Course No. : **ENTO-242**

Course Title: **Insect Ecology and Integrated Pest Management Including Beneficial Insects.**

Course Credit: **3(2+1)**

Teaching Schedule (Theory):

Lecture No.	Topic
1	Insect Ecology: Definition – Importance of ecology and its scope.
	Environment : Its components
3	Effect of abiotic factors – temperature, moisture, humidity, rainfall, light. Atmospheric pressure and air currents.
4	Effect of biotic factors-food competition natural and environmental resistance.
5	Concepts of balance of life in nature, biotic potential and environmental resistance. Causes of pests outbreaks in agro-ecosystem.
6	Pest surveillance and pest forecasting.
7	Categories of pests.
8	IPM-Definition, importance, concepts, principles and tools of IMP.
9	Practices, scope and limitation of IPM.
10	Host Plant Resistance.
11	Cultural, mechanical. Methods of Pest control.
12	Physical, Legislative. Methods of pest control.
13	Biological methods of pest control.(Parasites, predators)
14	Microbial methods of pest control (Bacteria, Fungi, Viruses Nematodes, weed Killers.)
15	Chemical control- importance, hazards and limitations.
16	Classification of insecticides-Inorganic & organic
17	Mode of action of insecticides.
18	Novel insecticides IGR, chitin synthesis inhibitor, Juvenile Hormones mimic, ecdysone antagonistic
19	Toxicity of insecticides.

20,21 &22	Formulations of insecticides, pesticide application equipment Recent methods of pest control- repellents, antifeedants attractants, gamma radiation, genetic control (Transgenic crops)
23	Semio-chemicals
24	Insecticide Act 1968, important provisions.
25	Phytotoxicity and compatibility of insecticides.
26	Symptoms of poisoning, first aids and antidotes.
27	Mass multiplication techniques 1. *Trichogramma* 2. *Cryptolaemus* (coccinellids) 3. *Epiricania melanoleuca* 4. *Kopidosoma Koehleri* 5. *Chrysopids.*
28	Important group of microorganisms. Bacterial- mass multiplications *(Bt), Pseudomonas.* Fungi – mass multiplication *Verticillum lecanii, Beaveria, Metarrhizum.* Viruses – *Ha*NPV, *Sl*NPV, Mass multiplication.
29 & 30	Sericulture /Lac culture / apiculture.
31	Non-insect pests: mites, rodents, birds, and nematodes, snails.
32	Vermiculture: - importance, species of vermicompost, morphology, techniques of

INSECT ECOLOGY

- The term ecology was coined by a German biologist Ernst Haeckel (1869).
- The term ecology is derived from the Greek word "oikos" means "house or place to live" & "logous" means "the science of" or "the study of".
- Thus literally ecology is the study of earth's household comprising of the plants, animals, microorganisms and people that live together as interdependent components.

Definition of Ecology

- ✓ **Ecology: -** It is the science which deals with the study of relationship of organisms with their environment including both biotic & abiotic factors.
- ✓ **Insect Ecology: -** The science which deals with the study of relationship of insects to their environment.

Terminology Related to Ecology

- **Auto ecology: -** Study of an individual organism, its behavior and influence of environment on its life cycle.
- **Synecology: -** Study of groups of organism which are found as unite called community ecology.
- **Habitat ecology: -** Study of habitat and its effects on the organisms.
- **Ethology: -** Study of behavior of organisms under natural condition.
- **Habitat: -** It is the place where the organism lives.
- **Population: -** denotes groups of individuals of any kind of organism.
- **Community: -** in the ecological sense includes all the populations of a given area.
- **Ecosystem: -** A self-containing system they are composed of living organisms and the nonliving environment where continuous exchange of matter and energy takes place.
- **Biome: -** The grouping of communities that have similar structure composed of ecosystem of similar vegetation type.
- **Biota: -** Fauna and flora of a particular habitat are together called biota.
- **Biosphere: -** It is the largest ecosystem which includes all living organism on earth interacting with physical environment.
- **Ectone: -** Some communities which are considered to be transitional between two biomes called Ectone.
- **Inquilines: -** An animal lives in the habitat of another one with sharing its food.
- **Phoresy: -** A commensalistic relationship among the organisms in which one kind of organism attacks to another thereby gains mode of transportation.

ENVIRONMENT: ITS COMPONENTS

- ❖ The term environment entomologically means "Surroundings". Environment is a complex of living and non-living factors which surrounds on organisms.
- ⌘ **Environment: -** An environment is anything which surrounding to individuals that may influence its change to survive and multiply.

Components (Factors) of environment:-

Following components of environment affect or influencing on insect population.

A) Abiotic Factors: (Physical/non-living /Density independent factor)

1.) Climatic factor :-

i) Temperature
ii) Rainfall
iii) Humidity (Moisture)
iv) Air current (Wind)
v) Light
vi) Atmospheric pressure

2.) Topographic factor: -

i) Mountains
ii) Sea, Ocean, River
iii) Soil

B) Biotic factors: (Living /Density dependent factor)

1.) Food (Nutritional factor)
2.) Competition **(**Interspecific & Intraspecific Competition)
3.) Natural enemies (Predators, Parasite & Pathogen)

Abiotic Factors (Density independent factors)

Temperature

- Insects are the cold blooded animals; they do not have mechanism to regulate body temperature called **poikilothermic**.
- Insects survive at specific optimum temperature - Upper lethal limit is 40-50^{o}C (even up to 60^{o}C survival in some stored product insects) & Lower lethal limit - Below freezing point e.g. snow fleas.
- At low temperature (winter) insect takes more days to complete a stage (larval or pupal stage) **Larva, pupa commonly undergoes hibernation in winter.**
- At high temperature (summer) it takes less than to complete a stage. **Eggs undergo aestivation in summer.**
- Temperature effects on fecundity, migration & rate of development of insects.
- **E.g.** i) Grasshopper lays 20-30 times more eggs at 32^{o}C compared to 22^{o}C, ii) Oviposition of bed bug inhibited at 8-10^{o}C, iii) Thrips give few eggs at 8°c & more at 20-30°c, iv) Larval period of sugarcane internode borer is very short in summer & prolonged in winter & v) Swarm migration of locust occurs at 17-20^{o}C.

- **Rainfall**
  - Heavy rainfall has adverse effect on small insects like aphids, Jassids, thrips, white fly, mealy bugs, diamond back moth (DBM) and scale insects etc. which are washed out from plants & killed in flooded soil.
  - Rainfall also effect on the abundance of insects.
  - Rainfall is essential for adult emergence of cutworms and RHC.

- **Humidity / (Moisture)**
  - It is essential for physiological activities like metabolic reactions and transportation of salts in insects.
  - Insect get die when water content increases or decreases termed as **lethal wetness** or **lethal dryness.** Moisture scarcity leads to dehydration and death of insects.
  - High humidity causes development / Encourages of disease causing pathogens on insects (fungi). e. g. White halo fungus *Verticillium lecanii* on coffee green scale requires high RH for multiplication and spread, Termites prefer high humidity 90-95% RH
  - Humidity also effect on fecundity & normal development of insects.
  - **E.g.** Locust does not lay eggs if there is no sufficient moisture. It mature quicker & give more eggs at 70% relative humidity, Low RH in rainfed groundnut crop induces leaf mines incidence.

- **Air current (Wind)**
  - The disposal of insects to great extent depends upon wind.
  - It interferes with feeding, mating & oviposition of insects.
  - Many insects fly with the air current & get transfer from one place to other. Many of them die by falling in rivers or sea. Many insects are known to spread in new countries through air currents.
  - Large number of aphids has been found after a strong wind & many of them are destroyed by falling in the sea & rivers etc.
  - Thus air current also play an important role in natural control of insects.

- **Light**
  - Light plays an important role in growth, development & survival because it is prime source of energy in all organisms.
  - Light control locomotive activities of insects by direct action this phenomenon is called as ***Phytokinesis***. The movement of animal in response to light called ***phototaxis***. The response of organism towards the length of day light called as ***Photoperiodism.***
  - Photo period influences induction of diapause (a resting stage) in most of the insects E . g . Short day species- mulberry silk moth & Long Day Species- Pink bollworm.

- Some insects are active in night (**Nocturnal**), Some are active during the day (**diurnal**) & Some active during dawn and dusk (**Crepuscular**).
- In many insects oviposition is stimulated by exposure to light or darkness. E.g. Fruit flies lays eggs in **light**, Lepidopterans like cotton bollworm, Red hairy caterpillar (RHC) oviposit in **dark.**

Atmospheric pressure

- The insects are more affected in low atmospheric pressure than in high atmospheric pressure.
- The phototrophic insects are more active during periods of high atmospheric pressure.
- The activities of some insects are directly influenced by pressure. E.g. due to the low atmospheric pressure a chances of rain increased resulting the emergence of ants.

Topographic factors

- Major topographic factors like mountain, rivers, sea are act as physical barriers to the spread of insects.
- Lake & ponds affect the nature of insects of that region.
- **Water current -** Larva of mosquitoes & beetles are able to live only in standing water & running water is preferred by Dragonfly and Caddis flies.
- **Soil type -** Wire worm, multiplies in heavy clay soil with poor drainage whereas termites, white grubs & cut worm prefer light, loamy soil.

Biotic Factors (Density dependent factors)

Food (Nutritional factor)

- Insects are heterotrophic hence they cannot synthesize their own food they depend on plants for food.
- The quantity and quality of food/nutrition plays important role in survival, longevity, distribution, reproduction and speed of development
- **Quantity of food -** Short supply of food causes intraspecific and interspecific competition.
- **Quantity of food -** This depends on nutritional availability of plants. Crop varieties/species differ in nutritional status which affects insects.

Competition

- Insect species are likely to be competing with one another or with members of another species for limited resources like food, mates, suitable site for oviposition or pupation. Such competition operates whenever the population is increasing and the resources are limited.
- **a) Intraspecific competition:** When members of population of the same species compete for resources. Examples are as follows;
- i) **Cannibalism** in American bollworm larvae,

ii) **Cannibalism** in later stage grubs of Chrysopid,
iii) **Crowding** in aphids result in **alate** (winged) form for migration,
iv)) Reduction in fecundity (egg laying) in rice weevil during **overcrowding**.
v) Crowding in honeybees leads to swarming.

- **b) Interspecific competition:** This is the competition occurring between members of two or more species. Two or more competing species with identical requirements cannot coexist in a same place for a long time. The elimination of one species by another as a result of interspecific competition. It gives by Russian scientist **G. F. Gause** called **competitive exclusion principle or Gause's hypothesis / principle.**
- **E.g. i)** Accidental introduction of oriental fruit fly into Hawaii eliminated by Mediterranean fruit fly & ii) *Trichogramma* & *Crysoperla* compete for *Helicoverpa* eggs in cotton.

  - ✓ **Cannibalism: -** It is the phenomenon where the insects feed on the individuals of the same species when crowding is occurring.
  - ✓ **Colonization:** - Grouping of free living individuals to form colonies to have better protection from natural enemies or environmental conditions for improved utilization of food.
  - ✓ **Aggregation:** - Tendency of congregating in large numbers than normal distribution for mating, food etc.

Natural enemies

Every insect has a number of natural enemies in the nature viz; parasitic insects, predatory insects, mites, spider, birds, mammals, reptiles, fishes & diseases causing fungi, bacteria & viruses. They keep the insect population in check and thus natural balance within limits is almost always maintained.

- **Predators:** Predators are free living organisms that feed on living insects & consume more than one individual during their lifespan. Major insect predators are as follows;
  - ✪ **Lady bird beetle** (Coccinellids) **-** Feed on aphids & leaf hoppers.
  - ✪ **Green lace wing** (Chrysoperla spp.) **-** Feed on aphids & other sucking pests.
  - ✪ **Mantid, Dragon fly & Syrphid fly -** Feed on different insects.

- **Parasitoid**: An insect parasite of an arthropod that is parasitic in its immature stage killing the host in the process of development and adults are free living. Major insect parasitoids are as follows;
  - ✪ ***Trichogramma spp.*** - Feed on Sugarcane borers & Cotton bollworms.
  - ✪ ***Apanteles flavips*** **-** Feed on lepidopteran larvae.
  - ✪ ***Epiricania meloneuca*** **-** Feed on sugarcane pyrilla.
  - ✪ ***Capidosoma koeheleri & Chilonus blackberni*** **-** Feed on potato tuber moth.

- **Parasites:** Parasites are organisms which live on other organisms for getting food & shelter. The association of parasite and host known as parasitism. A parasite weakens or kills the host while feeding requires only one part of one host to reach maturity. E.g. ticks, mites, Protozoa, Nematodes and other arthropods.
- **Pathogens:** Disease causing microorganisms called as pathogens. Certain fungi bacteria & viruses cause disease in many insects & reduce their population in nature. The important microorganisms which cause disease in insects are as follows;
    - ✪ **Fungi -** E.g. *Verticillium lecanii* (White halo fungus) cause disease in mealybugs & aphids, *Beaveria bassiana* (White muscardine fungus) cause disease in lepidopteran larvae & *Metarhizium anisopliae* (Green muscardine fungus) in coconut rhinoceros beetle.
    - ✪ **Bacteria -** E.g. *Bacillus thuringiensis* effective against lepidopteran larvae & *Bacillus popilliae* attacking on beetles.
    - ✪ **Virus -** E.g. ***HaNPV*** (*Helicoverpa armigera* nuclear polyhedrosis viruses) against American bollworm. & ***SlNPV*** - (*Spodoptera litura* nuclear polyhedrosis viruses) against tobacco leaf eating caterpillar.
- **Other Natural Enemies:** Frog, Toad, reptiles, birds, rats, bears, snakes & lizard

Environmental Resistance & Pest Outbreaks

⌘ **Agroecosystem -** Any ecosystem largely created and maintained to satisfy a human want or need.

- It is not a natural ecosystem but is man-made.
- Agroecosystem is the basic unit of pest management - a branch of applied ecology.
- A typical agroecosystem is composed of;
  i) More or less uniform crop-plant population
  ii) Weed communities
  iii) Animal communities (including insects)
  iv) Macrobiotic communities
  v) and the physical environment the react with.

⌘ **Balance of Nature -**

✓ **Definition -** "The maintenance of more or less fluctuating population density of a given organism over a period of time with in certain definable upper and lower limits by action of abiotic and biotic factors". **Or** a tendency of population density of all species in a same area to maintain a constant number of individuals in the physical environment.

✓ The concept of **Balance of Nature** was given by **Smith** in1935.

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

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

Factors that determine insect abundance:-

1) **Biotic potential -** It is the innate ability of the population to reproduce and survive.
   - ➲ It depends on the inherited properties of the insect i.e., reproduction and survival.
   - ➲ **Potential natality** is the reproductive rate of the individuals in an optimal environment.
   - ➲ Survival rate depends on the feeding habits and protection to young ones.

- Generally insects with high reproductive rate tend to have low survival rate and vice versa.
- Insect pests with high reproductive rate and low survival rate are called **r strategists** named after the statistical parameter r, the symbol for growth rate coefficient. E.g. Aphids.
- **K strategists** reproduce slowly but effectively compete for environmental resources and so their survival rate is high. (K letter denotes flattened portion of growth curve) e.g. Codling moth of apple.
- Birth rate or **natality** is measured as the total number of eggs laid per female per unit time. Factors determining birth rate are fecundity, fertility and sex ratio.
- Death rate or **mortality** denotes the number of insects dying over a period.

2.) Environmental resistance - It is the physical and biological restraints that prevent a species from realizing its Biotic potential.

- Environmental resistance may be of 2 types.

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

✪ **'K' Mortality -** it is that factor existing in natures that are responsible for mortality of the insects.

Population dynamics:-

⌘ Insect populations grow in two contrasting ways.

1. J- shaped growth form
2. S- Shaped or sigmoid growth form

- **In the J - shaped growth form,** the population density increases in exponential or geometric fashion.
- Populations with this kind of growth form are unstable. Their reproductive rate is high and survival rate is less and so they are r strategists. Factors other than density regulate the population. (e.g.; Aphids).
- **In the S-shaped growth pattern** the rate of increase of density decreases as the population increases.
- Their reproductive rate is less and survival rate is more. So they are K strategists. This pattern has more stability since the population regulates itself. (E.g. Hymenopterans).

- **Life table:** Life tables are tabular statements showing the number of insects dying over a period of time and accounting for their deaths.
  - Life table is a 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 -** It is based on the observations made on single generation in different region.
    2.) **Time specific (Vertical) life table -** It is based on the observations made on overlapping/multiple generation.
- **Uses of life table :**

i.) Number of generations per year of an insect can be known.
ii.) Age of different life stages can be known.
iii.) Key mortality factor & critical stages affected can be known.
iv.) Population models can be developed from life table.
v.) Pest surveillance, pest forecasting & prediction of pest can be possible.
vi.) It is possible to regulate beneficial processes like parasitism, predation, inter & intraspecific competitions etc.

Causes of pests outbreaks in agro-ecosystem

Pest outbreaks: - The phenomenon of sudden increases in pest population due to the effect of different biotic & abiotic factors.

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

1.) Bringing forest area under cultivation or destruction of forest.
2.) Destruction of natural enemies of pests.
3.) Intensive and Extensive cultivation.
4.) Introduction of new varieties and crops.
5.) Improved agronomic practices.
6.) Introduction of new pest in new area or environment.
7.) Accidental introduction of pests from foreign countries (through air/sea ports)
8.) Large scale storage of food grains
9.) Lack of adopting IPM strategies.
10.) Resurgence of sucking pests.

- **Bringing forest area under cultivation or destruction of forest.**
  - The insects feeding on the forest trees & plants in the forest are driven to neighboring areas where they may infest the cultivated crops and become new pests.

- **Destruction of natural enemies of pests.**
  - Due to excess use of insecticides, natural enemies are killed. This affects the natural control mechanism and pest outbreak occurs, e.g. Synthetic parathyroid insecticides kill natural enemies.
- **Intensive and Extensive cultivation.**
  - Monoculture (Intensive) leads to multiplication of pests. Extensive cultivation of susceptible variety in large area - No competition for food multiplication increases e.g. Stem borers in rice and sugarcane.
- **Introduction of new varieties (Strain) and crops.**
  - New plant may serve as new host for some of the insect species. Mostly improved strains of crop plants are susceptible to pests whereas character near to their wild parents is resistant to pest attack.
  - Varieties with favorable physiological and morphological factors cause multiplication of insects.
  - E.g. Succulent, dwarf rice varieties favors to leaf folder, Cambodia cotton favors stem weevil and spotted bollworm & Hybrid sorghum (CSH 1, HB1) favors shoot flies and gall midges.
- **Improved agronomic practices.**
  - Application of more nitrogenous fertilizers leads to crop growth which increase stem borer incidence in rice & sucking pests in cotton.
  - Closer planting in rice increase incidence of brown plant hoppers & leaf folder.
- **Introduction of new pest in new environment.**
  - Pest multiplies due to absence of natural enemies in new area. E.g. Apple wooly aphid multiplied fast due to absence of *Aphelinus mali* (Parasite) in Nilgiri hills.
- **Accidental introduction of pests from foreign countries.**
  - Diamondback moth on cruciferous crops, Potato tuber moth on potato, Cottony cushion scale on wattle tree, Wooly aphid on apple, Psyllid on subabul & Spiralling whitefly on most of horticultural crops.
- **Large scale storage of food grains.**
  - Serve as reservoir for stored grain pests & Rats found in underground drainage.
- **Resurgence of sucking pests.**
  - **Definition: -** Tremendous increase in pest population brought about by insecticides despite good initial reduction in pest population at the time of treatment called resurgence.
  - Deltamethrin, Quinalphos & Phorate cause resurgence of BPH in rice, Synthetic pyrethroids cause resurgence of Whitefly in cotton & Carbofuran cause resurgence of Leaf folder in rice.

Pest surveillance and pest forecasting

✪ **Pest Monitoring -** It is the estimation of changes in insect distribution and abundance, information about insects & life history, influence of biotic & abiotic factors on pest population.

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

- There are three basic components of pests surveillance;
  - i.) Determination of the level of incidence of the pest species,
  - ii.) Determination of the loss caused by the incidence &
  - iii.) Determination of the economic benefits, the control will provide.

⌘ **Objective of pests surveillance**

1.) To know the existing and new species of pests.
2.) To assess the pest population and damage at different growth stage of crop.
3.) To study the different weather parameters on pests.
4.) To study changing pest status (Major & minor).
5.) To assess natural enemies and their influence on pests.
6.) To study effect of new cropping pattern and varieties on pest.

✪ **Pest forecasting -** Forecasting of pest incidence or outbreak based on information obtained from pest surveillance.

⌘ **Uses of pest forecasting -**

i.) Predicting pest outbreak which needs control measure.
ii.) To know the suitable stage at which control measure gives maximum protection.

✓ **Types of pest forecasting -**

1.) Short term forecasting- one or two crop seasons.
2.) Long term forecasting- cover large areas & based on weather conditions.

✓ Pest forecasting comprises following three main points: -

- Quantitative measurement of population of pest on ecological zones.
- Study of life history of the insect pest.
- Study of fluctuation in pest population due to natural enemies & other factors.

 Survey: - Conducted to study the abundance of a pest species.

⌘ Types of survey -

1.) Roving survey
2.) Fixed plot survey

✪ **Roving survey**

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

- Fixed plot survey
  - Assessment of pest population/damage from a fixed plot selected in a field.
  - The data on pest population/damage recorded periodic from sowing till harvest.
  - Qualitative survey - Useful for detection of pests.
  - Quantitative survey - Useful for enumeration of pest.

⌘ Sampling technique -

1.) Absolute - To count all the pests occurring in a plot

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

Methods of sampling -

a.) In situ count - Visual observation on number of insects on plant canopy (either entire plot or randomly selected plot).

b.) Knock down - Collecting insects from an area by removing from crop and (Sudden trap)counting (Jarring).

c.) Netting - Use of sweep net for hoppers, odonata, grasshopper**.**

d.) Narcotized collection - Quick moving insects anaesthetized and counter.

e.) Trapping - Light trap - Phototropic insects, Pheromone trap - Species specific, Sticky trap - Sucking insects**,** Bait trap - Sorghum shoot fly & Fishmeal trap Emergence trap - For soil insects.

f.) Crop samples - Plant parts removed and pest counted e.g. Bollworms

⌘ Decision Making/Concept of injury level

- ✓ Population or damage assessed from the crop compared with ETL and EIL.
- ✓ When pest level crosses ETL, control measure has to be taken to prevent pest from reducing EIL.
- ✓ Concept of injury level was given by **Stern *et al.* 1959.**

Economic Injury level (EIL): - The lowest pest population density that will cause economic damage. Also defined as a critical density where the loss caused by the pest equals the cost of control measure.

Economic Threshold Level (ETL) or Action threshold: - The pest population density at which control measures should be applied to prevent the economic yield loss of crop.

ETL is always less than EIL.

General equilibrium position (GEP):- The average density of a pest population over a long period of time, around which the pest population tends to fluctuate due to biotic and abiotic factors and in the absence of permanent environmental changes.

Damage boundary (DB):- The lowest level of damage which can be measured. Provides sufficient time for control measures.

CATEGORIES OF PESTS

- ✓ Pest- Derived from **French word** '**Peste'** and **Latin term** '**Pestis'** meaning plague or contagious disease.
- ✓ Pests include insects, nematodes, mites, snails, slugs, etc. and vertebrates like rats, birds, etc.
- ✓ Depending upon the importance, pests may be agricultural forest, household, medical, aesthetic and veterinary pests.
- ✓ **Definition -** Pest is any animal, pathogen, insects which cause damage to man, his animals & crops. **Or** Pest is any animal which is noxious, destructive or troublesome to man or his interests.

✪ **Economic Pest: -** The pest which causes more than five percent economic yield loss.

✪ **CATEGORIES OF PESTS**

A.) According to frequency of occurrence: -

1.) **Regular pest**: Certain pests **occur most frequently** on crop form **close association** with particular crops. E. g. Gram pod borer, Thrips on chilies, Aphids on cotton, soot & fruit borer on Brinjal & bhendi & Epilachna beetle on Brinjal.

2.) **Occasional pest:** Certain pests **occur rather infrequently** on crop & there is **no close association** with particular crops. E. g. Caseworm on rice, Mango stem borer.

3.) **Seasonal pest:** Occurs during a **particular season** every year. E. g. Grasshoppers on safflower in kharif, Red hairy caterpillar on groundnut in kharif, White grub

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

5.) **Sporadic pests**: Pest which **occurs in few isolated localities** during some period. E. g. Coconut slug caterpillar, Rice ear head bug.

B.) According to intensity of pest or Based on level of infestation : -

1.) **Epidemic:** Sudden outbreak of a pest in a **severe form in a region** at a particular time. E. g. Brown plant hopper in Tanjore, Red hairy caterpillar in Madurai,

2.) **Endemic:** Occurrence of the pest **in a low level, regularly** and confined to particular area. E.g. Rice gall midge in Madurai, White grubs on sugarcane in Kolhapur district, Groundnut in sangali, Rice stem borer in Raigad district.

C.) According to losses caused by pest or According To EIL, GEP And DB: -

1.) **Negligible:** If the insect causes less than 5% yield loss.

2.) **Minor pest:** If the insect causes 5-10% yield loss. E.g. Rice hispa, Ash weevils.

3.) **Major pest:** If the insect cause more than 10% yields loss. E.g. Cotton jassid, Rice stem borer.

4.) **Key pest:** Most severe and damaging pests & GEP lies above EIL always hence the environment must be changed to bring GEP below EIL. E.g. Cotton bollworm, Diamond back moth.

D.) 'r' pest: small size insects having strong dispersal & more host finding ability

Host Plant Resistance

- ✓ **Definition: -** The ability of some varieties to produce good quality yield than ordinary varieties at the same level of insect population.
- ✓ **R.H. Painter (1968):** He defined as relative amount of heritable quality possessed by a plant which influences the ultimate degree of damage done by the insect.
- ✓ He also referred as a Father of HPR.
- ✓ R.H. Painter (1936, 1941) classified the mechanisms of resistance into (i) **Non preference** (ii) **Antibiosis** (iii) **Tolerance**.

Mechanism of Insect Resistance: -

- **Antixenosis (Non-preference): -** It results from some morphological characters like- i) Absence of attractant, ii) Presence of repellent and allelochemic / morphological characters. It is used to denote the group of plant characters and insect responses that keep away an insect from using a particular plant (or) variety, for oviposition, food (or) shelter (or) combination of the three (Painter, 1951). It is proposed by Kogan and Ortman (1978). Morphological characters include plant character such as (1) trichomes, (2) surface waxes, (3) hardiness of plant tissues, (4) thickening of cell walls and (5) cuticle, (6) rapid proliferation of tissues, (7) colour, and shape etc. E.g. Trichomes in cotton - resistant to whitefly, Wax bloom on carucifer leaves - deter feeding by DBM Plant, shape and colour also play a role in non-preference, Open panicle of sorghum - Supports less *Helicoverpa*.

- **Antibiosis: -** Adverse effect of host plant on the biology of insects. This is due to the presence of toxic metabolites - alkaloids, glucosides, anions Absence / insufficiency of essential nutrients unbalanced proportion of nutrients Presence of antimetabolites that renders some essential nutrients unavailable to insect. Presence of enzymes inhibits normal process of food digestion and consequently utilization of nutrients.

Salicylic acid	Rice stem borer
Gossypol (Polyphenol)	*Helicoverpa armigera* (American bollworm)
Sinigrin	Aphids, *Myzus persicae*
Cucurbitacin	Cucurbit fruit flies
DIMBOA (Dihydroxy methyl benzoxazin)	Against European corn borer, *Ostrinia nubilalis*

- **Tolerance: -** ability of host plant to withstand and give good quality yield even if the sufficient infestation of insects are observed. Tolerance has no adverse effect on the insects. Known component of this form of resistance includes. i) General vigour of plant, ii) Compensatory plant growth in individual plant / population, iii) Wound healing, iv) Mechanical supports in tissue and organs v) Changes in photosynthate partitioning.

- **<u>Avoidance or Escape</u>: -** Escape of a variety from insect attack either due to earliness or its cultivation in the season where insect population is very low.

✓ **Major gene resistance:** Controlled by one or few major genes **(vertical resistance).**

✓ **Minor gene resistance:** Controlled by many minor genes. The cumulative effect of minor genes is called adult resistance or mature resistance or field resistance. Also called **horizontal resistance.**

❖ **Advantages of HPR as a component in IPM**

- ✓ Specificity: Specific to the target pest. Natural enemies unaffected
- ✓ Cumulative effect: Lasts for many successive generations
- ✓ Eco-friendly: No pollution. No effect on man and animals
- ✓ Easily adoptable: High yielding insect resistant variety easily accepted and adopted by farmers.
- ✓ Less cost.
- ✓ Effectiveness: Res. variety increases efficacy of insecticides and natural enemies
- ✓ Compatibility: HPR can be combined with all other components of IPM
- ✓ Decreased pesticide application: Resistant varieties require less frequent and low doses of insecticide.
- ✓ Persistence: Some varieties have durable resistance for long periods

INTEGRATED PEST MANAGEMENT (IPM)

✪ **History of IPM: -**

- ✓ **Michel bacher and Bacon (1952)** coined the term "integrated control".
- ✓ **Stern et *al*. (1959)** defined integrated control as "applied pest control which combines and integrates biological and chemical control"
- ✓ The idea of managing pest population was proposed by ***Geiger and Clark (1961)*** who called this *concept* as "protective population management".
- ✓ **Geier (1966)** coined the term "pest management".
- ✓ Council on Environmental Quality (CEQ, 1972) gave the term "Integrated Pest Management"
- ✓ IPM Working Group (IPMWG-1990) was constituted to strengthen implementation of IPM at international level.
- ✓ **In 1997, Smith and Adkisson** were awarded the **World Food Prize for pioneering work on implementation of IPM.**
- ✓ **NCIPM:** National Centre for Integrated Pest Management at **Faridabad (Near Delhi) (1988).**
- ✓ In **1967** a broader definition was adopted by **FAO (Food Agricultural Organization, Italy- Rome)** Panel of experts as -

 Definition: - 'It is the pest management system in context of associated environment and population dynamics of pest species utilize all the suitable techniques and methods in as compatible manner as possible and maintains pest populations at level below those causing economic injury.'

- **Need for Pest Management -**

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

- **Objectives of pest management**

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

- **Principles of Pest Control:**
  1. Identification/Monitoring insect pests and natural enemies of pest.
  2. Insect classification and life history.
  3. Understanding the pest population dynamics & Concepts of injury levels.
  4. Understanding the agro-ecosystem.
  5. Knowledge of introduced pest.
  6. Economics of the pest control.
  7. Consumers pressure.
  8. Preventive control.
  9. Knowledge of various pest control methods/Integration of pest control tactics.
  10. Extension Education.

⌘ Advantages/Importance/Significance of IPM :-

1) It minimizes residue & toxic hazards.
2) It helps to minimize the development of pesticide resistance in the pest.
3) It gives scope to biological control & bio-agents.
4) It is easy to adopt.
5) It is cheaper & most efficient way of utilizing chemical insecticides.
6) It is ecologically beneficial to both human & animals.
7) Export of agricultural commodities.

⌘ Limitations/Disadvantages of IPM: -

1) Lack of planning in national economic planning.
2) Lack of IPM information to the farmers.
3) Pesticide industries create a situation that chemicals give effective control of pest

Tools/Methods of IPM

✪ **Preventive methods of IPM include the following**

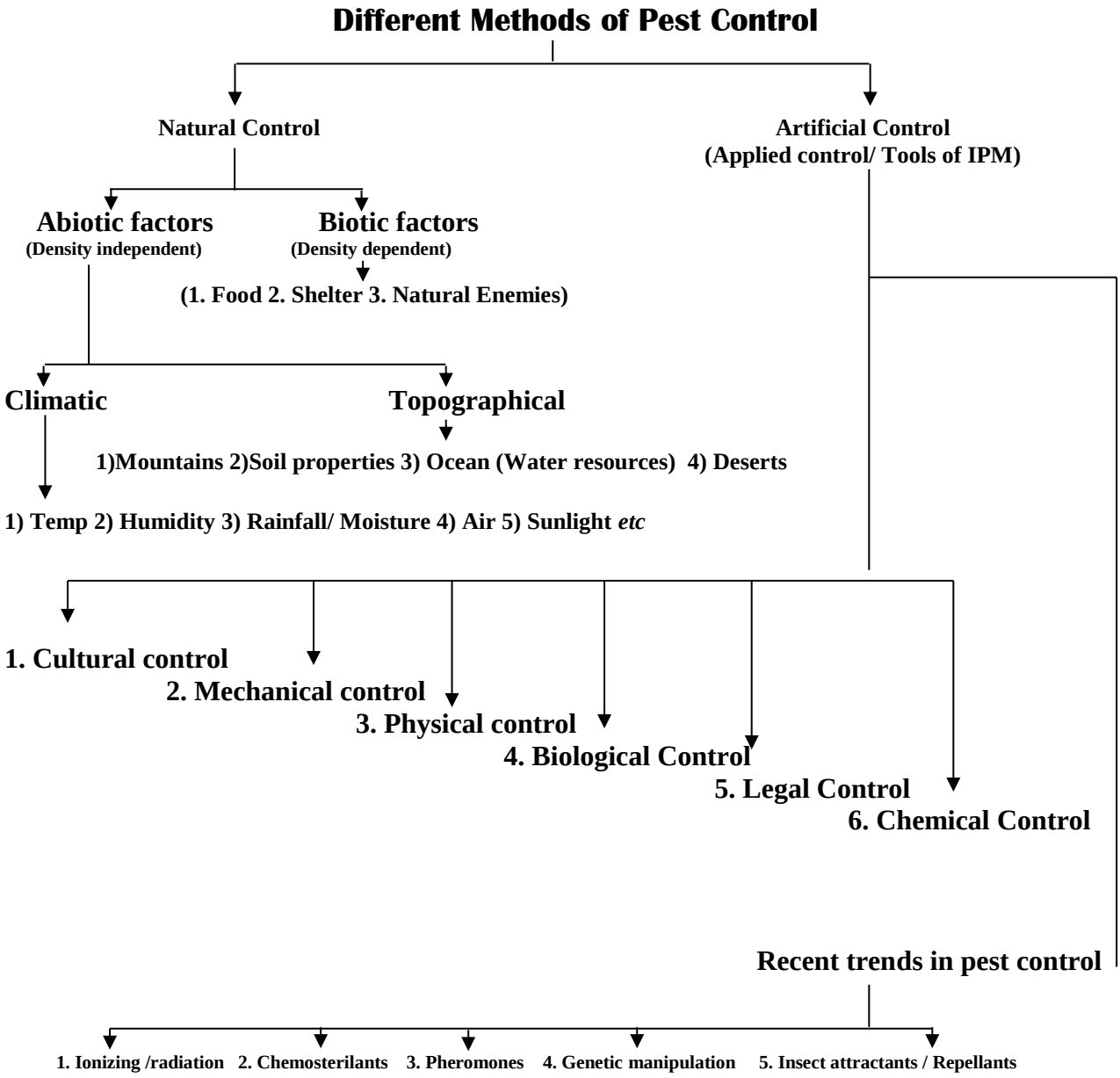
a. Natural enemies
b. Host plant resistance
c. Legal control (Plant Quarantine)
d. Cultural control

✪ **Curative methods of IPM include the following**

a. Physical methods
b. Mechanical methods
c. Chemical methods
d. Biological methods
e. Insect Growth Regulator (IGR)

✓ Preventive methods can be used, irrespective of the level of pest incidence. It can be followed as a routine, even if the pest is at a low level.

✓ Curative methods have to be followed only when the pest attains economic threshold level (ETL).



A) CULTURAL CONTROL/METHODS: -

- ✓ **Definition:** Regular farm operations, so performed as to destroy the insects or prevent them from causing injury. Cultivation practices employed in a manner that makes the environment less suitable for growth & reproduction of the insects.

1) **Tillage operations –** Ploughing & other tillage operations expose the insects to upper soil surface which are picked by birds or destroyed by heat. e.g. Bihar hairy caterpillar, fruit fly, gram pod borer. It also helps in removal of weeds which may serve as host for insects.

2) **Crop rotation –** Practice the crop rotation in such a manner which will break the continuous supply of food to the major pests of that crop. Growing of non-host crop reduces the pest attack on crop. Okra followed by cotton increases the pest attack.

3) **Trap cropping –** The trap crops are those crops which are used to control the pest of main crop. Trap crop plants are harvested early or used as a fodder. Okra is good trap crop for cotton to attract Jassids & spotted bollworms.

4) **Sanitation of field –** removal & destruction of all undesirable plants, plant debris, weeds & clean cultivation of field. Insects use the plant residues, weeds as a host & increase the pest attack in next season. e.g. sugarcane borer, Jowar stem borer, etc.

5) **Time of sowing/planting –** By adjusting time of sowing infection of some pests can be prevented. If egg laying period of a pest is avoid; young plants can be establish before the attack starts. e.g. Early sowing of kharif Jowar to escape from attack of Jowar shoot fly.

6) **Use of resistant varieties –** some morphological or genetic factors associated with the variety make the variety resistant for some pests. e.g. Deshi cotton is more resistant to Jassids whitefly & bollworms than American cotton.

7) **Other cultural methods –** management of seed rate, pruning, clipping of tips in rice, earthing-up & flooding like cultural practices help to control the pest incidence on the crop. E.g. flooding rice nurseries to eliminate attack of armyworms. Clipping of rice tips at the time of transplanting to eliminate egg masses of stem borer.

Merits: -

i) It not increase the production cost.
ii) Environmentally safe.
iii) It is well-matched with other methods of pest control.
iv) It gives least chance of insect development.

Demerits: -

i) Knowledge of ecology & biology is essential.
ii) The control measures should be taken well in advance.
iii) It should be supplemented with other methods.

B) MECHANICAL CONTROL/METHODS: -

Definition: The method with which insect population is directly beat by mechanical devices or manual operations.

1) Hand picking & destruction: - Insects are picked out & destroyed from the crops. This method is applied when the insects are in large number & easily accessible to picker.

i) By use of hand nets – e.g. butterflies, moths, grasshoppers, etc.
ii) By use of iron hook – e.g. rhinoceros beetles from coconut.
iii) Beating with brooms – e.g. locust
iv) Shaking of plants – Shaking of babul& neem to collect adult beetles of white grub.
v) Sieving and winnowing – used for insects pest of stored grains. E.g. grubs of khapra beetle.

vi) Rope dragging – Passing of rope across the rice crop to dislodge caseworms over the standing water which then drained out to collect the pests at corner of field.

2) Mechanical exclusion or provision of preventive barriers: - Use of devices by which insects is physically prevented from reaching the crop or the produce.

i) Collar around the plants – Paper & tin collars around potato & tobacco to protect from cutworms.

ii) Tin bands – fixed over coconut to prevent damage by the rats.

iii) Sticky bands – oily bands around mango tree to prevent upward movement of mealy bugs.

iv) Trenches around fields – migration of rice armyworms prevented by digging 60×60cm trenches.

v) Bagging of fruits – fruit is covered by bags to protect from fruit sucking moth.

vi) Use of ant pans – use of four leg rack in vessels containing water to prevent from ants.

vii) Screening of houses – screening the windows, doors, etc. to prevent from mosquitoes.

viii) Bird scarer – device used to scare away the birds by explosive sounds called bird scarer.

3) Use of Mechanical Devices: -Various traps are used for collecting & killing of insects.

i) Light traps – Light is used to attract the insects. e.g. moths, beetles *etc.*

ii) Air suction traps – the traps are fixed in godowns against stored grain pests.

iii) Electric trap – live metal screen on which birds & insects are electrocuted.

iv) Use of flame thrower – burning of locust adults or hoppers with the help of flame.

Merits: -

i) Insect population is directly hit by mechanical devices or manual operations.

ii) Environmentally safe.

iii) Highly special equipments not required.

iv) They are economically good & generally popular.

v) It is more useful in highly pest populated areas.

Demerits: -

i) It requires more time to get result *i.e.* it is time consuming method.

ii) These methods are ineffective on large areas & cannot be apply commercially.

C) PHYSICAL CONTROL/METHODS: -

Definition: Use of the physical forces or factors of environment for the eradication of insects.

1) Application of Heat – Heating of the empty godowns above 50°c kills the hibernating stored grain pests. Exposing infested grains to the sun in summer also kills stored grain pests. Flame thrower is used to control the locust.

2) Application of cold – refrigeration at 5-10°c of edibles including dry fruits will kill the insect. Many insects fail to multiply below 10°c. Potato is stored at low temperature.

3) Manipulation of moisture – By draining away the stagnant water mosquito's reproduction stops. Reducing the moisture content of grains below 8% can save from most of the insects.

4) Radio activity – High frequency radio waves generate about 80°c temperature in grains to kill weevils. Male insect can make sterile by gamma radiation.

5) Manipulation of soil – Steam sterilization of soil is done to kill soil insects and nematodes.

6) Sound – Exposure of insects to ultrasonic waves of 100 kilocycles for 4-30 minutes at 500 watts has been found to be lethal to most of insects.

Merits: -

i) It gives immediate results.

ii) These methods are generally popular & believable to farmers.

iii) Insects are killed by physical action hence environmentally safe.

Demerits: -

i) These methods are time consuming & costly.

ii) These methods are useful only when much more damage has done.

iii) Special equipment are required for heating & refrigeration.

BIOLOGICAL METHOD

- **Definition:** Destruction, regulation or suppression of undesirable insects, other animals or plants by introduction, encouragement or artificial increase of their natural enemies.
- **Paul Debach (1973) -** The study and utilization of parasitoids, predators and pathogens for the regulation of pest population densities.
    - **Predators:** Predators are free living organisms that feed on living insects & consume more than one individual during their lifespan. They attack on prey at larval & adult stage. **E. g. Lady Bird beetle, Green lace wing, Mantid, Dragon fly, Syrphid fly etc.**
    - **Parasitoid:** An insect parasite of an arthropod that is parasitic in its immature stages killing the host in the process of development and adults are free living. **E. g. *Trichogramma* spp., *Apanteles flavips, Epiricania meloneuca, Capidosoma koeheleri, Chilonus blackberni, Braconid wasps etc.***
    - **Parasites:** Parasites are organisms which live on other organisms for getting food & shelter. The association of parasite and host known as parasitism. A parasite weakens or kills the host while feeding requires only one part of one host to reach maturity. **E.g. ticks, lice, Bed bugs, Protozoa, Nematodes, Mosquitos etc.**

Differentiating points –

Sr. No.	Properties	True Parasite	Parasitoids	Predator
1	**Size**	Smaller than host	Same as that of host	Larger than host
2	**Feeding stages**	Larvae and adults	Only larvae adults are free living (Feed on nectar of flowers)	Larvae and adults
3	**No. of host needed**	One	one	More than one
4	**Injury to the host**	Feed without killing	Paralyze to oviposit and kill	Kill to devour
5	**Activity**	Functions at low host density, so efficient	Functions at low host density, so efficient	Functions at higher host density
6	**Host specificity**	Great	Great	Not so great
7	**Suitability for biological control**	Not suited	Best suited	Suited
8	**Examples**	ticks, lice, Bed bugs, Protozoa, Nematodes, Mosquitos etc.	*Trichogramma* spp., *Apanteles flavips, Epiricania meloneuca, Capidosoma koeheleri, Chilonus blackberni, Braconid wasps etc.*	E. g. Lady Bird beetle, Green lace wing, Mantid, Dragon fly, Syrphid fly etc.

History of biological control

- ✓ The term biocontrol first time used by **H. S. Smith** in 1919. He is also referred as father of biocontrol. **Paul Debach (1973) -** He is a pioneer worker in biocontrol.
- ✓ **Ancient times** - In China Pharoah's ant was used to control stored grain pest. Red ant also used to control foliage feeding caterpillar, **1762** - 'Mynah' bird imported from India to Mauritius to control locust, 1770 - Bamboo runways between citrus trees for ants to control caterpillar.
- ✓ **November 1888 - First well planned and successful biological control attempt made -**
- In California (USA) Vedalia beetle (*Rodolia cardinalis*) introduce from Australia to control of cottony cushion scale, pest of citrus, by the scientists **Mr. C.V. Riley & Mr. Albert Koeble.** This is the first classical example of biological control.
- ✓ **1898 - First introduction of natural enemy into India-**
  - **1898 -** A coccinellid beetle (Australian lady bird beetle), **Cryptolaemus montrouzieri** was imported into India from Australia and released against coffee green scale, *Cocus viridis.* Even today it is effective against mealybugs in South India.
  - **1920 -** A parasitoid *Aphelinus mali* introduced from England into India to control Woolly aphid on Apple, *Eriosoma lanigerum.*
  - **1929-31 -** *Rodolia cardinalis* (common names vedalia beetle or cardinal ladybird) is a species of ladybird beetle that is sometimes described as endemic to Australia.

imported into India (from USA) to control cottony cushion scale *Icerya purchasi* on Wattle trees.

- ✓ Regional Station of Commonwealth Institute of Biological Control (CIBC) established at Bangalore in 1957. Presently Project Directorate of Biological Control (PDBC) Bangalore looks after Biocontrol in India. Recently it called as International Center for Agricultural Important Insects in 2006.

✪ Characteristics of ideal parasites/Qualities of an effective natural enemy

- ✓ **Adaptability:** It should be Adapted to varied environmental condition & survive in all habitats of pests.
- ✓ **Host specific:** It should be Monophagous and should be narrow host range.
- ✓ **Fast multiplication:** Multiply faster than the host Short life cycle with high fecundity and high female: male ratio.
- ✓ **High host searching capacity**.
- ✓ **Easy rearing and mass multiplication**/culturing in laboratory.
- ✓ **Disperse** quickly in locality.
- ✓ It should be **free from hyper parasites**.
- ✓ It should not harmful to other beneficial species and plant species.
- ✓ It should withstand refrigeration.
- ✓ It should be small and tiny.

Types of parasites -

1) **Primary parasites: -** The parasites attack on crop pests.
2) **Secondary parasites: -** The insects which parasitize the primary parasites of pest called secondary parasites.
3) **Tertiary parasites: -** The parasites attack on secondary parasites.
4) **Hyperparasites: -** All parasites that are parasite upon other parasites are collectively called as Hyperparasites.
5) **Super parasitism: -** It is a type of parasitism where more individuals of the same species are present in a single host they can complete their development in normal way. E. g. Larva of pin sawfly carry tachinid fly.
6) **Multiple parasitisms: -** It is a type of parasitism where the host is attacked by two or more species of parasitoids.

   E.g. **Ecto parasitoid -** Feed externally e.g. *Bracon brevicornis*

   Endo parasitoid - Feed internally e.g. *Chelonus blackburni*

Methods/ Techniques in Biological Control:

- Three major techniques of biological control

1. **Conservation and encouragement of indigenous natural enemies –**
    - It refers to avoid use of those pest control measures that destroy natural enemies.
    - It can be achieved by use of selective insecticides which do not kill the natural enemies and development of resistant strains of parasite to pesticides. E. g. Endogramma of *Trichogramma* spp. this is resistant to Endosulfan.
    - Avoidance of those cultural practices which are harmful for natural enemies.
    - Preservation of inactive stages of natural enemies.
2. **Importation or Introduction –**
    - Natural enemies are introduced from other areas into a new locality (mainly to control introduced pests)
    - The organization which helpful for finding exotic predator like-
        1) Commonwealth Institute of Biocontrol-Trinidad, West Indies
        2) International Organization for Biocontrol of noxious animals and plants- Zurich, Switzerland
        3) International Center for Agricultural Important Insects- Bangalore, India
3. **Augmentation –**
    - It includes activities designed to increase the numbers or effect of existing natural enemies.
    - Propagation (mass culturing) and release of NE to increase its population.
    - It may be two types-

      a. Inoculatve release: This type of release may be made as infrequently as once a year or season to re-establish a species of natural enemies.

      b. Inundative release: It involves mass culture and release of natural enemies to suppress the pest population directly.

Natural enemies used in Biological control:

I] Insects:

a) **Predaceous insects** –

- ✓ *Chrysoperla carnia* (Green Lace Wing) feed on Aphids, Jassids, whitefly, etc.
- ✓ *Cryptolaemus montrouzieri* (Australian Ladybird beetle) feed on mealy bugs.
- ✓ *Coccinella septumpunctata* (Ladybird beetle) feed on aphids
- ✓ Syrphid fly - Feed on different insects.
- ✓ Vedalia beetle feed on cottony cushion scale.
- ✓ *Dipha (Conobathra) aphidivora* feed on sugarcane wooly aphids.

b) **Parasitic insects - (Parasitoids)**

- ✓ Egg Parasitoids - *Trichogramma japonicum*: parasite of stem borer of paddy. *Trichogramma chilonus* - parasite of Cotton bollworms & sugarcane stem bores.
- ✓ Larval Parasitoid - *Bracon kirkpatrickii* & *Apanteles angaleti* parasite of cotton bollworms.

- ✓ Egg-Larval Paranoids - *Capidosoma koeheleri* & *Chilonus blackberni* - parasite of potato tuber moth.
- ✓ Nymphal & Adult Parasitoid - *Epiricania meloneuca* - parasite of sugarcane pyrilla. *Aphelinus mali* - parasite of Apple wooly aphids.

II] Predatory vertebrates:

- ✓ Birds – Useful birds which destroyed crop pests includes king-crow & myna. Ducks used in rice to control bug.
- ✓ Fishes – Destroy large number of mosquito larva.
- ✓ Frog – Destroy paddy stem borer.
- ✓ Toad & wall lizard – Live on insects such as termites‟ crickets, grasshoppers, bug, etc.
- ✓ Snakes –feed on rats.

III] Nematode parasites:

- ✓ 46 nematodes species, parasitizing various species of beetle, grasshoppers, cockroaches, moths etc.
- ✓ *Neoaplectana glaseri* used for control of Japnese beetle.
- ✓ Nematodes especially rhabditids are found to have a symbiotic relationship with the bacteria, forming disease complex. E.g. **DD-136** Association beetween the nematode *Neoplanctana caprocapsi* and bacterium *Acromobacter nimatophilus* against Codling moth of apple.

IV] Pathogens:

- Certain microorganism able to causing diseases in insects which includes fungi, bacteria, viruses, protozoa, rickettsia and nematodes.
- **Microbial control: -** It is a branch of biological control which deals with study and utilization of microorganism for the suppression of pest population density.
- The Microbial control first time used by the **E. A. Steinhause** in 1949 referred as a ‘Father of Insect Pathology’ worked on Muscardine diseases of silkworm.

1) **Fungi –** The fungi which cause disease in insects called as **Entomopathogenic fungi.** Adults are more affected than larvae to Entomopathogenic fungi. Fungi require high atmospheric humidity to germinate. Fungi get entry through integument, via respiration. Fungus gets entry with the help of aspersoria which is present on conidia. They are usually attack on dipteran insects followed by Hemiptera, lepidopteran & coleopteran. Besides Entomopathogenic fungi the other fungi is also attack on insects like **Entomophilic fungi** (insect loving) and **Entomophagous fungi** (feed on insects) E.g. **Green muscardine fungus-** *Metarhizium anisopliae* attack on coconut rhinoceros beetle & sugarcane pyrilla, **White muscardine fungus-** *Beaveria bassiana* against lepidopteran larvae, **White halo fungus-** *Verticillium lecanii* on coffee green scale & *Entomophthora grylli* on grasshoppers.

2) **Bacteria –**The bacteria cause disease in the insects when they infect through ingestion.
   a) Spore forming (Facultative, Crystelliferous) - They produce spores and also toxin (endotoxin). The endotoxin paralyses gut when ingested by insects e.g. *Bacillus thuringiensis var. kurstaki* effective against lepidopteran & it is stomach poison. Commercial products - Delfin, Dipel, Thuricide
   b) Spore-forming (Obligate) - e.g. *Bacillus popilliae* attacking on beetles cause 'milky disease'. Commercial product - 'Doom' against 'white grubs'
   c) Non-spore forming - e.g. *Serratia entomophila* on grubs
3) **Viruses –**
   There are six families of insect viruses. Among them baculoviridae is important which includes the nuclear polyhedrosis & granulosis are most lethal & promising viral insecticides which cause disease in Lepidoptera larvae. Insect viruses have great potential for field because of their specificity & effectiveness against important crop pests. Two types of viruses are common.
   a) **NPV** (Nucleo polyhedrosis viruses) - e.g. **HaNPV** (*Helicoverpa armigera* nuclear polyhedrosis viruses) against American bollworm, **SlNPV** (*Spodoptera litura* nuclear polyhedrosis viruses) against tobacco leaf eating caterpillar.
   b) **GV** (Granulovirus viruses)-e.g. **CiGV** (*Chillo infuscatellus* Granulovirus viruses)
4) **Protozoa –**
   The role of protozoa as microbial agents in artificial control is limited because of difficulties in their mass multiplication for field release. E.g. *Nosema bombycis* on silkworm and *Perezia pyraustae* on Eropian corn borer.
5) **Biological control of weeds**

- ✓ *Lantana camara* (Ghanery) control by Lantana seed fly *Agromyza lantinae.*
- ✓ Maxican beetle, *Zygogramma bicolorata* effective against *parthenium.*
- ✓ Leaf eating weevils, *Neochetina* spp. feed on water hyacinth.

Advantages of biological control: -

i) Complete control over large area is possible.
ii) Co-operative efforts of farmers of a locality are not necessary.
iii) It is cheap method as it useful to long time.
iv) Biological agents will survive as long as the pest is survive.
v) It is environmentally safe.
vi) There is no pest resistance problem.

Demerits biological control: -

i) It is slow process & takes long time.
ii) Not suitable where immediate control required.
iii) Effectiveness depends upon climate.
iv) Multiplication on large scale is difficult i.e. storage not possible.
v) The work cannot be restricted at a particular area.
vi) If alternate hosts are present it may not give desired effect.
vii) Work of biological agents may affect due to the Hyperparasites.

LEGAL METHODS

- ✓ **Definition:** It is defined as way of controlling pests by imposing various legal restrictions in order to prevent the entry of foreign pest or to prevent the spread of pests within country.

Pests Accidentally Introduced into India (Exotic pests)

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

Foreign Pests from Which India is Free- 1. Mediterranean fruit fly, 2. Cotton boll weevil & 3. Codling moth of apple.

Quarantine - Isolation to prevent spreading of infection.

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

Pest Legislations

1905 - 'Federal Insect Pest Act' - first Quarantine act against San Jose scale in USA.

1912 - 'US Plant Quarantine Act'

1914 - 'Destructive Insects and Pests Act' of India (DIPA)

1919 - 'Madras Agricultural Pests and Diseases Act'

1968 - 'The Insecticides Act'

Different legislative measures:

i) Legislation to prevent the introduction of new pest, diseases & weeds from foreign countries.

ii) Legislation to prevent the spread of already established pest, diseases & weeds from one part of country to another.

iii) Legislation to enforce upon the farmers for application of effective control measures to prevent the damage by already established pest, diseases & weeds.

iv) Legislation to prevent the adulteration & misbranding of insecticides & to determine the permissible residue tolerances in food stuffs.

v) Legislation to regulate the activities of pest control operations & the application of hazardous insecticide.

Categories of legal Methods/Different Classes of Quarantine:

1) Foreign quarantine:

- Legislation to prevent the introduction of new pest, diseases & weeds from foreign countries.
- To prevent the entry of foreign pests, in the world have restrictions on the import of infested or infected plant materials under the provisions of quarantine laws. These plants materials examined at each seaports like Mumbai, Calcutta, Cochin & Chennai and airport like Amritsar, Mumbai, Calcutta, and Chennai & New Delhi.
- These stations operate under the provision made under the Government of India's Destructive Insects and Pests Act of 1914.
- The **"Phytosanitary Certificate"** should be issued by the officer of Department of Agriculture of exporting country as to their freedom from pest & diseases.
- The Central Directorate of Plant Protection and Quarantine was established in 1946.

2) Domestic quarantine:

- Legislation to prevent the spread of already established pest, diseases & weeds from one part of country to another.
- "The Bombay Agricultural Pests and Diseases Act" was passed in 1947 and accordance with this the domestic quarantine in the state is being implemented.
- The Directorate of Plant Protection, Quarantine and storage is overall Incharge for this work and it operates through several Inter-State check posts.
- So far Cottony cushion scale and San Jose scale were covered under this type of quarantine.

3) Pest Act:

- Legislation to enforce upon the farmers for application of effective control measures to prevent the damage by already established pest, diseases & weeds.
- Under the provision of "The Bombay Agricultural Pests and Diseases Act" State Government may declared that certain pest is injurious in given area & carry out preventive and remedial measures in order to eradicate the pest within a specified period.

4) Insecticides Act:

- Legislation to prevent the adulteration & misbranding of insecticides & to determine the permissible residue tolerances in food stuffs.
- The manufacture of insecticides should resister themselves stating the name and address of the manufacturer, the brand and trade name of the insecticide, active ingredient and other constituents of the product to be manufactured, its net contents in an unit pack which should also carry in detailed directions for use including the antidote against the insecticide in case of poisoning. The container should carry "poison label" with warning or caution statement.

- The Government of India passed the **Insecticide Act, 1968 (No. 46 of 1968) on 2nd September, 1968** to regulate the import, manufacture, sale, transport, distribution and use of insecticides with a view to prevent risk to human beings and animals.
- **The Insecticides Rules** framed under the Insecticide Act, 1968 (46 of 1968) came in to force in **1st Jan, 1971.**
- **Licensing authority -** In Maharashtra the commissioner of Agriculture, M.S. Pune is the Licensing authority. However on behalf of him, Chief Plant Protection Officer, MH State, Pune act as licensing officer for manufacture and formulation of pesticides and for sale and stock concerned Divisional Superintending Agriculture Officer acts as licensing officer.

  Appellate Authority - any appeal against any decision of the licensing officer is made to Appellate Authority. In MH, Joint Director of Agriculture (Extension), Department of Agriculture M. S. Pune acts as Appellate Authority.

  Insecticides Inspectors (Quality Control Officers) - The District Agriculture Officer of Z.P. & Sub-divisional Agricultural Officers of Department of Agriculture can collect the insecticides samples from the shops to ascertain their purity through insecticidal residue laboratories.

Objectives:

1. To prevent the adulteration & misbranding of insecticides.
2. To regulate the import, manufacture, sale, transport, distribution and use of insecticide.
3. To help and guide farmers for the use of insecticides.

CHEMICAL CONTROL

- **Chemical Control**: Management of insect pests using chemical pesticides is termed as chemical control. **Or** Pest control with the help of various chemicals is called as chemical control.
- **Pesticides: -** The chemicals which applied for control of insect pests are called as pesticides.

❖ History of insecticides development

Year	Chemicals Discovered
900	**Arsenites** used in China (Inorganic compound)
1690	Tobacco extract used in Europe (Plant/natural product)
1787	Soaps used in Europe
1858	**Pyrethrum was first time used** for insect control in USA
1867	Paris Green in US
1874	**DDT synthezized by Zeidler**
1883	Bordeaux Mixture used in France
1892	Lead arsenate was used for control of Gypsy moth in USA
1925	Dinitro compounds used **(First synthetic organic insecticide)**
1939	Discovered of insecticidal property of **DDT** by **Paul Muller** in Switzerland. (Awarded Nobel Prize in 1948)
1941	**BHC** used or discovered the insecticidal property in France and UK (in 1942) (BHC is presently called as **HCH**)
1944	Parathion (Organophosphate) discovered by Gerhard Schrader in Germany
1945	Chlordane (Cyclodian compound) used in Germany
1947	Carbamate insecticides in Switzerland
1962	**Miss Rachel Carson's** wrote the book name **'Silent Spring'** in US which gives the impact of insecticides on environment.
1967	First JH mimic **(Juvenile Hormone mimic)** used in US (Insect growth regulator)
1970	Development of synthetic pyrethroids (UK) (Fast degradation) (Effective at very low doses)
1980	Discovery of **avermectins** (derived from bacteria). Effective at low dose. Fast degradation.
1990	Discovery of newer groups like (1) **Neonicotinoids** (Imidacloprid), similar to natural nicotine, (2) Spinosyns (e.g. Spinosad) derived from **actinomycet**

Various generations of insecticides

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

⌘ Classification of Pesticides/Pesticides Groups

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

1. Based on organism against which the compounds are used

Sr. No.	Name of insecticides	Definition
1	Insecticides	Chemicals used to kill or control insects. E.g. Carbaryl, malathion
2	Rodenticides	Chemicals used to kill the rodents called rodenticides. E.g. Zinc phosphide
3	Acaricides/Miticides	Chemicals used to kill the mites, ticks and spider called acaricides. E. g. Dicofol, Properguite
4	Avicides	Chemicals used to repel the birds. E.g. Anthraquionone
5	Molluscicides	Chemicals used to kill the snails and slugs. E.g. Metaldehyde
6	Nematicides	Chemicals used to control nematodes E.g. Ethylene dibromide
7	Fungicides	Chemicals used to control plant diseases caused by fungi. E.g. Copper oxychloride
8	Bactericide	Chemicals used to control plant diseases caused by bacteria. E.g. Streptomycin sulphate
9	Herbicide	Chemicals used to control weeds. E.g. 2,4,D
10	Algicides	Chemicals used to control algae.
11	Arboricides	Chemicals used to control trees or shrubs.
12	Piscicides	Chemicals used to control harmful fishes.

2. Classification based on Mode of entry

a) Stomach poison –

- ✓ Insecticides applied on leaves and other parts of plants when ingested get entry in insects & act on digestive system to cause death of the insect. This type of chemicals is limited mainly to the chewing type of insects like grasshopper, beetles, caterpillar etc.
- ✓ The stomach poison should be sufficiently stable, cheap, and palatable for the pest, available in large quantities.
- ✓ These chemicals may be applied in the form of dust or spray or in poison bait.
- ✓ E.g. *Bt*, Organochlorine and organophosphates insecticides etc.

b) Contact poison –

- ✓ The toxicant which causes death of insect by means of contact with insecticide. Insecticides get absorb by the sutures, membrane & tracheal system on insect body. This is achieved by direct application of insecticides on pest species.
- ✓ E.g. Nicotine, Pyrethrum, quinolphos, Malathion, synthetic pyrethroids etc.

c) Fumigants –

- ✓ Toxicant which in its gaseous state or in vapour form penetrate in insect through the tracheal system (respiratory poison) through spiracles & kills the insect.
- ✓ Their application is limited to plants or plant products in air-tight enclosures.
- ✓ E.g. Methyl Bromide, Hydrogen cyanide (HCN), ethylene dibromide, DDVP, Lindane.

d) Systemic poison -

- ✓ Chemicals when applied to plant or soil are absorbed by foliage (or) roots and translocated through vascular system and cause death of insect feeding on plant.
- ✓ It is effective against the pest having sucking type of mouth parts such as aphid, jassid, thrips, white fly etc.
- ✓ E.g. Dimethoate, Imadaclopirid, Phorate, carbofuran etc.

3. Classification based on mode of action: -

a) Physical poison – Chemical which can kill insects by following three ways;

- ✓ **Asphyxiation** – A physical poison kill the insects exert by physical effect through asphyxiation i.e. exclusion of air called physical poison. E.g. effect of heavy oil & Tar oil on scale insects.
- ✓ **Moisture stress –** Loss of moisture from insect body by inert dust, charcoal, activated clay, ash etc.
- ✓ **Mechanical injury –** Epicuticle of insect gets lacerated by abrasive dust like aluminum oxide & this may cause water loss.

b) Protoplasmic poison –

- ✓ Toxicant responsible for precipitation of protein, destruction of midgut epithelium called as protoplasmic poison.
- ✓ E.g. Heavy metals like mercury, copper, Fluorine.

c) Respiratory poison –

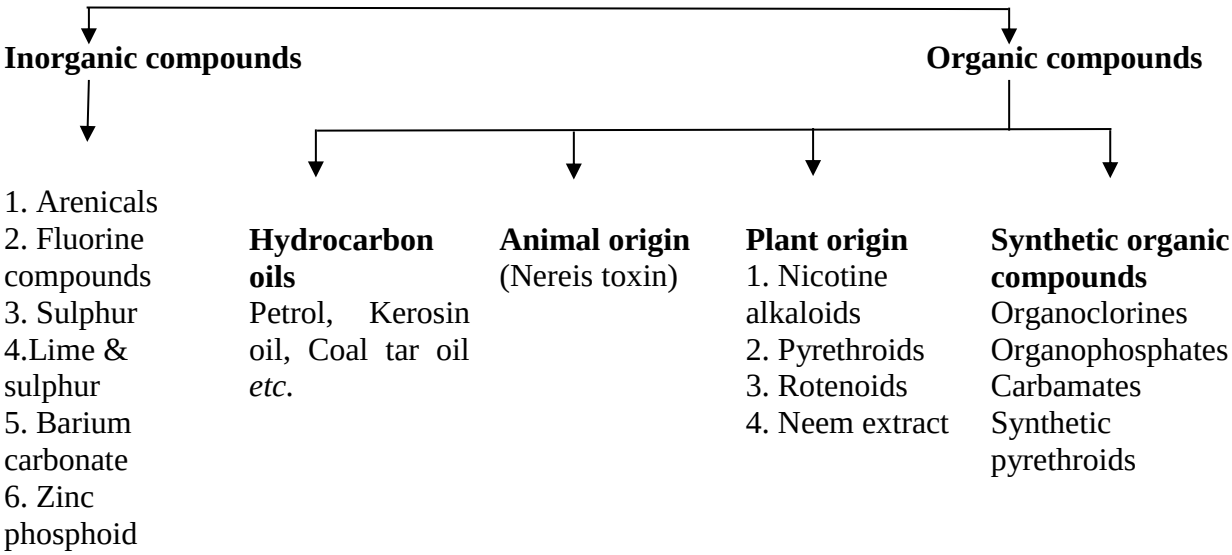
- ✓ The chemical which block cellular respiration, inactivation of respiration & respiratory enzymes. This is known as **anoxia**.
- ✓ E.g. Hydrogen cyanide (HCN), Carbon monoxide (CO).

d) Nerve poison –

- ✓ The chemicals which affect the nervous system of the insect or Chemicals inhibit the production of acetylcholinesterase enzyme in insects called as nerve poison.
- ✓ E.g. organophosphate, carbamate, organochlorines, pyrethrum and nicotine.

e) Chitin inhibition - Chemicals inhibit chitin synthesis. E.g. Diflubenzuron

1. Classification based on the Chemical nature of insecticide



A) Inorganic Compounds: -

- ✓ The insecticides derived from naturally occurring elements which do not contain carbon.
- ✓ It comprises compounds of mineral origin and element Sulphur and phosphorus.
- ✓ They are stable, non-volatile and soluble in water.
- ✓ Many of them are persistent and because of their residual persistent high mammalian toxicity it's a limited used.
- ✓ Both boric acid and silica used in baits for controlling the household pests like cockroaches and ants.

1) Arsenicals -

- These are stomach poisons formed of toxic compounds of non-toxic elements arsenic.
- They are phytotoxic & not applied on plants.
- It is used in poison baits.
- They kill the insects due to the inhibition of respiratory enzyme.
- They are more stable and not harmful to plants.
- E.g. lead arsenate, Calcium arsenate, Sodium arsenate, *etc.*

2) Fluorine compounds -

- They kill the insects more rapidly than arsenicals. They are cheaper & less toxic to higher animals.
- They are stomach & contact poison.
- They are irritating to the appendages of insects.
- These are cheaper and non-toxic to plants and animals.
- E.g. Sodium fluoride, Sodium fluosilicate.

3) Sulphur -

- It is a contact poison.
- It is available in the form of both formulation dust as well as Wettable powder.
- It is used as acaricide as well as fungicide.

4) Lime Sulphur -

- It is prepared by boiling lime & Sulphur together in water (1:2).
- It is used against aphids, mites, San Jose Scale etc.

5) Zinc-phosphide -

- It is rodenticide used to control rat.
- It is heavy dark grey powder with disagreeable odour.
- Baits containing 2 % zinc phosphide are recommended for control of rats. In rats the chemicals reacts with the hydrochloric acids present in the stomach and release phosphine gas which is lethal to the rats.

6) Barium carbonate-

- It is also acts rodenticide.
- After ingestion internal bleeding of intestinal tract & kidneys occurred.

B] Organic Compounds: -

✓ These are man-made or extracted pesticides consisting of carbon, hydrogen and chlorine, oxygen, sulphur, phosphorus and nitrogen.

a) Hydrocarbon oils:

- Oils composed of hydrogen & carbon. It has two groups *viz.*
- **1) Mineral oils –** These are petroleum oils derived from secondary rocks. E.g. Kerosene, Petrol, Lubricants oil etc.
- **2) Coal-tar oils** – These are creosol oil & green oils are useful for insecticidal purpose. E.g. summer oils, dormant oils, spray oils, supreme spray oils and Borer solution to control bark borer, stem borer.

b) Animal origin insecticides:

- A toxin isolated from Marine annelids, *Lumbrineris heteropoda* & *Lumbrineris vicirra.* i.e. **Nereis toxin.**
- Insecticidal properties of **Nereis toxin** has been found by Nitta in 1934 and it is given by Sakai in 1964.
- Common name of Nereis toxin is Cartap and Trade name is Padan.
- It is effective against rice stem borer & cabbage diamond moth.

c) Plant origin insecticides: (Botanicals insecticides/Natural insectcides)

- ✓ Toxicants derived from plants & used in insect control.
- ✓ It includes nicotine, pyrethrum, rotenone, Azadirachtin, Scilliroside, Pongram, Rynia, Sabadilla.
- ✓ Certain plant products also used as a nematicides, insect attractants and repellants and as diluents in insecticidal formulation.

1) Nicotine -

- Tobacco was used in insect control as early as 1763, the principal alkaloid **Nicotine** was discovered in 1828.
- The chief source is *Nicotiana tabaccum* & *Nicotiana rustica*. 12 alkaloids have been isolated from tobacco and alkaloid Nicotine constitutes 97% of the total alkaloids.
- Nicotine in leaves of *N. tabacum* is 2-5%. Nicotine is obtained from leaves and stem of waste tobacco by steam sterilization.
- It is nerve poison & highly toxic when absorbed through cuticle/trachea.
- The commercial product is Nicotine sulphate containing 40% alkaloid.
- It is water soluble. It may be used as a spray or dust.
- It is effective against soft bodies insects like thrips, hoppers, *etc.*
- It is also a neuro-muscular poison in man and animal hence its used is discouraged.

2) Neem -

- The neem tree i.e. *Azadirachta indica* which is indigenous to India having the various medicinal and insecticidal values. Now days it is assuming as an International Tree.
- All parts of neem possess insecticidal activity but seeds are main source which is most effective.
- Neem bark leaves and neem oil as well as extracts with various solvents like ethanol are found effective.
- **Azadirachtin** is the main active ingredient present in neem with other alkaloids like limonoids and protolimonoids which shown repellent, antifeedants and insecticidal activity.
- The antifeedants activity against desert locust which is shown by Pradhan et al. in 1962.
- It is used as growth inhibitor, cause egg sterility & adverse effect on fecundity.
- It is effective against American bollworm, leaf eating caterpillar, Diamond back moth, and armyworm and sucking pest like leaf hoppers, thrips.
- Many commercial formulations are available in market like Achook, Bioneem, Econeem, Neemark, Neemazal, Neem oil.
- 5% Neem Seed Kernel Extract (NSKE) is mostly used in IPM programmes.

3) Pyrethroids/Pyrethrums/Pyrethrins -

- These are extracted from Chrysanthemum flower which contain active ingredients pyrethrin I and II & cinerin I and II.
- Pyrethrums are dried flower powder of Chrysanthemum, Pyrethrins are all the active toxins of pyrethrum and Pyrethroids are synthetic derivatives of pyrethrin.
- All pyrethroids are lipophilic (Fat loving) compounds and insoluble in water.

- It show higher toxicity against insects & very safe to mammals.
- These are contact poisons.
- Synthetic Pyrethroids like Cypermethrine, Permethrin, Deltamethrin, Decamethrine and fenvalerate are effective against soft bodies & lipidopterous insects which are contact and stomach poisons.
- **Allethrin** was the **first synthetic analogue of pyrethrum** developed in **1949**.

4) Rotenone -

- It is derived from roots of bean legumes, *Derris eliptica*.
- Used in 1848 against leaf eating caterpillar.
- The active ingredient i.e. rotenone is isolated by the scientist Geoffroy I 1882.
- It is a contact and stomach poison.
- It inhibits respiratory metabolism".
- It is extremely toxic to fish hence used as a **piscide** (The chemical which is used to kill the fishes).

5) Scilliroside -

- These are obtained from the bulb of Red Squill, *Urginea maritime*.
- The active ingredient presents i.e. **Scilliroside** which is generally used as rodenticides.
- It is a stomach poison.
- It is used to control the rats and mice.

6) Pongramm -

- These are derived from the plant *Pongamia pinnata* (Karanj).
- The active ingredient presents i.e. **Pongram** has been identified as '**karanjin'**.
- Karanj oil applied as surface protectant and repellent.
- It is used against pulse beetle and sucking pests.

7) Sabadilla -

- It is an alkaloid extracted from seeds of *Schoenocaulon officinale.*

8) Rynia -

- It is extracted from stem, roots, leaves and stalks of tropical shrub of *Ryania speciosa*. Salicaceae, South American plant.
- It is water soluble powder.
- Extract contains several structurally related ryanoids including –**ryanodine** and 9, 21-dehydroryanodine.
- The extract has a very low acute toxicity to mammals.
- Used for control of both adults and larval Lepidoptera.

d) Synthetic organic insecticides: -

- ✓ These are dominating the field of pest control today.
- ✓ Historically Denitrophenols come first in 1925.
- ✓ It includes organochlorine, organophosphate, carbamates and synthetic pyrethroids.

1) Dinitrophenols: ((DNOC)

- They are Stomach poison with ovicidal effect on eggs of certain insects.
- E.g. Dinocap

2) Organic Thyocinates:

- It cause quick knock down effect.
- It is contact poison.
- E.g. **Loro -** Used against thrips, mites and aphids. **Thanite -** Used against housefly and cattle pests.

3) Chlorinated hydrocarbons or organochlorines compounds:

- ✓ It includes DDT, BHC and Cyclodiene compound.
- ❖ **DDT-** (Dichlorodiphenyl trichloroethane)
  - It was **synthesized** by a German chemist **Zeidlar** in 1874.
  - Its **insecticidal properties** were given by **Paul Muller** in 1939.
  - The proper chemical name of DDT is 2, 2-bis (P-chlorophenyl) 1, 1, 1-(trichloroethane).
  - It was very effective against flies, mosquitoes, lice and fleas and also used in agriculture and horticulture sector.
  - It has long residual life and persistence in the soil in aquatic environment and also accumulates in plant and animal tissue hence it's used is banned in agriculture.
  - **DDT analogues -** DDD (Dichloro diphenyl dichloroethane), Dicofol (Kelthane-It is an acaricides), Methoxychlor.
- ❖ **BHC-** (HCH)
  - The proper chemical name of HCH is 1, 2, 3, 4, 5, 6- Hexachloro cyclohexane and common name is benzene hexachloride.
  - It is **synthesized** by a **Michael Faraday** in 1825.
  - Its **insecticidal properties** were given by A.P.W. Dupire in 1941 and F.D. Leicester in 1942.
  - BHC is a mixture five isomers in which gamma isomers were found to have insecticidal properties is known as HCH.
  - A product containing 99% pure gamma isomers called **lindane** name proposed after Vander Lindane, who was isolate this isomers in 1912.
  - HCH is stomach and contact poison and has fumigant action.
  - Lindane mostly used in control of stored grain pests.
- ❖ **Cyclodiene compound -**
  - Due to the persistence in the soil, resistance in insect, fish toxicity and serious environmental hazards is being banned insectcides.

- It includes Endosulfan, Aldrin, Dieldrin, Heptachlor and chlordane.
- **Endosulfan -**
  - Its insecticidal properties were first discovered by W. **Finkenbrink** in1956.
  - It is a stomach and contact poison.
  - It is effective against sucking pests, caterpillars and borers.
  - It is available in the form of dust, EC and granule formulations.

❖ **Chlorinated terpenes -** e. g. Toxaphene

4) Organophosphorus insecticides or organophosphates:

- ✓ They comprise a large group of compounds.
- ✓ They are generally acutely toxic to man and animals and they are non-persistent.
- ✓ They have a short residual activity.
- ✓ They are nerve poison which inhibits the cholinesterase enzyme.
- ✓ These are stomach, contact and systemic in activity.
- ✓ It has been used in large scale for agriculture because of its high efficacy against many insects-pests, low mammalian toxicity, short residual activity and little resistance among insect-pests.
- ✓ Insecticides like Dematon, Dimethoate, Phorate, Phosphamidon and Monocrotophos have asystemic action hence it is used against sucking pests.
- ✓ Dichlorvos or 2, 2-dichlorovinyl dimethyl phosphate (commonly abbreviated as **DDVP**) and Tetraethyl pyrophosphate, (abbreviated **TEPP)** is an organophosphate, widely used as an insecticide to control household pests, in public health, and protecting stored product from insects.
- ✓ Monocrotophos shows the some acaricidal activity and Dichlorvos shows the fumigant action.
- ✓ Examples - Monocrotophos, Dichlorovos, Triazophos Chloropyriphos, Profenophos, quinophos, Malathion, Phosphamidon, Fenthion, Methyl parathion, Trichlorofon, Methyl dematon, Ethion, Formothion, Fenitrothion, Dematon, Dimethoate, Acephate, Phorate, Fipronil, Indoxacarb, etc.

5) Carbamates:

- ✓ These are ester of carbamic acids.
- ✓ They generally have a short residual activity and a very broad-spectrum effectivity as insecticides, miticides, nematicides and molluscicides,
- ✓ **Carbary -**
  - The trade name of carbaryl is Sevin.
  - It is contact and stomach poison.
  - It is available in the form of dust, granules and Wettable powder formulation.
  - It is very popular in horticulture for pest management.
- ✓ **Carbofuran -**
  - The trade name is Furadan.
  - It is systemic in action hence effective against sucking pests.
  - It is also used as nematicides and soil pests.
- ✓ Other examples of carbamates such as Aldicarb, Mythomyl, Thiodicarb, Oxamyl etc.

6) Synthetic pyrethroids -

- ✓ These are extracted from Chrysanthemum flowers.
- ✓ These are the mixtures of six esters named pyrethrin I and II, cinerin I and II and jasmolin I and II.
- ✓ Generally it is botanical insecticides but as they contain only one of these esters, isect species tend to develop resistance to them.
- ✓ Generally pyrethroids shows low mammalian toxicity but pyrethrum, are highly toxic to fish and bees because they having all six esters properties hence it is not suited in agriculture.
- ✓ These are contact and stomach poisons.
- ✓ Examples - Allethrin, Resmethrin, Deltamethrin, Permethrin, Fenvalerate, Cypermethrin, Cyfluthrin and Bifenthrin.

7) Fumigant:

- ✓ These are the substance which produces gas, vapour, fumes or smoke intended to kill insects, nematodes, bacteria or rodents.
- ✓ Generally these are solid, liquid or gaseous substances which contain halogen atoms.
- ✓ They are used to disinfect the buildings, stored produce or the soil.
- ✓ Chloropicrin is called as "tear gas".
- ✓ E.g. Chloropicrin, Aluminium phosphide tablets, Ethylene dibromide, Methyl bromide, Formaldehyde, Phosphine, Naphthalene.

New groups of insecticides/ Newer Insecticides

A) Neonicotinoids -

- ✓ These are new class of insecticides with novel mode of action.
- ✓ It is effective against sucking pests.
- ✓ It acts on the nicotine acetylcholine receptors (nAChR) at the synaptic junctions of insect central nervous system.
- ✓ Examples - Imidacloprid, Acetamiprid, Thiomethoxam, Thiocloprid, Clothianidin etc.

❖ **Imidacloprid -**

- The trade name is Confidor (Bayer), Gaucha (Bayer), Admire etc.
- It is effective as a seed dressing Gaucha (Bayer) and foliar application Confidor (Bayer) against sucking pests like Aphid, Jassids, Thrips and White fly.

❖ **Acetamiprid -**

- The trade name is Pride, Dhanprit, Manik, Lift, Polar, mudra, Record, Enova.
- It is broad spectrum insecticides effective against sucking pests.

❖ **Thiomethoxam -**

- The trade name is Cruiser (Syngenta), Actara (Syngenta).
- It is broad spectrum insecticides effective against sucking pests as a seed treatment Cruiser (Syngenta) and foliar spray Actara (Syngenta).

❖ **Thiocloprid -**

- The trade name is Alanto, Calypso.
- It is broad spectrum insecticides effective against the insect pests.
- It acts as a stomach poison.

B) Spinosyns -

❖ **Spinosad -**

✓ It is introduced by Dow-Elango in 1994.
✓ It is derived from new species of Actinomycetes, *Saccharopolyspora spinose.*
✓ It is commercially available as Spinosad (Tracer).
✓ It acts as stomach and contact poison.
✓ Spinosad is a mixture of spinosyns A and D.
✓ It is broad spectrum insecticides effective against caterpillars.
✓ It acts on the nicotine acetylcholine receptors (nAChR) at the synaptic junctions of insect central nervous system.

C) Avermectins -

✓ These are generally best for the control of greenhouse pests and insects like leaf miners, spider and mites.
✓ It possess novel mode of action by acting on GABA (Gamma Amino Butyric Acid) regulated chloride channels of central nervous system in insects.
✓ They are derived from *Streptomyces avermitilis* by Merck & Co.

❖ **Abamectin -**

- The trade name is Vertimec.
- It is a mixture of two analogs i.e. 80% Avermectins B1a and 20% B1b.
- It acts as a systemic action.

❖ **Emamectin Benzoate -**

- The trade name is Proclaim, Derim, Safari, Tatkal .
- It is analog of abamectin.
- It is effective against caterpillars.
- It acts as a both stomach and contact poison.

C) Oxadiazines -

❖ **Indoxacarb -**

- Commercially available as an Avaunt.
- It is sodium channel blockers in nervous system.
- They have a novel mode of action and it is effective against those pests which developed resistance against synthetic pyrethroids.

D) Phenypyrazoles -

❖ **Fipronil -**

- Commercially available as an Icon and Regent.
- It is effective against those pests that are already become resistance to pyrethroids, organophosphates and carbamates.
- It possess novel mode of action by acting on GABA regulated chloride channels of central nervous system in insects.
- It is stomach and contact poison with systemic action.
- It can use as a foliar, seed treatment and soil application for controlling pests.

E) Diamides -

- ✓ These are the Ryanodine receptors modulators. A large Ca++ release channel in the membrane of muscle sarcoplasmic reticulum (SR) is called the ryanodine receptor, because of sensitivity to inhibition by a plant alkaloid ryanodine.
- ✓ **Ryanodine -** It is neutral alkaloid isolated from the stem, roots, leaves and stalks of plant *Ryania speciosa.*
- ✓ It is contact as well as stomach poison.
- ❖ **Flubendiamide -**
    - First synthetic ryanodine receptor insecticide to be commercialized.
    - Commercially available as Fame (Bayer) in Suspension Concentrate (SC) formulation and Takumi (TATA) in Granule formulation.
    - It is effective against lepidopteran pests.
    - It is safe to bees and other natural enemies.

- ❖ **Rynaxypyr (Chlorantraniliprole) -**
    - Commercially available as Coragen (Dupont).
    - It is effective against lepidopteran pests.
    - It is available in Suspension Concentrate (SC) formulation.
    - Rynaxypyr controls insect pest by activating insect ryanodine receptors.
- ❖ **Cyazypyr (Cyantraniliprole) -**
    - Commercially available as Benevia (Dupont).
    - It is available in Oil Dispersion (OD) formulation**.**
    - It is effective against lepidopteran pests and also sucking pests.
    - It also shows ovicidal and larvicidal effect.
    - It also harmful to bees and other natural enemies.

F) Cartap Hydrochloride -

- ✓ It is Nereistoxin analog means animal originated insecticides.
- ✓ It is extracted form a marine annelids, *Lumbriconereis heteropoda*.
- ✓ It is contact, stomach and systemic poison.
- ✓ It is effective against chewing and sucking pests.
- ✓ Commercially available as Caldan, Padan, Campas.
- ✓ It is available in the formulation of Soluble Powder (SP).

G) New Pyrethroids -

- ✓ Examples - Lambda-cyhalothrin (Karate, Matdor, Riva), Bifenthrin.
- ✓ The mode of action is same as that of synthetic pyrethroids.
- ✓ They have broad spectrum activity against white fly, mites and cotton bollworm.
- ✓ Lambda-cyhalothrin is also used for control of mosquitoes and thrips.

H) New Acaricides / miticides -

- **Fenazaquin -**
  - Commercially available as a Magister.
  - It is contact poison.
  - It is a Mitochondrial Electron Transport Inhibitor.
  - It is environmentally safe.
- **Propergit -**
  - Commercially available as an Omite, Proguard, Indomite.
  - It is stomach poison and fumigants action.
- **Spiromesifen -**
  - Commercially available as an Oberon.
  - It is lipid biosynthesis inhibitor.
  - It is available in Suspension Concentrate (SC).

I) Insect Growth Regulators (IGR's)

- ✓ Insect Growth Regulators (IGRs) are compounds which interfere with the growth, development and metamorphosis of insects.
- ✓ It acts on the endocrine system of insects.
- ✓ It is environmentally safe.
- ✓ IGRs include synthetic analogues of insect hormones such as ecdysoids and juvenoids (JH Mimics), non-hormonal compounds such as Anti JH and chitin synthesis inhibitors**.**

⌘ **Juvenile Hormones Mimics (JH Mimics)-**

- JH mimics were first identified by **Williams and Slama** in the year 1966.
- JH Mimics have anti-metamorphic effect on immature stages of insect.
- JH Mimics are larvicidal and ovicidal in action and they disrupt diapause and inhibit embryogenesis in insects.
- Methoprene, Fenoxycarb, Novaluron Pyriproxyfen are used as Juvenile Hormones Mimics.
- Fenoxycarb has been used for fire ant management.
- It sterilized the queen of colony. Pyriproxyfen used for suppressing the pests like flies, mosquitoes.

⌘ **Chitin synthesis inhibitors -**

- Benzoyl phenyl urease has been found to have the ability of inhibiting chitin synthesis in vivo by blocking the activity of the enzyme chitin synthetase.
- It prevents the acetylation of glucose to form glucosamine which is one of the components of the insect exoskeleton. E.g. Lufenuron and Flufenoxuron.
- Two important compounds in this category are Diflubenzuron (Dimilin) and Penfluron.
- Another compound from the class is thiadizines, buprofezin has been effective against hemipteran insects like white fly. It inhibits the biosynthesis of chitin.

Recent /Newer Methods of Pest Control

1) Attractant
2) Repellents
3) Antifeedants/Feeding deterrents
4) Sterility technique
5) Hormones
6) Gamma radiation
7) Genetic control (Transgenic crops)

1) Insect Attractant

- ✓ Chemicals that cause insects to make oriented movements towards their source are called insect attractants.
- ✓ They influence both gustatory (taste) and olfactory (smell) receptors.
- ✓ The interspecific semiochemicals that favor the producer are called Allomones. While those favors the receiver called as Kairomones.

❖ **Types of Attractants:**

a) Pheromones: Pheromones are chemicals secreted into the external environment by an animal which elicit a specific reaction in a receiving individual of the same species.

i) Sex pheromones – A sex pheromones released by one sex only to attract the other sex of the species. E.g. For cotton bollworm- Vitlure & Ervitlure for spotted bollworm, Helilure & Hexalure for American bollworm.

ii) iii) Aggregation pheromones – The pheromones released by one sex only give response in both sexes of a species. E.g. Melon fruit fly attracted by cue-lure.

b) Food lures: Chemical present in plants that attract insect for feeding. They stimulate olfactory receptors.

List of natural and synthetic food lures

Insect-Pests	Natural and synthetic food lures
Natural	
Pests of cruciferous	Iso-thiocyanates from seeds of cruciferous
Onion fly	Propylmercaptan from onions
Bark beetle	Terpenes from barks
Housefly/Moths/Butterflies	fermenting syrup, Sugar and molasses
Synthetic	
Oriental fruit fly	Methyl eugenol
Mediterranean fruit fly	Cuelure
Melon fruit fly	Trimedlure
DBM (Diamond Back Moth)	Sinigirin

c) Ovipositional lures: - Chemicals that govern the selection of suitable sites for oviposition by adult female. E.g. paramethyl-acetophenon = Rice stem borer, *Helicoverpa* lay eggs more on plants which dipped in juice of corn silk.

2) Repellents

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

❖ **Types of repellents**

I) Physical repellents: Produce repellence by physical means

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

II) Chemical repellents:

❖ **Repellents of Plant origin:**

- Essentials oils of Citronella, Camphor and cedar wood act as repellents.
- Commercial mosquito repellent 'Odomos' uses citronella oil extracted from lemongrass, Andrpogon pardus as repellent.
- Pyrethrum extracted form Chrysanthemum is a good repellent.
- Creosol and coal-tar oil protect wood form termite attacks.

❖ **Synthetic repellents: Repellents synthetically produced.**

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

3) Antifeedants/Feeding deterrents

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

❖ **Groups of antifeedants**

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

4) Sterility technique

- **Definition -** Control of pest population achieved by releasing large number of sterilized male insects, which will compete with the normal males and reduce the insect population in subsequent generation.
- It is usually referred as SIT (Sterile insect technique) or SIRM (Sterile insect release method).
- Sterile insect release method is a genetic control method. This is also called autocidal control since insects are used against members of their own species.
- **E.F. Knipling in 1937** in South East USA used the SIRM technique to control the screw worm fly a serious livestock pest. It is also referred as '**Father of Male Sterility Technique'.**

❖ **Methods of sterilization-**

1. **Chemosterilants:** Any chemical which interfere with the reproductive capacity of an insect. They inhibit nucleic acid synthesis, inhibit gonad development, and produce mutagenic effect which prevents the production of F1 generation. E.g. TEPA (Tetraethylenepentamine), Metapa, thiotepa, apholate, Chloro ethylamine, 5-Fluororacil, Amithopterin. 0.5% TEPA reduced housefly population. apholate solution cause male sterility in boll weevil.
2. **Irradiation:** Irradiation done by exposing insects to radiations, X rays and neutrons of these, radiation by Cobalt 60 is the most common method.

Limitations-

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

5) Genetic control (Transgenic crops)

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

1. **Wide hybridization**: This technique involves transfer of genes from one species to other by conventional breeding. The genes for resistance are transferred from a different species. E.g. WBPH resistant gene has been transferred to *Oryza sativa* from *O. officinalis.*
2. **Somaclonal variability**: The variation observed in tissue culture derived progeny. E.g. Somaclonal variants of sorghum resistant to *Spodoptera litura* have been evolved.
3. **Transgenic plants**: Transgenic plants are plants which possess one or more additional genes. This is achieved by cloning additional genes into the plant genome by genetic engineering techniques. The added genes impart resistance to pests.

✓ Transgenic plants have been produced by addition of one or more following gene *Bt.* endotoxin from Bacillus thuringiensis, Protease inhibitors, Amylase inhibitors, Lectins and Enzymes.

✓ ***Bt.* endotoxin gene**: The gram positive bacteria *Bacillus thuringiensis* produces a crystal toxin called (delta) endotoxin. The endotoxin is a stomach poison and kills the lepidopteran insects if consumed.

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

Transgenic *Bt* plants	**Target insect pests**
1. Cotton	Bollworms, *S. litura*
2. Maize	European corn borer
3. Rice	Leaf folder, stem borer
4. Tobacco, Tomato	Cut worms
5. Potato, Eggplant	Colorado potato beetle

Toxicity of insecticides

Terminology -

- **Toxicology:** Toxicology is the science which deals with study of the poisons and their effect on living organisms.
- **Toxin/Poison:** A substance which produces harmful effect when ingested /inhaled/ absorbed by the human being.

  Poison is a substances which when taken orally in quantities even less than 4 gm or inhaled in concentrations less than 200 parts per million (ppm) in air quickly fatal, by means other than physical or mechanical.
- **Toxicity:** Toxicity is the inherent ability of a pesticide to cause harm to a specific organism.

➢ **Types of toxicity :**

1) **Acute Toxicity** - It is result of single dose, which causes death of insects.
2) **Chronic Toxicity** - It is result of cumulative effect of several small doses, each dose not produces symptoms of death.

- **Degree of toxicity / Toxicity parameters -**

1.) **LD_{50} (Median lethal dose)**: LD_{50} defined as the amount of insecticide per unit weight which will kill 50% of the test organism / insect.

✓ LD_{50} usually expressed as mg/kg body weight or g/larva or adult insect.

2.) **LC_{50} (Median lethal concentration)**: LC_{50} defined as the percentage of toxicant required required to kill 50% of the given organism or insect.

✓ This is used when the exact dose per insect is not known, but the concentration is known.

✓ LC_{50} is expressed in PPM (1/1,000,000) or Percentage (1/100)

3.) **LT_{50} (Median lethal time)**:LT_{50} is defined as the total time required to kill 50% of the insect population at a certain dose or concentration.

✓ LT_{50} expressed in hours or minutes.

✓ LT_{50} is used in field studies and also for testing insect viruses (NPV).

4.) **KD_{50}: Median knockdown dose**
KT_{50}: Median knockdown time } Dose of insecticide or time required to knockdown 50% of the insects.

✓ KD_{50} and KT_{50} are used for evaluating synthetic pyrethroids against insects.

5.) **ED_{50}: Median effective dose**
EC_{50}: Median effective concentration } These terms are used to express the effectiveness of Insect Growth Regulators (IGR)

➢ ED_{50} and EC_{50} are defined as the dose or concentration of the chemical (IGR) required to affect 50% of population and produce desired symptoms in them.

Based on their **LD_{50}** values pesticides can be classified are as follows;

1) **Extremely Toxic** - LD_{50} up to 50 mg/kg. e.g Phorate.
2) **Highly Toxic** - LD_{50} between 51-500 mg/kg. e.g. Phosphamidon.
3) **Moderately Toxic** - LD_{50} between 501-5000 mg/kg. e.g. Dimethoate.
4) **Slightly Toxic** - LD_{50} = 5000 mg/kg and above. e.g. Malathion, Carbaryl.

Categorisation of pesticides

Depiction				
Colour of lower triangle	Bright red	Bright yellow	Bright blue	Bright green
Toxicity class	Extremely toxic	Highly toxic	Moderately toxic	Slightly toxic
Oral LD_{50} value (mg/kg	<50	51-500	501-5000	>5000
Signal words (Upper half)	POISON (In red)	POISON (In red)	DANGER	CAUTION
Warning words (Outside the diamond)	Keep out of reach of children. If swallowed or symptoms of poisoning occur, call doctor.	Keep out of the reach of children.	Keep out of the reach of children.	---

Formulations of insecticides

Formulation: - Incorporation of pesticide into a suitable carrier, solvent and the supplementary agents or adjuvant is known as formulation.

- ✓ It is mixture of active and inactive ingredients.

Necessity of formulation -

i) Pure pesticide is costly; the formulations give cheaper & safe form of insecticide.
ii) High concentrations may prove to be phototoxic.
iii) Easy distribution on large area due to large volume formulation.
iv) Pure material is highly hazardous in handling, formulation decreases the residual hazards.
v) To improve effectiveness of insecticides.

Types of Formulations -

Liquid formulation	Dry Formulation
Emulsifiable Concentrate (EC)	Dustable Powder (DP)
Solution (SL)	Wettable Powder (WP)
Suspension Concentrate (SC)	Soluble Powder (SP)
Concentrate Emulsion (EW)	Water Dispersible Granule (WG)
Micro emulsion (ME)	Granule (G)
Aerosol (Aer)	
Soluble Liquid (SL)	
Ultra-Low Volume Liquid (ULV)	
Oil Dispersion (OD)	

Dry Formulation

1) Dusts:

- ✓ In this formulation the toxicant is diluted either by mixing with or by impregnation on carrier.
- ✓ The carrier may be an organic flour (Walnut shell flour, wood bark) or pulverized mineral (Sulphur, Lime, Gypsum, talc) or clay (attapulgite, bentonites, kaolins).
- ✓ The toxicant in a dust formulation ranges from 065% to 25%.
- ✓ Those having particle size less than 100 micron.
- ✓ Dust formulation must be done in a calm weather and early in the morning when plant is wet with dew.
- ✓ It is denoted by ‘D’
- ✓ E.g. Lindane 0.65%, Malathion5%, Carbaryl 10%.

- **Advantages:**
  - i) Dust can be used where water supply is difficult & inadequate.
  - ii) Less quantity required as compared to spray material.
  - iii) Application is faster than spray solution.
  - iv) Due to the light in weight it can be used in hilly areas or muddy fields.
  - v) It is cheaper and requires less cost.
- **Disadvantages:**
  - i) Drift problems - dust are likely to blow away along with wind velocity.
  - ii) Due to the less diposition on plants its efficiency is decreases.

2) Wettable powders/Water dispersal powders:

- ✓ WP is the powdered formulation which gives stable suspension when diluted with water.
- ✓ The toxicant/active ingredient in a formulation ranges from 15% to 95%.
- ✓ It is formulated by blending the toxicant with diluents such as attapulgite, a surface active agents and auxiliary material such as sodium salt & sticker is also added.
- ✓ It is more effective than dust.
- ✓ It is denoted by 'WP/WDP'
- ✓ E.g. Carbaryl 50% WP.

3) Granules:

- ✓ It is a granular formulation of insecticide composed of inert material (Carrier, diluents like vermiculite) or vegetable carrier impregnated. or fused with toxicant.
- ✓ The particle size ranges from 250 to 1250 microns.
  The formulation contains 2 to 10% concentration of toxicant.
- ✓ This formulation is used for the control of weeds, plant diseases and insect-pests, nematodes, snails & slugs, rodents.
- ✓ It is denoted by 'G'.
- ✓ E.g. Phorate 10%, Carbofuran 3%, Quinalphos 5%.
- **Advantages:**
  - i) No undue loss of insecticide.
  - ii) Undesirable contamination is prevented.
  - iii) Water is not requiring for application.
  - iv) Less harmful to natural enemies.
- **Disadvantages:**
  - i) Not as effective as spray.
  - ii) Scorching may occur if toxicant in concentrated.

4) Soluble Powder (SP)

- ✓ Similar to the Wettable powder, but dissolve readily and forms a true solution.
- ✓ It composed of pesticides, water soluble diluents, Wetting and dispersing agents.
- ✓ E.g. Acephate75 SP.

5) Water Dispersible Granule (WG)

- ✓ It composed of active ingredients, diluents, Wetting and dispersing agents.
- ✓ E.g. Thiomethoxam 25 WG

Liquid formulation

1) Emulsifiable Concentrate:

- ✓ The formulation contains the toxicant, a solvent of toxicant and an emulsifying agent.
- ✓ It is clear solution which gives an emulsion of oil-in water type when diluted with water to spray.
- ✓ When sprayed the solvent evaporates quickly leaving a deposits of toxicant from which water also evaporated.
- ✓ Emulsifying agents used are alkaline soap, organic amines, carbohydrates, gum, lipids, proteins etc.
- ✓ It is denoted by 'EC'.
- ✓ E.g. Chlorpyriphos 20 EC, Profenophos 50 EC.
- ❖ **Advantages:**
  - i) Dilution of chemical with water is possible.
  - ii) Better contact with insect cuticle.
  - iii) Surface tension of the spray reduced.
  - iv) Even distribution of insecticides possible.

2) Solution: (SL)

- ✓ Toxicants dissolved in organic solvent such as Amyl acetate, Carbon tetrachloride, Ethylene dichloride, Xylene, Petroleum & Kerosene.
- ✓ It is mostly used to control household pests & aquatic insects like mosquitoes.
- ✓ It is denoted by 'SL'.
- ✓ E.g. Imidacloprid 17.8SL

3) Aerosol:

- ✓ The toxicant is suspended in mixture particles (Size ranges from 0.1 to 50 microns) in air as a fog or mist.
- ✓ This is achieved by i) burning the toxicant with heat, ii) the toxicant dissolved in liquefied gas.
- ✓ When released the toxicant particles to float in air with the rapid evaporation of the released gas.
- ✓ Effective against flying insects and the pests in dense foliage.
- ✓ E.g. Aerosol bomb.

4) Fumigants: -

- ✓ A chemical compound which is volatile at ordinary temperature & sufficiently toxic is known as fumigants.
- ✓ It is used against stored grain pest & nematodes.
- ✓ E.g. Aluminium phosphide tablets, Ethylene dibromide, ED/CT Mixtures.

- **Adjuvants :**
  - ✓ Supplementary agents which do not contribute directly to the toxic effect of pesticide but are used for improving physical condition of pesticides so that pesticide become more effective in action.
  - ✓ **Types of Adjuvants**
    - **Dust carriers -** Organic flour, lime, gypsum, talc, kaolin,& volcanic ash.
    - **Solvents -** Amyl acetate, Carbon tetrachloride, Ethylene dichloride, Xylene, Petroleum & Kerosene, pin oil.
    - **Dispersing agents -** Polyfon H, Blancol, Daxad 21.
    - **Emulsifiers (Emulsifying agents) -**
      - It is surface active agents.
      - The principal function is to modify the properties.
      - They may be O/W (oil in water type) or W/O (water in oil type).
      - The pesticidal emulsions are oil in water type.
      - E.g. Alkaline soaps, Carbohydrates, proteins, organic amines.
    - **Wetting and spreading agents -** Soaps, Teepol, Tergitos, Triton X-100.
    - **Stickers -**
- **Synergists:** Chemicals which by themselves are nontoxic or only slightly toxic but when mixed with pesticides increase their toxicity. E.g. Sesamin, Sulphoxide.
- **Antagonistic:** The chemicals when mixed together reduce the toxicity of mixture

PLANT PROTECTION APPLIANCES

- **Dusters: -** Appliances/equipment that is used for applying dry dust formulations of pesticides is called as dusters.
  - **Parts of typical duster: -**
    - ✓ **Hopper or Container-** To hold the dust.
    - ✓ **Blower or Bellows-** To create air current for ejecting out the dust.
    - ✓ **Operating mechanisms-** Required to work equipment.
    - ✓ **Agitator-** To stir the dust in the hopper.
    - ✓ **Feed mechanisms**
    - ✓ **Discharge line**
    - ✓ **Mounting**.

Types of duster-

1. **Rotary dusters:** They are also known as crank dusters and fan type dusters. They vary in design and may be shoulder mounted, back mounted or belly mounted. The capacity of rotary duster is 4-5 kg dust. They are used for dusting field crops, vegetables and small trees and bushes in orchards. The efficiency is 1 to 1.5 per day.
2. **Knapsack dusters:** The capacity of knapsack duster is 2 to 5 kg. They are used for low crops and for spot application.

3. **Power operated dusters:** This may be from Knapsack types with engine motive power to powerful row crop or trees dusters pulled by tractor. These dusters are useful for covering larger area and tall trees.
4. **Plunger duster:** The capacity of plunger duster is ½ kg. It is used kitchen garden.
5. **Bellow duster :**

- **Sprayers-**

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

- **Parts of typical sprayer: -**
  - ✓ **Tank:** To hold the spray fluid during spraying.
  - ✓ **Pump:** The pump is necessary for creating the energy required for atomization of spray fluid.
  - ✓ **Agitator:** Used for dispersing the pesticide uniformly.
  - ✓ **Pressure gauge:** It is connected to the pipe line near the nozzle usually.
  - ✓ **Valves:** They govern the direction of the flow of the spray fluid.
  - ✓ **Filter:** This is provided mainly to protect the pump from abrasion, to avoid interference with the function of valves and to prevent blocking of nozzles.
  - ✓ **Pressure chamber:** It prevents fluctuation in the pressure & records it.
  - ✓ **Hose:** For conduction of the spray fluid from sprayer to lance.
  - ✓ **Spray lance:** It is useful for spraying under surface of leaf.
  - ✓ **Cut-off valve:** It is used to shut off the liquid.
  - ✓ **Spray boom:** Spray bars carrying more than one nozzle is known as spray booms.
  - ✓ **Nozzle:** It breaks the liquid into droplets and spread them into spray droplets. It consists of Body, Cap, Swirl plate, Washer (sealer), Stainer.

- **Types of nozzles-**
  - ❖ **Fan spray nozzles:** It is recommended for spraying flat surface such as soil. Usually for spraying herbicides.
  - ❖ **Hollow cone (ring) nozzles:** It is used for insecticide and fungicide spraying.
  - ❖ **Solid cone nozzles:** It is used for herbicide spraying.
  - ❖ **Flood jet nozzle:** It is used for herbicide spraying.

Types of sprayers –

A. Hand Sprayer or Manually operated-

- **Hydraulic sprayers-**

1. **Hand syringe:** It is useful to operate only a small area. It is single acting pump working on the principle of cycle pump.

2. **Hand sprayer:** The tank capacity is 0.5 to 1.0 litres. It also used for spraying small kitchen garden.
3. **Bucket pump sprayer (Stirrur pump):** Mostly buckets are used as containers for holding spray fluid at time of spraying. This is suited for small scale spraying. About 1 to 1.5 hectare area can be covered in a one day.
4. **Knapsack sprayer:** Also known as Backpack. The tank capacity is 10 to 14 litre capacity. The pressure is developed with help of level handle. They are useful for small scale spraying or spot spraying gardens, vegetables plots, vineyards etc. About 0.5 hectare area can be covered in a one day.
5. **Rocker sprayer:** It is used for spraying fruit trees and tall crops.
6. **Foot sprayer (pedal pump):** Used for spraying field as well as fruit crops. Principle is same as in case of rocker sprayer but it is operated by foot instead of hand. About 1 to 1.5 hectare area can be covered in a one day.

B. Manually operated compression sprayers: These are also known as pneumatic sprayers.

a. **Pneumatic hand sprayer:** It is mostly used in glass houses and kitchen garden.
b. **Pneumatic knapsack sprayer:** It is also known as shoulder mounted sprayer. The capacity is 18 liter. It is used for field and vegetable plots, flower garden.

C. Power Operated sprayer:

a. **Mist blower cum duster- (Motorized knapsack sprayer)(Gaseous energy sprayer):-** Worked by petrol driven engine. It produces very fine droplet size 50 to 150 micron. About cover 3 hectare areas in a one day.
b. **Portable power sprayer-** Useful for large scale spraying in plantation, orchard, flowers and vegetables gardens.

D. Ultra-low volume sprayer (ULV) (Hand carried, battery operated spinning dis-sprayer): Here the pesticides are applied as such or with less than 5 liters spray fluid produces fine droplets (80 μm).

E. Electrodyn sprayer (EDS): Electrodyn sprayer is completely a new system of spraying for the controlled droplet application of chemicals (CDA).

Other appliances:-

1. **Soil injecting gun-** It is used for fumigating the soil at different depths to control the nematodes and soil insects.
2. **Bird scarer-** It is mechanical device produced loud noise at regular interval and used to scare away the birds. It consists of a big chamber to hold calcium carbide and water. Due to the combustion of this mixture acetylene gas is produce.
3. **Flame thrower-** It is ordinary pneumatic sprayer filled with kerosene for producing flame. It is used to destroy locust swarm, hairy caterpillars.
4. **Rat fumigation pump (Cynogas pump) -** It is used for blowing calcium cyanide into rat holes, termite mounds. This kills rats, mites, termites.
5. **Granular applicator-** Use for granular application.

SEMIO-CHEMICALS

- ✓ The word "Semion" means "Signal". Chemicals involved in the communication are termed as a semiochemicals.
- ✓ Semiochemicals are chemical substances that mediate communication between organisms.
- ✓ Most secreted by exocrine glands in insects.
- ✓ Can be divided into two groups based on who `sends' a massage and who `received'.
- ✓ Semiochemicals may be classified into Pheromones (intraspecific semiochemicals) and Allelochemicals (interspecific semiochemicals).

  i) **Intraspecific semiochemicals: -** These are responsible for behavioral changes among individuals of the species. E.g. Pheromones

  ii) **Interspecific semiochemicals: -** These are responsible for behavioral changes between the individuals of different species. E.g. Allelochemicals

✪ Pheromone

- Pherein = to carry,
- Hormone = to excite

- ➢ In 1959, German chemists Karlson and Luscher coined the term pheromone.
- ➢ Pheromones are exocrine secretions of insects which are used for communication among different individuals of the species (Karlson and Luscher, 1959).
- ➢ **Definition: -** A substance that is secreted by an organism to the outside environment and cause specific reaction in a receiving organism of the same species.

✓ **Pheromones can be classified into 2 groups**

1) **Primer pheromones:** Primer initiates changes in development, such as maturation. They act through gustatory (taste) sensilla. e. g. Caste determination and reproduction in social insects like ants, bees, wasps, and termites are mediated by primer pheromones. These pheromones are not of much practical value in IPM.
2) **Releaser pheromones:** Releaser which induce immediate behavioural change. This pheromones act through olfactory (smell) sensilla and directly act on the central nervous system of the recipient and modify their behavior. They can be successfully used in pest management programme.

   Releaser pheromones may be further subdivided into
   - Sex pheromones
   - Aggregation pheromones
   - Alarm pheromones
   - Trail pheromones

1.) Sex pheromones

- ✓ A substance generally produces by a female to attract the male for the purpose of mating.

- ✓ In 1959, A. A. Butenandt isolated and identified the first pheromone, a sex attractant from silkworm moths, Bombykol.
- ✓ They are most commonly released by females but may be released by males also.
- ✓ **Insects order producing the sex pheromones**
    - Lepidoptera, Orthoptera, Dictyoptera, Diptera, Coleoptera, Hymenoptera, Hemiptera, Neuroptera and mecoptera.
- ✓ In Lepidoptera, sex pheromone system is highly evolved.
- ✓ **Pheromone producing glands**: In Lepidoptera they are produced by **eversible glands** at the tip of the abdomen of the females. Aphrodisiac glands of male insects are present as **scent** brushes at the tip of the abdomen. E. g. Male butterfly. **Andraconia** is glandular scales on wings of male moths producing aphrodisiacs. **Aphrodisiacs** are substances that aid in courtship of the insects after the two sexes are brought together. In many cases males produce aphrodisiacs.
- ✓ **Pheromone reception:** Female sex pheromones are usually received by olfactory sensillae on male antennae. In pheromone perceiving insects, the antennae of male moths are larger and greatly branched than female moths to accommodate numerous olfactory sensilla.
- ✓ **Chemical nature of sex pheromones:** In general pheromones have a large number of carbon atoms and high molecular weight. It is a primary alcohol. It is in slow release dispensers (rubber septa hollow fibers) that are used as lures in traps of various designs.

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

Sr. No.	Name of the Insect	Pheromone
1.	Silkworm, *Bombyx mori*	Bombykol
2.	Gypsy moth, *Porthesia dispar*	Gyplure, disparlure
3.	Pink bollworm ,*Pectinophora gossypiella*	Pectinolure, Gossyplure
4.	Cabbage looper, *Trichoplusia ni*	Looplure
5.	Tobacco cutworm, *Spodoptera litura*	Spodolure,
6.	Gram pod borer, *Helicoverpa armigera*	Helilure
7.	Honey bee queen, *Apis sp.*	Queen's substance
8.	Spotted/Spiny bollworm *Earis vitella*	Erilure
9.	Diamond Back Moth	DBM Lure
10	Brinjal shoot & fruit borer	Leucinolure

- ✓ Examples of male sex pheromones
    - o Cotton boll weevil (Grandlure), Cabbage looper, Mediterranean fruit fly

2.) Aggregation pheromones

- ✓ A substance produces by the one or both sexes that bring both sexes together for feeding and reproduction.
- ✓ These are released by members of one sex only but elicit responses in members of both sexes of a species. e. g. Bark and ambrosia beetles.
- ✓ Generally found in Coleoptera & Dictyoptera order.

3.) Alarm pheromones

- ✓ A substance produces by an insect to repel and disperse other insects in the areas.
- ✓ These pheromones are reported in Homoptera, Isoptera and Hymenoptera.
- ✓ E. g. Poison glands in ants, Cephalic glands in termites, Sting and mandibular glands of workers bees and cornicles in aphids.
- ✓ An individual also release them when an enemy attacks.

4.) Trail pheromones

- ✓ Trail marking pheromones are substance of low persistence that are released and perceived by individuals in trail.
- ✓ These pheromones are specially found in social insects like hymenopterans and termites.
- ✓ The ants (*Formic rufa*) use formic acids as a trail marker. They facilitate migration of colony to new site in search of food.

⌘ **Uses of pheromones**

- Monitoring
- Mass trapping
- Mating disruption

✪ Allelochemicals

- ✓ R. H. Whittaker coined the term Allelochemicals in 1970.
- ✓ It is defined as non-nutrient substance originating from an organism (Plants & Animals), which affect the behavior condition or ecological welfare of organisms of another species.
- ✓ Allelochemicals affects the behavior, growth and development of an insects as well as their natural enemies.
- ✓ Allelochemicals are divided in following sub-categories.
  - Allomones
  - Kairomones
  - Synomones
  - Apneumones

- **Allomones -** A chemical substances produce by organisms that favourable to the emitter but not to receiver e.g. Venon secreted by social wasps
- **Kairomones-** A chemical substances produce by organisms that favourable to the receiver but not to emitter.
- **Synomones-** A chemical substances produce by organisms that favourable to the both receiver and emitter.
- **Apneumones-** A chemical substances produce by non-living material that favourable to the receiving organisms but detrimental to an organisms of another species that is found on or in non-living material.

THE INSECTICIDES ACT, 1968

✪ The insecticides act was passed by the parliament of India in 1968. There were 38 sections of this act in which the sections 4, 7, 8 & 36 were enforced from 1/3/1971 and remaining from 1/8/1971.

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

✪ Salient features of the Insecticides Act

✓ **Compulsory registration** of the product at the Central level and licenses for manufacture, formulation and sale at state level.

✓ Inter – departmental / ministerial / organizational co-ordination is achieved by a high level advisory board **"Central Insecticides Board"** with 24 members (to be raised to 29 by an amendment) drawn from various fields having expert knowledge of the subject.

✓ **"Registration Committee"** to look after the registration aspects of all Insecticides.

✓ Establishment of enforcement machinery like Insecticide Analysts and **Insecticide Inspectors** by the Central or State Government.

✓ Establishment of **Central Laboratory** Power to prohibit the import, manufacture, and sale of pesticides and also confiscate the stocks. The offences are punishable and size and other penalties are prescribed. Both the Central and State Governments are empowered to make rules, prescribe forms and fees.

✪ The Central Insecticides Board (CIB)

➢ The Central Insecticides Board advices on matters relating to:

- The risk to human beings or animals involved in the use of insecticides and the safety measures necessary to prevent such risk.
- The manufacture, sale, storage, transport, distribution of insecticides with a view to ensure safety to human beings and animals.
- Board members
  The Director General Health Services ➜ Chairman
  The Drugs Controller, India
  The Plant Protection Adviser to the Government of India
  The Director General, ICAR
  The Director General, ICMR
- Totally 24 members – others from various other fields such as BIS, Animal husbandry, Pharmacology, Fisheries, Wild life etc

✪ The Registration Committee (RC)

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

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

- **Role of RC**
  - ✓ To register insecticides after scrutinizing them with regard to efficacy and safety.
  - ✓ **Registration of Insecticides -** When applied for registration, the RC allots a registration number within a period of 12 months. When pesticide registered for first time in India, provisional registration for two years given initially. After data generation full registration allowed.

✪ The Central Insecticides Laboratory (CIL)

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

✪ Insecticide Inspectors

- ✓ Central or State Government appoints person called Insecticide Inspector who is empowered.
- ✓ a. To enter and search premises
- ✓ b. To stop the distribution or sale or use of insecticide
- ✓ c. Take samples of insecticide and send for analysis

✪ The Insecticides Rules, 1971

- ✓ There are nine chapters in the insecticide rule, 1971 relating to the functions of CIB, RC, CIL, grant of licenses, packing, labelling, first aid, antidote protective clothing etc.,
- ✓ It has 46 rules.

✪ Insecticide residues and waiting period

- **Residues**- The toxicant that remains in the environment (like soil, water, plant harvested produce, etc.) after the application of insecticides.
- **Persistence-** The duration of retention is called persistence.
- **Waiting period-** is the minimum period allowed between time of application of pesticide and harvest of commodities.
- MRL (maximum residue limits) - In order to allow the toxicant residue level to come below MRL.

Phytotoxicity and compatibility of insecticides

Phytotoxicity

- ✓ Phytotoxic means harmful or lethal to plant.
- ✓ Phytotoxicity is the degree to which a chemical or other compound is toxic to plants.

Compatibility

- ✓ Cox (1941) coined the term compatibility.
- ✓ In pest control treatment, two or more pesticides, fungicides or even fertilizers are sprayed or applied in the same operation to minimize cost of labour.
- ✓ Before mixing two different chemicals, their physical and chemical properties should be well understood.
- ✓ Incompatible pesticides should not be mixed. Only compatible pesticides can be mixed.
- ✓ When two or more ingredients a successful spray or dust mixture they are said to be complete.
- ✓ Incompatibility of pesticides may be of following types

Chemical incompatibility

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

Biological incompatibility (Phytotoxic incompatibility)

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

Physical incompatibility

The physical form of the pesticides change, and one of them become unstable or hazardous for application.

- ✓ Gray (1914) worked on pesticides combination and also he divided the mixtures of insecticides and fungicides into 5 classes designated by letters A-I, A, B, C, and D.

❖ Insecticides mixtures: -

- ✓ Recently combination of insecticides are recommended to control insect pest which are resistant to major pesticides that are used commonly because these insecticides mixtures are usually prepared which have different modes of action i.e. organophosphates or carbamates with synthetic pyrethroids so that the development of resistance to these combinations is extremely rare but they are not prepared by combining organophosphates and carbamates which have same mode of action.

Table of insecticides mixture

Sr. No.	Insecticides	Trade Name
1	Chlorpyriphos 50% EC + Cypermethrine 5% EC	Nurelle D 505
2	Profenophos 40% EC + Cypermethrine 5% EC	Polytrin C 44EC
3	Chlorpyriphos 16% EC + Alphamethrin 1% EC	Duet 17 EC
4	Deltamethrin 1% EC + Triazophos 35% EC	Spark 36 EC
5	Ethion 40% EC + Chlorpyriphos 5% EC	Nagata 45 EC

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

❖ **Swallowed poison -**

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

❖ **Skin contamination -**

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

❖ **Inhaled poison -**

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

⌘ Antidotes :-

➢ **Definition: -** The substances that are used to cure the cases of insecticidal poisoning are known as antidotes.

✓ There are two types of antidotes;

1.) Universal Antidotes - It contains 2 parts of activated charcoal + 1 part of magnesium oxide + 1 part of tannic acid + ½ glass of warm water.

- It is useful for acids and heavy metal poisoning.

2.) Specific Antidotes - Which varies with toxicant as follows;

Antidotes and other medicine for treatment in pesticide poisoning

S.	Antidote / Medicine	Used in poisoning due to
1.	Common salt (Sodium chloride)	Stomach poison in general
2.	Activated charcoal (7g) in warm Magnesium oxide (3.5g) water Tannic acid (3.5g)	Stomach poison in general
3.	Gelatin (18 g in water) or Flour or milk power (or) Sodium thiosulphate	Stomach poison in general
4.	Calcium gluconate	Chlorinated insecticide, Carbon tetrachloride, ethylene dichloride, Mercurial compound
5.	Phenobarbital (or) Pentobarbital intravenous administration	Stomach poison of chlorinated hydrocarbon
6.	Sodium bicarbonate	Stomach poison of organophosphate
7.	Atropine sulphate (2-4 mg intramuscular / intravenous administration) or PAM (Pyridine-Z aldoxime-N-methliodide)	Organophosphate Compounds
8.	Atropine sulphate (2-4 mg intramuscular / intravenous administration)	Carbamates
9.	Phenobarbital	Synthetic pyrethoid
10.	Potassium permanganate	Nicotine, Zinc phosphide
11.	Vitamin K1 and K2	Warfarin, Zinc phosphide
12.	epinephrine	Methlyl bromide
13.	Methyl nitrite ampule	Cyanides

APICULTURE

✓ **Definition:** The art of scientific beekeeping for the profitable production of honey and wax is called apiculture.

❖ **Important Species producing Honey**(Family : Apidae, Order : Hymenoptera)

Common name	Scientific name	Honey/Year/Colony
Indian honeybee	*Apisceranaindica*	**3-5 kg**
Italian/Europeahoney bee	*Apismellifera*	**45-180 kg**
Giant or Rock honey bee	*Apisdorsata*	**27-36 kg**
Little bee or **Dwarf** bee	*Apis florae*	**0.45-0.50 kg**
Mosquito or **Dammer** bee	*Melipona/ Trigona irridipennis*	**Traces**

✓ Darling of bee keeping industry world over - **Italian bee: *Apismellifera***

Why the bees are important:-

✓ **BEE PRODUCTS -** Honey Bees, Wax, Royal Jelly, Bee Venom, Propolis.

✓ **Composition of fully ripened honey-** Lrvulose, Dextrose, Sucrose, Dextrins, Minerals, Water, Undetermined (Enzymes, Vitamins, Pigments, etc.).

✓ **Pigments -** Carotene, Chlorophyll, Xanthophyll

✓ **Minerals include-**Potassium, Calcium, Phosphorus, Sodium, Magnesium, Manganese, Copper, Sulphur, Silica, Iron.

✓ **Vitamins-**Vit. B1 (Thiamine), B2 (Riboflavin), Nicotinic acid, Vit.K, Folic acid, Ascorbic acid, Pantothenic acid.

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

⌘ Division of labor-

Queen -Reproductive female
Drone - Reproductive Male
Worker -Degenerative female

Duties of a queen-

1. The only individual which lays eggs in a colony. (Mother of all bees).
2. Five to Ten days after emergence, she mates with drones in one or more nuptial flights.
3. The secretion from mandibular gland of the queen is called queen's substance.
4. The queen can lay either fertilized or sterile eggs depending on the requirement

Duties of a drone-

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

Importance of worker honey bees-

1. Workers are imperfectly developed females. From the third day of development their ovipositor modified in to poison sting to defend the colony.
2. There are 99 percent workers individuals in each colony
3. In 6 weeks (42 Days) life span they totally serve for the welfare of colony

✪ **First 3 weeks (first half of life) – indoor works**

a. Build comb with wax secretion from wax glands.
b. Feed the young larvae with royal jelly secreted from hypopharyngeal gland.
c. Feed older larvae with bee-bread (pollen+ honey)
d. Feeding and attending queen & Feeding drones.
f. Cleaning, ventilating and cooling the hive & Guarding the hive.
h. Evaporating nectar and storing honey.

✪ **Later 3 Weeks (second half of life) – out door works**

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

✪ **Worker bees have following glands –**

Gland	Secretion
1. Pharyngeal glands	Royal jelly / Bee milk
2. Wax gland	Wax
3. Acid glands	Bee venom
4. Mandibular glands	Wax softening fluid

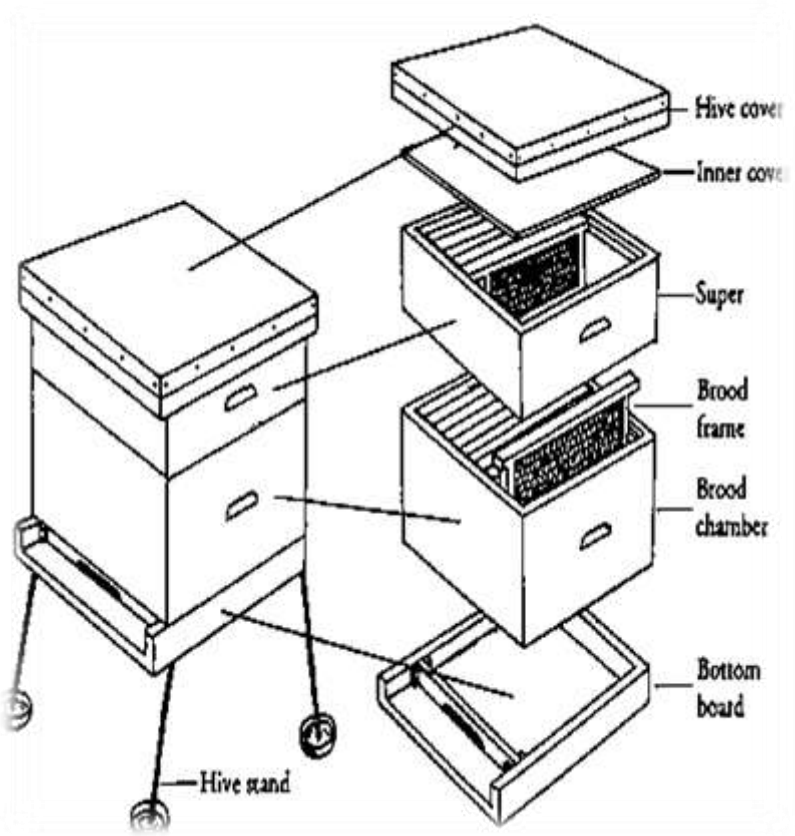
Life cycle of honey bee

Caste	Egg Stage (Days)	Grub stage (Days)	Pupal stage (Days)	Total life cycle(Days)	Adult longevity
Queen	3	5	7-8	15-16	2-3 Years
Worker	3	4-5	11-12	18-20	6 Weeks
Drone	3	7	14	24	3 Months

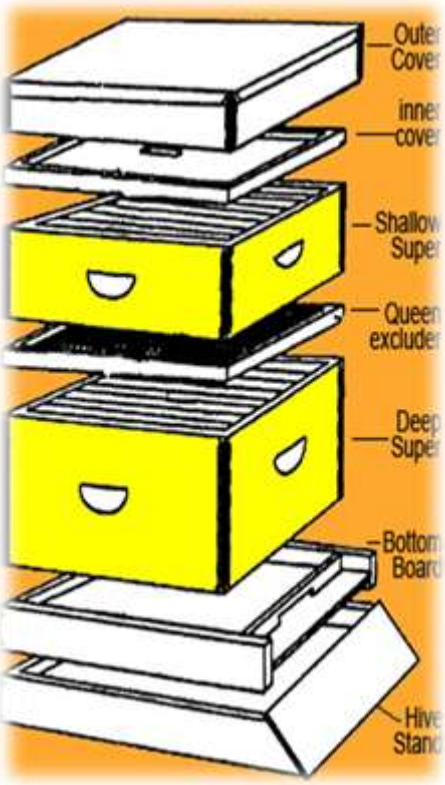
✓ **Apiary :-** The place where the bee and bee hives placed for the production of honey is called apiary

✓ The modern bee keeping became possible after the discovery of movable frame hive in 1851 by **Rerd. L. L. Langstroth**.

✓ **In India beekeeping was introduced in 1882 in Bengal.**



Reverant Lorenzo Lorraine Langstroth (1810-1895) **(Bee Hive)**



The ISI Newton frame hive

Modern Bee hive

- Following types of hives are in use
    1. Langstroth frame hive - For Italian bees.
    2. Newton frame hive - Most popular for Indian honey bees.

⌘ Beekeeping appliances

Following equipment are essential to organize the beekeeping on modern lines.

1. <u>Hives</u>: - The modern hive; the home of the bees. The hive is wooden structure consisting of several parts. There are three parts of hives.

i) The langstroth hive, ii) The jeolikote hive iii) The ISI hive (Newton frame hive).

✓ The langstroth hive is recommended for Italian bees where as other two are used for Indian bees.

Other appliances:-

1)	**Bee veil**-(mosquito netting) - mosquito attack.	**2)**	**Hand gloves**-during apiary operation.
3)	**Queen Excluder**-separate brood chamber from super.	**4)**	**Queen's cage**-introduction of new queen in the new colony.
5)	**Queen cell protector**-protection to developing queen (cane shaped structure of wire).	**6)**	**Bee escaper**-funnel shaped structure for the bees to go out of super.
7)	**Comb foundation sheet**-Sheet of bees wax on both sides. It is fitted on frame.	**8)**	**Honey extractor**-centrifugal machine with revolving chamber into which frames are fit.
9)	**Feeder**-keeping of liquid food for bees.	**10)**	**Overall**-white cloth of apiary working person.
11)	**Ant barrier**-prevent attack of ants	**12)**	**Honey tanks**-storage of honey.
13)	**Painting the hive**-to reflects sunlight.	**14)**	**Drone trap**-trapping of drones or

✪ Pest of Honey bee

- Greater Wax moth
- Lesser Wax moth
- Wax beetle
- Yellow banded hornate
- Bee hunter
- wasp
- Myna
- Bee eater

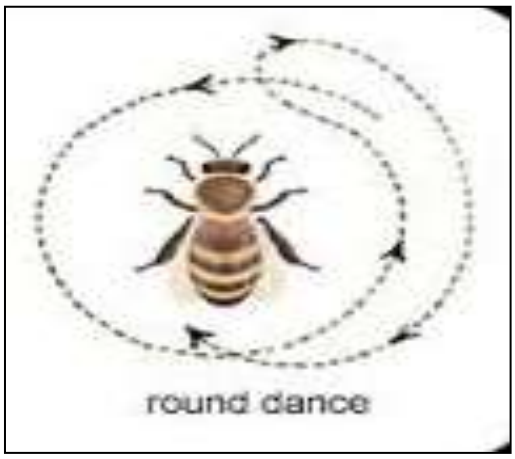
✪ Diseases of Honey bee

- Acarine disease / Isle of Wight (Mite)
- Nosema disease (Protozoa)
- Amoebic disease (Protozoa)

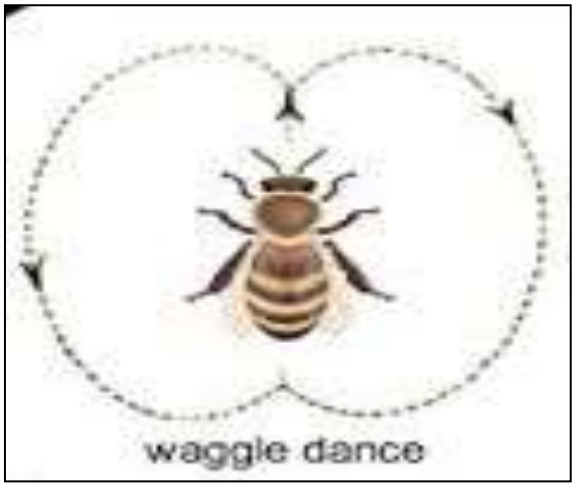
- American foul brood (Bacteria)
- European foul brood (Bacteria)
- Chalk brood (Fungi)
- Stone brood (Fungi)
- Thai Sac brood (Virus)
- CCD - Colony collapse disease: It occurs due to adverse environmental conditions or mall nutrition**.**

✓ Dance Language In Honey Bee-(Prof. Karl Von Frisch)

1. **Round Dance:** It consist circling to the left and then to the right and then repeating it over. The purpose of the dance to inform other bees the source of food located within the distance of 50 meters.



2. Tail wagging Dance: In this type of dance a worker bee first does a half circle and then moves in straight line and then complete the other half circles. The key part of the dance is the run up in the straight line between the two half circles. While tacking this path the bee waggles her abdomen from side to side. The purpose of the dance to inform other bees the source of food located more than the distance of 50 meters



How the honey is produce by honey bees

- ✓ **Bees** have amazing communication and organizational skills.
- ✓ When a **bee** finds a good source of nectar it will share this with the hive by performing a 'waggle' dance.
- ✓ **Bees** start **making honey**, which is their food, by visiting flowers. They collect a sugary juice called nectar from the blossom by sucking it out with their tongues. They store it in what's called their **honey** stomach, which is different from their food stomach.
- ✓ When they have a full load, they fly back to the hive & The **bee** then moves this watery **honey** mix from its tummy, into its mouth, and then into the honeycombs of the hive.
- ✓ But this new nectar mix is still quite watery & then bees naturally broken down into simple sugars and stored / deposited in the honeycombs. The process of ripening by which bees convert nectar into honey consist of converting sucrose in nectar into glucose, by the enzymes Invertase & evaporation of excess water to prevent fermentation. This process takes place in honey cells of the comb where nectar is deposited.
- ✓ The honey is concentrated (thickened) by evaporation of water caused by fanning of wings by hive bees.
- ✓ The bees consume nectar along with saliva, and afterwards regurgitate into honey cells of the comb. 100000-200000 trips are needed to collect nectar enough to produce 1kg honey.

➢ Terms & facts related to Apiculture

1. Swarming: The process of leaving off the colony by queen with some of the worker bees to establish colony at newer place is called swarming.

2. Absconding: Migration of complete colony from one to another place due to some unfavorable weather conditions of life such as shortage of food, attack of enemies is termed as absconding.

3. Supersedure: When egg laying capacity of the old queen is lost or it suddenly dies, a new and young vigorous queen takes the position of old queen in a colony is known as Supersedure.

4. Honey bees are **social** in behavior.

5. Unfertilized eggs of honey bee **produce male**, whereas **fertilized eggs** produce **workers or queen bees**.

6. In honey bees **queen** substance is secreted from **mandibular glands.**

7. The **workers bees' milk (Royal jelly)** is secretion of **pharyngeal glands** which are located in **the head.**

8. The bee **venom** is **ecto harmone** its ingredients are Melittin, phospholipase A, Hyaluronidase, histamine, Acid phosphatase.

9. Propolis is known as **bee glue** which is sticky substance for repair comb.

10. Pinocembrin is one antioxidant only found in honey.

11. Males of honey bees are called as **drones**.

SERICULTURE

(French word Seris = Silk, Culture = raising)

- **Sericulture: -** The art of manufacturing commercial silk by tending of silkworm from egg to cocoon.
- **Silk: -** It is the secretion of spinneret of the caterpillars of silkworm about to pupate.

- **Important Species silkworm producing silk**(Order : Lepidoptera)

Sr. No.	Common name	Scientific name	Family	Host Plants	Botanical Name
1	**Mulberry silkworm**	*Bombyx mori*	Bombycidae	Mulberry	*Morus alba*
2	**Eri silkworm**	*Philosomia ricini*	Saturniidae	Castor	*Ricinus communis*
3	**Tassar silkworm**	*Anthreaea mylitta*	Saturniidae	Shisav, Arjun, Ber	*Dalbergia Sp. Terminalia polyantha Zizyphus mauritiana*
4	**Muga silkworm**	*Anthrea assama*	Saturniidae	Som & Soalu	*Machilus bombycina, Litsaea polyantha*

Rearing of Mulberry silkworm:-

- ✓ **Mulberry cultivation (Moriculture):-** Cultivation of mulberry plant (*Morus alba)* called as moriculture.

1) Choice of variety:-The quality & quantity of silk produced by silk worm depend on the mulberry leaves feed to them. The varieties recommended for Maharashtra are Kanva-2, S-45, and S-54.

2.) Planting Method: -

- Mulberry is propagated by seed, root graft & stem cutting.
- Planting method:-Row & pit system. Spacing:-60×30cm in row system.
- Rainfall:-700-1000mm.
- Temperature:-25°c-30°c.
- Humidity:-70-85%.
- Harvesting:-leaf picking, branch cutting & top shoot harvesting. The tender leaves are given to the younger larvae, mature leaves to the older larvae. The entire branch cutting offered to third instar larvae.

3.) Production of Silk:-

a) Climate: -Places like Kashmir, Karnataka are suitable. July- Feb & Oct-Feb in Maharashtra (Western Ghats). The worm does not thrive well if the temp is above 32.5°cor below15°c.Temperature & humidity has great effect ton silkworm rearing. Optimum temperature for rearing is 27-29°c & relative humidity is 65-70°c.

b) Equipment/materials:-

- ✓ Mulberry planting material, implements, tools, land, etc.
- ✓ Bamboo tray for rearing caterpillars.

- ✓ An iron or wooden shelf for keeping trays.
- ✓ Bamboo basket with lid for keeping cocoons & rearing full bred worms about to spin the cocoon.
- ✓ Two baskets are sufficient for 1000 spinning worms are sufficient.
- ✓ Dry straw grass, paper, mango leaves, should be kept in bamboo basket in which caterpillar about to pupate are kept.
- ✓ Glazed paper for egg laying.
- ✓ Small circular baskets for keeping eggs.

c) Rearing: -

I. **Feeding schedule: -**After hatching the young tiny larvae should be fed 2 times in a day with tender leaves, after first & second molt 3 times a day, after third molt 4 times a day. After fourth moult 5 times a day (twice at night). Larvae of different instar are kept in different batches.

II. **Careat the moulting:-**Moulting worms should not be disturbed. Full grown worms should be transferred to Bamboo flat baskets; **Chandrika** covered with lids. It can be taken for granted that rearing is successful if the mortality does not exceed 15%.

d) Precautions:-

- In summer trays should be covered with moist cloth.
- Fresh delicate leaves should only be fed at proper times.
- Keep all equipment vary clean & hygienic.
- Select disease free eggs for rearing (most important).

e) Preparation of silk:-

- Expose pupa to hot sun for 3 days after pupation is completed.
- Keep part of cocoons for maintenance of brood & allow them to emerge.
- Soak the boiled cocoons in boiling water or treat them with steam for 20-30 minutes.
- Dry the cocoons to avoid purification & Peel them & obtain silk.

✓ **Rearing of Tassar silk worm**

1. Newly hatched larvae can be directly transferred to tree branches.
2. A small twig should be placed over each newly hatched larva and then tied on the tree for uniform distribution.
3. The first instar can be reared under controlled conditions on cut twig, kept in the cage.
4. The bottom of the twigs should be immersed in water kept in a bottle or earthen vessels to prevent quick drying of leaves.
5. The rearing of the larvae continued up to 3rd instar under nylon netting.
6. Fourth instar can be transferred to forest plantation. Moulting of I to IV instars occur in 3-4,5-7,7-8 and 8-10 days respectively while the V instar takes 15 days during which it feed voraciously to become full grown at maturity it measures 12-15cm and weighs 45 to 50g.
7. The cocoons are collected by tribal and stifled.

✓ **Stifling and reeling of cocoons**

1. Tassar silkworm cocoons are rather hard and they are first soaked in 5% Na_2CO_3 solution for 18 hrs.
2. They are then subjected to steam cooking in pressure chamber for 2 ½ hours.
3. After 24 hours, the cocoon washed in 0.5% formalin for 15-20 minutes.

4. These steps give silk fibers a greater tensile strength.
5. Cocoons are squeezed to expel water and reeled on a reeling machine.
6. Threads from 4 cocoons used for reeling.

⌘ **Diseases of Silk worms**

1. Pebrine (Protozoa), 2. Flacherie (Bacteria), 3. Grasserie/ Jaundice (Virus), 4. Muscardine (Fungi), 5. Septicemia (Bacteria)

✓ **Uzi fly is major pest of silkworm**

Sericulture Research Institutes

Name of the Institute	Place
Central silk board	Bengaluru, Karnataka
Central Sericulture Research and Training Institute	Mysore, Karnataka
Central Muga - Eri Research and Training Institute	Titibar, Assam
Central Tasar Research and Training Institute	Ranchi, Zarkhand
Central Sericulture Research Station	Behrampur, Odisha

✪ Important Terms & Facts In Sericulture

- Silk fiber (Bave) is made up of two proteins Viz. **Fibroin and sericin at 75 and 25** parts on weight basis
- A bale of silk from India weights **50 Kg**
- Newly hatched silkworms called as **kegs, Chawki, ants** etc.
- **Hot HCL** treatment is use to **break the egg dormancy**
- The place where the disease free eggs produced on scientific lines is called as **Grainage.**
- **Mulberry silk worm is Monophagous insect**
- Tassar silk worms diapause in **pupal stage having peduncle to cocoon**
- Silk glands are **ectodermal** in origin
- To produce one kg raw silk 10 to 12 kg cocoons required
- To produce one kg silk 120 to 160 kg leafy material required
- **Denier** is the weight of 9000m long silk thread in gram
- The silk thread reeled from two cocoons is called as **Dupion Silk**
- **Karnataka** is the leading state in mulberry silk production
- **China** is the world's largest silk producing country

LAC CULTURE

- ✓ **Lac:** Lac is resinous secretion of a tiny lac insect (*Kerria lacca).*
- ✓ **Lac culture -** Lac culture is a science which deals with rearing of lac insects and production of commercial lac.
- ✓ **Family**: -Lacciferidae **Order**: -Hemiptera.

Host Plants of Lac Insect- Palas, Kusum, Ber, Babul, Pipal, Khair, Sal, Tur etc.

✪ Life cycle of lac insect

- ✓ A healthy female produces 300-1000 nymphs.
- ✓ The **crawlers** emerge from the female cells moves on host tree in search of food they settle the place.
- ✓ A day or so after settling the nymph start secreting resin from **resin glands** which are distributed all over the body except mouth parts, two breathing tubes & anus.
- ✓ **The nymphs moult thrice**, after the first moult both male and female loose their legs, antennae and eyes and become degenerate. During the second moult males regenerate the appendages while a female doesn't.
- ✓ **Males** developed as **winged** ones which live only for 62 to 90hrs &**Females** are **apterous**.
- ✓ The females remain inside their lac cells and start growing for several weeks.
- ✓ As they grow become globular when they are about to lay eggs they shrink in size providing a space for eggs.
- ✓ At that time the two *yellow spots* appear at the rear end of the cell. The spot enlarge and become *orange* coloured. When this happens the females oviposited large number of eggs in the space called ovisac under their tail ends.
- ✓ It is the appropriate time that the twigs (brood lack) are cut from the trees for the purpose of inoculation to new trees.
- ✓ It takes 4 to 8 months to complete its life cycle.
- ✓ **Females are the major contributors of lac production.**

⌘ Terminology used in lac culture

1. Crawlers: The nymphs of lac insect called as crawlers

2. Swarming: Emergence of nymphs from lac incrustation is called as swarming

3. Brood lac: The lac sticks bearing alive mother cells which produce lac larvae are known as brood lac.

4. The stick lac: Sticks carrying ripened lac incrustation cut away from the host tree is termed as stick lac

Stick lac is of two types -

i. Arilac: It is stick lac cut away from host tree before the swarming and containing some living insects. **ii. Phunky lac:** It is Stick lac cut after swarming and containing dead females.

Lack Cultivation:-

- ✓ Carried out in forest or semi forest areas. Success of lac cultivation depends upon the management, proper pruning, Harvesting & method of inoculation.

1. **Pruning: -**Pruning of host plant is done to obtain the succulent branches for feeding lac insects.
2. **Inoculation:** -The brood lac sticks should be cut in convenient lengths of 15-30cm & tied to succulent shoot of the host tree longitudinally or laterally. Longitudinal inoculation allows maximum contact between brood & host. The brood used for inoculation should not be left on tree beyond three weeks. Which cause attack of lac insect enemies on host.
3. **Harvesting:** - For stick lac:-April-May. Brood purpose:-October-November.
4. **Preparation of shellac:** - Process of manufacturing refined product.
5. **Production of crushed lac: -**

- ✓ Ripened lac sticks cut from host tree called as stick lac.
- ✓ **Arilac-** when itis cut before swarming & containing some living insects.
- ✓ **Phunki lac-** When itis cut after swarming & contains dead females. The stick lac then scraped &crushed coarsely. The crushed lac contain 3-6% wax called lac wax.
- ✓ **Seed lac: -** Crushed lac is then washed in stone/cement vats/steel barrels in order to separate dead insects & other impurities. Later on they are taken out & spread on the floor for drying. This dried material is called as seed lac.
- ✓ **Shellac: -**

The preparation of Shellac:

- The process of manufacturing this refined product is completed in three stages-
- Production of crushed/dust lac, Production of seed lac & the shellac.
- **Crushed lac / Dust lac:** It is the lac incrustation scrapped from the stick lac and crushed coarsely.
- **Seed lac:** It is the purified and dried lac obtains from crushed lac after removing dead insects and impurities. Shellac: It is the final heat refined marketable product of seed lac.
- **The seed lac** is filled in coarse cloth bag & held the bag in front of charcoal fire.
- Lac starts melting by heat.
- The fused mass is then squeezed out of bag by twisting bag at both ends.

- The filtered lac is collected is earthen vessels containing hot water where it spread into a thin sheet.
- The shellac can also obtain by dissolving the seed lac in methylated aspirator placing seed lac in autoclave or with the help of modern machine.

✪ **Harvesting:** For obtaining the maximum yield of stick lac it is best to cut the crop in April-May and for brood purpose it should be harvested fully in October- November

✪ **Lac Crops/ Strains of lac insect**

- Two major strains of lac insects are known in India i.e. Kusumi and Rangeeni
- **Kusumi strain** grown on kusum tree while **Ranginee strain** grown on hosts other than kusum.
- **Rangeeni Strain** contributes about 90% of total production so called major crop.

➢ **Chemical composition of lac**- i)Resin - 75%, ii) Dye- 6%, iii)Wax-5-6%, iv) Aluminous matter - 12-13%, v) Mineral matter -3-7%, vi) Water -3%

✪ **Pest of Lac insect**- White enemy, Black enemy, Chrysopa

❖ Uses of lac

Used in preparation of -
1 furniture polish
2 bangles and pens
3 Leather finishes
4 Sealing wax
5 Filling ornaments and jewelry
6 Colour dies
7 Paints
8 Insulation in electrical equipment's
9 Printing

✪ The **Indian Institute** of Natural Resins and Gums (acronym IINRG), formerly known as the **Indian Lac Research Institute**, is an autonomous **institute**, established under the umbrella of **Indian** Council of Agricultural **Research** (ICAR) by the Ministry of Agriculture, Government of **India** for advanced **research** on **lac**.

✪ **Indian Lac Research Institute located at Namkum, Ranchi (Jharkhand).**

NON INSECT-PESTS

Rodents

Class :Mammalia
Order :Rodentia
Family:Muridae

Common Name	Scientific Name
House Rat or Black Rat	: *Rattusrattus*
House mouse	: *Mus musculus*
Drain Rate or Brown rat	: *Rattusnorvegicus*
Field Rats	: *Bandicotabengalensis*
Large bandicoot	: *Bandicotaindica*

HOST:- Rats are highly polyphagous, feed on different stored grains and other food material and damage the different crops in field

Nature of Damage:

- ✓ The common rats cause damage to matured palms.
- ✓ Rats remain in the crown of coconut palm and feed on developing nuts.
- ✓ They make hole through the husk and drink sweet liquid and the damage leads 5.7 to 9.4%.
- ✓ Rats' damage (nibble) the earheads and feed on the developing grains of standing crop in the field.
- ✓ They also carry grains to their burrows.
- ✓ The damage is also equally serious on threshing yards and godowns.
- ✓ It has been noticed that a house rats eats 10 g of food grains/day, while bandicoot takes 15g. The damage to field crop may be from 5 to 25 per cent.

LIFE CYCLE:-

- ✓ Rats produces 6-12 young ones in every three months.
- ✓ The newly born are blind & without hairs.
- ✓ It takes nearly 20 days for the eyes to develop and coat of hairs to form.
- ✓ The rat development is extremely rapid and grows @gm/day feeding only on milk of mother. After 21 days they sneak out with mother and then alone. In about 6 months the rats are mature to breed and may live for 3-5years.
- ✓ The house rat will always prefer cotton, waste paper pieces for bedding to lay young ones.
- ✓ Other rats will lay young ones inside the nest in burrow.
- ✓ Rats are prolific breeder they start breeding at the age of 3 to 4 months and breed throughout the year.
- ✓ A single female can liter as many as 10 young ones at a time with frequency of 10-12 times during a year under favorable conditions. Thus, one pair may give rise to about 800 young ones / year.
- ✓ Life period 3-5 year.

MANAGEMENT PRACTICES:-

I) Mechanical Control :

1. Hunting : It consists of engaging of persons who dig out rat burrows and kill the rat with help of trained cats and dogs
2. Trapping: Rats can be caught by traps containing attractive food.
3. Flooding
4. Guarding by rodent proof material
5. Electronic rodent deterrent: In recent year, ultrasonic sounds have been used for repelling rats and mice from godowns. Sound frequency of 20 KHz prevents rats from feeding and reproducing.

II) Chemical Control :Poisoning-

- ✓ Chemicals used for the control of rodents are called **rodenticides**. They include.
- ✓ **Zinc phosphide:** It most commonly used **chronic rodenticide** for baiting. It is a **black amorphous poisonous powder**. It has **garlic like odour**. It evolves phosphine (PH_3) gas when it comes in contact with hydrochloric acid (HCL) in stomach. It is to be used in the ratio of 2 parts zinc phosphide with 96 parts food grains and 2 parts sweet oil. This kills rat from within 3 hours onwards, requires 2-3 days pre-baiting with plain bait as it may develops bait shyness.
- ✓ **Warfarin:** This is an anticoagulant type of rodenticide. In the market it is available as **Rodafann 'C'.** It causing internal hemorrhage as it stop secretion of **prothrombin.** In this case prebaiting not required readymade wafarin baits are available. The rats go eating and are bleeding to death. It takes minimum 4 days at a concentration of 0.025%.It is **chronic rodenticide.**
- ✓ **Aluminium phosphide:** It is acute poison used for used for fumigation of rat burrows. It is sold as **Celphos tablets.** It is available in the form of tablets in sealed containers. Two tablets of 0.5% could be dropped in the burrow opening and holes closed by wet mud, the tablets in contact with moisture liberate phosphine gas that kills the rat

Mites-

- ✓ **Acarology: -** The science which deals with the study of ticks and mites called acarology.

✪ **Characteristics: -**

- It belongs to phylum- Arthopoda, class-Archinida, order- Acarina and four families such ac., i) Tetranychidae, ii) Tarsonemidae, iii) Eriophyidae, iv) Tenuipalpidae.
- They have a four pairs of legs, antennae are absent, body is divided into two region- i) Cephalothorax and ii) Abdomen.
- It is a non-insect pests and polyphagous in nature.
- These mite has an egg, three nymphal (Protonymph, deutonymph and tritonymph) & adult stage.

- Damaging stage is both nymphs and adults.
- Newly hatched is known as larva that has only 3 pairs of legs.
- **Host Plants:** Highly polyphagous, damaging different field crops and horticultural crops.

➢ **Important species of mites-**

1) Two spotted spider mites- *Tetranychusurtichae*, Tetranychidae
2) Red/carmine spider mites- *Tetranychuscinnabarinus,* Tetranychidae
3) Sugarcane mites- *Oligonychusindicus,* Tetranychidae
4) Yellow mite- *Polyphagotarsonemus latus,*Tetranychidae
5) Wooly mite/Eriophyide mite- *Aceria* spp. Tetranychidae

➢ **Nature of Damage:** suck the cell sap, usually colonize the lower surface of the leaves prefers the N-riched young leaves also can use older leaves they spin the webbing and covers the entire plant. Browning of the leaves and heavy leaf drop observed. Infested leaves turn chlorotic, with small transparent lesions. Bright yellow patches develop finally turning dark. Heavy infestation results in to leaf and fruit drop

➢ **Some of the species is also act as a vector of plant diseases such as-**

❖ Pigeon pea sterility mosaic- *Aceriacajani*

❖ Sugarcane streak mosaic virus- *Aceriasacchari*

❖ Wheat streak mosaic virus- *Aceriatulipae*

❖ Fig mosaic diseases- *Aceriaficus*

MANAGEMENT PRACTICES:-

a) Cultural practices-

1. Avoid monoculture
2. Encourage intercropping
3. Destruction of infested plant
4. Clean cultivation

b) Predators - Use of predatory mites

c) Chemical control-

- Chemicals used for the control of mites are called as **acaricides.**
- E. g. Dicofol 0.05, fluvalinite0.012% , abametin 0.0025%, flufenoxuron 0.01 etc
- Spray Wettable sulphur 0.2% or Dicofol 0.03% 0r dusting of 300 mesh sulphur dust @ 25 kg/ha.

Nematodes

- **Nature of damage: -** After hatching the juveniles (larvae) enters into the roots and feed within the roots by sucking cell sap. Plant parasitic nematodes are associated with plants. Live in top 20-25 cm layer of soil. They suck the cell sap through root. Before sucking they inject some saliva in cell, the enzymes contained in it predigest the cell contents. Majority of nematodes are root feeders
- **Symptoms of nematode damage: -**

  i) Symptoms are nonspecific & often likely to be confused with those caused by other pathogens or soil factors like bad drainage, lack of nutrition, drought, alkalinity or salinity.

  ii) Stunting & wilting, leaf curl, leaf & fruit dropping, Premature ripening of fruits, extra branching on plant or root, chlorosis & yellowing of plants, development of root galls, etc.
- **Life History:** The females lay the eggs on surface of feeder roots in masses in gelatin matrix. The life cycle is completed within 3-5 weeks depending on climatic conditions.
- **Management Practices:**

  A) Cultural methods: 1) Summer follow and ploughing, 2) Crop rotation with non-host plants, 3) Soil solarization before sowing seed of vegetable crops, 4) Intercropping by sowing the crops like tagetes, sunnhemp, mustard, fenugreek etc., 5) Application of F.Y.M., organic amendments oil cakes like neemcake, caranjkake etc. @ 2 t/ha., 6) Discoiuraging the planting seedlings of vegetables or fruit crops from nematode infested fields.

  B) Biological control: Use of fungal biopesticidal formulations comprising Trichoderma and paecalomyces.

  C) Chemical Control: Chemical which kill the nematodes is called as **nematicides**. E.g. Application of granular insecticides like carbofuran 3G or phorate 10G @ 1 to 2 kg a.i. /ha for vegetables and other seasonal crops and 4 kg a.i./ha for grown-up fruit crops.

Snails & Slugs

- **What are they?**

  Slugs and snails feed on a variety of plants as well as on decaying plant matter, chewing irregular holes on the leaves of plants. There are around thirty species of slugs in Britain. Slugs and snails move by means of a muscular foot which secretes mucus along which the animal glides. This mucus later dries to form the tail.
- **How do they live?**

  Snails lay approximately 80 round white eggs into holes in the soil. It takes about two years for snails to mature and about approximately one year for slugs to reach maturity. Both slugs and snails need moisture and are most active at night or during cloudy and rainy days. On dry, sunny days snails shut themselves into their shells, sealing the entrance to keep moist during cold weather slugs and snails hibernate in the topsoil.

✪ **Control**

- Eliminate, as far as practicable, anywhere where snails or slugs can hide during the day.
- Stones, debris, vegetation growing close to the ground, giving dense ground cover make ideal hiding places. Reducing hiding places allows fewer snails and slugs to survive
- Hand picking slugs and snails can also control them. If you water infested areas of your garden in late afternoon you will encourage slugs and snails to come out.
- Searching the area at dusk and removing the slugs and snails can be a very effective form of control. Put them in a plastic bag for disposal.
- Snails and slugs can be trapped under boards or flower pots positioned throughout the garden. Beer-baited traps are effective although their range is confined to only a few feet.
- The chemical used for soft bodies' insects (Mollusca e .g Snails & Slugs) are called as **molluscicides.** Slug pellets Slug pellets containing **metaldehyde** are a useful form of chemical control.

Birds-

✓ Some birds are harmful to crops which causes considerable yield loss.

✓ **Crow: -**The common house crow as well as jungle crow. Managed by destroying eggs & nest during June– Aug. A piece of chapatti dip in 0.3% methyl parathion placed on top of the roof.

✓ **Parrots: -** They cause damage to the fruits.

✓ **Sparrows: -** They common birds. Control by destroying eggs, a piece of chapatti dip in 0.3% methyl parathion placed on top of the roof. Use the sound producing machines or drums.

VERMICOMPOSTING

- ✓ In general earthworm is divided into two groups, 1) Microdrilli worms (Aquatic) and Megadrilli (Terrestrial).
- ✓ *Eisenia foetida* is also called as a **red worms, tiger worms and manure worms**. It is the **world most widely used** earthworm species.
- ✓ *Eudrilus eugeniae* is the **fastest growing species** of earthworm and **second most widely used.** It is popularly known as **Night Crawlers**. It is recommended for Vermiculture in Pune and North Kokan in Maharashtra.

- ➢ **Phylum -** Annelida
- ➢ **Class -** Oligochaeta
- ➢ **Order** - Haplotoxida
- ➢ **Sub-order -** Enchytraeina, (*Eisenia foetida*), Lumbricina (*Eudrilus eugeniae*)
- ➢ **Family -** Lumlaricidae (*Eisenia foetida*), Eudirilidae (*Eudrilus eugeniae*)
- ➢ **Species** -

i) *Eisenia foetida* (Most widely used)
ii) *Eudrilus eugeniae*
iii) *Megascolex(Lampito) mauritlii* (South Indian Earthworm)
iv) *Pheritima elongate*
v) *Lumbicu rebellus* (European Earthworm)

❖ Morphology of earthworm -

- ✓ Earthworm is a **bilaterally symmetrical** and body is cylindrical in shape.
- ✓ **Segmentation -** The earthworm body is divided into similar ring like segments called as **metameres or somites**. The segments are separated from each other by distinct ring like grooves.
- ✓ **Head -** Earthworm lacks a distinct head and sense organs (Eyes and tentacles). The first segment at the anterior body is called as **buccal cavity or peristomium** which bears mouth.
- ✓ **Clitellum -** Every mature earthworm bears a thick collar or girdle like glandular thickening of body wall called as clitellum. The main **function** of clitellum is **to secrete mucus and egg case or cocoon for eggs.**
- ✓ **Regionation -** Due to the clitellum the body of earthworm is divided into three regions- **preclitellar, clitellar & post-clitellar**.
- ✓ **Setae -** Each segment bears setae except peristomium and clitellum. **These assist in locomotion.** These **setae made up of** nitrogenous substance called as **chitin**.
- ✓ **Coelom -** The body cavity of earthworm is a **true coelom** which lies between body wall and alimentary canal.
- ✓ **Digestive System -** Alimentary canal is differentiating into mouth, buccal cavity, pharynx, esophagus, stomach, gizzard, intestine, rectum and anus. **Crop is absent**.
- ✓ **Feeding action -** They feeds on organic matter along with soil. Ingested food is lubricated by mucin and protease enzymes. **Calciferous glands present in stomach secrete a substance to neutralize the humic acid present in soil. Intestine is the principal site of digestion.**

- ✓ **Circulatory system -** Earthworm have a closed type of circulatory system which consist of blood vessels and capillaries. Blood contains red pigments such as hemoglobin or erythrocruorin.
- ✓ **Excretory System -** It contains coiled tubes called nephiridia for excretion. Nephiridia are present in all segments except first three segments.
- ✓ **Respiratory System -** Respiration takes place by diffusion of gases through a body surface.
- ✓ **Nervous System -** It consist of central, peripheral and sympathetic nervous system. They contain both sensory and motor neurons.
- ✓ **Reproductive system -** They are monoecious (A plants or invertebrate animals having both the male and female reproductive organs in the same individual; hermaphrodite.). Two pairs of testis and ovaries are present. They cannot fertilize their own eggs. Cross fertilization takes place by cocoon formation hence fertilization takes place in cocoon. Clitellar glands that form a membranous band around clitellum secrets chitinous substance for cocoon formation. The newly hatched earthworms resemble the adult except for size and absence of clitellum.
- ✓ **Sense organs -** They don't have special sense organs. Epidermal receptors are sensitive to touch. Buccal chamber sensitive to taste and smell. They are negatively phototrophic to strong light and positive to weak light.
- ✓ **Regeneration -** They have a great capacity for regeneration. At the cut surface the wound is first sealed with dense mass of undifferentiated cells called **Blastema**.
- ✓ **Colour -** The intensity of colouration may differ from anterior to posterior and dorsal to ventral side. The presence of **porphyrin** pigments is responsible for colouration.

- ✪ **Vermiculture: -** It is the scientific method of breeding & raising earthworms in controlled conditions.
- ✪ **Vermicomposting: -** It is a method of making compost with the use of earthworms, which generally live in soil, eat bio-mass & excrete it in digested form called vermicomposting.
- ✪ **Vermicompost: -** The compost formed by the Vermicomposting.

✪ Procedure of Vermicomposting: -

- Select the place for Vermicomposting. Place should have sufficient shed.
- Make a thick layer (7-8cm) of stubbles & locally available weeds in suitable size bed.
- Make second layer of same thickness of partially decomposed FYM.
- A Vermicompost layer of 1.5-2cm containing earthworm is spread on it.
- Make 5-6cm thick layer of partially decomposed bio-Agri waste materials is spread at the top.
- The total height of may be maintained about 0.30-0.45m from ground level.
- This heap is then covered by jute or gunny bags.
- Each layer is sprinkled with water. Water should be frequently applied to heap to maintain 30-40% moisture. The temperature of heap should not exceed from 35°c.

Harvesting the earthworms & compost: -

- Empty the content of worm bean into a plastic sheet where there is strong sunlight or artificial light.
- Wait 20-30 minutes, and then scrap off the top layer of Vermicompost.
- The worm will move away from light, so you can scrap more compost off every 20minutes.
- After several scraping you will find worms in cluster; just pick up the worms & gently return them to the fresh bedding.

Advantages: -

i) Chemical fertilizers increases the soil pollution, they are not used for second season & harmful to soil microorganisms. Some also get leached with water.

ii) Vermicompost also minimizes hazards caused by soil pollution.

iii) It increases soil fertility as well as soil productivity.

iv) To improve soil structure & texture.

v) The vermi-wash is also excellent fertilizer.

vi) It gives large amount of NPK to field.