea or coffee
- Take the patient for medical attention

Antidotes

A. General antidotes

a. Removal of poison: Remove poison by inducing vomiting.
b. **Universal antidote**: A mixture of 7g of activated charcoal, 3.5 g of magnesium oxide and 3.5 g fo fannic acid in half glass of warm water to neutralize poisons.

a. **Gastric lavage** (Removal of stomach contents): Do gastric lavage to remove poisons from the stomach
b. Demulcents (Substances having soothing effect) : After the stomach has been emptied, give raw egg white mixed with water or butter or milk or cream or masked potato.

B. Specific antidotes

OC- If swallowed give universal antidote, followed by gastric lavage and then give magnesium sulphate in a glass of water, followed by hot tea or coffee. Inject 10 ml of calcium gluconate intravenously.

OP- Give Antropine. Administer artificial respiration in case of respiratory failure.

Advantages of Chemical control

- Insecticides are only means of preventing economic damage
- Insecticides are readily to use
- A range of pesticides are available
- Easy to adopt in larger areas
- Work out under special conditions pest out break, pest complex
- Assured income to farmers
- Compatible with other components

Disadvantages of Chemical control

- High cost
- Toxic to natural enemy, bees etc.
- Cause environmental pollution
- Cause resistance and resurgence in insects

THIRD GENERATION PESTICIDES (BIORATIONALS)

1. SEMIO CHEMICALS

Definition

Chemicals that deliver behavioural messages which act either interspecially or intraspecifically.

Interspecific semiochemicals

1. **Allomone** - Interspecific semiochemical that favours the produces E.g. Repellents, Deterrents (feeding and ovipositional)
2. **Kairomone** - Interspecific semiochemical that favours the receiver E.g. attractants ' Food love"
3. **Synamone** - Interspecific semiochemical that favours both the producer and receiver E.g Plant odours attracting natural enemies of pests.
4. **Apneumone**: Chemical from non-living materials eliciting behavioural response. E.g. Fish meal attracting sorghum shoot fly

Intraspecific semiochemicals

1. **Pheromone-** Semiochemical used for intraspecific communication which is an exocrine secretion that causes specific reaction in the receiving individuals of the same species.
2. **Sex pheromone-** Female produce to attract males E.g. Bombyco (*Bombyx mori*) Cyplure (gypsy moth) and Gossyplure (Pink boll worm) (In American boll weevil males produce)
3. **Alarm pheromone-** Semiochemicals used to warm other fellow individuals from mandibular glands or anal glands. E.g. honey bees (E) B. Farnesene aphids.
4. **Trailmarking pheromone-** Semiochemicals used in route perception. Eg. Ants, termites.
5. **Aggregation pheromone-** Semiochemicals which attract other fellow members to a particular spot. E.g. Ferrolure of red palm weevil.

PHEROMONES IN INSECT PEST MANAGEMENT

The synthetic pheromones are used to monitor pest population attract and kill insects and confuse male from mating (mating disruption). Lures are available for following pests

1. *Helicoverpa armigera* - Heli lure
2. Tobacco caterpillar *S. litura* - Spode lure/Pherodin SL
3. Pink boll worm *Pectinphora gossypiella* – Pectinolure/Gossyplure
4. Rhionceros beetle *Orycetes rhinoceros* – Sime RB or Rhinolure
5. Red palm weevil – *Rhynchophorus ferrungineus* – Ferrolure
6. Spoted boll worm *Eavis* – Erin lure.
7. β Farnescene (EBF) has been identified as alarm pheromone of aphids – *Aphis gossypii*.

The number of traps required for monitoring is 12 /ha.
Set up at 1-2′ inch above the crop level

Types of pheromone trap

1. Funnel trap for mamy insects
2. Sticky trap / delta trap for pink boll worm
3. Bucket trap – red palm weevil & rhinoceros beetle

2. STERILITY METHOD/ STERILANTS

Sterility method envisages the use of insects to bring down the population. Insects are used against members of their own species to reduce the populations and hence called as autocidal control. Autocidal control received siginificance after E.F. Knipling, a USDA scientist in the 1950's when the population of screw wormfly ***Cochliomyia homvinvorax***, a parasite of cattle was eradicated in Curaca island in United State.

Principles of Autocidal control

1. Flooding a population with sterile males which mate with normal females
2. Such mating result in inviable eggs
3. With continued sterile male releases the population declines
4. The ratio of sterile to normal males increases until virtually no normal males remain
5. Population becomes extinct for lack of progeny

Release of sterile males in the ratio of 9:1 of the wild populations of male for successive generations results in the population reaching zero in F4 generations (This is called male sterile technique)

Methods of sterilization

A. Ionizing radiation

Electromagenetic radiation such as gamma rays and X rays cause sterilization in insects. At 200-500 kiloroads (k rads) ionizing radiation brings about complete death. At 100 krads ionizing radiation causes sterilization and subsequent death. At 8-10 krads ionizing radiation causes sterilization

B. Chemosterilants

Chemicals which deprive insect species of their ability to reproduce chemosterilants are dangerous and carcinogenic or mutagenic.

They are classified into

a. **Alkalating agents**. E.g. TEPA and Metapa. Tepa 0.025% ina protein hydrolysate trap is used for sterilizing the Mexican fruit fly.

b. **Antimetabolities**. E.g Amethopterin and
c. **Miscellaneous compounds. E**.g. Hempa and Hemel. They are effective against housefly.

The chemosterilants could be applied in traps containing attractants, so that the lured insects pick up the chemical and sterilized. Housefly, Mosquito, fruit fly, screw worm fly etc. are controlled by this male sterile technique.

3 INSECT GROWTH REGULATORS (IGRs)

IGRs are chemical that alter normal growth and development by interfering with the insect endocrine systems. Synthetic compounds possessing activities of juvenile hromone and moulting hormone of insects, often termed as ' miimics' or insect growth regulants.

JH analogues (interfere with the growth and development)

1. Methoprene (Altosid) - JH analogue effective against many dipeterans (Mosquito larvae)
2. Knioprene (Enstar) – JH analogue effective against whiteflies and mealy bugs.

Moulting inhibitors (inhibit chitin synthesis and moulting)

3. Diflubenzuron (Dimilin)- Inhibits chitin synthesis and thus affects the moulting effectice agaisnt Le. 2 col. Insects.
4. Buprofezin (Applaud) – Mould inhibitors effective agaisnt sucking pests (BPH)
5. Lufenuron – Available as Match 5 EC or ' Rimon' 10 EC (Especially for Helocverpa and Diamond Black moth)

Advantages : Low mamalion toxicity, environmentally compatible.

4. ATTRACTANTS (Kairomone)

Chemicals substances which elicit oriented movements by insects towards their sources are called attractants. These are mainly food attractants and oviposition attractants. Baits are prepared with these products and laced with insecticides to attract and kill insects. Example;

Methyl eugenol for fruit flies
Fish meal for shoot flies
Ricebran + jaggery for *Spodaptera larvae*.
The pheromones are also attractants.
Advantages : Specific and thus no harmful effects.

5. REPELLENTS (Allomone)

Chemicals which cause insects to move away from their sources are called repellents. Repellents are usually volatile chemicals. Example;

Citronell oil - mosquito repllent
Neem oil - feeding and oviposition repellent for insects
Bordeaux mixture- was the first synthetic chemical repellent for chewing insects and leaf hoppers.

Advantages : Low toxicity to higher animals and no resistance development

Disadvantages : Complete coverage required and possibility of increasing infestation near by.

6. ANTIFEEDANTS OR FEEDING DETERRANTS (Allomone)

Chemicals which inhibit feeding of insects on a treated surface without necessarily killing or repelling them are called antifeedants. Antifeedants inhibit the taste receptors of mouth region and in the absence of gustatony stimulus, the insects fails to recognize the treated leaf as food.

Carbamate – Arprocarb is a systemic antifeedant against boll weevil, ***Anthonomous grandis***

Botanical extracts – Pyrethrum. Azadirachtin and Many plant products / extracts are found to be repellents and antifeedants against many pests

NEWER INSECTICIDES / COMPOUNDS

I. Naturalytes

A. **Avermectins** : They are discovered from ***Streptomyces avermetilis*** by Merck & Co. **.** The analogue Avermectin B1 (Commercially available as Abamectin) is insecticidally most active (systemic).

B. **Spinosyns** : In 1994 Dow Elango – announced a new class of insect control active molecules called ' spinosyns'. They are naturally derived from a new species of Actinomycetes, ***Saccharopolyspora spinosa***. Commercially available as spinosad. It shows both contact and stomach activity against different types of insects. Spinosad causes persistent activation of Ach receptors in the insect nervous system.

C. **Cartap hydrochloride**: It is extracted from a marine annelid, ***Lumbriconereis heteropoda***.It has systemic, contact and stomach poisons. It is effective against chewing and sucking pests. Commercially available as Caldan 50SP.

II. Neo nicotinoids

a. **Chlornicotynyl compounds**

The chemical Imidocloprid (Bayer) is available as Goucho 70WS for seed treatment and Confidor 200SL for spray application.

b. **Thionictoynyl compounds**

The chemical Thiomethozam (Syngenta) is available as Cruiser 70WS for seed treatment and Actara 25WG for spray application.

c. **Thionictoynyl compounds :** Chemical is yet to come in this group

MOA : Neo nicotinoids bind the receptor portion of synape

III. Organophosphates

a. Profenofos

It is contact and stomach poison insecticide and also having translaminar in action. It is mainly targeted against suking pests, bollworms and mites in different crops. Commercially available as Curacron 50EC.

b. Triazophos

It is an effective acaricide and targeted against sucking and chewing insects. It is contact and stomach poison. Commercially available as Hostathion 40 EC

c. **Carbamates**: The following are the newer carbamates

Indoxacarb	-	Avaunt 14.5 SC
Thiocarb	-	Larvin 75 WP
Carbosulfan	-	Marshal 25 EC

These carbamates are contact and stomach poisons. Their effective against sucking and chewing insects.

d. Synthetic Pyrethroids

The following are the two newer synthetic pyrethroids having contact and stomach poison. They are effective against sucking and chewing insects.

Lamda cyhalothrin	-	Karate 5 EC, Kungfoo 2.5 EC
Beta cyfluthrin	-	Bulldock 0.25 SC

Lamda cyhalothrin is alo having phytotonic effect.

INTEGRATED PEEST MANAGEMENT

INTEGRATED PEEST MANAGEMENT

" It is a broad ecological pest control approach aiming at best mix of all known past control measures to keep the pest population below ETL.

It is the pest management system that utilizes all suitable techniques and methods in a compatible manner as possible and maintains pest populations at levels below those causing economic injury.

Why IPM?

It is an economically justified and sustainable system of crop protection that leads to maximum productivity with the least possible adverse impact on the total environment.

Objectives of IPM

- To keep the pest numbers below ETL instead of their eradication.
- To protect and conserve the environment including bio-diversity.
- To make plant protection feasible, safe and economical even for the small farmers.

History

- Chinese discovery of the use of soap to control pests in 1101 A.D.
- Concept of plant resistance in 1700 s
- In early 1900s rapid development of insecticides like DDT, organo phosphates etc.,
- The insecticidal approach become a major preoccupation in pest control
- The total use of pesticides was 434 tones in 1954 and now it is > 1,00,000 tons in 2000-2001
- Pesticide usage solved pest problems initially but has given rise to development of resistance, resurgence, destruction of beneficial organisms, besides affecting human health and degrading quality of the environment.
- After 1970s IPM gained momentum with the concept of integration of control techniques.

Strategies

- Do nothing when pest densities are below ETL.
- Reduce pest population numbers- usually when pest densities reach ETL
- Reduce crop susceptibility to pest injury -most effective and environmentally desirable strategy HPR and environmental manipulation.
- Reduce both population numbers and crop susceptibility.

Components IPM

These are cultural, physical, mechanical, biological, HPR and insecticidal control methods.

Definitions of IPM

The concept of 'IPM' from pest control has emerged during late 1960's. IPM is an ecologically based system approach by harmonious of carefully selected pest control practices based on economical and social consequences.

Smith, 1978 defined IPM as a multi-disciplinary ecological approach to the management of pest populations, which utilizes a variety of control tactics compatibly in a single coordinated pest management system.

Frisbie and Adikisson (1985) defined IPM as a pest population management system that utilizes all suitable techniques in a compatible manner to reduce pest populations and maintain than at levels below those causing economic injury.

Luckman and Metcalf (1994) defined IPM as the intelligent selection and use of pest control tactics that will ensure favourable economical, ecological and sociological consequences.

Objectives of Integrated Pest Management (IPM)

- To keep the pest numbers below ETL instead of their eradication.
- To protect and conserve the environment including bio-diversity.
- To make plant protection feasible, safe and economical even for the small farmers.

Constraints (demerits) of IPM

- **Institutional constraints** : like lack of coordination among faculties, institutional barriers to research scientists.
- **Informational constraints**: Lack of IPM technology among farmers.
- **Sociological constraints**: Coordinating of most farmers to use insecticides, lack of coordination in society.
- **Economic constraints**: Farmers depend on shopkeepers or pesticide dealers for pesticides on credit and for information about the pest control methods.
- **Political constraints**: Subsidy by government for insecticides major constraints to farmers acceptance of IPM.

Potential (merits) of IPM

- Sustainability
- Economics -lower economic costs
- Health - low health hazards
- Environmental quality- environmental safety to non-targets organisms- no environmental pollution.
- Social and political stability-through utilization of local inputs.
- Local knowledge -indigenous farming, traditional cultivation, practices can also be integrated.
- Export of agricultural commodities - produced through organic farming.
- No chance for resurgence or resistance.
- Well suited for rural areas.

INTEGRATED PEEST MANAGEMENT IN RICE

In India the first IPM Programme in rice was started in 1975 at Cuttack covering an area of 1000 ha in 10 villages. Pesticides usage is reduced by 50-100% in IPM fields. At the same time, there was an increase in yield by 6.2-42.1% in IPM fields as compared to non-IPM fields (Rajak et al, 1997).

Cultural

- Remove and destroy stubbles after harvest.
- Trimming and plastering of field bunds
- Synchronized sowing
- Leaving rogue space
- Avoiding closer spacing in endemic areas
- Judicious water management
- Avoiding excess fertilization especially nitrogenous fertilizers
- Removing the stem borer egg masses.

HPR

- Use resistant varieties E.g. TKM 6 against stem borer, P4, CO 42, IR 64 against BPH and MDU 3 against gall midge.

Behavioural

- Using traps for monitoring and trapping

Biological

- Conserving spiders, mirids and other natural enemies by reduced rounds of insecticidal sprays and spraying safer insecticides.
- Release *T. Japonicum* @ 1 lakh per ha twice on 30 and 37 DAP against stem borer and *T. chilonis* @ 1 lakh per ha thrice on 37,44 and 51 DAP against leaf folder.
- Release *Platygaster oryzae* parasitized galls @ 1 /10^2 10 days after planting against gall midge.

Chemical

- Avoiding resurgence inducing insecticides like guinalphos methyl parathion, phorate and synthetic pytothroids.
- Need based application of insecticides at recommended doses.

Plant products

- NSKE 5% or Neem oil 3% can be sprayed against BPH, leaf folder and GLH.
- Ipomea leaf powder and Prosopis leaf powder are effective against earhead bug.

Rat management

- Dig and destroy the burrows and rats after harvest.
- Maintain narrow bunds
- Set up owl perches
- Use poison leaf at 1 part Zn phosphide with 49 parts of popped corn /rice/dry fish or warfarin 1 part with19 parts of popped corn/rice/dry fish or bromodiolone (1:49) cakes.

INTEGRATED PEEST MANAGEMENT IN COTTON

In India, IPM in cotton was studied in Punjab in 1975. The adoption of IPM technology resulted in 74.7% and 12.4% reduction in insecticide usage against sucking pests and boll worms respectively. Yield of cotton from IPM fields increased by 21-27% as compared to non-IPM areas.

General packages

- Remove cotton crop and dispose off as soon as harvest is over
- Avoid staking of stalks in the field
- Avoid ratoon and double cotton crop
- Synchronized sowing within 10-15 days
- Choose and grow one variety in a village
- Use acid delinted seeds.
- Avoid other malvaceous crops in the vicinity
- Maintain fields weed free
- Adopt timely earthing up
- Follow judicious fertilizer (N) and water management
- Set up specific pheromone traps of pink boll worm *Spodoptera* and American boll worm for monitoring the moth activity.
- Collection and destruction of egg masses, damaged plant parts, fallen squares, flowers and bolls.
- Avoid usage of pesticides indiscriminately. Avoid usage of a single pesticide continuously. Follow need based (ETL) application of insecticides.

Specific IPM packages

1. White fly

Cultural

- Crop rotation -non hosts
- Destruction of alternate weed hosts like Abutilon
- Avoid cultivation of brinjal, tobacco, tapioca, chillies, pulses, bhendi in vicinity.
- Follow judicious use of 'N'

Behavioural

- Monitor the activity of adults by setting up yellow pan traps and sticky traps

Mechanical

- Collection and removal of white fly infested leaves on plants and fallen on ground.

Chemical

- Spray neem oil 3% or fish oil rosin soap @ 1 kg /40 lit of water
- Use of synthetic pyrethoids should be avoided.
- Use only recommended insecticides.

2. Helicoverpa

Cultural

- Synchronized sowing with short duration varieties
- Crop rotation with non host crops
- Optimum use of Nitrogenous fertilizer and water

Mechanical

- Collection and destruction of infested bolls, squares and flowers and grown up larvae.

Biological

- Apply NPV @ 500 LE /ha in the evening Hours with teepol (0.1%) and adjuvant (jaggery) at 7th and 12th week of sowing.
- Inuntative release of Trichogramma @ 6.25 cc/ha at 15 days interval from 45 DAS.
- Release of chrsoperla @ 1 lakhs / ha at 6th,13th and 14th week after sowing.

Behavioural

- Set up light trap @ 1 /2 ha and pheromone traps @ 12/ha to monitor and trap adult moths.

Chemical

- Discourage indiscriminate use of insecticides, especially syn. Prethroids.
- Avoiding combination of insecticides as tank mix.
- Use after insecticides to natural enemies and use the insecticides in rotation.

3. Spodoptera

Cultural

- Growing castor (trap crop) along border and irrigation bunds.
- Removal and destruction of egg masses in trap crops and cotton and early stage gregorious larvae.
- Hand picking and destruction of grown up caterpillars.

Behavioural

- Set up light trap, pheromone traps.
- Spread blue cloths (0.5 x 0.5 m size) in field during evening collet and destroy congregating larvae in the next day morning.
- Poison baiting with rice bran 12.5 kg, jaggery or molasses 1.25 kg, carbaryl 1.25 kg + 7.5 litres of water. These are mixed together and made into pellets. The pellets are dropped in the field during evening hours.

Biological

- Spray NPV @ 250 LE /ha in the evening Hours.

Chemical

- Spray recommended insecticides at recommended doses using high volume sprayers.
- Cover thoroughly the foliage and soil surface.
- Spraying insecticides in the evening Hours.

BIOTECHNOLOGICAL APPROACHES IN PEST MANAGEMENT

Recent advances in molecular biology aimed at developing host plant resistance by exploiting biotechnology and genetic engineering.

Transgenic plants

The application of transgenic plants through genetic engineering is the latest concept in IPM. These transgenic plants produce inseciticidal or anti-feedant proteins continuously in the plant under field conditions. Bt endotoxin gene and cowpea protease inhibitor (Cp Ti) genes are the common genes conferring insect resistance.

The genome responsible for δ endotoxin is isolated and introduced into plants and thus the plants with expression of the introduced genes are called transgenic plants.

A. Bt endotoxins

Bt toxins are highly specific and sotomach poisons. Bt toxins are produced from B.t. var. kystaki (Btk) for Lepidopteran pests and Bt var *israeliensis* (Bti) for dipteran pests.

In July 1987, a Belgian Biotechnology company (Plant Genetic systems) developed transgenic plants of tobacco containing δ endotoxins against *Manduca sexta* and *Helionthis* . Monsanta company – developed transgenic tomato plant against tobacco hornworm *M.sexta*.

Transgenic plants carrying Bt genes have been produced in tobacco, tomato, potato, cotton, maize, rice, soybean, sugarcane, apple, peanut, chick pea, and alfalfa with different crystal protein genes. Recently the Mahyco introduced transgenic cotton into India for cultivation with resistance against boll worms especially Helicoverpa.

B. Protease inhibitors

The protease inhibitors gene have been introduced into a variety of different transgenic plants like apple, pea, potato, rice, tobacco, tomato etc.,

The cowpea trypsin inhibitor (CpTi) has been found an ideal candidate for genetic transformation and found to import resistance against *Heliothis, Spodaptera* etc.,

Transgenic plants in IPM

- Transgenic plants are compatible with all other tactics
- Transgenic plants do not need any insecticide application against target pests.
- Transgenic plants slow down the development of resistance
- Transgenic plants would provide protection to these plants parts which are difficult to be treated with insecticides
- No need for continuous monitoring of pests

- No environmental pollution or risk, sage to non-target species and human beings.

Biotechnology has the potential to move farming closer to ecologically sustainable practices, both in developed and developing countries and thuscould make considerable impact on agricultural systems in the future.

PESTS OF STORAGE

Insects that are associated with stored grain and grain products constitute beetles, weevils and moths. Several hundred species of insects are associated with stored grain and stored grain products but only 15 species are well adopted for living in stored grain and responsible for most of the damage.

The group of insects that damage stored grain can broadly be placed in three groups. The first group, internal feeders spend the most of their life, feeding within the kernel of grain and the second group, external feeders spend their life feeding on the surface of grain or on the finished products of grain. The third group comprises of secondary pests and scavengers where the larvae and adults feed on broken grains or on materials, which are out of condition or damp.

I. INTERNAL FEEDERS

1. **Rice weevil**: *Sitophilus oryzae* (Curculionidae: Coleoptera)

   The weevil measuring 4 mm long is dark brown and has four light reddish or yellow spots on elytra. The female makes a small hole on the grain, deposits an egg and covers it with a gelatinous fluid. The apodous grub feeds inside the grain, pupates there itself and emerges through an irregular hole made on the grain

2. **Leser grain borer or paddy borer beetle**: *Rhyzopertha dominica* (Bostrychidae: Coleoptera)

   The dark brown beetle measuring about 4 mm in length has its head bent under the thorax and the posterior abdominal end blunt. Antenna is serrated and three segmented. The grubs develop within kernels or may feed in wood and paper. It is particularly a pest of unhusked paddy becoming serious occasionally. It also attacks wheat.

3. **Cigarette or tobacco beetle**: *Lasioderma serricorne* (Anobiidae: Coleoptera)

   The light brown round beetle has its thorax and head bent downward and this presents a strongly humped appearance to the insect. The elytra have inute hairs on them. Antenna is of uniform thickness. The whitish hairy grubs feed on stored tobacco, ginger, turmeric and chillies. The creamy white oval eggs are laid on the surface of stored material .

4. **Drug store beetle**: *Stegobium paniceum* (Anobiidae: Coleoptera)

The reddish brown small beetle has striated elytra and measures 3 mm long. Antenna is clubbed. Grub is not hairy but is pale white, fleshy with the abdomen terminating in two dark horny points. It tunnels into stored products like turmeric, ginger, coriander and dry vegetables and animal matter.

5. **Pulse beetle**: *Callosobruchus chinensis* (Bruchidae: Coleoptera)
   C.maculatus

The beetle is small, dark brown and rounded abruptly posteriorly. White, elongate eggs are laid on the grain surface. The grubs feed on the inner contents of pulses and pupate inside them. It causes appreciable damage to stored cowpea, grams, *Lab-Lab niger*, etc. It also infests redgram pods in the field.

6. **Tamarind beetle**: *Caryedon serratus* (Bruchidae: Coleoptera)

The grubs of the grey beetle attack the seeds of tamarind in storage as well as on trees.

7. **Angoumois grain moth**: *Sitotroga cerealella* (Gelechiidae: Lepidoptera)

The yellowish white moth has pale fore wings and uniformly grey pointed hind wings with fringes of hairs. The caterpillars feed on the internal contents of grains and pupate inside the grains. It inflicts severe damage to unhusked paddy. It attacks ripening grains of paddy, cholam and ragi in the standing crop and the grains in storage.

II. EXTERNAL FEEDERS

8. **Red flour beetle**: *Tribolium castaneum* (Tenebrionidae: Coleoptera)
   T.confusum

The beetle is small, reddish brown and flat. It attacks grains, seeds, vegetable powders, dry fruits, oil cakes, nuts, museum specimens like dry insects and stuffed material, etc.

9. **Indian meal moth/ Almond moth**: *Plodia interpunctella* (Phycitidae: Lepidoptera)

The moth has brown forewings with white band. The larvae feed on grains, dried fruits, etc.

10. **Fig moth/ Warehouse moth**: *Ephestia (=Cadra) cautella* (Phycitidae: Lepidoptera)

The small moth has greyish forewing. The caterpillars web together the grains and feed on them. It attacks stored grains, cashew, groundnut, wheat, etc.

11. **Rich moth**: *Corcyra cephalonica* (Galleriidae: Lepidoptera)

The adult moth is greyish brown. The caterpillars web together the grains and feed within. It attacks broken grains and flour especially the milled products which are heavily damaged, if neglected.

12. **Khapra beetle**: *Trogoderma granarium* (Dermestidae: Coleoptera)

The reddish brown beetle measures 4-6 mm long. The yellowish brown grubs are clothed with long hairs. It attacks stored wheat.

III. SECONDARY PESTS AND SCAVENGERS

13. **Saw toothed grain beetle**: *Oryzaephilus surinamensis* (Silvanidae: Coleoptera)

The slender dark brown much flattened beetle has a row of saw like sharp teeth on each side of the prothorax. It feeds on grains, dried fruits, etc. by scarring of grain surface or burrowing holes in them. Generally it does not cause serious damage.

14. **Long-headed flour beetle**: *Latheticus oryzae* (Tenebrionidae: Coloptera)

It occurs as a secondary infestation in stored wheat, cholam, etc. The beetle is light reddish and resembles *Tribolium castaneum.*

15. **Flat grain beetle**: *Cryptolestes ferrugineus* (Cucujidae: Coleoptera)

It resembles *Latheticus oryzae* but has long antennae. It feeds on broken grains secondarily.

MANAGEMENT OF PESTS OF STORED FOOD GRAIN

The following are the important methods which can help in safe storage of food grains particularly at farmer's level .

1. Preventive measures
2. Curative measures

1. Preventive measures:

"Prevention is better than cure". Hence the following preventive measures are recommended:

i. Hygiene or sanitation
ii. Disinfection of stores / receptacles
iii. Legal method

2. Curative measures:

The infestation of stored grain insect pests can be controlled by the following methods.

I. Non-chemical control measures
II. Chemical control measures

I. Non-chemical control measures:

The measures where chemicals are not used for control of insect pests of stored grains are:

a. Ecological control measures:

The infestation of stored grains by insect pests largely depends on the three factors *viz.*,

- Temperature
- Moisture content of grain
- Availability of oxygen

All these factors are required for normal development and multiplication of insects. Hence, they have to be properly manipulated through design and construction of storage structures / godowns and storage practices so as to create ecological conditions unfavourable for attack by insects.

b. Mechanical control measures:

Among other methods, mechanical methods are quite practicable. Several mechanical devices have been designed and developed both for monitoring and mass trapping stored product insects. The behaviour of the stored product insect is exploited here. The various devices are:

i. Entoleter:

A direct method of controlling insect infestation is by removing insects from the infested commodity. Equipments used to remove dockages should also remove insects that are outside of the seeds. This would not work for the immature stages of *Sitophilus spp*. or *R. dominica*. Flourmills often pass flour through the sieves that remove foreign matter including insects, just before it is packaged. By far the most extensively used direct means of mechanical control are the Entoleters, which use centrifugal force to impact insects or seeds containing insects. Entoleters are used primarily in flourmills. Kernels infested with primary feeders such as *Sitophilus* sp. and *R. dominica* break apart and are separated from intact kernels.

Apart from the above device, there are several traps, which can be used for detection of insect infestation. They are:

1. Probe trap
2. Pulse Beetle Trap
3. Pitfall traps
4. Light traps
5. Sticky traps
6. Bait traps
7. Pheromone traps
8. Storage container for automatic removal of insects from grains.

Recently, storage container models of 2 kg, 25 kg, 100kg, and 500 kg capacity which can remove insects automatically have been designed and developed by Tamil Nadu Agricultural University. The structure has four major parts namely outer container, inner performed container, collection vessel and the lid. This device exploits wandering behaviour of stored product insects as well as the movement of these insects towards well aerated regions. The space between inner and outer container provides good aeration for the insects.

Insects, while wandering, enter the perforation to reach the aerated part and while doing so, get slipped off and fall into the collection vessel though a pitfall mechanism provided in the collection vessel. In order to quickly collect the insects, as and when they emerge for grains, perforated (2mm) rods are fixed in the inner container.

c. Physical control measures:

i. Heat treatment

ii. Controlled atmosphere
iii. Mixing of inert products / plants oils (neem seed kernel powder 3% / plants oils like edible oil, neem oil, pungam oil 1%)
iv. Use of plant products
v. Use of activated clay

c. Cultural control measures:

i. Splitting of pulses
ii. Time of harvesting
iii. Resistant cultivars

e. Engineering control measures:

i. Hermetic or airtight storage.

Food grains kept in airtight sealed structures remain insect free, reason being that during storage the grain respires and liberates carbon dioxide. Excessive CO_2 accumulation and depletion of oxygen do not allow the insects to survive.

ii. Drying of grains:

In grains having moisture content below 10% most of the insect species do not survive / multiply.

II. Chemical Control Measures:

Amongst the present methods of insect control, chemical control is the most popular and perhaps most effective one. They may be used for both types of treatments.

a. Prophlactic treatment
b. Curative treatment]

Prophylactic treatment

1. If the produce is meant for seed purpose, mix 1 kg of activated kaolin or malathion 5% D for every / 100 kg of seed and store / pack in gunny or polythene lined bags.

2. Apply one of the following pesticides at the specified dosage over the bags.
   Malathion 50EC 10 ml / litre of water and 3 litre of spray solution per 100 sq.m.

3. Air charge alleyways or gangways with one of the following chemicals.
   Malathion 50EC 10 ml / litre of water or DDVP 76% SC 7 ml / litre of water

Apply one litre of spray solution for every 270 cu.m. or 10,000 cu.feet.

Spray the chemicals on the walls and floors and repeat the treatments based on the extent of flying and crawling insects.

4. Gunny bag impregnation: Empty bags are soaked in 0.1 % malathion emulsion for 10 minutes and dried before used grain storage.

b. Curative treatment:

4. Draw samples of seeds or grains at fornighly intervals and classify the infestation as follows.

   When there is no pest - Free from infestation

   Up to 2 insects - Mild

   More than 2 insects - Severe

5. Decide the need for shed fumigation (entire store house of godown) or cover fumigation (only selected blocks of bags)

6. Choose the fumigant and work out the requirement on the following guidelines.
   i. Aluminium phosphide:

- For cover fumigation 3 tablets of 3 grams each per tonne of grain
- Fro shed fumigation 21 tablets of 3 grams each for 28 cu. Meters.
- Period of fumigation 5 days

ii. Ethylene dibromide:

a. Shed fumigation 22 grams per cu. meter
b. Small fumigation 3 ml per 100 kg of grain
c. Period of fumigation 7 days
d. Not to be used for oilseeds, moist grains and milled products.

RODENTS OF AGRICULTURAL IMPORTANCE

Rodents constitute the largest order of existing mammals. Management of rodents is a very intricate as well as a ticklish problem. Rodents infest an area throughout the year as compared to other pests which appear sporadically only for short period in certain seasons. Rodents continue to damage standing food crops and stored food grains.

The following species of rats (Rodentia: Muridae) are important pests of cultivated crops in Tamil Nadu.

1. **Lesser bandicoot, mole rat or field rat**: *Bandicota bengalensis*

The mole rat is dark greyish brown in colour with a greyish white belly and a bare tail; head and body 15 to 23 cm and tail 15 to 18 cm long. It makes large ramifying burrows in soil extending to a depth of 1 to 1.5 m and laterally 9 to 12m; the burrow along its course is provided with many walls or earthern blocks for protection. There are 4 or 5 openings for the burrow; the entrances are protected by heaps of excavated soil. Separate chambers for bed, breeding and food storage are provided in the burrow. It usually lives alone, one in a burrow. It feeds upon grass, grains and tubers and damage to rice crop is considerable in Tamil Nadu. In rice it appears late in the cropping season and damages the crop most severely. It shot blade stage it cuts tillers and the affected area is seen as circular patches in a field. The rat revisits the same area next night and spread the damage. It cuts earheads and carries to its burrow and in a burrow up to 2 kg of hoarded grains can be noticed.

2. **Grass rat**: *Millardia meltada*

The grass rat is smaller in size, dark brownish grey above and pale grey below with soft fur. Head and body is about 13 cm long and tail 10 cm long. The burrows of the grass rat are similar to that of the mole rate excepting that they are smaller in length and diameter and that usually more than one adult rat occupies a single burrow. It attacks rice in all stages and feeds upon young germinating grains, cuts and feeds on tender seedlings and also grown up plants in the shot-blade stage. It damages green cotton bolls in black cotton soils.

3. **Gerbil rat**: *Tatera indica*

The Indian gerbil rat is reddish grey in colour with white underside and it equals the common house rat in size with about 18 cm long head and body and hairy tail little longer than the head and body. It generally feeds on grains, grass, roots and fruits.

4. **Indian field mouse**: *Mus booduga*

The body of the Indian field mouse is about 5 to 8 cm long with 5 cm long tail. It is brown in colour with a white belly. It burrows in field bunds causing extensive damage to bunds and wastage of water. It cuts and removes grains from rice crop.

5**. Common rat**: *Rattus rattus wroughtoni*

The common rat is reddish or yellowish brown with a pure white belly. It is destructive to tender coconuts. It lives and breeds inside nests specially constructed in the crowns of the palms. In closely planted gardens it can jump from palm to palm. It bites holes through the husk and drinks the sweet liquids; spoilt nuts fall down in large numbers.

6. **Common house rat:** *Rattus rattus rufescens*

It is brownish grey with a dark undersurface and feed on all kinds of vegetable and animal food. It lives in roofs of houses and underground burrows. Its damage is great in warehouses and storage godowns.

Integrated Rodent Management

The poisons used for the control of rodents are either acute poisons (single dose and quick acting) or chronic poison (multiple dose and slow acting). A rodenticide must have three ideal attributes- toxicity, acceptability and safety in use. The acute poisons are better for giving a quick knockdown, but they have little selectivity and poor efficacy. They require pre baiting as rodents develop bait shyness for them. Anticoagulants have advantage as for as efficacy and safety are concerned, but are slow in action, more laborious and hence the treatment cost is comparatively higher.

Rodenticides

Zinc Phosphide

It is a greyish black powder having garlic odour of phosphine. Its toxicity is due to the evolution of phosphine gas from the molecule. Zinc phosphide baits are stable in air and non-acidic media, but when ingested, the acid present in stomach releases phosphine gas, which produces necrotic lesions and kidney damage causing death from heart failure. Death may occur within two hours of bait intake. It should not be used at a concentration above 2 per cent that may reduce the bait acceptability and increase poison aversion. Zinc phosphide is equally toxic to man, animals and poultry. Hence, dead rats should be removed from the field immediately.

Anticoagulant rodanticides

Warfarin was the first compound developed. Bromadiolone was first registered in India and is in use since 1988. Anticoagulants constitute more than 95 per cent of total rodenticide usage.

Multidose anticoagulants

Warfarin and fumarin are used at 0.5 per cent concentration as fresh baits.

Singledose anticoagulants

Bromadiolone used as fresh bait (0.25%) ready to use bait (0.005%).

Plant products

Certain plant products were known to cause anti fertility effects (*Gloriosa supeprba, Cannabis sativa, Calotropis gigantia, Azadirachta indica)*

Traps and trapping

Live traps: Pot trap, wonder trap and Sherman trap are some of the live traps in use.

Kill type: Tanjore trap, arrow trap, bamboo trap, stone trap and break back (snap trap) are some of the kill type traps. Tanjore trap is used in the wet land rice fields. Break-back is used commonly in all places. Glue boards are newer type where small boards (22 x 17.5 cm) are plastered with polybutanes and thickener for indoor use.

Owl perches (50/Ha) may be setup in the fields to reduce the menace of rats

BIRDS OF AGRICULTURAL IMPORTANCE

A. Birds as pests of crops

Birds are vertebrate warm-blooded animals and the total number of bird species known to science as inhabiting the earth today has been estimated to be about 8600. Birds cause considerable damage to growing field crops, fruit trees, orchards, threshing yards and in houses.

Birds of economic importance-causing damage to crops.

1. House sparrow: *Passer domesticus*
2. Parrot: *Psittacula eupatria; P. krameri; P. cyanocephale*
3. Crow: *Corvus splenderis*
4. Pigeon: *Columba livia*
5. Peacock: *Pava cristatus*
6. Bulbul: *Pycnonotus cafer*
7. Baya: *Ploceus philippinus*
8. Myna: *Aeridothares tristis*
9. Green bea eater: *Merops orientalis*
10. Wild duck: *Pterocyanea discors*

House sparrow

It is omnivorous, eats grain, insects, fruit buds, flower nectar and kitchen scraps. It causes severe damage to sorghum, smaller millet, wheat, rice and small succulent fruits both under field conditions and in storage. It usually lives and build its nest in a hole in ceiling niche in wall, inverted lamp shade and every conceivable site within or without an occupied building.

Crow

It is the most familiar bird of Indian towns and villages. Live in close association of man and obtain its livelihood from his works. They have been reported to cause heavy damage to maturing or ripe crops of agricultural and horticultural importance specially to sorghum, groundnut, wheat, chillies, smaller millets, papaya, mango, guava, etc. Besides they are also menace to poultry farming as they take away young chicken and eggs and to the livestock breeder as they peck the eyes out of newly born lambs. It is also a useful scavenger.

Parrot

Parrot is one of the most familiar of Indian birds. They often band into large flocks. It is highly destructive at all times to crop and orchard fruit, gnawing and wasting far more that it actually eats and cause heavy damage to agricultural and horticultural crops specially to sunflower, maize, sorghum, smaller millets, wheat, gram, pea, guava, jamun, mango, papaya and other fruits.

Bulbul

Bulbul are found throughout India. They are common in gardens and light scrub jungles, both near and away from human habitations. Large numbers collect to feed on grain crops, newly sprouting vegetables and fruits and termite swarms.

Pigeon

It is a grey coloured bird with its neck and upper breast of a greenish, purple and mangenta sheen. Two dark bars on the wings and a band across the tail are prominent. The pigeons can be commonly seen on old buildings, churches, temples, railway stations, warehouses, etc. They are well adapted to noisy places. They fly to threshing floors, grain fields, and pickup grains. Since they fly in large numbers, the losses are high.

B. Insectivorous Birds *(Avian insectivory)*

Insects form major source of natural food for birds. Many orders of these birds feed entirely on insects. This list includes swifts, night jars, drongos, bee eaters, pittas, tits, woodpeackers, swallows, warblers, babblers, ioras, flycatchers, wagtails and pipits. Several species of bulbuls, mynas and starlings, orioles, crows and treepies, rollers and hoopoes are insectivores. Other birds like kingfishers, storks, herons, egrets, lapwings, kites, falcons, eagles, merlins, terns, owls, blackbirds, chats, thrushes, cuckoos, koels, malkohas, magpies, tree creepers, robins , fowls, jays, minivets, chloropses, pastors and other also make insects part of their diet. Even such birds like sparrows, bayas and munias feed their chicks with insect diet. It was observed that even the nectar feeding sunbirds feed on many soft bodied insects such as scales, aphids and psyllids.

Insectivorous birds in Horticulture

Trunk and barkborers

The cerambycid borers attack mango, jack, cashew, citrus species, silk cotton, ornamental trees and a variety of softwooded trees like silk cotton, moringa, ailanthus and *Ficus* spp. A variety of forest trees like teak, rosewood, cassias, acacias, bamboo, terminalias and even rubber are severally affected by these pests. Under natural conditions various species of wood peckers could alone control these pests effectively.

Bark borers are the caterpillars of *Indarbela tetraonis* and *I. quadrinotata* of lepidoptera. These caterpillars attack mango, jack, sapota, millingtonia, sandal, sapota, champak, and other ornamental trees. The caterpillars bore into the bark and feed on the bark tissues. In higher incidence, the bark gets detached from trunk and tree dried out. Besides the stem and bark borers, woodpeckers also destroy arboreal termites to a larger extent.

Insectivorous birds and foliage feeding insects

The common crows (*Corvus splenders)* have great potential in managing the cassia defoliator. The jungle crow, *Crovus macrorhynchos* is also a potential predator of these caterpillars. Leaf webbers of mango, sapota and tabernemontana (*Glyphodes unionalis*) are often checked by insect feeding birds.

Terrestial and other soil inhabiting pests

These include babblers, mynas, nightjars, crows, pheasants, partidges, quails, lapwings drongos, rollers, robings, magpie robin, herons and egrets, hoopoes, wagtails, pipits, thrushes, jungle fowls, peafowls, pittas, snipes and frogmouths.

Airborne and other flying insects

Such birds particularly bee eaters, drongos and fly catches are more harmful to honey bees and cause problems to commercial apiculture by heavy predation of honey bees.

Management of Bird Pests

1. Destruction of nests and roosting places. This practice is applicable against parrot, *Myna (Acridotheres tristis)* and other birds.

2. Trapping: Some birds are trapped by using a sticky material. They are used for meat purpose.

3. Baiting: Chapati or grains soaked in insecticide solution can be used for killing some birds. Proper disposal of such birds is a necessity.

4. Destruction of eggs: Nests may be located and eggs destroyed.

5. Use of bird scarer: Various devices like erecting a dummy model or making arrangement for beating of empty kerosene tins or acetylene guns to create loud noise at regular intervals.

6. Use of resistant variety: Varieties of sorghum and *bajra* have been identified which are not attacked by birds.