Theory Lecture Outlines

	Plant derived insecticides - neem based products - different commercial formulations containing azadirachtin, neem seed kernel extract, neem cake and their uses – nicotine, rotenone, plumbagin and pyrethrum – source – properties and uses.	
15	Synthetic organic insecticides – chlorinated hydrocarbons – Dichloro Diphenyl Trichloroethane (DDT) and Hexa choloro Cyclo Hexane (HCH) . Cyclodiens - aldrin, dieldrin, heptachlor and endosulfan - toxicity and mode of action. Organo phosphates - systemic, non-systemic and translaminar action of insecticides with examples – brief mode of action – toxicity, formulations and uses of malathion, methyl parathion, diazinon,dichlorvos, fenitrothion,quinalphos, phosalone, chlorpyriphos, phosphomidon, monocrotophos, methyl demeton, dimethoate, triazophos, profenophos, acephate and phorate. Carbamates - mode of action – toxicity, formulations and uses of carbaryl, propoxur, carbofuran, aldicarb and methomyl - Insecticides with nematicidal and acaricidal properties.	75-80
16	Synthetic pyrethroids - brief mode of action – toxicity, formulations and uses of allethrin, resmethrin, bioresmethrin, bioallethrin, fenvalerate, permethrin, deltamethrin, cypermethrin, lambda cyhalothrin, cyfluthrin, fenpropathrin, flucythrinate, fluvalinate and fenfluthrin. Insecticides of other groups - fixed oils; Novel insecticides – nicotinoid insecticides - brief mode of action – toxicity, formulations and uses of imidacloprid, acetamiprid, thiamethoxam and clothianidin; Phenyl pyrazoles - brief mode of action – toxicity, formulations and uses of fipronil.	81-85
17	Macro cyclic lactones – spinosyns - brief mode of action – toxicity, formulations and uses of spinosad; Avermectins –brief mode of action – toxicity, formulations and uses of abamectin and emamectin benzoate; Oxadaizines – brief mode of action – toxicity, formulations and uses of indoxacarb; Thioureas - brief mode of action – toxicity, formulations and uses of diafenthiuron; Pyridine azomethines - brief mode of action – toxicity, formulations and uses of pymetrozine; Pyrroles - brief mode of action – toxicity, formulations and uses of chlorfenapyr. Formamidines – brief mode of action – toxicity, formulations and uses of chlordimeform and amitraz; Ketoenols - brief mode of action – toxicity, formulations and uses of spirotetramat, spiromesifen and spirodiclofen.Diamides brief mode of action – toxicity, formulations and uses of Chlorantraniliprole, cyantraniliprole and flubendiamide	86-89

30	Rodents- Important major rodent sps.- Nature of damage-management	157-160
31	Other non insect pests- important bird, crabs, snails and animal pest damage to crops- management strategies.	161-163
32	House hold and live stock insect pests- Important pests of domestic and veterinary importance and their management.	164-167

PRACTICALS:

1. Study of distribution patterns of insects in crop ecosystems
2. Sampling techniques for the estimation of insect population and damage
3. Pest surveillance through light traps, pheromone traps and forecasting of pest incidence
4. Calculation of doses/ concentrations of different insecticidal formulations
5. Acquaintance of insecticide formulations
6. Compatibility of pesticides with other agrochemicals and phytotoxicity of insecticides
7. Acquaintance of mass multiplication techniques of important predators – *Cheilomenes, Chrysoperla and Cryptolaemus*
8. Acquaintance of mass multiplication techniques of important parasitoids – egg, larval and pupal parasitoids
9. Acquaintance of mass multiplication techniques of important entamopathogenic fungi
10. Acquaintance of mass multiplication techniques of Nuclear Polyhedrosis Virus (NPV)
11. Study of insect pollinators, weed killers and scavengers
12. Extraction of nematodes from soil and roots-preparation of temporary and permanent slides
13. Identification of different types of nematodes
14. Identification of different mite species
15. Identification of different non-insect pests-birds, rodents, crabs and snails
16. Identification of different non-insect pests-house hold and veterinary insect pests

Note: Submission of well maintained insect specimens during the final practical examination is compulsory

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LECTURE NO. 1

INSECT ECOLOGY

The word ecology is the modified form of 'Oekologie' derived from the Greek 'Oikos', meaning 'Home' and 'Logos' meaning 'Discourse' introduced by Reiter in 1869 and later anglicized to 'Ecology'.

Ecology is a multidisciplinary subject and derives support from other sciences. Individual organisms of the same species live together as a 'Population'. Population can be defined as 'a group of individuals or a species occurring in a given area or locality at a specific time'. Populations of different species live together and form a 'Community', meaning 'all populations in the area at a specific time'. The community is influenced by its physical environment. The complex system of biotic and abiotic factors constitutes an 'Ecosystem'. Whereas the crops, insects, other animals and the physical abiotic factors together constitute an 'Agro-ecosystem'.

Ecology is 'the science of inter-relations between living organisms and their environment including both the physical and the biotic environments and emphasizing inter species and intra species relations' (Allee, 1949).

Odum (1953) defined ecology as 'the study of the structure and functions of nature (or Environmental biology)'.

Ecology is divided mainly into 'Autecology' and 'Synecology'. Autecology is the study of individual organisms or an individual species in relation to the environment while Synecology is the study of the group or groups of organisms associated in a community in the same environment *i.e.,* in relation to various other species living in the same environment.

Importance of Ecology in Pest Management:

Indiscriminate uses of pesticides lead to a regular resurgence of pests due to the fact that the natural enemies get killed. The increase in pest population is also due to the interference of man by monoculture, using high yielding and susceptible varieties, giving more number of irrigations, use of high nitrogenous fertilizers *etc*. Because of which the balance of life in nature gets upset and the pest appears in severe form every year. The importance of ecology was then felt and integrated approaches in pest management are now made to avoid the violent fluctuations in pest populations.

Ecological studies assist pest control programmes by explaining pest problems and suggesting alternate ways of combating insects. The outbreaks of the pests can also be predicted. The ecological studies investigate the causes for the changes in population number and the mechanism of natural control. The key mortality factors in a natural population help to integrate the various methods of control, without disturbing the balance of nature. The pest surveillance programmes form a part of ecology. Forecasting of the possible attack by different pests can be done and accordingly the control measures can be initiated in time. Suitable chemicals can be selected depending on the presence or absence of natural enemies. As such ecological studies form a basic part of the approach to the integrated pest management (IPM).

In nature the living organism and the non-living substances of environment interact to form ecosystem. The environmental complex constitute

(1) Biotic factors known as 'Density dependent factors' include

a) Food and b) Other organism and

2) Abiotic factors known as 'Density independent factors' comprise

a) Temperature b) Humidity c) Rainfall d) Light e) Air f) Water g) Soil *etc*.

LECTURE NO. 2

ABIOTIC FACTORS –TEMPERATURE, MOISTURE, RAINFALL, LIGHT & OTHERS

Effect of Abiotic Factors on Insect Population

a) Temperature

This is the most important physical factor which determines the duration of the various stages in the insect life cycle and consequently the number of generations during any period of time. It acts on insects in two fold manner

1. By acting directly on the survival and development which determine the abundance of a pest
2. Indirectly through food and other environmental factors such as moisture, rainfall, wind *etc*.

Depending on the maintenance of body temperature, animal kingdom is divided into

1) **Warm Blooded Animals (Homeothermic)**: These animals maintain a constant body temperature within certain narrow limits irrespective of the temperature variations in the external environment. These are also called as 'Endothermic animals' because they rely on internal source of heat to compensate the lost heat to cooler surroundings. Eg. Mammals

2) **Cold Blooded Animals (Poikilothermic) :** These animals are not capable of maintaining constant body temperature .They do not have internal mechanism of temperature regulation and therefore their body temperature varies with that of the surroundings. These are also called as 'Ectothermic animals' as they depend upon the environment than the metabolic heat to raise their body temperature. Eg. Insects

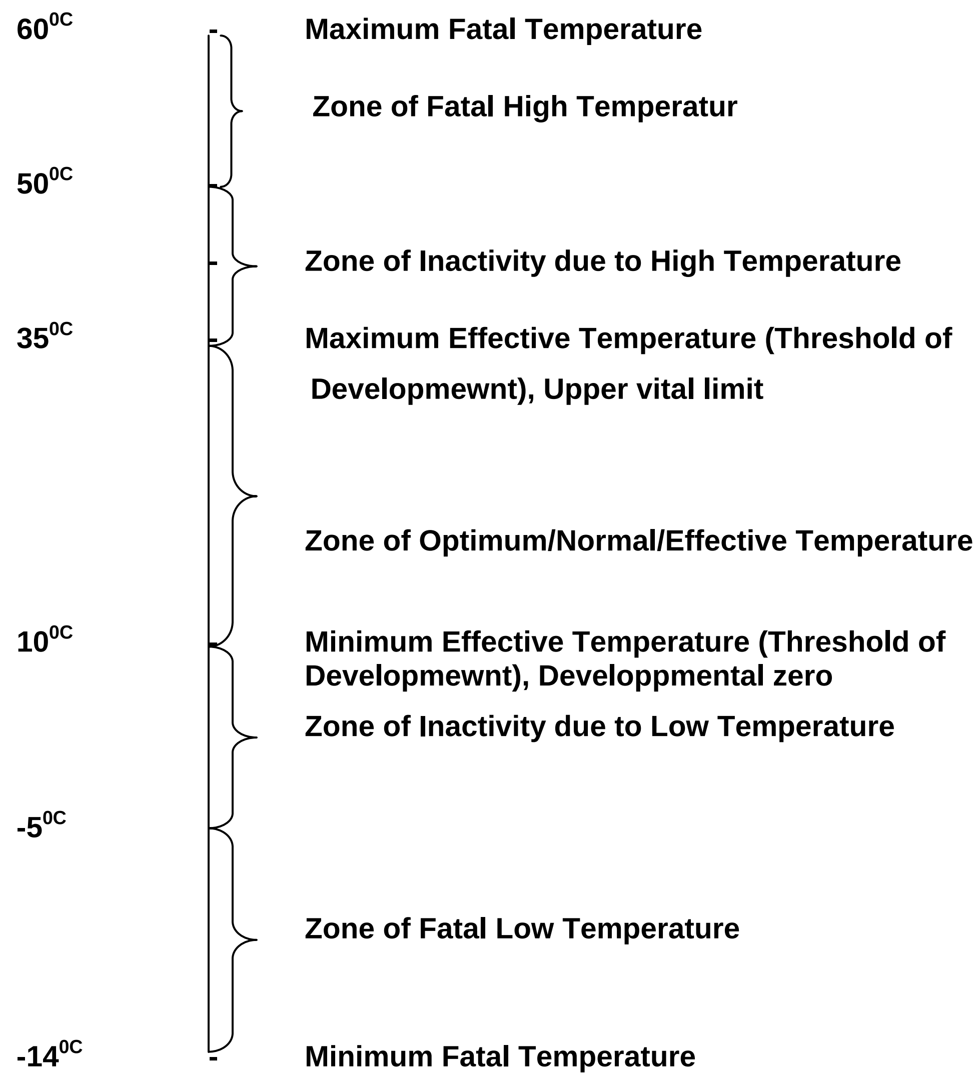
3) **Socio-homeothermic Animals:** These organisms maintain their body temperature slightly above the atmospheric temperature and are able to air condition their nests. They maintain their own temperature inside their colony irrespective of the temperature outside. Eg. Honey bees

Temperature regulates the development, fecundity, feeding, movement and dispersal and distribution of insects.

Development

In general insects grow more rapidly in warm weather than in cold weather. A given species of insects is active within certain limits of temperature. In general the optimum temperature for the normal development of insects is 10 to 35°C and is known as 'Zone Of Optimum or Normal Development'.

Depending on the development of insects at different temperature levels, the temperature is divided into different zones as follows:



1. **Zone of Effective Temperature (10 to 35°C)** in which some development takes place, the limits of which are known as

a) **Minimum effective temperature or threshold of development (10 to - 5°C)**: at which on descending scale development ceases and on ascending scale the development starts. The growth of poikilothermic animals is arrested at 0°C and this temperature is called as ‘Developmental zero’

b) **Maximum effective temperature (35 to 50°C)**: The upper vital limit at which on ascending scale the development ceases and on descending scale the development begins.

2. Temperature Zones of Inactivity

The temperature immediately above and below the zone of effective temperature are the ‘Zones of inactivity’. In these zones the insect is alive but there will not be any development and they can recover if removed to favourable temperature.

3. Fatal Zones of Temperature

Beyond the zones of inactivity are the 'Fatal high (50 to 60°C)' and 'Fatal low (-5 to -14°C)' temperature zones, indicating 'Minimum fatal (-14°C)' and 'Maximum fatal (60°C)'.

Death at fatal high temperature is due to loss of water, coagulation of proteins, high metabolic rate, accumulation of toxins and affected enzymatic activity. Death at fatal low temperature is due to low enzymatic activity, low metabolic rate and freezing of body fluids.

Some insects do not freeze but survive even under 0°C as their body fluids contain polyols like glycerols.

If an insect is given a choice to move along a temperature gradient it prefers a narrow limit of temperature known as the 'Temperature preferendum' or 'Preferred temperature'.

Thermal constant: The total heat energy required to complete a certain stage of development in the life cycle or in the completion of a physiological process of a species is constant and is termed as thermal constant and measured in Day - Degrees.

Under unfavourable seasonal temperature the insects suspend their activities. These are of two types

1) Hibernation: A period of suspended activity in individuals occurring during seasonal low temperature

2) Aestivation*:* A period of suspended activity of individual occurring during seasonal high temperature or in a dry weather.

Fecundity

Insects fecundity will be maximum at moderately high temperatures and declines at upper and lower limits of favourable temperature. Aphids remain parthenogenetic under high temperature and many hours of sunshine while the opposite condition give rise to oviparous forms.

Distribution:

Tropical and subtropical conditions as in India are ideal for the distribution and establishment of insects. Mediterranean fruit fly *Ceratitis caiptata* Wiedemanncould not establish in England and North Europe since its immature stages cannot stand below 10°C. Mosquitoes are more abundant at 70 to 80°F but are rare at 112 to 113°F. Pink boll worm of cotton *Pectinophora gossypiella* (Saunders) is serious in Punjab where the temperature is within 95.5°F in August and September and not present in West Pakistan due to high temperatures at that period (99° F).

Dispersal and Movement:

Insects try to move away from unfavorable temperatures. The rice weevil *Sitophilus oryzae(*Linnaeus) is found in the upper layers of bins irrespective of whether the initial infestation started at the depth of the bin or at surface due to rise in temperatures *i.e.* when the temperature reaches 32°C, the adults migrate to cooler upper layer. Mass flight of desert locust *Schistocerca gregaria* (Forskal) or migration starts at 17 to 22°C and they do not migrate when temperature is in between 14 to 16°C.

Adaptations to temperature: At high temperature, locusts expose minimum body surfaces to sun's rays by lying parallel to them while they expose maximum body surface to sun's rays at low temperature lying at right angle to them.

b) Moisture

Insect body consists of 80 to 90 per cent water. Aquatic larvae contain about 98 per cent while insects which feed on dry food like *Tribolium* sp,*Sitophilus*sp etc. constitute about 50 per cent. Water is generally lost through spiracles and integument. Insects cannot afford to lose more water than they take and hence conserve water depending on the situation.

Adaptations to conserve moisture:

1. Body pigments:

Insects develop dark pigment in cooler areas which help to absorb more heat from sun for raising body temperature. This aids in getting rid of excessive moisture from the body. Light colour in desert insects helps to reflect sun's rays and save them from excessive evaporation.

2. Integument:

Well developed integument and fused sclerites in beetles end weevils aid in conserving body moisture. Waxy coating of integument also saves from excessive evaporation.

3. Winglessness:

Grasshoppers and crickets in arid regions have poorly developed wings and some are wingless by which the area of evaporation is reduced.

4. Pilocity:

Dense hairs on the body prevent evaporation.

5. Form of body:

Oval and compressed body of some desert beetles protects them from hot winds. Some desert insects have burrowing habit by which they go into deeper layers of soil when sufficient moisture is not available.

6. **By reabsorption** of water from products of excretion.

7. Some insects links *Amsacta* spp. enter into **aestivation** when dry conditions prevail.

The fall of water content of body below a certain minimum proves disastrous to insects and if it is considerably above the normal (in very wet places) harmful effects like disease outbreaks are noticed in insects.

Humidity:

Unlike in temperature, there are no definite ranges of favourable humidity to all insects. Different species and their different immature stages have their own range. Humidity effects the speed of development, fecundity, colour etc. If water content of the body is high, dry air accelerates the development. Locusts sexually mature quicker and the number of eggs laid are more at 70% R.H. Rhinooceros beetle develops dark chitin in moist air and light chitin in dry air. Survival is indirectly affected by extremely high humidity conditions thatfavours the spread of diseases in insects.

c) Rainfall:

Relative humidity is dependent on rainfall. The total amount of rainfall distribution in time influences the abundance of insects in an area. More than 12.5 cm rain during May-June results in increase in soil moisture which is not favorable to the cutworms and hence forced to come out of the soil and fall a ready prey to their parasites and predators. On the other hand if the rainfall is less than 10 to 12.5 cm during summer, cutworms remain protected in soil and there is outbreak of the pest in next season**.** Hence, the outbreak of pest can be forecasted, if the number of wet days (0.8 cm) during May-July isnoted. If there are less than 10 wet days there will be an increase of cutworms in the following year. If there are more than 10 wet days there will be a decrease. Desert locust does not lay eggs and even if laid does not hatch unless soil has sufficient moisture. Rainfall also plays an important role in movement of swarms of desert locust. Saturated condition of moisture is injurious for the development of spotted boll worm *Earias fabia* Stoll. Red pumpkin beetle *Aulacophora foveicollis* Lucas withholds eggs until it come across moist soil. Rain induces emergence of most of the insects from soil.

Eg: Ants, termites, red hairy caterpillar, root grub beetles etc., emerge out from the soil after the receipt of rains.

LECTURE NO.3

Light

Sunlight is the greatest single source of energy for all most all biological systems. Light as an ecological factor has been defined as all shorter wavelengths of radiant energy up to and including the visible spectrum which is measurable. Wavelengths of visible parts of spectrum range from 4000 (Violet) to 7600 (Red) Angstroms.

Light is a non lethal factor. It helps in orientation or rhythematic behaviuour of insects, bioluminescence, period of occurrence and inactivity. The different properties of light that influence organisms are illumination, photoperiod, wave length of light rays, their direction and degree of polarization. Visible and ultra violet light influences the following:

1. **Growth, moulting and fecundity**: silkworms develop faster in light than in darkness. Grubs of *Trogoderma* also develop more rapidly in light. Moths of spotted boll worm of cotton and red hairy caterpillar lay most of their eggs during periods of darkness. The bean weevil lays more eggs in total darkness than in light.

2. **Other activities:**

In honey bees there is a correlation between hours of sunshine and their activity. Orientation of animals through directed movements by light is called phototaxis which also depends on temperature, moisture, food and age. Green leafhopper, *Nephotettix* spp. are attracted to light on hot and humid evenings but is indifferent to it during dry weather. Chafer beetles, many moths pass the day in concealment. Cockroaches hide during day time. Dusk is most usual time for flight and copulation of moths, for emergence of winged whiteants etc.

Based on daily activity cycle, insects or animals are categorized as

Diurnal: Insects whichare active during daylight hours
Nocturnal: Insects whichare active at night
Crepuscular: Insects whichare active at dusk

Photoperiodism: The number of hours of light in a day length (24 hours) is termed as photoperiod and the response of organisms to the photoperiod (length of the day) is known as photoperiodism, photoperiod induces diapause. Insects in which dispause is induced by long day are known as short day species. Eg: Mulberry silkworm *Bombyx mori* (Linnaeus*).*While the insects in which diapause in induced by short day lengths are known as long day species. Eg. Pink bollworm of cotton, *Pectinophora gossypiella*. Photoperiod also known to control mode of reproduction, body form etc. In reduced photoperiod sexual forms (winged) are produced in aphids.

3. Oviposition: Light stimulates oviposition in mantids and inhibits in *Periplaneta* sp.

4. Pigmentation: In dark areas, pigmentation develops in insects *i.e.,* dark colour develops in dark areas.

Bioluminescence: Famous luminous insects are the glow-worms and fireflies. The enzyme luciferase in the presence of oxygen and adenosine triphosphate (ATP) promotes the oxidation of luciferin. This causes the production of light in insects. In most cases, females produce flash of light to attract males for mating.

Use of light as a factor in insect management:

Many insects are either attracted or repelled to artificial light and this reaction is known as phototaxis. Grubs of *Trogoderma* sp. show negative reaction and are termed photonegative species. Most of the moths are attracted to light and are known as photopositive or phototropic. Based on this principle artificial light can be employed as a source for attracting insects and there after they can be trapped and destroyed and these devices are known as light traps.

e) Other factors:

i) Atmospheric pressure:

it is generally of little importance.Locust show great excitement and abnormal activity about half an hour before the occurrence of storm when the atmospheric pressure is low.

Drosophila flies stop moving when put under vacuum.

ii) Wind and Air currents:

Most of the insects will not take flight when speed of wind exceeds the normal flight speed. Air currents, especially in the upper air being strong, carries many insects like aphids white flies, scales etc. to far-off places and is an important factor in dispersal. Air movement may also be directly responsible for death of insects.

Severe wind coupled with heavy rains cause mortality and moisture evaporation from body surface of insects.

f) Edaphic (Soil) factors:

Loamy soils allow digging and burrowing operation and are usually favourable for insects. *Agrotis* splive in soil of fairly light texture in which they move around freely in response to daily or seasonal temperature and moisture changes.

BIOTIC FACTORS

A) Food:

Each insect species has certain nutritional requirements for completion of its life cycle. Under normal conditions there is a happy adjustment between the host and particular species of insect. But in the event of sudden increase in population, the densities of population become too high to be supported by the food available in the area. Hence competition for food as well as space will be there.

According to nutritional requirements, insects are categorized into:

1. **Omnivorous:** Which feed on both plants and animal. Eg. Wasps, cockroaches
2. **Carnivorous:** which feed on other animal as parasites and predators.
   Eg: Predators (Lady bird beetles and Mantids)
3. **Herbivorous:** which feed on living plants (crop pests) and these can again be categorized into
   (a) **Polyphagous**: which feed on wide range of cultivated and wild plants. Eg. Locusts, grasshoppers
   (b) **Monophagous:**which feed on single species of plants. Eg: Rice stem borer
   (c) **Oligophagous:**which feed on plants of one botanical family.
   Eg: Diamondback moth, Cabbage butterfly.
4. **Saprophagous (Scavengers):** which feed on decaying plants and dead organic matter. Eg: Drosophila flies, House flies, scarabaeid beetles.

B) Other organisms: Includebeneficial and harmful insects. Associations of individuals of the same species is known as intra specific relations and it may be beneficial. Such association of two sexes, parental care, associations of social insects etc., phenomenon like overcrowding is harmful since shortage of food and space results. Disease outbreak may occur. Cannibalism may occur.

Eg. Preying mantids, larvae of *Helicoverpa*, *Tribolium* feeds on its own eggs.

Associations of individuals of different species are known as **inter-specific relations** and these may be beneficial or harmful.

Beneficial associations:

i) Symbiosis: Inter relationship between organisms of different species which live in close union without harmful effects are known as **symbiosis**, each member being known as **symbiont**.

ii) Commensalism: One insect is benefited by living on or inside another insect without injuring the other and is known as **comensal** and it lives on the surplus food or the waste food of its host. Eg: Gall forming insects. When the commensal uses its host as a means of transport the phenomenon is termed as **phoresy.**

Eg: *Telonomus beneficiens*parasitoid attaches themselves to the anal tufts of female moths of rice stem borer *Scirpohaga incertulas* (Walker) for their transport. The parasitoid parasitizes freshly laid eggs.

iii) Mutualism: When both the symbionts are benefited by the association it is known **mutualism** Eg: Ants and aphids. Termites and flagellates.

Harmful associations:

Those that live with the expense of other living organisms are **parasites** and **predators**.

Parasite: Parasite is one which attaches itself in the body of the other organism either externally or internally for nourishment and shelter at least for a shorter period if not for the entire life cycle. The organism which is attacked by the parasite is called host.

Parasitoid: An insect parasite of arthropod is parasitic only in immature stages, destroys its host in the process of development and free living as an adult or Parasitoid is an insect that feeds on the body of another insect or arthropod during the larval stage of the their life cycle and adult is a free-living insect, no longer dependent on the host.

Parasitisation: It is the phenomenon of obtaining nourishment at the expense of the host to which the parasite is attached.

Parasites can be grouped into,

Depending upon the nature of host, as

1. **Zoophagous** : That attack animals (Cattle pests)
2. **Phytophagous** : That attack plants (Crop pests)
3. **Entomophagous**: That attack insects (Parasitoids and Predators)

Predators and Predatism:

A predator is one, which catches and devours smaller or more helpless creatures by killing them in getting a single meal. Insect killed by predator is known as prey.

Insect Predator:

It is defined as the one, which is

- Large in size
- Active in habits
- Capacity for swift movements
- Structural adaptations with well developed sense organs to catch the prey
- May remain stationary and sedentary
- Suddenly seize the pray when it comes with in its reach Eg. Antlions
- Feed upon large number of small insects every day
- May have cryptic colourations and deceptive markings

  Eg. Preying mantids and Robber flies

LECTURE N0. 4

CONCEPT OF BALANCE OF LIFE

The population of an insect or any animal may be defined as the number of individuals of a particular species existing in a particular area at a time. The population never remains constant for long, but it tends to oscillate all the time about a theoretical optimum for the species. Balance of life in nature is the maintenance of a more or less fluctuating population density of an organism over a given period of time within certain definite upper and lower limits by the action of biotic and abiotic factors.

Factors Contributing to Population Increase

Any organism will multiply enormously if the environment is optimum. Different organisms multiply at different rates. Hence it is well known that every organism has an inherent capacity to survive, reproduce and multiply in numbers. The extent to which a species can multiply in a given period of time if no adverse factors interfere is called its **'Biotic potential'** which is also known as **'Maximum reproductive power'**. This concept was first introduced by R.N. Chapman in 1928. The biotic potential or innate capacity to increase depends on

1) Initial population: The more the initial population of an organism the more will be its progeny,

2) Fecundity: It is the average number of eggs laid by a female in its life. The more the fecundity the more will be the resultant population.

3) Sex ratio: It is the ratio of females to the total population and is represented by number of females / Total number of males and females. Up to a limit the more the proportion of females, the more the multiplication capacity.

4) Number of generations in an unit time or a year: Obviously the greater the number of generations in a unit time the larger will be the resultant population.

Based on the above factors the biotic potential can then be represented by the formula,

$$B.\ P. = P\ (f\ s)^n$$

Where, P = Initial population

f = Fecundity

s = Sex ratio

n = Number of generations in a unit time.

Some insects like whiteant queens and house flies lay large number of eggs while others lay very few eggs. Some insects reproduce very fast. Mustard aphid has over 40 generations a year. If all survive, a single pair of house flies may produce 191, 010, 000, 000, 000, 000, 000, flies from April to August which if spread over the entire earth form a layer about 14 meters deep. Similarly a progeny of a pair *Drosophila* flies produced in a year would cover the whole of Indian subcontinent and Myanmar with a solid cake of flies. Such is the biotic potential of insects when there is no interference of biotic and abiotic factors of the environment.

Factors Tending to Reduce Populations:

However, in naturethere are other powerful factors working against the biotic potential. These are (1) Abiotic or climatic factors and (2) Biotic factors. These biotic and abiotic factors are known as the constituents of environmental resistance which always tend to destroy a considerable proportion of insect life.

The proportion of the population which is normally eliminated as a result of environmental resistance is known as **'Normal Coefficient of destruction'** which can be expressed by the formula,

$$Q_n = 1 – (1/s)^n / fn.$$

Where,

'Q '= the coefficient of destruction,

's= the sex ratio when population is taken as 1

n = the number of generations in a unit interval of time and

'f '= fecundity.

Balance of Life

In nature there are two sets of tendencies namely the biotic potential tending to increase the population and the environmental resistance tending to reduce the population. As such there is a constant interaction between these two opposing forces and then maintains a dynamic equilibrium known as **'Balance of life'**.

It is evident from the above that in any case, the insects or other animals never attain the high density which they are potentially capable of doing which is because of environmental limiting factors like abiotic factors comprising mainly temperature and humidity which at too high or too low levels adversely affects insects. Natural disturbance like heavy rain, hail storms, snow, sand storms, dust storms, and very high wind velocity are adverse to insect life. Biotic factors *i.e.* limitation of food, competition for food and space and natural enemies act adversely depending on the density of population.

Causes for Outbreak of Pests in Agro-ecosystems

The insect's pest problems in agriculture are probably as old as agriculture itself. However, under subsistence agriculture the pest numbers were generally low as the productivity was poor. The insects under favorable conditions multiply enormously and different species multiply at different rates.

When the numbers of an insect increase, it reaches the pest status. Rapidly increasing human population during last century has necessitated intensification of agriculture through expansion of irrigation facilities, growing of new crops, introduction of improved and exotic varieties, application of increased amounts of agrochemicals.. Definitely modern agriculture technology package hasresulted in increased higher yields and it has also contributed in severe outbreaks of insect pests in agricultural crops.

Following are a few of factors that have contributed in outbreak of crop pests

1. **Excessive use of nitrogenous fertilizers:**

   Excess use of inorganic nitrogenous fertilizers creates congenial conditions for rapid multiplication and subsequent outbreaks of pests. Application of nitrogenous fertilizers gives luxurious growth of the crop and makes it more vulnerable to insect attack as in case of rice and cotton which show higher incidence of yellow stem borer and sucking insects like aphids, whiteflies and leafhoppers, respectively, because there will be no competition for food.

2. **Indiscriminate use of pesticides:**

   Sometimes use of insecticides as a prophylactic or curative measure results in reducing one of the competitive species of pests while allowing the others to multiply.Repeated use of same insecticides may also lead to the secondary infestation in which it is not effective. Continuous spraying of carbaryl on cotton against bollworms and on brinjal against shoot and fruit borer results in the mite infestation which is often very severe.

   Indiscriminate use of pesticides also destroys the natural enemies of the pest and sometimes leads to the pest outbreak. Application of deltamethrin, phorate etc in rice fields against BPH destroy its natural enemies like mirid bugs and spiders which are bioagents of BPH and sometimes enhance the population of BPH. Similarly, indiscriminate use of insecticides on cotton resulted in the outbreak of whitefly in Guntur and Prakasam districts during 1985.

3. **Use of high yielding varieties and introduction of new crops:**

   Mostly improved strains of crop plants are susceptible to pests. Sometimes, the insects which are considered of minor importance, become major importance with the introduction of new varieties and strains. The improved combodia cotton strains are highly susceptible to the spotted bollworm *Earias* sp. and the stem weevil *Pempherulus affinis*. The hybrid sorghum CSH-1 was severely attacked by shoot fly, *Atherigona varia soccata* stem borer *Chilo partellus* and ear head gall midge *Stenodiplosis sorghicola*. The rice variety RP 4-14 was subjected to severe attack by BPH. Spread of the gall midge resistant varieties surekha and kakatiya in Telangana region made the gall midge incidence negligible while other pests like BPH, stem borer and whorl maggot became serious pests on paddy.

   The growing of cabbage crop in the plains of Madurai district (Tamil Nadu) as a new venture resulted in the wide spread incidence of the green semilooper, *Trichoplusia ni*

4. **Destruction of forests and bringing forest area under cultivation:**

   The destruction of forest over wide areas for cultivation affects several of the weather factors *viz.,*temperature, humidity, rainfall, wind velocity etc., in that locality and thus set conditions favourable for some insects to develop enormously. The insects feeding on the trees and plants in the forest area are driven to neighboring areas where they may infest the cultivated crops and become new pests.

5. **Monoculture** (intensive and extensive cultivation of crops without proper crop rotation).

When a single crop is raised over extensive area, limitation of food gets nullified and there is no competition for food and shelter and these results in the increase in pest populations. The effect is more pronounced if the cropping is done in more than one season for the year.

The incidence of borers is high when sugarcane crop is raised over extensive areas continuously.

Rice grown continuously creates favourable conditions for stem borer, BPH , green leafhoppers.

Cotton monocropping over large areas, prolonging the crop growth beyond the regular duration and non removal of crop residues before the next crop accentuates population of American bollworm *Helicoverpa armigera* and pink bollworm *Pectinophora gossypiella*

Even if there is crop rotation with closely related crops or when there are alternative food plants for the insect pests concerned, again the population of insect pests is likely to increase.

Cotton followed by bhendi increases the incidence of pests like bollworms, aphids, mites, whiteflies etc.

6. **Introduction of a new pest in a new area:** when an insect gets introduced into a favourable new area without its natural enemies it becomes more abundant. The wooly aphid, *Eriosoma lanigerum*, became a serious pest of the apple in Niligiris as there was no natural enemy of the pest to check its multiplication. It was brought under control only when its specific parasitoid *Aphelinus mali* was introduced from Punjab.

7. Accidental introduction of foreign pests: Immature and adult stages of certain insects adhere closely to the plants such as scales and aleurodids and those which bore into the tissues of plant parts such as leaf miners, stem borers, gall insects etc., and are more liable to be introduced into other countries. Some of such insects introduced into India from foreign countries are the diamond back moth *Plutella xylostella* on cruciferous vegetables the Sanjose scale *Quadraspidiotus perniciousus*on fruit trees on hills, the green mealybug *Coccus viridis* on coffee and the potato tuber moth *Phthorimoea operculella*, cotton cushiony scale, *Icerya purchasi* , serpentine leaf miner *Liriomyza trifolii,* Spiralling whitefly, *Alerodicus dispersus* , Coconut mite *Aceria guerreoronis* etc,

8. Destruction of natural enemies: The natural enemies keep the insect pests under check. The destruction of these either by man or other agencies tends to increase the population of insect pests in an area. Sometimes the weather conditions may be favourable to the pest and unfavourable to its natural enemies. The insecticides may often affect the parasitoids and predators more than the host insects. DDT kills parasitoids and predators and thus encourages aphids, scales mealybugs and spider mites to multiply into enormous proportions.

9. Large scale storage of food grains: Large scale storage of food grains also leads to pest problems since there is plenty of food for stored product insects to feed, breed and multiply.

LECTURE NO. 5

PEST SURVEILLANCE

Pest surveillance is the systematic monitoring of biotic and abiotic factors of the crop ecosystem in order to predict the pest outbreak or it is the study of the ecology of the pest which provides the necessary information to determine the feasibility of a pest management programme. By the Pest surveillance programmes, the population dynamics and the key natural mortality factors operating under field conditions can be known which in turn helps in devising the appropriate management strategies.

Advantages

1. One can know how a pest is multiplying in an area and when it is expected.
2. Minimize the cost of plant protection by reducing the amount of pesticides used and in turn reduce environmental pollution.
3. Pest control measures can be initiated in time due to advance forecasting.
4. Useful for pest forecasting.
5. To find out natural enemy population
6. To study the influence of weather parameters on pests
7. Mark endemic areas
8. Maintain the stability of the agro ecosystem.

Components of pest surveillance

1. Identification of the pest.
2. Distribution and prevalence of the pest and its severity.
3. The different levels of incidence and the loss due to the incidence.
4. Pest population dynamics.
5. Assessment of weather.
6. Assessment of natural enemies etc.

This study will give advance knowledge of probable pest infestation and will help to plan cropping patterns and to get best advantage of pest control measures.

Forecasting for Pest Management

The Pest surveillance programmes are highly useful in forecasting of the pests. It is the advance knowledge of probable infestation by the pests in a crop. Insect forecasting service may serve

(1) To predict the forthcoming infestation levels of a pest which is very useful in taking control measures and

(2) To findout the critical stages at which the application of insecticides would afford maximum protection.

During 1941 a nation wide pest forecasting system was established in Japan. Locust warning station in India was established in 1939.

Forecasting is mainly of two types.

1) **Short term forecasting:** Covers one or two seasons mainly based on the populations of the pest within the crop by sampling methods.
2) **Long term forecasting:** It covers large areas and based mainly on the possible effects of weather on the insect abundance. Eg. Locust warning stations.

Forecasting is made through

1. Population studies carried over several years.
2. Studies on the pest life history.
3. Field studies on the effect of climate on the pest and its environment.
4. Predictions form the empirical data on the pests of the previous season.

Pest surveillance and monitoring in India : Pest surveillance and monitoring form an integral part of IPM technology. Directorate of Plant Protection , Quarantine and Storage (DPPQS), Faridabad, is organizing regular rapid roving pest surveys on major field crops in different agro ecosystems in collaboration with ICAR and SAU's and a consolidated report then issued by Plant Protection Adviser (PPA) to the Government of India.

INSECT PESTS

The word '**Pest'** derived from the Latin word '**Pestis'** meaning Plague. An insect reaches the status of a pest when its number increases and inflicts significant damage.

'Pest' is defined as insect or other organism that causes any damage to crops, stored produce and animals. Damage boundary is the lowest level of injury where the damage can be measured.

Insect pests are divided into a) negligible 2) minor and 3) major depending upon the severity of damage caused on the plant.

Pests that cause less than 5% loss in yield, is said to be negligible. Insects which normally cause a loss ranging from 5 to 10% are said to be minor pests and those which cause a loss of 10% or more in general called as major pests.

Different Categories of Insect Pests

The different categories of insect pests are

1. **Regular pest**: Occur most frequently (regularly) in a crop and have close association with that particular crop. Eg: Chilli Thrips *Scirtothrips dorsalis* , brinjal shoot and fruit borer, *Leucinodes orbonalis*
2. **Occasional pests**: Here a close association with a particular crop is absent and they occur infrequently. Eg: Rice case worm, *Nymphula depuctalis* castor slug caterpillar, *Parasa lepida* , mango stem borer, *Batocera rufamaculata*

3. **Seasonal pests**: Occur mostly during a particular part of the year, and usually the incidence is governed by climatic conditions. Eg: Red hairy caterpillar on groundnut-June - July, Rice grasshoppers –June-July, Paddy climbing cutworms.
4. **Persistent pests**: Occur on a crop almost throughout the year.Eg: Scales and mealybugs on many crops, thrips on chillies, paddy stem borer.
5. **Sporadic pests**: Occur on a few isolated localities. Eg: coconut slug caterpillar – *Macroplectra nararia, Contheyla rotunda,* Rice earhead bug - *Leptocorisa acuta,*, castor slug caterpillar-*Latoia lepida*
6. **Epidemic pest**: Occur in a severe form in a region or locality at a particular season or time only. Eg: Rice hispa, *Dicladispa armigera*, rice leaf roller, *Cnaphalocrocis medinalis*
7. **Endemic pest**: Occur regularly and confined mostly to a particular area or locality. Eg: Red hairy caterpillar *Amsacta albistriga*on groundnut in Kurnool, Ananthapur, Kadapa, Chittoor, Srikakulam and Vizag districts, stem borers of rice, paddy gall fly in Warangal districts.

LECTURE 6

INTEGRATED PEST MANAGEMENT (IPM)

Modern concept of pest management is based on ecological principles and integration of different control tactics into a pest management system

Integrated control was defined by Stern *et al.,* (1959) as applied pest control which combines and integrates the biological and chemical control. Later the concept of pest management has gained importance .The idea of managing pest population was proposed by Geier and Clark 1961 who called their concept as protective management which later was shortened as pest management.

Later Smith and Van Den Borsch in 1967 mentioned that the determination of the insect numbers is broadly under the influence of total agro ecosystem and the role of the principle element is essential for integrated pest management.

In 1972 the term IPM was accepted by CEQ (Council of Environmental Quality) where IPM includes

I - Integration that is harmonious use of multiple methods to control the impact of single pest as well as multiple pests.

P - Pest- any organism that is detrimental to humans including vertebrates and invertebrate or weed or pathogens.

M - Management refers to a set of decisions or rules based on ecological principles, economic and social consideration.

The backbone of management of pest in an agricultural ecosystem is the concept of economic injury level (It is the level of the pest up to which the damage can be tolerable)

According to FAO (1967), IPM was defined as “a pest management system in the context of associated environment and population dynamics in pest species. It utilizes all suitable techniques and methods in as compatible manner as possible and maintains the pest population at levels below those cause economic injury.

OR

Protective management of the noxious pest in which all available techniques should be evaluated and consolidated to manage pest population so that economic damage is avoided and adverse side effects on the environment are minimized (Gieir and Clark, 1961).

Evolution of IPM

Green revolution has attain self sufficiency in food through introduction of hybrids and high yielding varieties. Intensive cultivation of HYV invited or demanded more of inputs in the form of fertilizers especially inorganic which in turn attracted more of pest and diseases. This necessitated intensive control measures to curtail the damage caused to the crops and the control was achieved mainly through chemical pesticides. Continuous use of chemical pesticides led to pest resurgence, resistance, residues and ecological imbalance by killing predators and parasitoids thus affecting prey-predator dynamics and resulting in environmental pollution. The importance of integrated approaches to pest control was then felt and the concept of IPM evolved.

Why Pest Management

1) Collapse of control system:

After World War II the use of pesticides mushroomed, but with all the benefits of the use pesticides, it has adverse side effects not just on humans but also in animals. During the massive use of pesticides, Rachel Carson, an American biologist, warned the people about the side effects of the use of pesticides through her book entitled, *Silent Spring*. Through her book, she raised a lot of questions about the real benefits of the use of pesticides as well as the risks of pesticides rendered in the environment and public health. An over-reliance on chemical pesticides led to development of pesticide resistance, development of multiple resistance , emergence of secondary pest as major pests, resurgence of pests, elimination of natural enemies of pests, hazards to non-target species, hazards to agricultural workmen and deleterious effects on the environment,

2) Phases of crop protection (Collapse of control systems)

Smith. R.F (1969) has classified World wide patterns of crop protection in cotton agro ecosystem into the following phases which are also applicable to other crop ecosystems

A) Subsistence phase

The crop is usually grown under non irrigated conditions. Crop does not enter the world market and is consumed in the villages or bartered in the market place. Crop yields are low. Crop protection is through natural control, hand picking, host plant resistance, other cultural practices and rarely insecticides are used.

B) Exploitation phase

The agricultural production increased from subsistence level to higher so as to reach the market. Pest control solely depend on chemical pesticides. These are used intensively, often at fixed intervals. Chemical control measureswere exploited to the maximum extent wherein new synthetic insecticides, new methods of application, intensive use of pesticides resulted in higher yields.

C) Crisis phase

After few years in exploitation phase, more frequent applications of pesticides and higher doses are needed to obtain effective control. Insect populations often resurge rapidly after treatments and the pest population gradually becomes tolerant to the pesticide. Another pesticide is substituted and pest population becomes tolerant to it too. Occasional feeders become serious pests. Excessive use of insecticides over a number of years led to serious problems like

i) Pest resurgence

ii) Pest resistance to insecticides

iii) Change of pest status

iv) Increase of production costs, etc.

D) Disaster phase

As a result of all deleterious effects, the cost of cultivation got increased and the crops were not grown profitably. There were frequent encounters of crop failures and produce not acceptable at market (rejection of the produce due to residues), and finally collapse of the existing pest control system.

E) Integrated control phase

In this phase it is aimed to give the control measures to the optimum and not to the maximum. Pest management concept is followed to avoid crisis and disaster phases by

a) Combination of the resources
b) analysis of eco- factors
c) optimization of techniques
d) recognizing or restoring the pest at manageable level

3) Environmental contamination

Presence of residues in foods, feed and organisms caused widespread concern about contamination of Environment

Concepts of IPM

IPM seeks to minimize the disadvantages associated with use of pesticides and maximizing socio, economic and ecological advantages**.**

1. Understanding the agricultural ecosystem

An agro ecosystem contains a lesser diversity of animal and plant species than natural ecosystem like forests. A typical an agro ecosystem contain only 1-4 major crop species and 6-10 major pest species. An agro ecosystem is intensively manipulated by man and subjected to sudden alterations such as ploughing , inter cultivation and treatment with pesticides. These practices are critical in pest management as pest populations are greatly influenced by these practices. Agro ecosystem can be more susceptible to pest damage and catastrophic outbreaks owing to lack of diversity in species of plants and insects and sudden alternations imposed by weather and man.

However, agro ecosystem is a complex of food chains and food webs that interact together to produce astable unit.

2. Planning of agricultural ecosystem

In IPM programme the agricultural system can be planned in terms of anticipating pest problem and also the ways to reduce them that is to integrate crop protection with crop production system. Growing of susceptible varieties should be avoided and related crops shouldn't be grown. Bhendi followed by cotton increases incidence of the spotted borer. Groud nut followed by soybean increases incidence of the leaf miner.

3. Cost benefit ratio

Based on the possibility of pest damage by predicting the pest problem and by defining economic threshold level, emphasis should be given to cost benefit ratio. The crop life table to provide solid information analysis of pest damage as well as cost benefit ratio in pest management. Benefit risk analysis comes when a chemical pesticide is applied in an agro ecosystem for considering its impact on society as well as environment relevant to its benefits.

4. Tolerance of pest damage

The pest free crop is neither necessary in most cases for high yields nor appropriate for insect pest management. Castor crop can tolerate upto 25 per cent defoliation. Exceptions occur in case of plant disease transmission by vectors.

The relationship between density of pest population and profitability of control measures is expressed through threshold values.

The terms used to express the levels of pest population are

a) Economic Injury Level (EIL): Lowest population at which the pest will cause economic damage or it is the pest level at which the damage can no longer be tolerated and therefore it is the level at or before which the control measures are initiated. The amount of injury which will justify the artificial control measures is termed as economic damage. EIL is usually expressed as the number of insects per unit area

b) Economic Threshold Level (ETL): It is the index for making pest management decisions. ETL is defined as the population density at which control measures should be applied to prevent increasing pest population from reaching the economic injury level.

Relationship between EIL and ETL can be expressed as when no action is taken at ETL the population reaches or exceeds EIL.

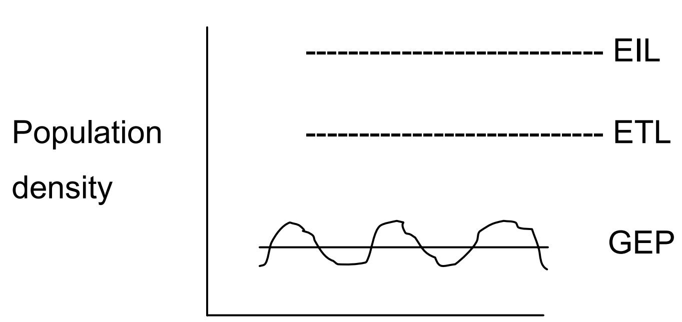
E.g.:- ETL value for BPH in rice is 25 insects/hill; Grasshoppers or cutworms is 1 insect/hill; rice stem borer -5% dead hearts; Gall midge of rice-5% silver shoots.

c) General equilibrium position(GEP)

It is the average population density of insect over a long period of time unaffected by temporary interventions of pest control .However the economic injury level may be at any level well above or below the general equilibrium.

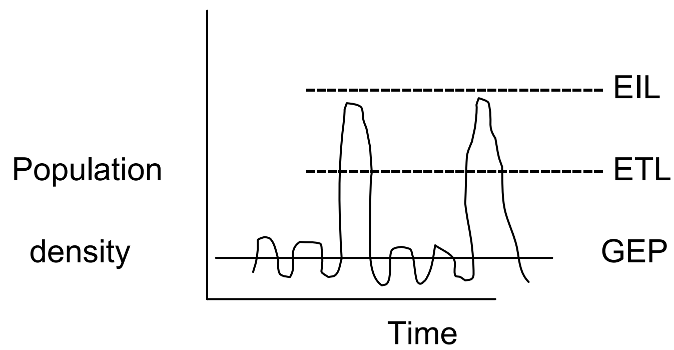
The EIL may be at any level from well bellow to well above the GEP. Based on this insects can be grouped into FOUR categories

a) Negligible pest: Pop density never increases high enough to cause economic injury.

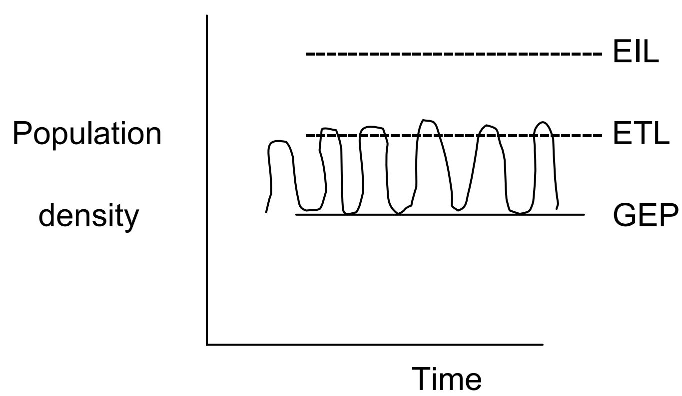


Time

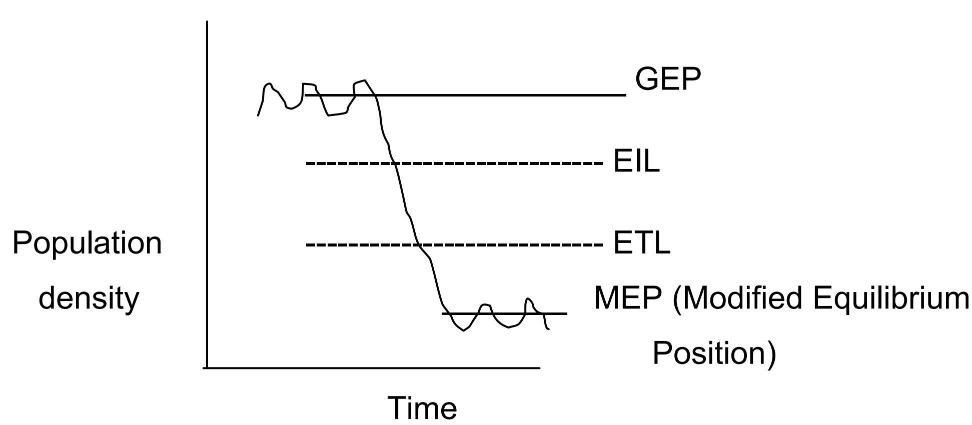
b) Occasional pest: Occasionally their density reaches EIL when their population is affected by unusual weather conditions or the injudicious use of insecticides. At their peaks of population density, some sort of intervention usually an insecticide is required to reduce their numbers to tolerable level.



c) Perennial pest: EIL's are slightly above the GEP and intervention is necessary at nearly every upward population fluctuation. The general practice is to intervene with insecticides whenever necessary to produce a modified average population density well below the EIL.



d) Severe pest: They have EIL below the GEP. Regualr and constant interventions with insecticides are required to produce marketable crops.



EIL decreases as the value of crop increases. It also depends on the stage of the crop, stage of the pest etc.

5. Leaving a pest residue

Natural enemy population isgradually eliminated not only in the absence of their respective insect hosts because of the indiscriminate use of broad spectruminsecticides, which inturn also eliminate natural enemies. Therefore, it is an important concept of pest management, to leave a permanent pest residue below economic threshold level, so that natural enemies will survive.

6. Timing of treatments

Treatment in terms of pesticide spray should be need based, with minimum number of sprays, timely scheduled, combined with improved techniques of pest monitoring and crop development

E.g.: Use of pheromone traps for monitoring of pest population

7. Public understanding and acceptance

In order to deal with various pest problems special effort should be made for effective communication to the people for better understanding and acceptance of pest management practices. The IPM practices followed should be economical and sustainable.

Limitations of IPM: An IPM program requires a higher degree of management: Making the decision not to use pesticides on a routine or regular basis requires advanced planning and therefore a higher degree of management. This planning includes attention to field histories to anticipate what the pest problems might be, selecting crop varieties which are resistant or tolerant to pest damage, choosing tillage systems that will suppress anticipated pest damage while giving the crop the greatest yield potential.

IPM can be more labour intensive, consistent, timely and accurate field scouting takes time. Without this information,intelligent management decision cannot make.

Success of IPM programmes can be weather dependant. Therefore good IPM planners will have a alternate plan for when these problems arise.

Different components or tools of IPM include,

1) Pest serviellance
2) Cultural methods
3) Mechanical methods
4) Physical methods
5) Biological methods
6) Legislative methods and
7) Chemical methods

LECTURE No 7

HOST PLANT RESISTANCE

Relative amount of heritable qualities possessed by the plant which influence the ultimate degree of damage done by the insect is called 'Host plant resistance' to insect attack.

Lesser damage than average damage is taken as resistance while more damage than average damage constitutes susceptibility. A resistant variety produces higher yield than susceptible variety when both are subjected to the same extent of infestation by same insect at the same time. Resistance is a relative term only compared with less resistance or susceptibility.

Absolute resistance or Immunity refers to the inability of a specific pest to consume or injure a particular variety under any known-conditions. Immune varieties are rare.

Ecological Resistance or Pseudo Resistance or Apparent Resistance

Ecological resistance relies more on environmental conditions than on genetics.

Certain crop varieties may overcome the most susceptible stage rapidly and thus avoid insect damage. Early maturing crop cultivars have been used in agriculture as an effective pest management strategy. However, plants that evade insect attack by this mechanism are likely to be damaged if the pest populations build-up early. **Pseudoresistance** may be one or combination of the following:

1**. Host evasion**: Under some conditions , a host plant may pass through the most susceptible stage quickly or at time when insects are less in number .

Eg:Early planting of paddy in *kharif* minimize the infestation of stem borer *Scirpophaga incertulas*

Sowing of sorghum soon after onset of monsoon in June helps to overcome shoot fly infestation

2**. Induced resistance**: is a form of temporarily increased resistance asresulting from some conditions of plant or its environment such as changes in the amount of nutrients or water applied to the crop.

Eg: Application of potassium fertilizers.

3. **Host escape**: It refers to lack of infestation or injury to the host plant because of transitory circumstances like incomplete infestation, thus finding of uninfested plant in a susceptible population does not necessarily mean that it is resistant.

Genetic Resistance

The factors that determine the resistance of host plant to insect establishment include the presence of structural barriers, allelochemicals and nutritional imbalance. These resistance qualities are heritable and operate in a concerted manner, and tend to render the plant unsuitable for insect utilization.

Genetic resistance may be grouped based on,

A. Number of genes

i) **Monogenic resistance:**When resistance is controlled by a single gene, it is called monogenic resistance

ii) **Oligogenic resistance**: When resistance is governed by a few genes, it is called oligogenic resistance.

iii) **Polygenic resistance**: When resistance is governed by many genes, it is called polygenic resistance. This is also termed as horizontal resistance.

B. Major or minor genes

i) **Major gene resistance**: The resistance is controlled by one or few major genes. Major genes have a strong effect and these can be identified easily. This is also called Vertical resistance.

ii) **Minor gene resistance**: The resistance is controlled by a number of minor genes, each contributing a small effect. It is called minor gene resistance. This is also referred to as horizontal resistance.

C. Biotype reaction

i) Vertical resistance: If a series of different cultivars of a crop show different reactions when infested with different insect biotypes, resistance is vertical. In other words, when infested with the same insect biotype, some cultivars show a resistant reaction while others show a susceptible reaction. It is also referred to also as a qualitative or biotype-specific resistance. Vertical resistance is generally, but not always, of a high level and is controlled by a major genes or oligogenes. It is considered less stable.

ii) Horizontal resistance: Horizontal resistance describes the situation where a series of different cultivars' of a crop show no differential interaction when infested with different biotypes of an insect. All resistant cultivars show similar levels of resistance to all biotypes. This type of resistance is called biotype-non-specific resistance, general resistance or quantitative resistance. Generally, horizontal resistance is controlled by several poly genes or minor genes, each with a small contribution to the resistance trait. Horizontal resistance is moderate, does not exert a high selection pressure on the insect, and is thus more durable or stable.

Host Plant Selection Process by an Insect

Host plant selection is a process by which an insect detects a resource providing plant within an environment of large population of diversified plant species.

The process of host plant selection involves a sequence of five steps

1. **Host-habitat finding:** The adult population of any species arrives at general host habitat by phototaxis or anemotaxis and geotaxis. Temperature and humidity play important role .Normally crop pests stay within general area where crops are planted and hence, this becomes less important in host plant selection.

2. **Host finding:** After locating habitat the insect pest makes a purposeful search to locate its appropriate host plantfor its establishment. The essential visual or olfactory mechanisms help the contact**.** Once the pest reaches orcontacts the host plants, tactile and olfactory sensory organs arrest further movement causing the insects to remain on the plant.
3. **Host recognition**: Although larvae are with sensorial receptors for host recognition, this phase is usually taken care of by ovipositing female adult. It is usually done with the help of specific volatile from the plants. Eg:-Onion maggots,*Delia sp* attracted to its host by the odour of propryl disulphide. Cabbage maggot fly,*Delia brassica* get attracted by crucifer due to presence of few glucocyanolides.
4. **Host acceptance:** Various chemicals present in the host species actually govern the feeding process of insects. These chemicals responsible for initial biting,swallowing and continuation feeding. Eg: Presence of phagostimulants like *morin* in mulberry *Morus alba*is key in continuation of feeding of silkworm *Bombyx mori.*
5. **Host suitability**: The nutritional value in terms of sugars, proteins, lipids and vitamins or absence of deleterious toxic compounds determines the suitability of the host for the pest in relation to the development of larvae, longevity and feeding.

Mechanisms of Host Plant Resistance

R. H. Painter (1951) has grouped the mechanisms of host plant resistance into three main categories.

1. Non-preference (Antixenosis) 2. Antibiosisand3. Tolerance

Though various workers have attempted to classify the mechanisms of resistance, the terms defined by Painter (1951) - non preference, antibiosis and tolerance were widely accepted. However, Kogan and Ortman (1978) proposed that the term non preference should be replaced by antixenosis because the former describes a pest reaction and not a plant characteristic. The three types of resistance are described in the context of the functional relationships between the plant and the insect.

Non-preference or Antixenosis:

The term ‘Non-preference’referes to the responce of the insect to the charecteristics of the host plant, which make is unattractive to the insect for feeding, oviposition or shelter.Kogan and Ortman (1978) proposed the term ‘Antigenosis’, as the term ‘Non-preference’ pertains to the insect and not to the host plant.

Some plants are not choosen by insects for food shelter or oviposition because of either the absence of desirable characters in that plant like texture, hairyness taste, flavour, or presence of undesirable characters. Such plants are less damaged by that pest and the phenomenon is called non preference

Eg. Hairy varieties of soybean and cotton are not preffered by leafhoppers for oviposition

Open panicle of sorghum supports less *Helicoverpa armigera*

Wax bloom on crucifers deter diamondback moth *Plutella xylostella*

Antibiosis:

Antibiosis refers to the adverse effect of host plant on the insect due to the presence of some toxic substances or absence of required nutritional components. Such plants are said to exhibit antibiosis and hence do not suffer as much damage as normal plants. The adverse effects may be reduced fecundity , decreased size , long life cycle , failure of larva to pupate or failure of adult emergence, and increased mortality. Indirectly, antibiosis may result in an increased exposure of the insect to its natural enemies.

Eg: The most classical example ofhost plant resistance is DIMBOA (2,4 Di hydroxy -7- methoxy – 1,4 benzaxin – 3) content in maize which imparts chemical defense against the European corn borer *Ostrinia nubilalis.* Nutrionally related antibiotic effect in rice variety Mudgo which is resistant to BPH. When young females fed on variety Mudgo, ovaries of BPH are underdeveloped andcontain few mature eggs in it due to less quantity of aminoacid asparagine content in the resistant variety.

Tolerance:

Some plants withstand the damage caused by the insect by producing more number of tillers ,roots, leaves etc in the place of damaged plant parts such plants are said to be tolerant to that particular pest .Tolerance usually results from one or more of the following factors

1. General vigour of the plant, 2.Regrowth of the damaged tissues 3.Strength of stems and resistant to lodging 4. Production of additive branches 5. Efficient utilization of non vital plant parts by the insect and 6. Compensation by growth of neibhouring plants

Eg: Early attack by the sorghum shoot fly on main shoot induced the the production of a few synchronous tillers that grow rapidly and survive to produce harvestable ear heads. LRG 41 Red gram for *H. armigera*

Transgenic Plants (Genetically modified or GM crops)

A transgenic crop plant contains a gene or genes which have been artificially inserted instead of a plant acquiring them through pollination or simply a normal plant with one or more additional genes from diverse sources .Transgenic plants produce insecticidal or antifeedant proteins continuously under field conditions that proteins are enough to kill target pests.*Bacillus thuringensis* and cowpea trypsin protease inhibitors are ideal to impart resistance to insect attack.

B.t a naturally occurring gram positive soil bacterium, upon sporulation forms a parasporal crystal proteins called delta endotoxins. The cry proteins have selective toxicity to certain category of insects and require certain specific conditions for their effective action. The protein has to be ingested by the target insects which happens when they feed on the transgenic plant tissues. It requires an alkaline pH of 9.5 or above for effective processing into an active molecule which binds to specific receptors for binding before it can kill the target insect. All these conditions are available in the target insects and therefore they succumb when they feed on *Bt*-plants. Toxins binds to midgut and creates pores in the intestinal lining resulting in ion imbalance , paralysis of digestive system, after a few days that leads to insect death

To develop a *B.t* transgenic plant,

- Selection of strain of *B.t*
- Identify the genome
- Isolation of genes (Cry genes,Cry1A, Cry1Ac &Cry3Ab*)*
- Introduction into plants through genetic engineering methods

Transgenic technology can be utilized to develop plants with various beneficial traits such as

a) Crop protection traitswhich include resistance to pests, diseases and herbicides
b) Abiotic stressin the form of tolerance to drought, heat, cold or salinity, thus enabling plants to be grown in inhospitable habitats, adding more land for cultivation; and
c) Quality traitsleading to enhanced nutrition; prolonged shelf-life or improved taste, colour or fragrance of fruits, vegetables and flowers; and increased crop yield

India made its long-awaited entry into commercial agricultural biotechnology when the Genetic Engineering Approval Committee (GEAC), Ministry of Environment and Forests, Govt of India, at its 32nd meeting held in New Delhi on 26th March 2002 approved three *Bt*-cotton hybrids for commercial cultivation. This is a historic decision as *Bt*-cotton became the first transgenic crop to receive such an approval in India. These transgenic hybrids were developed by MAHYCO (Maharashtra Hybrid Seed Company Limited) in collaboration with Monsanto.

IMPORTANCE AND HISTORY OF PLANT PROTECTION

In modern India scientific study of insects was undertaken only from 18th Century. In 1898 the historical announcement was made on the discovery that *Anopheles* mosquitoes were the carriers of the malaria.

Important institutions or organizations that contribute much for the plant protection in India are the Indian Agricultural Research Institute (IARI) which was the first established in Pusa in Bihar in 1905 and later shifted to New Delhi in 1937. Indian

Council of Agricultural Research (ICAR) was established in 1929. The Division of Entomology was established in 1905 as one of the five major Divisions of the then Agricultural Research Institute located at Pusa, Bihar and later it was shifted to New Delhi. Eminent entomologists like H.M. Lefroy, T. B. Fletcher, H.S. Pruthi, S. Pradhan and K.N. Mehrotra laid strong foundation for basic and applied research in insect science.

After the realization of the harm, the pests are doing to human beings by carrying the diseases, the Plague Commission was established in 1905 and the Central Malaria Bureau was established in 1909 in New Delhi. The Government of India established a permanent Locust Warning Station in 1939 after experiencing the effect of locust cycle in 1926-32.

The acute food shortage after the World War II and the Bengal famine in 1943 resulted due to the failure of rice crop by a paddy disease (*Helminthosporiumoryzae.*) which drew the attention of Govt. to prevent the damage of crops by pests and diseases to various crops.

In 1946 the Government of India started the Directorate of Plant Protection, Quarantine and Storage .Plant protection schemes were introduced in different states from 1947 to look after the pest problems, to advise the Central and State Governments and to enforce quarantine laws for preventing the possible introduction of new pests from foreign countries along with imported materials.

The Commonwealth Institute of Biological Control (CIBC) established its Indian station in 1957 at Bangalore. The Project Directorate of Biological Control (PDBC), Bangalore established in 1993, is nodal agency in India for organizing biological control research on agricultural pests at the national level. PDBC was upgraded as National Bureau of Agriculturally Important Insects (NBAII) in 2009 in order to exploit the agricultural insect resources from various agro climatic zones.

In Andhra Pradesh, Central Plant Protection Training Institute was established at Hyderabad in 1966 mainly to train the personnel in plant protection. Later it was named as National Plant Protection Training Institute (NPPTI) and recently during 2008 renamed as National Institute of Plant Health Management (NIPHM).

National Centre for Integrated Pest Management (NCIPM), was established at Faridabad in 1988 to cater to the emerging plant protection needs of different agro-ecological zones of the country. Later it was shifted to New Delhi in 1995.

Plant Protection Measures for Pest Control

Early man caught the intruders by hand, killed them or cut away the infested parts of the plant and burnt them. These mechanical and cultural methods are followed till to date in pest management.

Insecticides were in use from as early as 200 BC. A boiling mixture of bitumen and blowing the fumes through grape leaves was advocated to deter the insects, at about 100 BC. Sulphur was considered as pest averting material. Toxic nature of Arsenic was made to known in 40-90 AD. Chinese used Arsenic sulphides before 900

AD to control garden pests. Arsenic in honey was suggested as an ant bait since 1669. By 1690, tobacco was being used to control lace bugs on pear trees and other soft bodied insects. Pyrethrum was used before 1800 in Persia.

Modern use of insecticides started with paris green in 1867 against Colorado potato beetle, *Leptinotarsa decemlineata* and lead arsenate in 1892 against the same. HCN (Hydrocyanic acid) fumes were used against scales in 1892.

Discovery of the insecticidal properties of DDT in 1939 by Paul Muller revolutionized the insect control by chemicals and Muller was honered with Nobel prize in 1948 in medicinefor his dicovery. DDT was first synthesized by the German scientist, Orther Zieldler in 1874. Later so many other chemicals were evolved.The practical development of organophosphorous insecticide took place with the pioneering work of Schrader and his associates beginning in 1937.

Indian pesticide market is the 12^{th} largest in the World, which is 1.6 per cent of the global market. However per hectare consumption of pesticides in India is very low at 0.5 kg when compared to developed countries. In India 217 pesticide molecules (CIB, 2009) are registered for use, and 65 technical grade pesticides are manufactured indigenously. There are around 400 manufacturing units involved in production of technical grade pesticides and their formulations.

Crop Losses Due to Insect Pests

Insect pests cause huge losses ranging from 5 to 80% of even upto 100%. Acute food shortage following world war –II and Bengal famine (1943) due to failure of rice crop due to a paddy disease indicate the severity of the loss, caused by the pests and diseases. The insects in storage on an average consume and spoil an additional 4 million tones of grains every year .All this indicates the importance of plant protection by which we can save millions of tones of food grains which are otherwise eaten away by different pests. Losses due to insect pests in Indian agriculture are 23.3 per cent .One of the practical means of increasing crop production is to minimize the pest associated losses.

Methods of Pest Control

Any factor that is capable of making life hard for the insect that will repel or interfere with its feeding, mating, reproduction or dispersal can be taken as a method of insect control in its broadest application.

They can be divided into two major categories

1. Natural control
2. Applied control

Under natural control the population is kept under check by the environmental resistance without the interference of man. The control measures adopted by human agency are called applied or artificial control measures. Depending on the time of taking action the applied control measures may be

i. Preventive or prophylactic i.e. action taken to prevent the occurrence or spread of infestation and
ii. Curative or remedial measures i.e. measures which are taken to kill the already existing pest population.

Different meyhods of pest control / Components or tools of IPM are,

I) Cultural methods
II) Mechanical methods
III) Physical methods
IV) Biological methods
V) Legislative methods and
VI) Chemical methods

LECTURE NO. 8

I) Cultural Methods of Pest Control

The manipulation of cultural practices at an appropriate time for reducing or avoiding pest damage to crops is known as cultural control. The cultural practices make the environment less favorable for the pests and or more favorable for its natural enemies. It is the cheapest of all methods.

There are two categories of cultural methods,

(a) Normal agricultural practices, which incidentally ward off certain pests:

By adopting these, the farmers get two-fold benefits

(1) Improvementof crop yields and

(2) The population of certain pests do not increase abnormally

i) Proper preparatory cultivation: Several insects which live or hide in the soil get exposed to sun as well as predators like birds etc due to Proper preparatory cultivation. Eg.Pupae of moths, roots grubs etc.

ii) Clean cultivation: Removal of weeds which act as alternate hosts.

Eg. Paddy gall fly *Orseolia oryzae* breeds on grasses such as *Panicum* sp., *Cynodon dactylon* etc.

Fruit sucking moth larvae *Eudocima ancilla* on weeds of Menispermaceae

iii) Systematic cutting and removal of infested parts: Keeps down subsequent infestation.

Eg. Removal of sugarcane shoots affected by borers,

Cutting and removal of infested parts of brinjal attacked by *Leucinodes orbonalis*

Pruning of dried branches of citrus eliminates scales and stem borer.

Clipping of tips of rice seedlings before transplanting eliminate the egg masses of stem borer.

Clipping of leaf lets in coconut reduces the black headed caterpillar Ploughing and hoeing help to burry stages of insects or expose soil inhabiting insects to be picked up by birds.

Pests like coccids get carried over to the next season through stubbles, which should be promptly removed.

iv) Changes in the system of cultivation :

Change of banana from perennial to annual crop reduced the infestation of banana rhizome weevil *Cosmopolitus sordidus* in addition to giving increased yields.

Avoiding ratoon redgram crop during offseason helps in reducing the carry over of pod fly *Melangromyza obtusa* and eriophyid mite *Aceria cajani*

v) Crop rotation: Crop rotation is most effective practice against pests that have a narrow host range and dispersal capacity. Lady's finger followed by cotton will suffer from increased infestation of pests. Hence if a non-host crop is grown after a host crop,it reduces the pest population.

Eg. Cereals followed by pulses.

Cotton should be rotated with non hosts like ragi, maize, rice to minimize the incidence of insect pests.

Groundnut with non leguminous crops is recommended for minimizing the leaf miner incidence.

vi) Mixed cropping: Intended for getting some return when one crop is attacked, the other escapes.

Eg. Garden peas and sunhemp

vii) Growing resistantvarieties: certain varieties resists pest attack .

Eg: GEB-24 and MTU–5249 resistance to paddy BPH, Surekha variety to gall midge, TKM -6 and Ratna for stem borer.

(b) Cultural practices specially adopted for certain pests

1. Adjusting planting or sowing or harvesting times to avoid certain pests : The manipulation of planting time helps to minimize pest damage by producing asynchrony between host plants and the pest or synchronizing insect pests with their natural enemies.

Eg. Early planting of paddy in *kharif* and late planting in rabi minimize the infestation of rice stem borer.

Delaying the sowing of sunhemp till the onset of South West Monsoon avoids sunhemp hairy caterpillar (*Utethesia lotrix)* attack.

Early sown sorghum in kharifreduces the infestation of shoot fly

Timely and synchronous planting has been found to reduce bollworm damage in cotton and stem borer damage in sugarcane.

2. Trap cropping: Growing of susceptible or preferred plants by important pests near a major crop to act as a trap and later it is destroyed or treated with insecticides. Trap crop may also attract natural enemies thus enhancing natural control.

Eg:

Trap crop	**Main crop**	**Insect pest**
Castor	Chillies	Tobacco caterpillar *Spodoptera litura*
Tomato	Citrus	Fruit sucking moths *Otheris spp*
Marigold	Cotton	American bollworm *Helicoverpa armigera*

3. Trimming field buds: Grasshopper eggs, which are laid in field bunds are destroyed by trimming field bunds

4. Flooding the field: Flooding of fields is recommended for reducing the attack of cutworms, army worms, termites, root grubs etc,.

Eg: For cutworms like paddy swarming caterpillar (***Spodoptera mauritinana** and S. exiqua)* and ragi cutworm by flooding the fields caterpillars float and leave the plants

5. Draining the fields: In case of paddy case worm *Nymphula depunctalis* which travel from plant to plant via water. it can be eliminated by draining or drying the field.

Draining the rice fields for 3-4 days during infestation controls BPH and whorl maggot.

Alternate drying and wetting at 10 days interval starting from 35 DAT reduces the BPH and WBPH.

6. Alley ways: Formation of alley ways for every 2 m in rice field reduces the BPH *Nilaparvata lugens*

(c) Other cultural methods

1. Root weevil, *Echinonemus oryzae* damage in rice can be overcome by applying 20 kg ammonium sulphate and 40 kg single super phosphate in rice .
2. Raking up and hoeing of the soil around gourds, mango and other fruit trees serves to destroy pupae of fruit flies.
3. Adoptation of high seed rate in sorghum and later removal and destruction of shoot fly (*Atherigona soccata)* affected ones.
4. Trash mulching @ 3 t/ha 3 days after planting or earthing up at a month or two after planting minimize early shoot borer (*Chilo infuscatellus)* attack in sugarcane
5. Destruction of crop residue: Stubbles of sugarcane and paddy that harbour borers should be ploughed up and burnt.
6. Deep ploughing in summer exposes most of the soil inhabiting insects to sun and hot winds and get them killed
7. Periodical drying of stored produce against stored grain pests.
8. Pruning of dried twigs/ branches to eliminate pests like scales and orange borer

B. Mechanical Methods of Pest Control : Reduction or suppression of insect pest population by means of manual devices or labour

Hand picking and collection with hand nets and killing insects: Handpicking is most ancient method which can prove fairly effective under certain conditions. Egg masses, larvae or nymphs and sluggish adults can be handpicked and destroyed.

Eg.

- Egg masses of paddy stem borer *(Scirpophaga incertulas)* and groundnut hairy caterpillar
- Early stages of *Spodoptera litura* and hairy caterpillars are easily located by their typical damage symptoms
- The moringa caterpillars, which collect at tree trunks in the mornings can be burnt.
- Most of the insects can be collected with hand nets and destroyed.
- Collection and destruction of fallen fruits is effective against fruit flies and fruit borers.

- Manual collection and destruction of pink bollworm attacked rosette flowers, withered and drooped terminals infested by spotted bollworm can reduce the incidence of these pests in cotton.

Provision of preventive barriers: Digging of 30 -60 cm wide and 60 cm deep trenches or erecting 30 cm height tin sheets barriers around the fields is useful against pests like hairy caterpillars.

Bagging / wrapping of pomegranate and mango fruits in paper bags avoids the infestation of pomegranate butterfly *Virachola isocrates* and mango fruit fly *Bactrocera dorsalis*

Tin bands are fixed over coconut palms to prevent damage by rats.

Other mechanical methods:

1. Extraction of adult Rhinoceros beetle (*Oryctes rhinoceros)* from the crown of coconut trees using an arrow headed rod/hook.
2. Construction of rat proof godowns
3. Use of an alkathene band around the tree trunks of mango to check the migration of first instar nymphs of mealybugs and red ants
4. Sticky bands around tree trunks against red tree ant (*Oecophylla samaragdina)*
5. Systematic shaking of root grub adults harbored trees during evening hours to dislodge and destroy by dumping in fire.
6. Shaking ofredgram plantsto collect and destroy later instars of *Helicoverpa armigera*
7. Shaking the trees and bushes by which the insects fall to the ground and they can be collected
8. Sieving and winnowing against stored grain pests
9. Using mosquito nets fly proof cages etc.

LECTURE NO. 9

PHYSICAL AND LEGISLATIVE METHODS OF PEST CONTROL

II) Physical Methods of Pest Control: Use of certain physical forces to minimize the pests

- A material called drie-die, consist of highly porous, finely divided silica gel which when applied abrades the insect cuticle thus encouraging loss of moisture resulting in death. It is mainly used against stored product pests.
- Kaolinic clay after successive activation with acid and heat can be mixed with stored grain. The clay minerals absorb the lipoid layer of the insect cuticle by which the insects lose their body moisture and die due to desiccation.
- Artificial heating and cooling of stored products will prevent insect damage. Usually high temperatures are more effective than low temperatures.
- Stored products can be exposed to 55^{0}C for 3 hours to avoid stored product pests
- Steam sterilization of soil kills soil insects
- Vapour Heat Treatment (VHT): Heated air is saturated with water (>RH 90%) for specified period of 6 to 8 hours for raising pulp temperature to 43-44.5°C in case of mango against fruit flies.
- Oxygen stress and carbon dioxide concentration: In air tight containers small volume of air is enclosed, the available oxygen is quickly utilized by insects and raise concentration of carbon dioxide. High concentration of carbon dioxide leads to death of stored products insects.
- Male insects can be made sterile by exposing them to gamma radiation or by using chemicals. When sterile males are released in normal population they compete with normal males in copulation and to that extent reductive capacity of the population are reduced. By sterilizing the pupae of screwworm, livestock pest (*Cochliomyia hominivorax*) with radiations, sterile males were obtained. They were released @ 400/sq mile for 7 weeks. By this method total eradication was achieved in South East parts of America and in the Curacao islands in case of screwworm.
- Light traps are arranged for attracting the insects, which are trapped by keeping water or oil in a container or a killing bottle below the light trap. Light traps are useful for monitoring the population of important insect pests in an area. Eg: Most of the moths and beetles.
- Flame thrower is a compressed air sprayer with kerosene oil for producing flames. There is a lance, which is fitted with a burner. When the burner is heated, the kerosene oil is released and it turns into flames. Used for burning locust populations, congregation of caterpillars, patches of weeds etc.

III) Legislative / Legal / Regulatory Methods of Pest Control :

In early days there were no restrictions on the transport of plants and animals from one country to another since the danger involved in it is not realized, which resulted in introduction of pests form one country to another. In many countries many of the dangerous pests have frequently been found to be foreign pests and they inflict greater damage than the indigenous ones. Potato tuber moth *Pthorimea operculella*, cotton cushiony scale *Icerya purchasi,* wooly aphis on apple *Eriosoma lanigerum,* san jose scale *Quadraspidiotus perniciosus*, golden cyst nematode *Globodera rostochinesis* and the giant African snail ,*Achatina fulica (Predatory snail Eugladina rosea)* , serpentine leaf miner *Liriomyza trifolii,* Spiralling whitefly, *Alerodicus dispersus* , Coconut mite *Aceria guerreoronis* etc,are some exotic pests introduced into our country.

Quarantine: The word quarantine is derived from Latin word Quarantum which means 'forty (40)'. Plant quarantine is defined as the legal enforcement of the measures aimed to prevent pests from spreading or to prevent them to multiply further in case they have already gained entry and have established in new restricted areas.

The importance of imposing restrictions on the movement of pest-infested plants or plant materials from one country to another was realized when the grapevine phylloxera got introduced into France from America by about 1860 and the San jose scale spread into the USA in the later part of the 18^{th} century and caused severe damage.

The first Quarantine Act in USA came into operation in 1905. While Govt. of India passed an Act in 1914 entitled "Destructive Insect and Pests Act of 1914" to prevent the introduction of any insect, fungus or other pests into our country. This was later supplemented by a more comprehensive act in 1917.

The legislative measures in force now in different countries can be grouped into five classes. They are,

1. Legislation to prevent the introduction of new pests and weeds etc from foreign countries (International quarantine)
2. Legislation to prevent the spread of already established pests, diseases and weeds from one part of the country to another (Domestic quarantine)
3. Legislation to enforce upon the farmers regarding the application of effective control measures to prevent damage by already established pests.
4. Legislation to prevent the adulteration and misbranding of insecticides and determine their permissible residue tolerance levels in food stuffs and
5. Legislation to regulate the activities of men engaged in pest control operations and application of hazardous insecticides

1) Legislation to prevent the introduction of foreign pests:

To prevent the entry of foreign pests all countries have restrictions. They enforce quarantine laws. The imported plant material has to be thoroughly examined at the ports of entry.

The Directorate of Plant Protection Quarantine and Storage was established in Faridababd in 1946. Prior to which customs authorities did the enforcement of quarantine laws. From 1949, DPPQS deals with the commercial import of consignments of grains, plants and plant products for consumption through its network of 35 Plant Quarantine Stations spread across the country including seaports, airports and land frontiers

These operate under the provisions made under the “Destructive Insect and Pests Act of 1914”. Further Government of India has approved NBPGR, New Delhi for quarantine processing of all germplasm including transgenic planting material under exchange for research purposes, Forest Research Institute(FRI) Dehadradun for forest plants and Botanical Survey of India (BSI), Kolkatta for ornamental plants to enforce quarantine laws.

The importation of plant material from foreign countries has to be done only through any of these ports.The consignment should also be accompanied with the certificate issued by the Officers of agriculture department of the exporting country so as confirm that the consignments are pest free. This certificate is called as ‘Phytosanitory certificate’.

Import of plants by post or air is not permitted, except by experts for scientific purpose. Import of potatoes from areas known to be infected with wart disease or golden cyst nematode is totally prohibited in to our country.

2) Legislation to prevent the spread of already established pests:

The Destructive Insect and Pests Act, 1914, have empowered the states to enact such laws as are necessary to prevent the spread of dangerous insects within their jurisdiction.

The Madras Government enacted the Madras Agricultural Pests and Diseases act in 1919 and was the first state to enact such laws in our country. This act was passed to prevent the spread of pests or diseases or weeds form one part of the state to another.

Cottony cushiony scale when localized in Nilgiris and Kodiakanal none of the alternate host plants were permitted to get transported from these areas. Quarantine stations were opened at Mettupalayam and Gudalur of Nilgiris and at Shenbegmur station of Kodaikanal in 1943 and were closed subsequently.

3) Legislation to enforce the application of effective control measures to prevent the damage by established pests.

Under the state pests act, the farmers were asked to remove and destroy coconut leaf lets infested with black headed caterpillar *Opisina arenosella* around Mangalore in 1923 and in 1927 in Krishna and Guntur districts. Later it was withdrawn as the pest was successfully controlled by biological control agents.

4) Legislation to prevent the adulteration and misbranding of the insecticides.

To avoid malpractices and supply of substandard chemicals, the pesticide products are to be standardized through the Indian Standards Institute. Such products carry **ISI mark** and are expected to confirm the level of *a.i* (Active ingredient)

The Insecticide Act, 1968 has been enforced on 2nd September, 1968 by the Government of India to regulate the import, manufacture, sale, transport and distribution and use of insecticides. The government of India also constituted the Central Insecticide Board (CIB) to advise the state and central governments as per this act. The insecticide rules of 1971 framed under the Insecticides Act 1968 had come in to force in 1971.

5) Legislation to regulate the activities of men engaged in pest control operations: They have to take certain precautionary measures to avoid pesticide poisoning and undergo regular medical checkup.

Invasive Alien Species (IAS): is a species outside of its native range whose introduction and or spread threatens biodiversity.

LECTURE NO. 10

BIOLOGICAL CONTROL

The successful management of a pest by means of another living organism (parasitoids, predators and pathogens) that is encouraged and disseminated by man is called biological control. In such programme the natural enemies are introduced, encouraged, multiplied by artificial means and disseminated by man with his own efforts instead of leaving it to nature.

Techniques in biological control:

Biological control practices involve three techniques *viz.,* Introduction, Augmentation and Conservation.

1. Introduction or classical biological control: It is the deliberate introduction and establishment of natural enemies to a new locality where they did not occur or originate naturally. When natural enemies are successfully established, it usually continues to control the pest population.

2. Augmentation: It is the rearing and releasing of natural enemies to supplement the numbers of naturally occurring natural enemies. There are two approaches to augmentation.

a. Inoculative releases: Large number of individuals are released only once during the season and natural enemies are expected to reproduce and increase its population for that growing season. Hence control is expected from the progeny and subsequent generations and not from the release itself.

b. Inundative releases: It involves mass multiplication and periodic release of natural enemies when pest populations approach damaging levels. Natural enemies are not expected to reproduce and increase innumbers. Control is achieved through the released individuals and additional releases are only made when pest populations approach damaging levels.

3. Conservation: Conservation is defined as the actions to preserve and release of natural enemies by environmental manipulations or alter production practices to protect natural enemies that are already present in an area or non use of those pest control measures that destroy natural enemies.

Important conservation measures are

- Use selective insecticide which is safe to natural enemies.
- Avoidance of cultural practices which are harmful to natural enemies and use fauorable cultural practices
- Cultivation of varieties that favour colonization of natural enemies
- Providing alternate hosts for natural enemies.
- Preservation of inactive stages of natural enemies.
- Provide pollen and nectar for adult natural enemies

Parasite:A parasiteis an organism which is usually much smaller than its hostand a single individual usually doesn't kill the host. Parasite may complete their entire life cycle (eg. Lice) or may involve several host species. Or Parasite is one, which attaches itself to the body of the other living organism either externally or internally and gets nourishment and shelter at least for a shorter period if not for the entire life cycle. The organism, which is attacked by the parasites, is called hosts.

Parasitism: Is the phenomena of obtaining nourishment at the expense of the host to which the parasite is attached.

Parasitoid: is an insect parasite of an arthopod, parasitic only in immature stages, destroys its host in the process of development and free living as an adult. Eg: Braconid wasps

Qualities of a Successful Parasitoid in Biological Control Programme

A parasitoid should have the following qualities for its successful performance.

1. Should be adaptable to environmental conditions in the new locally
2. Should be able to survive in all habitats of the host
3. Should be specific to a particulars sp. of host or at least a narrowly limited range of hosts.
4. Should be able to multiply faster than the host
5. Should be having more fecundity
6. Life cycle must be shorter than that of the host
7. Should have high sex ratio
8. Should have good searching capacity for host
9. Should be amendable for mass multiplication in the labs
10. Should bring down host population within 3 years
11. There should be quick dispersal of the parasitoid in the locality
12. It Should be free from hyperparasitoids

Some successful examples

- Control of cottony cushion scale, *Icerya purchasi* on fruit trees by its predatory vedalia beetle, *Rodolia cardinalis* in Nilgiris. The predator was imported from California in 1929 and from Egypt in 1930 and multiplied in the laboratory and released. Within one year the pest was effectively checked.
- For the biological suppression of Water Fern, *Salvinia molesta,*the weevil, *Cyrtobagous salviniae*, was imported from Australia in 1982. Exotic weevil, *C. salviniae* was released for the control of water fern, S. molesta in a lily pond in Bangalore in 1983-84. Within 11 months of the release of the weevil in the lily pond the salvinia plants collapsed and the lily growth, which was suppressed by competition from salvinia resurrected.
- Biological Control of Water Hyacinth**,** *Eichhornia crassipes* ,three exotic natural enemies were introduced in India viz.,hydrophilic weevils – *Neochetina bruchi* and *N. eichhorniae* (Argentina) and galumnid mite *Orthogalumna terebrantis* (South America) in 1982 for the biological suppression of water hyacinth.

- Apple woolly aphis, *Eriosoma lanigerum* in Coonor area by *Aphelinus mali* (parasitoid)
- Control of shoot borers of sugarcane, cotton bollworms, stem borers of paddy and sorghum with the egg parasitoid, *Trichogramma australicum* @ 50,000/ha/week for 4-5 weeks from one month after planting
- *Centrococcus isolitus* on brinjal; Pulvinaria *psidi* on guava and sapota; *Meconellicoccus hirsutus* on grape and *Pseudococcus carymbatus* on citrus suppressed by *Cryptolaemus montrouzieri.*

Parasites can be grouped as furnished below

1. Depending upon the nature of host,

1. Zoophagous	- that attack animals (cattle pests)
2. Phytophagous	- that attack plants (crop pests)
3. Entomophagous	- that attack insects (parasites)
4. Entomophagous insects	- parasitoids

II. Based on the specialization of the site of parasitisation

1. Ectoparasites: they attack its host from the outside of the body of the host. The mother parasite lays its eggs on the body of the host and after the eggs are hatched the larvae feed on the host by remaining outside only. Head louse; *Epiricania melanolenca, Epipyrops* sp. Sugarcane fly.

2. Endoparasites :they enters the body of the host and feeds from inside. The mother parasite either lays its eggs inside the tissues of the host or on the food material of the host to gain entry inside.

Eg.Braconids & Icheneumonids, *Apanteles flavipes* on jowar stemborer larvae.

III. Specialization based on the stage of the host

Eg. Host: Coconut black headed caterpillar, *Opisina arenosella*

TAMGESTT

1. Egg parasite : *Trichogramma australicum*
2. Early larval parasite – *Apanteles taragama*
3. Mid larval parasite – *(Micro*) *Bracon hebtor*
4. Prepupal parasite – *Gonizus nephantidis*
5. Prepupal parasite – *Elasmus nephantidis*
6. Pupal parasite –*Stomatoceros sulcatiscutellum*
   Trichospilus pupivora, Testrastichus israeli,

IV. Depending upon the duration of attack

1. **Transitory parasite :**It is not permanent but transitory parasite which spends a few stages of its life in one host and other stages on some other species of hosts or as a free living organism.
   Eg. Braconids and Ichneumonids
2. **Permanent parasite :**
   Which spends all the stages of its life on the same host.Eg**.** Head louse

V. Depending upon degree of parasitization

1. Obligatory parasites: Parasite, which can live only as a parasite and cannot live away from the host even for shorter period. Eg. Bird lice, Head louse.

2. Facultative parasite: Parasite, which can live away from the host at least for a shorter period Eg. Fleas.

VI. Depending upon the food habits

1. **Polyphagous:** develops on number of widely different host species Eg. *Bracon* sp. *Apanteles* sp on lepidopteran caterpillars
2. **Oligophagous:** which has very few hosts (more than one host) but all the hosts are closely related. Eg. *Isotema javensis* on sugarcane and sorghum borers.
3. **Monophagous**:which has only one host sp. and can't survive in another sp. i.e. host specific. Eg. *Gonizus nephantidis* on *Opisina aresosella*

Kinds of Parasitism

1. **Simple parasitism :**Irrespective of number of eggs laid the parasitoid attacks the host only once. Eg. *Apanteles taragamae* on the larvae of *Opisina arenosella*, *Goniozus nephantids*
2. **Super parasitism :**phenomenon of parasitization of an individual host by more larvae of single species that can mature in the host. Eg. *Apanteles glomeratus* on *Pieris brassica, Trichospilus pupivora* on *Opisina arenosella*.
3. **Multiple parasitism :**Phenomenon of simultaneous parasitization of host individual by two or more different species of primary parasites at the same time. Eg:*Trichogramma, Telenomous and Tetrastichus* attack eggs of paddy stem borer *Scirpophaga incertulas*.

   Super parasitism and multiple parasitisms are generally regarded as undesirable situations since much reproductive capacity is wasted

4. **Hyper parasitism:**When a parasite itself is parasitized by another parasite. Eg. *Goniozus nephantidis* is parasitized by *Tetrastichus israeli,* Most of the Bethylids and Braconids are hyper parasites.

Primary parasite:A parasite attacking an insect which itself is not a parasite (Beneficial to man.)

Secondary parasite:A hyperparasite attacking a primary parasite (Harmful to man)

Tertiary parasite: A hyperparasite attacking a secondary parasite (Beneficial to man)

Quaternary parasite :A hyperparasite attacking tertiary parasite (Harmful to man)

A primary parasitoid becomes harmful in case of productive insects like silkworms, *Bombyx mori* and lac insect *Kerria lacca*.

Predators and Predatism

A predator is one which catches and devours smaller or more helpless creatures by killing them in getting a single meal. It is a free living organism through out its life , normally larger than prey and requires more than one prey to develop.

Insect predator qualities

1. A predator generally feeds on many different species of prey , thus being a generalist or polyphagous nature
2. A predator is relatively large compared to its prey , which it seizes and devours quickly
3. Typically individual predator consumes large number of prey in its life time
   Eg: A single coccinellid predator larva may consume hundreds of aphids
4. Predators kill and consume their prey quickly , usually via extra oral digestion
5. Predators are very efficient in search of their prey and capacity for swift movements
6. Predators develop separately from their prey and may live in the same habitat or adjacent habitats
7. Structural adaptation with well developed sense organs to locate the prey
8. Predator is carnivorous in both its immature and adult stages and feeds on the same kind of prey in both the stages
9. May have cryptic colourations and deceptive markings

Eg. Preying mantids and Robber flies

Predatism

Based on the degree of use fullness to man, the predators are classified as on

1. Entirely predatory, Eg. lace wings, tiger beetles lady bird beetles except *Henosepilachna* genus
2. Mainly predator but occasionally harmful. Eg. Odonata and mantids occasionally attack honey bees
3. Mainly harmful but partly predatory. Eg. Cockroach feeds on termites. Adult blister beetles feed on flowers while the grubs predate on grass hopper eggs.
4. Mainly scavenging and partly predatory. Eg. Earwigs feed on dead decaying organic matter and also fly maggots. Both ways, it is helpful
5. Variable feeding habits of predator, eg: Tettigonidae: omnivorous and carnivorous but damage crop by lying eggs.
6. Stinging predators. In this case, nests are constructed and stocked with prey, which have been stung and paralyzed by the mother insect on which the eggs are laid and then scaled up. Larvae emerging from the egg feed on paralyzed but not yet died prey. Eg. Spider wasps and wasps.

Differences Between predator and a parasite

Predator		Parasite
1.	Mostly a generalized feeder excepting lady bird beetles and hover flies which show some specificity to pray	Exhibits host specialization and in many cases the range of host species attacked is very much limited
2.	Very active in habits	Usually sluggish one the host is secured.
3.	Organs of low common sense organs and mouth parts are well develop	Not very well developed and some times reduced even, Ovipositor well developed and oviposition specialized
4.	Stronger, larger and usually more intelligent than the prey	Smaller and not markedly more intelligent than the host
5.	Habitat is in dependent of that of its prey	Habitat and environment is made and determined by that of the host
6.	Life cycle long	Short
7.	Attack on the prey is casual and not well planned	Planning is more evident
8.	Seizes and devours the prey rapidly	Lives on or in the body of the host killing it slowly
9.	Attack on prey is for obtaining food for the attacking predator itself, excepting in wasps which sting the caterpillars to paralyze the and provide them as food in the nest for the young	It is for provision of food for the off spring
10.	A single predatory may attack several hosts in a short period	A parasite usually completes development in a single host in most cases

LECTURE No. 11

MICROBIAL CONTROL

Microbial control refers to the exploitation of disease causing organism to reduce the population of insect pest below the damaging levels. Steinhaus (1949) Coined the term 'Microbial Control' when microbial organisms or other products (toxins) are employed by man for the control of pests on plants, animals or man.

1. **Bacteria :** More than 100 pathogenic bacteria were recorded of which i. *Bacillus thuringiensis* (*B.t.*) is important and is isolated from flour moth, *Ephestia kuhniella* by Berliner (1915) *B.t.* known as a bacterial insecticide is now being using by farmers mostly on lepidopterous larvae. It can infect more than 150 species of insects. The entry of the bacteria is by ingestion of the bacteria, which infect the mid gut epithelia cells and enter the haemolymph to sporulate and cause septicemia.

Properties of *B.t.*

1. Highly pathogenic to lepidopterous larvae
2. Non-toxic to man
3. Non-phytotoxic
4. Safer to beneficial insects
5. Compatible with number of insecticides
6. So far no resistance is developed in insects
7. Synergistic in combination with certain insecticides like carbaryl
8. Available in different formulations(Trade names Thuriocide, Delfin, Bakthane, Biobit, Halt, Dipel etc).
9. Formulation is so standardized that 1 gm of concentration spore dust contains 100 million spores

Bacillus popillae (available as Doom) causes milky disease on Japanese beetle, *Popillia japonica*

2. Viruses: NPV (Borrellina virus): About 300 isolates of Nuclear polyhedral virus have been isolated from the order Lepidoptera. Among these viruses Baculoviruses (Baculoviridae) are successful in IPM. The NPV is observed to affect 200 species of insects like *Corcyra cephalonica, Pericallia ricini, Amsacta albistriga, Spodoptea litura, Heliothis armigera* etc., by ingestion. The virus infected dead larvae hanging upside down from plant parts (Tree top disease). The cuticle becomes fragile, rupturing easily when touched, discharges liquefied body fluids. NPV multiplies in insect body wall, trachea, fat bodies and blood cells. The polyhedra are seen in nuclei. The polyhedral bodies enlarge in size destroying the host nuclei to get released into the insect body cavity.

3. Fungi: The fungal disease occurrence in insects is commonly called as mycosis. Most of the entomopathogenic fungi infect the host through the cuticle. The process of pathogenesis begins with

- Adhesion of fungal infective units or conidium to the insect epicuticle
- Germination of infective units on cuticle,
- Penetration of the cuticle
- Multiplication in the haemolymph
- Death of the host (Nutritional deficiency , destruction of tissues and releasing toxins)
- Mycelial growth with invasion of all host organs
- Penetration of hyphae from the interior through the cuticle to exterior of the insect
- Production of infective conidia on the exterior of the insect.

Most of the entomopathogenic fungi infect their hosts by penetration of the cuticle by producing cuticle digesting enzymes (Proteases , lipases chitinases).The typical symptoms of fungal infection are, mummified body of insects and it does not disintegrate in water and body covered with filamentous mycelium.

Specific requirements for successful commercial production and use of entomopathogenic fungi as mycoinsecticides are

- The fungal isolate selected for mass production or commercialization should posses rapid growth , high pathogenicity to target pests and sporulate profusely
- A simple medium with cheap and easily available components should be developed
- The production procedure should be easy and also keep the production costs low.
- Formulation with long shelf life at room temperature without any loss of infectivity and viability for at least for 12 – 18 months

More than 5000 species of entomopathogenic fungi are recorded. Important species are, *Entomophthora, Metarhizium, Beauveria, Nomuraea* and *Verticillium.*

Eg: *Entomophthora grylli* on grasshoppers; *Aspergillus flavus* on *Epilachna* beetles; *Spicaria* sp. on castor whitefly: *Metarhizium anisopliae* (Green muscardine) on Orthoptera, white muscardine, *Beauveria bassiana* on *Leptinotarsa decemlineata*.

Protozoa : Their mass production is difficult. They infect insect orders like Lepidoptera, Coleoptera, Orthoptera, Hemiptera and Diptera.

Eg: *Farinocystis triboli* on *Tribolium castaneum, Malpighamoeba locustae* on grasshoppers and *Nosema bombycis* (Pebrine disease) on silk worms. Here it is harmful since silk worm is a productive insect.

Entomopathogenic nematodes (EPNs)

Nematodes about 1000 species are known to attack insects. Especially Rhabditids (Rhabditidae) are found to have a symbiotic relationship with the bacteria, forming a disease complex. The best known disease complex was discovered by Dutky and Hough in 1955 in the caterpillars of the Codling moth, *Cydic pomonella* on apple. The complex is known as DD-136 though the nematode itself is often called so. The nematode involved was *Neoaplectana carpocapsae* (also known as Dutky nematode) and the bacterium *Achromobacter nematophilus.* The nematode serves as a vector for the bacterium, which produces a septicemia (sporulation in blood; Milky disease) in the insect body. The bacteria are retained in the nematode intestine as the latter does not feed during its free-living existence. When such bacteria possessing nematodes invade fresh insect hosts, the latter are killed. Though a few nematodes can kill the host, sufficient number of them should invade the host. In India entampapthogenic nematodes were tried against rice and sugarcane borers.

The EPNs *Steinernema sps* and *Heterorhabditis sps* from the families, Heterorhabditidae and Steinernematidae have the mutualistic association with bacteria *Photorhabdus* and *Xenorhabdus spp.,* respectively.

EPN are obligatory requiring living host for its survival. The only stage that survives outside the host is the non – feeding 3rd stage Infective Juvenile (IJ). The IJ carries cells of their bacterial symbiont in their intestinal tract. After locating suitable host insect, the IJ enters into its haemocoel through natural openings or through the thin cuticle. Once the nematode (IJ) enters into haemocoel it releases the bacteria into the blood where they multiply. The bacteria propagate and produce substances that rapidly kill the host and protect the cadaver from colonization by other micro organisms. The nematode starts developing inside the cadaver, feeding on bacteria and host tissues metabolized by the bacteria and go through 1-3 generations. New colony of IJ emerges from the insect cadaver and start searching for new living host insect.

Nematode genus	Nematode species	Bacteria genus	Bacteria species
Steinernerma	*Affinis*	*Xenorhabdus*	*Bovienii*
	Carpocapsae		*Nematophilus*
	intermedia		*Bovienii*
Heterorhabditis	*argentinensis*	*Photorhabdus*	*Undescribed*
	bacteriophora		*Luminescens*

Advantages of Biological control

1. Control of the insect is achieved in a wide area.
2. The pest is hunted out and thus complete control over a large area is possible.
3. Biological agent survives as long as the pest is prevalent and hence control is effective over longer periods.
4. Though the initial cost is more it will be cheaper in a long run since after, few years of field, release, when it got established there may not be any necessity to propagate it further.
5. Compatible with other methods

Disadvantages:

1. It is a slow process and takes a long time.
2. Natural enemies can not be restricted to particular pest, crop or areas.
3. Presence alternate hosts delays the biological control
4. If hyper parasites are there the effect of parasites is adversely affected.
5. Expensive to develop and supply bioagents

<u>LECTURE NO. 12</u>

BENEFICIAL INSECTS

Pollinators

In the higher plants, sexual reproduction and perpetuation of species are brought about through pollination. These plants may be self-fertile or self-infertile, which require cross pollination. The good example of the dependence of plants upon insects for pollination is Smyrna fig that is dependent on agaontid fig wasp, *Blastophaga psenes* that transfers pollen from Capri fig. The process of fertilizing figs with fig wasps is called caprification. To aid the cross pollination for effective seed/fruit set, pollinators are required. There are different species of pollinators that are found in the nature. The important one being honey bees. The practice of rearing bee colonies for pollination service started in USA by about 1910. The number of colonies to be kept in a field for obtaining maximum yields also matters and it is generally recommended that five colonies are required for two hectares of crop.

Management of honey bees for pollination

- Place bee hives very near to the field to save bee's energy
- Place bee hives in field at 10% flowering of crop
- Place2- 3 colonies per ha
- The colonies should have full strength of bees
- Allow sufficient space for pollen and honey storage
- Provide artificial sugar syrup and water if required

Pollination Syndromes

Pollination syndromes are suites of flower traits that have evolved in response to natural selection imposed by different pollen vectors, which can be abiotic (wind and water) or biotic, such as birds, bees, flies etc. These traits include flower shape, size, colour, odour, reward type and amount, nectar composition, timing of flowering, etc. For example, tubular red flowers with copious nectar often attract birds; foul smelling flowers attract carrion flies or beetles, etc.

Two basic types of pollination exist: abiotic pollination and biotic pollination. Abiotic pollination occurs without intervention from another living organism. Biotic pollination occurs with the help of insects or other living creatures. Abiotic and biotic pollination may occur through different methods.

Pollination syndromes are

1. Abiotic pollination syndromes

Anemophily: Anemophily, or wind pollination, refers to the process in which the wind carries pollen from one plant to another, without being assisted by a living organism.

Hydrophily: The process of pollination by water is referred to as hydrophily

2. Biotic pollination syndromes:

Mostly biotic pollination is due to insects**.** Entomophily is a mode of pollination or transfer of pollen grains from anther to stigma through the agency of insects. The flowers which are insect pollinated are called entomophilous. The most common insect pollinators are bees, moths, flies, butterflies, wasps, beetles, etc.

Cross pollination aided by

Bees (Honeybees, bumble bees, Orchid bees, etc)	- **Melittophily**
Hawk moths	- **Sphingophily**
Small moths	- **Phalaenophily**
Flies (Syrphid flies)	- **Myophily**
Butterflies	-**Psychophily**
Beetles	- **Cantharophily**
Ants	- **Myrmecophily**

Insect weed killers:

Many insects feed upon unwanted weeds, just the same manner they do with cultivated plants. As they damage the noxious and menacing weeds, these insects are considered to be beneficial to man and called as weed killers. Successful eradication of certain weeds due to specific insects is achieved. Later certain insects are specifically employed against deleterious weeds and got rid of them. The classical example being prickly pear control with cochineal insect, *Dactylopius tomentosusLantana,* a troublesome weed was kept in check by the coccid, *Orthezia insignis*. Water hyacinth was controlled by bruchids, *Neochetina eichhorniae* and *Neochetina bruchi*

A successful weed killer

a) Should not itself be a pest of cultivated plants or later turn into a pest of cultivated crops.
b) Should be effective in damaging and controlling the weed
c) Should preferably be a borer or internal feeder of the weed and
d) Should be able to multiply in good numbers without being affected by parasitoids and predators.

In South Indian, *Opuntia dilleni* was wrongly introduced in 1780 in place *O. coccinellifera* for cultivating commercial cochineal insect *Dactylopius cocci,* valued for its dye. For controlling*Opuntia dilleni*, the insect *D. tomentosus* was introduced from Srilanka in 1926 and within 2 years it gave effective control of *O. dillenii*. The prickly pear *Opuntia inermis* in Australia was kept under check by the moth borer *Cactoblastis cactorum.*

Control of water-hyacinth: Water-hyacinth is a free-floating fresh water plant. It impedes flow of irrigation water, interferes with pisciculture etc. and can be effectively controlled by two weevils namely *Neochetina eichhorniae* and *N. bruchi* andmite *Orthogalumna terebrantis.* Control of *Parthenium hysterophorus* by beetle *Zygogramma bicolorata*

Scavengers

These are insects which feed upon the dead and decaying plant and animal matter. Since insects help to remove from the earth surface the dead and decomposing bodies, which would otherwise be a health hazard, they are referred to as scavengers. In addition to cleaning the filth from human habitations, these insects help to convert those bodies into simpler substances before recycling them back to soil, where they become easily available as food for growing plants. In this respect termite, maggots of many flies and larvae and adults of beetles are important.

The following are the important groups of insects that serve as scavengers in nature:

Coleoptera:

Rove beetles; Chafer beetles; Ptilinid beetles; Darkling beetles; Skin beetles; Nitidulids; The carrion beetles; Jewel beetles; Water scavenger beetles; Powder post beetles and bostrychids.

Diptera

Dady-long legs; Sand flies or moth flies; Midges or gnats; Fungus gnats; Hover flies; Root maggot flies; Muscids

Isoptera (whiteants) and **Hymenoptera** (ants) also live and feed upon dead wood, dead animal or decaying vegetable matter.

LECTURE NO.13

CHEMICAL CONTROL

Control of insects with chemicals is known is chemical control. The term pesticide is used to those chemicals which kill pests and these pests may include insects, animals, mites, diseases or even weeds. Chemicals which kill insects are called as insecticides.

Insecticide may be defined as a substance or mixture of substances intended to kill, repel or otherwise prevent the insects. Similarly pesticides include nematicides – which kill nematodes, miticides or Acaricides which kill mites, Rodenticides – which kill rats, weedicides- that kill weeds,Fungicides- that kill fungus etc.

Importance of chemical control:

Insecticides are the most powerful tools available for use in pest management. They are highly effective, rapid in curative action, adoptable to most situations, flexible in meeting changing agronomic and ecological conditions and economical.

Insecticides are the only tool for pest management that is reliable for emergency action when insect pest populations approach or exceed the economic threshold. A major technique such as the use of pesticides can be the very heart and core of integrated systems. Chemical pesticides will continue to be essential in the pest management programmes.

There are many pest problems for which the use of chemicals provides the only acceptable solution. Contrary to the thinking of some people, the use of pesticides for pest control is not an ecological sin. When their use made on sound ecological principles, chemical pesticides provide dependable and valuable tools for the biologist. Their use is indispensable to modern society.

General Properties of Insecticides

1. Pesticides are generally available in a concentrated from which are to be diluted and used except in ready to use dust and granules.
2. They are highly toxic and available in different formulations.

Properties of an ideal insecticide or pesticide:

1. It should be freely available in the market under different formulations.
2. It should be toxic and kill the pest required to be controlled.
3. It should not be phytotoxic to the crops on which it is used.
4. It should not be toxic to non target species like animals, natural enemies etc.
5. It should be less harmful to human beings and other animals.
6. Should not leave residues in crops like vegetables.
7. It should have wide range of compatibility.
8. It should not be toxic to bees and fish and other beneficial organisms.
9. It should have higher tolerance limits.
10. Should possess quick known down effect.
11. Should be stable on application.
12. Should not possess tainting effects and hould be free from offensive odour.
13. Should be cheaper

Different Classifications of Insecticides

Insecticides are classified in several ways taking into consideration their origin, mode of entry, mode of action and the chemical nature of the toxicant.

I. Based on the origin and source of supply

A. **Inorganic insecticides**: comprise compounds of mineral origin and elemental sulphur. This group includes arsenate and fluorine compounds as insecticides. Sulphur as acaricides and zinc phosphide as rodenticides.

B. Organic Insecticides:

1. Insecticides of animal origin: Nereistoxin isolated from marine annelids, fish oil rosin soap from fishes etc.
2. Plant Origin insecticides or Botanical insecticides: Nicotinoids, pyrethroids, Rotenoids etc.
3. Synthetic organic insecticides: Organochlorines , Organophosphorous, Carbamate insecticides etc.,
4. Hydrocarbon oils etc.

II. Based on the mode of entry of the insecticides into the body of the insect they are groups as

Contact poisons: These insecticides are capable of gaining entry into the insect body either through spiracles and trachea or through the cuticle itself. Hence, these poisons can kill the insects by mere coming in contact with the body of the insects. Eg.DDT and HCH.

Stomach poisons: The insecticides applied on the leaves and other parts of plants when ingested act on the digestive system of the insect and bring aboutthe kill of the insect. Eg: Calcium arsenate, lead arsenate.

Fumigants: A fumigant is a chemical substance which is volatile at ordinary temperatures and sufficiently toxic to the insects. Fumigation is the process of subjecting the infested material to the toxic fumes or vapours of chemicals or gases which have insecticidal properties. Chemical used in the fumigant and a reasonably airtight container or room is known as fumigation chamber or "Fumigatorium". Fumigants mostly gain entry into the body of the insect through spiracles in the trachea.

Commonly used Fumigants and their doses:

1. Aluminium phosphide, marketed as Celphos tablets used against field rats , groundnut bruchids etc
2. Carbon disulphide 8-20 lbs/1000ft^3 of food grains
3. EDCT (Ethylene Dichloride Carbon Tetrachloride) 20-30 lbs/1000cft of food grains
4. EDB Ethylene dibromide 1 lb/1000ft^3 of food grains.
5. SO_2: By burning sulphur in godowns SO_2 fumes are released.

Systemic insecticides

Chemicals that are capable of moving through the vascular systems of plants irrespective of site of application and poisoning insects that feed on the plants. Ex: Methyl demeton, Phosphamidon , Acephate

'Non systemic insecticides' are not possessing systemic action are called non systemic insecticides.Somenon systemic insecticides, however, have ability to move from one surface leaf to the other. They are called as 'trans laminar insecticides' . Eg.Malathion, Diazinon, spinosad etc.

An ideal systemic insecticide quality are

1. Should have high intrinsic pesticidal activity
2. The toxicant must be adequately liposoluble for it to be absorbed by the plant system and water soluble for it to be translocated in the plant system.
3. The toxicant or its metabolites should be stable for sufficiently long period to exercise residual effect.
4. Sufficiently soluble in water for translocation through vascular system
5. Should degrade to nontoxic form in reasonable time to avoid toxicity to consumer

Systemic insecticides are applied as seed dressing, granular formulations, sprays etc.In the leaf, the entry of the toxicant are through stomata and cuticle. On stem the entry is through lenticels and cracks in the cuticle. In the seed it is through seed coat especially through the micropyle. Systemic insecticides are highly useful against sap sucking and vectors such as leafhoppers, whiteflies, thrips, aphids etc.

III. Based on mode of action:

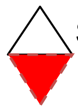
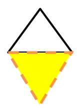
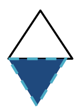
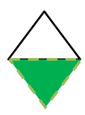
1. **Physical poisons**: Bring about the kill of insects by exerting a physical effect. Eg: Heavy oils, tar oils etc. which cause death by asphyxiation. Inert dusts effect loss of body moisture by their abrasiveness as in aluminium oxide or absorb moisture from the body as in charcoal.
2. **Protoplasmic poisons**: A toxicant responsible for precipitation of protein especially destruction of cellular protoplasm of midgut epithelium.

Eg. Arsenical compounds.

3. **Respiratory poisons:** Chemicals which block cellular respiration as in hydrogen cyanide (HCN), carbon monoxide etc.
4. **Nerve poisons:** Chemicals which block Acetyl cholinesterase(AChE) and effect the nervous system. Eg. Organophosphorous, carbamates.
5. **Chitin inhibitors:** Chitin inhibitors interfere with process of synthesis of chitin due to which normal moulting and development is disrupted. Ex Novaluron, Diflubenzuran, Lufenuron ,Buprofezin
6. **General Poisons:**Compounds which include neurotoxic symptoms after some period and do not belong to the above categories.

   Eg.Chlordane, Toxaphene, aldrin

IV. Based on toxicity:

Classification	Symbol		Oral LD_{50}	Dermal LD_{50}
1. Extremely toxic		Skull & Pioson Red	1-50	1-200
2. Highly toxic		Pioson Yellow	51-500	201-2000
3. Moderately toxic		Danger Blue	501-5000	2001-20,000
4. Less toxic		Caution Green	>5000	>20,000

V. Based on stage specificity:

1. Ovicides
2. Larvicides
3. Pupicides
4. Adulticides

VI. Generation wise:

First generation	- Inorganics and Botanicals
Second generation	- Synthetic organics
Third generation	- Recent chemicals for reproductive control, IGRs like MH & JH mimics
Fourth generation	- Synthetic pyrethroids
Fifth generation	- -DO-

1. Alfamethrin - Alfaguard/ Fartac 10 Ec
2. Fenpropathrin – Danitol 10 Ec
3. Bifenthrin – Taletar 10 Ec
4. Fluvalinate – Mavrik
5. Ethofenpron – Treban 10 Ec and Neonecotinoids

Toxicity evaluation of insecticides

LD $_{50}$ (Lethal Dose):

In 1952 Finney has given the computation methods. It is the amount of toxicant required to kill 50% of the test population and is expressed in terms of milligrams of the substance of toxicant per kilogram body weight (mg/kg) of the test animal (usually rat, when treated orally). As the test animals usually rat and some times rabbit it is also referred to as the mammalian toxicity. This forms the general criteria for acute toxicity and is also known acute oral LD_{50}.

In case of insects the LD_{50}**(Median Lethal Dose)**value is expressed in terms of micrograms of the toxicant per one gram body weight of the insect.

Eg. Phosphamidon – 28; Parathion 3.6 to 13; Malathion 2800; Hydrogen cynaide 1.0

The amount of toxicant required to be placed on the skin to cause death of 50% of test population is known as acute dermal LD_{50}. It must be understood that higher the LD_{50}.value lesser is the toxic nature of the chemical and vice - versa.

Acute toxicity refers to the toxic effect produced by a single dose of a toxicant where as chronic toxicity is the effect produced by the accumulation of small amounts of toxicant over a long period of time. Here the single dose produces no ill-effect.

LC $_{50}$ (Median Lethal concentration): It is expressed in terms of percentage of the toxicant required (concentration) to cause 50% kill of the population of a test animal and is usually determined by potters tower and probit analysis.

ED_{50}/ **EC_{50}**(Effective Dose/Concentration 50): Chemicals that gives desirable effects in 50% of test animals.

LT $_{50}$ (Lethal time 50):Time required to produce effect in 50% of population

KD_{50}/ KT_{50} (Knockdown Dose /Time 50) Dose / Time required for 50% of population having knockdown effect.

Bioassay of insecticides

Study of response of individual or group of organisms exposed to the toxicant is called ‘Bioassay’ or Any quantitative procedure used to determine the relationship between the amount (dose or concentration) of an insecticide administered and the magnitude of response in a living organism. Potter spraying tower apparatus is required for studying the biological effects of contact poisons on organisms. This air operated spraying apparatus applies an even deposit of spray over a circular area of 9 cm diameter. Suitable for studying the biological effects of chemicals, both when applied as direct spray on organisms or as a residual film. Bioassays are used for screening of potential insecticides, for determination of valuesLD_{50} and LC $_{50.}$ Estimation of residues, and quality testing of formulated insecticides

Formulations of Insecticides

It is essential that the toxicant must be amenable to application in an effective manner so as to come into direct contact with the pest or leaf and uniform and persistent deposit upon the plant surface. Since very small quality of toxicant is required to be distributed over a large area, insecticides are formulated in a form suitable for use as a spray, dust or fumigant.Formulation is the processing of a compound by such methods that will improve its properties ofstorage, handling, application, effectiveness and safety to the applicator and environment and profitability. It is the final physical condition in which insecticide is sold.

A single insecticide is often sold in several different formulations. Following are the different formulations of insecticides.

1. **Dusts (D):** These are ready to use insecticides in powder form. In a dust formulation the toxicant is diluted either by mixing with or by impregnation on a suitable finely divided carrier which may be an organic flour or pulverized mineral like lime, gypsum, talc etc., or clay like attapulgite bentonite etc.The toxicant in a dust formulation ranges from 0.15 to 25% and the particle size in dust formulations is less than 100 microns and with the decrease in particle size the toxicity of the formulation increases. Dusts are easy to apply, less labour is required and water is not necessary. However if wind is there, loss of chemical occurs due to drift hence dusting should be done in calm weather and also in the early morning hours when the plant is wet with dew.

   Eg. HCH 10% dust; Endosulfan 4% D.
2. **Granules or Pelleted insecticides(G):** These are also ready to use granular or pelleted forms of insecticides. In this formulation the particle is composed of a base such as an inert material impregnated or fused with the toxicant which released from the formulation in its intact form or as it disintegrates giving controlled release. The particle size ranges from 0.25 to 2.38 mm, or 250 to 1250 microns and contains 1 to 10% concentration of the toxicant. The granules are applied in water or whorls of plants or in soil. Action may be by vapour or systemic. In application of granules there is very little drift and no undue lose of chemical. Undesirable contamination is prevented. Residue problem is less since granules do not adhere to plant surface. Release of toxicant is achieved over a long period. Easy for application as water is not required for application. Less harmful for natural enemies.

   Eg: Carbofuran 3G, Phorate10 G, Cartap hydrochloride 4G
3. **Wettable Powders (WP)**: It is a powder formulation which is to be diluted with water and applied. It yields a stable suspension with water. The active ingredient (toxicant) ranges from 15 to 95%. It is formulated by blending the toxicant with a diluent such as attapulgite, a surface active agent and an auxiliary material. Sometimes stickers are added to improve retention on plant surface. Loss of chemical due to run off may be there and water is required for application.

   Eg: Carbaryl 50%WP, Thiodicarb 75% WP

4. **Emulsifiable Concentrates(EC):** Here the formulation contains the toxicant, a solvent for the toxicant and an emulsifying agent. It is a clear solution and it yields an emulsion of oil-in water type, when diluted with water. The active ingredient (toxicant) ranges from 2.5 to 100 %.When sprayed the solvent evaporates quickly leaving a deposit of toxicant from which water also evaporates. The emulsifying agents are alkaline soaps, organic amines alginates, Carbohydrates, gums, lipids, proteins etc.
   Eg: Endosulfan 35EC, Profenophos 50EC
5. **Soluble Powder or Water Soluble Powder (SP or WSP)**: It is a powder formulation readily soluble in water. Addition of surfactants improves the wetting power of the spray fluid. Sometimes an anti-caking agent is added which prevents formation of lumps in storage. This formulation usually contains a high concentration of toxicant and therefore convenient to store and transport.
   Eg: Acephate 75 SP.
6. **Suspension Concentrate (SC):** Active ingredient is absorbed on to a filler which is then suspended in a liquid matrix (water).It is not dusty and easier to disperse in water. Eg: Imidacloprid 50 SC
7. **Flowables (F):** When an active ingredient is insoluble in either water or organic solvents, a flowable formulation is developed. The toxicant is milled with a solid carrier such as inert clay and subsequently dispensed in a small quantity of water. Prior to application it has to be diluted with water. Flowables do not usually clog nozzles and require only moderate agitation.**Ex;**Methoxyfenozide*(* Intrepid 2F)
8. **Water Dispersible Granules (WDG):**This formulation appears as small pellets or granules. It is easier and safer to handle and mix than wettable powders. When the granules are mixed with spray water, they break apart and, with agitation, the active ingredient becomes distributed throughout the spray mixture. Ex: Thiamethoxam 25 WDG
9. **Solutions:** Many of the synthetic organic insecticides are water insoluble but soluble in organic solvents like amyl acetate, kerosene, xylene, pine oil, ethylene dichloride etc., which themselves possesses some insecticidal properties of their own. Some toxicants are dissolved in organic solvents and used directly for the control of household pests. Eg. Baygon
10. **Concentrated insecticide liquids:** The technical grade of the toxicant at highly concentrated level is dissolved in non-volatile solvents. Emulsifier is not added. Generally applied from high altitudes in extremely fine droplets without being diluted with water at ultra volume rates. There is greater residual toxicity and less loss through evaporation. Active ingredient ranges from 80-100%
    Eg: Malathion, Bifenthrin,Fenitrothion.

11. **Insecticide aerosels:** The toxicant is suspended as minute particles 0.1 to 30 microns in air as fog or mist. The toxicant is dissolved in a liquified gas and if

released through a small hole causes the toxicant particles to float in air with rapid evaporation of the released gas. Eg: Allethrin

12. **Fumigants:** A chemical compound which is volatile at ordinary temperature and sufficiently toxic is known as fumigant. Most fumigants are liquids held in cans or tanks and quite often they are mixtures of two or more gases. Advantage of using fumigant is that the places not easily accessible to other chemicals can be easily reached due to penetration and dispersal effect of the gas.

Eg; Aluminium phosphide

13. **Microencapsulation**: Microencapsulated formulations consist of dry and liquid pesticide particles enclosed in tiny plastic capsules which are mixed in water and sprayed. After spraying, the capsule slowly releases the pesticide. The encapsulation process can prolong the active life of the pesticide by providing timed release of the active ingredient.

    Ex: Lambda-cyhalothrin

14. **Insecticide Mixtures:** Insecticide mixtures involve combinations of two or more insecticides in the right concentration into a single spray solution. Insecticide mixtures are widely used to deal with the array of arthropod pests encountered in greenhouse and field production systems due to the savings in labor costs. Furthermore, the use of pesticide mixtures may result in synergism or potentiation (enhanced efficacy) and the mitigation of resistance. However, antagonism (reduction in efficacy) may also occur due to mixing two (or more) pesticides together. Judicious use of pesticide mixtures or those that may be integrated with biological control agents is especially important because parasitoids and predators (and even microbials such as beneficial bacteria and fungi) can suppress arthropod pest populations irrespective of the arthropod pests' resistance traits or mechanisms.

    Ex:Chlorpyriphos16% + Alphacypermethrin 1% EC
    Chlorpyriphos 50% + Cypermethrin 5% EC
    Quinolphos 20% + Cypermethrin 3% EC
    Profenofos 40% + Cypermethrin 4% EC
    Profenofos25% + Cypermethrin 5% EC
    Profenofos10% + Cypermethrin 20% EC
    Cypermethrin 20% + Permethrin 10% EC

15. Baits: In baits a.i is mixed with edible substance. These are always stomach poisons and are used for poison baiting which is chiefly made up of 3 components, Poison (Insecticide carbaryl), Carrier or base(Rice bran), and Attractant (Jaggery) at ratio of 1:10:1 . Poison should be strong and easily soluble. Base is the filler like rice bran with just enough water.

LECTURE NO. 14

INORGANIC INSECTICIDES

Arsenic compounds:

In an arsenical compound, the total arsenic content and the water soluble arsenic content are of importance, the water solubility of arsenic may result in entering the foliage and causing burning injury to plants, and hence water insoluble compounds are preferred for insect control. Arsenates are more stable and safe for application on plants then arsenites. Arsenites are mainly used in poison baits since they are phytotoxic. However arsenates are less toxic to insects then arsenites.

In insects arsenates cause regurgitation, torpor (sluggishness) and quiescence. Disintegration of epithelial cells of the midgut and clumping of the chromatin of the nuclei are the effects noticed in poisoned insects. Slow decrease in oxygen consumption is also evident and kill of the insect is primarily due to the inhibition of respiratory enzymes. Water soluble arsenic causes wilting followed by browning and shriveling of the tissue.

1. **Calcium arsenate:** It was first used by about 1906 as an insecticide. It is a white flocculent power, formulated as a dust of 25 to 30% metallic arsenic equivalent. Dosage – Calcium arsenate at 0.675 to 1.350 kg with equal quantity of slaked lime in 450 litres of water. LD_{50}.for mammals oral – 35 to 100. Being a stomach poison it was mainly used for control of leaf eating insects.
2. **Lead arsenate:** It was first used as in insecticide in 1892 for the control of gypsy moth. It is a stomach poison with little contact action LD_{50}.for rat oral 10-100, dermal 2400 mg/kg. . It is rarely used as dust. 450 g to 1800 g of load arsenate is diluted with 200-240 litres of water. An equal quantity of hydrated lime is some time added to prevent phytotoxicity to tender foliage. In baits it is used at 450 or900 g in 1200 g to 45000 g of carrier such as wheat bran or rice husk respectively.
3. **Arsenite:**

   Paris green:It is a double salt of copper acetate and copper arsenite. It was first used in 1867 for the control of Colorado potato beetle, *Leptinotarsa decemlineata*. It is now used as bait for the control of slugs. $LD_{50}$for rat oral- 22 mg/kg.Very good against termites.

Flourine Compounds

These compounds were used since 1890. They are principally stomach poisons and to a limited extent contact poisons. The kill is more rapid than that of arsenicals. Their insecticidal properties are related to the fluorine content and solubility in the digestive juices of insect. Flouride poisoning produces spasms, regurgitation, flaccid paralysis and death.

1. Sodium fluoride: It is a white power. Available in 93 to 99% purity in commercial products. It is highly phytotoxic and used in poison baits used exclusively against cockroaches, earwigs, cutworms, grasshoppers etc.

Other inorganic compounds

1. **Sulphur:** It is primarily fungicide and acaricide. Formulated as fine dust (90 to 95% a.i with 10% inert material. It is also formulated as wettable powders. Effectiveness increases with fineness of sulphur particles.
2. **Lime sulphur:** Aqueous solution of calcium polysulphide. It is prepared by sulphur solution in calcium hydroxide suspension, preferably under pressure in the absence of air and is used against scales, mites, aphids besides powdery mildew.

Properties

1. Affect nervous system causing excitement at lower doses and paralysis at higher concentration.
2. Not phytoloxic
3. Leave no harmful side effects.
4. Mighly toxic to mammals.
5. Disappear rapidly from the treated surface.
   So can be used safely before harvest of the produce.

Insecticides of plant origin

The insecticides of plant origin extracted from seeds, flowers, leaves, stem and roots, are termed as botanical insecticides. Insecticides of plant origin unlike synthetic organic insecticides are safer to use but since they are expensive and lack residual toxicity, their use has been limited in the country.

1) Neem (*Azadirachta indica)*

Perennial tree distributed in tropical, subtropical, semi-arid and arid zones. It posses medicinal, insecticidal, insect repellent, antifeedant, growth regulatory, nematicidal and antifungal properties. Neem seed extract and oil contains a number of components such as Azadirachtin, salannin, nimbin, epinimbin nimbidin that gives insecticidal, insect repellent, ovicidal, Antifeedant and growth regulator characters. Azadiractitin disrupts moulting by antagonizing the insect hormone ecdysone.Azadiractitin Acute oral LD_{50} for rat is 5000mg/kg, Acute dermal for rabbit is >2000mg/kg.

Preparation of Neem Seed Kernel Extract (NSKE 5%): Take 50 g of powdered neem seed kernels soak it in one litre of water for 8 hours and stir the contents often. Squeeze the soaked material repeatedly for better extraction of the azadirachtin in the aquous suspension. Filter the contents through muslin cloth. Make the filtrate to one litre. Add 1ml teepol or triton or sandovit or soap water (2%) and spray.

Prepartion of Neem Cake Suspension

Soak one kilogram of neem cake in 5 liters of water for 2 days and filter It through muslin cloth. Dissolve 200 g of soft soap in the filtrate and make upto 10 L of water before spraying. This controls tobacco cutworm, leaf miners of citrus, groundnut, tomato and beans etc.

Dried powder of neem leaves are used against stored grain insect pests. Leaf extracts showed insecticidal property against,*Plutella xylostella,Aproaerema modicella; Spodoptera litura etc.* Desert locust *Schistocerca gregaria* avoids feeding on neem leaves. Neem leaves are found as attractants to white grub *Holotrichia* adults. Neem seed/ kernel extract showed insecticidal properties against a number of sucking pest. Neem oil can be used against storage insect pests @ 1 to 2% and field insects @ (0.2 -0.4%, 1 to 2% 5% or 10% neem oil). Neem products are safer to honey bees, parasitoids, predators.

Commercial formulations of neem are available in 10000 ppm, 1500 ppm and 300 ppm the market. Some of the neem formulations are Margosan, Neemark, Neemrich, Achook, Bioneem, Neemazal, Neemax, Nimbicidine,Vepacide, Margocide , Neemgold etc

2) Nicotine: Nicotine is found in the leaves of *Nicotiana tabacum* and *N.rustica*from 2% to 14%.Nicotine sulphate has been mainly used as a contact insecticide with marked fumigant action in the control of sucking insect's*viz*., aphids, thrips, psyllids, leafminers and jassids. Nicotine sulphate is more stable and less volatile. It is a nerve poison being highly toxic when absorbed through the cuticle taken in through the tracheae or when ingested. It affects the ganglian blocking conduction at higher levels. Nicotine sulphate containing 40% alkaloid, is safer and is more convenient to use and the free alkaloid is liberated by the addition of soap lime or ammonium hydroxide to the spray solution. Dust formulation of nicotine sulphate releases nicotine in the presence of moisture. It is also used in aerosols. Tobacco decoction, useful for controlling aphids, Thrips etc. can be prepared by boiling 1kg of tobacco waste in 10lts of water for 30 minutes or steep it in cold water for a day. Then make it up to 30 litres and add about 90gm of soap. Addition of soap improves wetting, spreading and killing properties. Nicotine does not leave any harmful residue on treated surface. $LD_{50}$for rat oral- 50-60 mg/kg.

3) Rotenone: It is extracted from the roots of Derris plant which many contain 4 to 11% rotenone depending on the variety. Though rotenone is reported from 68 species of leguminous plants, principal commercial sources are *Derris ellipticaD. malaccensis*from Malaysia and *Lonchocarupus utilis* and*D. uruca* from S. America. Rotenone occurs in Derris roots (4-9%), Lonchocarpus (8-11%).

It is oxidized to non-insecticidal compound in the presence of light and air and hence rotenone residues are difficult to find after 5 to 10 days in normal sunlight. Insects poisoned with rotenone show a steady decline in oxygen consumption followed by paralysis and deaths. It is very specific being highly toxic to fishes and to most insect species but almost harmless to warm blooded animals except pigs LD_{50}.to white rat oral-130 to 1500. Dust or spray containing 0.5 to 1.0 per cent and 0.001 to 0.002 percentrotenone are used commercially.

4) Plumbagin:

Plumbagin is naturally occurring napthoquinone of plant origin from the roots of *Plumbago europea* L. (Plumbaginaceae) and named so in 1828 by Bulong d' Astafort. Plumbagin is known for its medicinal, antifertility, antimicrobial, molluscicidal, nematicidal and other pharmacological properties on diverse fauna. The yield of plumbagin ranges between 0.5-3.000percent on dry weight basis.

The elucidation of structure of plumbagin and its synthesis in 1936 led to detailed studies. More recently, its IGR properties *viz.,* inhibition of chitin synthetase and ecdysteroid titres have been demonstrated (Kubo et al., 1982)

The cold alcoholic extract (5%) of roots of *P. zeylanica* L was toxic to *Euproctis fraterna* larvae as contact spray. Contact toxicity of 5% petroleum ether extracts of *P. zeylanica* root against *Spodoptera litura* Fab. , *Dystercus koenigii*Fab.,*Dipaphis erysimi* Kalt, *Dactynops carthami* H.R.L, *Coccinella septumpunctata* L was also reported.

5) Pyrethrum: It is extracted from dried flower heads of *Chrysanthemum cinerariaefolium* (Asteraceae). The actual chemical ingredients having insecticidal action are identified as five esters. They are: Pyrethrin I, Pyrethrin II, cinerins-I and cinerin-II and Jasmoline, which are predominately found in achenes of flowers from 0.7 to 3 %.

The esters are derived from the,

Two acids – Chrysanthemic acid and Pyrethric acid

Three alcohols – Pyretholone, Cinerolone and Jasmolone

Active principles/Esters

Pyrethrin I = Pyrethrolone + Chrysanthemc acid

Pyrethrin II = Pyrethrolone + Pyrethric acid

Cinerin I = Cynerolone + Chrysanthemc acid

Cinerin II = Cynerolone + Pyrethric acid

Jasmolin II = Jasmolone + Pyrethric acid

Pyrethrum powder is prepared by grinding the flowers. The powder mixed with a diluent such as talc or clay is known as pyrethrum dust. It is prepared just before use. Otherwise it gets deteriorated rapidly. It is also used as emulsions, solutions, and aerosoles. Pyrethrum is unstable to light, air moisture and alkali. The residues deteriorate very rapidly after application. Pyrethrins are powerful contact insecticides but appear to be poor stomach poisons. A characteristic action of Pyrethroid is the rapid paralysis or ‘knock down’ effect and substantial recovery that follow it. This recovery is due to rapid enzymatic detoxification in the insect. To bring about mortality equivalent to knock down effect three times increase in dosage may be required.

Compounds such as piperonyl butoxide, propyl isome and sulfoxide are known to inhibit the detoxication enzyme and increase the toxicities of pyrethroids. These synergists are used at 10 parts to 100 part of pyrethroid. LD_{50}. for white rat oral-200 dermal for rat-1800. Pyrocon E 2/22 (1 part of pyrethrin + 10 parts of piperonyl butoxide) is used for the control of coconut red palm weevil. In household sprays and as a repellent against external parasites of livestock pyrethrum is useful. It is also mixed with grains in storage to protect from stored grain pests. Its use alone or in combination with piperonyl butoxide as food packages has been permitted by the food and Drug Administration in the U.S.A. and no other chemical has been approved.

Properties

1. Highly unstable in light, moisture and air.
2. Have no residual effect.
3. Paralyse by more contact.
4. Gains entry through spiracle and cuticle.
5. Act on central nervous system.
6. Having rapid knock down effect.
7. Practically no mammalian toxicity.
8. Good insecticides against household and cattle pests.

LECTURE NO. 15

SYNTHETIC ORGANIC INSECTICIDES

I) Chlorinated Hydrocarbons (Organochlorines)

The plant protection in India owes its growth to the chemicals under this group which have revolutionized the control of pests. The properties which have lead to their extensive use are high insecticidal efficacy, long residual action, wide range of insect susceptibility, cheapness per unit area and available in different formulations.They are also known as chlorinated synthetics or chlorinated organics or chlorinated hydrocarbons. The important organochlorines are

1. DDT

DDT was first synthesized in 1874 by Othmar Zeidler. In 1939 a Swiss entomologist, Paul Muller, found its insecticidal property for the first time. This discovery brought the `Nobel Prize' for medicine to Paul Muller in 1948 for the life saving discovery.

Dichloro Diphenyl Trichloroethane (DDT) is stomach and contact insecticide. It has got long residual action. It is also non-phytotoxic except to cucurbits. It is not much effective against phytophagous mites. Due to low cost of DDT and effectiveness against a variety of insects particularly against house flies and mosquitoes, it is much popularized but due to long residual life and accumulation, it is banned in several countries. The acute oral LD_{50} for rats is 113-118 mg/kg.

It does affect the nervous system preventing normal transmission of nerve impulses. DDT causes a violent excitatory neurotoxic system in most insects which are having uncoordinated movement and DDT Jitters (tremor of the entire body).

2. Hexa Chloro Cyclohexane (HCH)

It was first synthesised by Michael Faraday in the year 1825.The gamma-isomer of BHC has the insecticidal activity. BHC is a stomach and contact insecticide. It has got slight fumigant action. It is persistent insecticide. It is non-phytotoxic except cucurbits .It has been extensively used as soil insecticides particularly to control termites, white grubs and cutworms. Highly purified product containing 99% of gamma isomer of HCH is known as lindane, this name was proposed in 1949 after Vander Linden, a German chemist who isolated this isomer in 1912. Lindane is more acute neurotoxicant than DDT results in tremors, ataxia, convolutions, falling prostration and ultimately leading to death.

II) Cyclodines

Cyclodienes also act as neurotoxicants which disturb the balance of sodium and potassium ions within the neuron resulting into tremors, convulsions, prostration and ultimately the death.

The outstanding characteristic of the cyclodienes is their longer stability in the soil, resulting in more control of soil inhabiting insect pests. Some of the compound belonging to this group are chlordane (1945), aldrin and dieldrin (1948), heptachlor

(1949), endrin (1951), mirex (1954), endosulfan (1956) and chlordecone 1958). Among them aldrin, chlordane and heptachlor were often in use for termite control as they are most effective, long lasting and economical insecticides but now banned by GOI.

1) Aldrin

It is persistent and non-systemic soil insecticide. It is usually recommended for the control of termites throughout India. Two German chemists Otto Paul Hermann Diels and Kurt Alder first documented the Diels-Aldernovel reaction in 1928 for which they were awarded the Nobel Prize in Chemistry in 1950 for their work

Formulations: EC 30%, Granule 5% and Dusts 5%

Trade names: Octalene, Aldrex, Aldrosol, and Aldrite.

LD_{50} value: 67 mg/kg

2) Dieldrin

It is persistent and non-systemic insecticide used for mainly soil inhabiting insect pests. It is also not phytotoxic in recommended doses.

Formulations: Dust 2%

Trade names: Quintox, Alvit

LD_{50} value: 46 mg/kg

3) Heptachlor

It is a non-systemic, contact poison with fumigant action. It is effective against termites, white grubs, grass hoppers etc

Formulations: EC 20%, and Dust 5%

LD_{50} value: 100-162 mg/kg

4) Endosulfan:

It is a non-systemic, contact and stomach poison with slight fumigant action. It is effective against defoliators, borers, sucking insects and mites but harmless to honey bees at recommended doses for insect control. It is highly toxic to fish.

Formulations: EC 35%, Granule 4% and Dusts 4%

Trade names: Thiodan, Endocel, Endodhan, Endotaf

LD_{50} value: 80-110 mg/kg

III) Organophosphates

Organophosphate came to limelight during Second World War. The biological activity of these compounds was first discovered by W. Lange and Krueger in 1932. OP compounds as insecticides were mainly due to the work of Gerhard Schrader in 1937 in Germany. First OP compound TEPP (Tetra Ethyl Pyro Phosphate) followed by parathion and schradan, the first systemic insecticide. Organophosphate insecticides have two most important properties such as higher potency and low residual life. The organophosphates (OPs) inhibit the cholinesterase (Ch E) enzyme leading to blockage of synaptic transmission of nerve impulses and finally death.

1) Malathion

It is a non systemic contact and stomach insecticideand acaricide of low mammalian toxicity. Hence it is recommended on fruits and vegetables till a few days prior to harvest. It is also recommended for storage insects and also for external application for parasites on animals**.**

Formulations: EC 50 and Dusts 40

Trade names: Cythion and Himala

LD_{50} value: 2800 mg/kg

2) Methyl parathion:

It is a contact and stomach poison with slight fumigant action. It is widely used in for sucking insects and foliage feeders.

Formulations: EC 50 and Dusts 2

Trade names: Folidal, Metacid, Paratox, Dhanumar

LD_{50} value: 13 mg/kg

3) Diazinon:

It is a contact persistent insecticide with nematicidal properties. It is very much useful against household insects such as flies and cockroaches.It has contact, stomach poison and also fumigant action.

Formulations: EC 20 and 5G

Trade names: Basudin

LD_{50} value: 300-850 mg/kg .

4) Dichlorvos (Dimethyl Dichloro Vinyl Phosphate - DDVP)

It is contact poison but due to high vapour pressure it has got strong penetrating power. It is very effective against hidden insects due to its fumigation action. It is recommended for leaf miners and leaf webbers. It brings quick knock down effect. It does not leave toxicresidues. It is highly toxic to bees. It is acontact and stomach poison with fumigant action.

Formulations: EC 76 and 5G

Trade names: nuvan, vapona, Doom, Divap

LD_{50} value: 56 – 108 mg/kg.

5) Fenitrothion:

It acts as contact and stomach poison with broad spectrum activity and a selective acaricide. It is effective against sucking pests including mealy bugs, borer and mites and external parasites of livestock.

Formulations: EC 35, ULV 0.05 – 0.1 and 5 Dusts

Trade names: Sumithion, Folithion

LD_{50} value: 50 – 250 mg/kg.

6) Quinolphos:

It is contact poison having good penetrating power and It is having acaricidal properties.It is widely used against caterpillars and borer on cotton, vegetables and other crops.

Formulations: EC 25 and 5 G

Trade names: Ekalux, Shakthi Quick, Quinguard, Quinaltaf, Smash, Flash

LD_{50} value: 62–137 mg/kg.

7) Phosolone:

It is a non systemic contact insecticide and acaricide, effective against wide spectrum of species.

Formulations: EC 35

Trade names: Zolone

LD_{50} value: 135 mg/kg

8) Chlorpyriphos:

It is a non-systemic contact insecticide very effective against sucking and chewing insects.It is also recommended against house hold insect pests. It is widely recommended as seed treatment chemical against white grub and termites.

Formulations: EC 20

Trade names: Dursban, Chloroban, Durmet, Radar

LD_{50} value: 135-163 mg/kg

9) Phosphomidon:

It is a systemic insecticide having low contact action. It is very effective against sap sucking insect pests. On application it is absorbed in the plant tissues within 1-3 hours and is translocated more towards the top. It is less toxic to fish and more toxic to bees.

Formulations: 40 SL

Trade names: Demecron, Sumidon, Chemidan, Hydan, Phamidon

LD_{50} value: 17-30 mg/kg

10) Monocrotophos:

It is a systemic insecticide and acaricide with contact action. It has wide range of susceptibility of insects. It is toxic to bees.

Formulations: 36 SL

Trade names: Monocil, Nuvacron, Monophos, Monochem, Monostar

LD_{50} value: 14-23 mg/kg

11) Methyl demeton:

It is contact and systemic insecticide and acaricide.It is used against soft bodied insects, which suck the plant sap.

Formulations: 25 EC

Trade names: Metasystox and Dhanusyatax

LD_{50} value: 57-106 mg/kg

12) Dimethoate:

It is systemic insecticide and acaricide .It is widely used against sucking insect pests on various crops.

Formulations: 30 EC

Trade names: Rogor, Celgor, Novogor, Tara 909, roxion

LD_{50} value: 320-380 mg/kg

13) Triazophos:

It has insecticidal, acaricidal and nematicidal properties with trnalaminar action. It is very effective against variety of pests particularly Lepidoptera larvae on fruits and vegetables.

Formulations: 40 EC

Trade names: Hostathion, Trizocel, Truzo, Suthation

LD_{50} value: mg/kg

14) Profenophos:

It is a broad spectrum non-systemic insecticide.It is recommended against pest of vegetables. It is highly toxic to birds and fish.

Formulations: 50 EC

Trade names: Curacron, Celcron, Bolero, Carina, Proven

LD_{50} value: 358 mg/kg

15) Acephate:

It is a systemic andcontact poison.It has low toxicity and safe to environment.

Formulations: 75 SP

Trade names: Arthane, Starthane, Orthene

LD_{50} value: 866-945 mg/kg

16) Phorate:

It is a systemic granular insecticide and also possesses acaricidal properties.

It is very effective against sucking insects and also against maize borers, cut worms, white grubs etc.

Formulations: 10 G

Trade names: Thimet

LD_{50} value: 1.6 – 3.7 mg/kg

CARBAMATES

All carbamates are derivatives of carbamic acid. Many of the carbamic esters areinsecticidal and a few are effective molluscicides Like organophosphates, the carbamate insecticides interfere in cholinergic transmission. The carbamate enters the synapse and inhibits the acetylcholine-esterase as a result the acetylcholine contains to depolarize the post synaptic membrane, causing prolonged stimulation resulting into the failure of the nerve or effector tissue. Carbamates have an analogous action, carbamylating rather than phosphorylating the enzyme and the ChE recovers more readily from carbamates than from organophosphates. Thus, unlike, organophosphates, they are known as reversible inhibitors.

1. Carbaryl:

Carbaryl is a contact and stomach insecticide. It is most popular insecticide because it is effective against a wide range of insects and possesses very low mammalian toxicity. It is compatible with many pesticides except Bordeaux mixture lime sulphur and urea. It is not effective against mites.

Formulations: WP 50%, Granule 4% and Dusts 5%

Trade names: Sevin.

LD_{50} value: 400 mg/kg

2. Propoxur(Arprocarb)

It is a broad spectrum, contact and stomach poison with good knock down properties. It is effective in controlling house hold pests such as cockroaches, crickets, flies etc. It has long residual action.

Formulations: 20% EC, 50% WP

Trade names: Baygon, Blattamen, Saphaer

LD_{50} value: 90-128 mg/kg

3. Carbofuran.

It is a plant systemic broad spectrum and long residual insecticide, miticide and nematicide. It is recommended as soil insecticides against plant sap sucking and borer pests.

Formulation: 3G,48F

Trade names: Furadan

LD_{50} value: 8-14 mg/kg

4. Carbosulfan.

It is a systemic insecticide, and nematicide. It is recommended as seed dresser insecticide

Formulation: 25 DS

Trade name: Marshal

5. Thiodicarb

It is a insecticide with ovicidal properties, and molluscicide.

Formulation: 75 WP

Trade name: Larvin

6. Aldicarb

It is systemic pesticide usually applied in soil as seed furrow, band or broadcast treatments either pre-plant or at planting as well as post emergence side dress treatments. It has also possessing acaricidal property and toxic to higher animals

Formulation: 10 G

Trade names: Temik

LD_{50} value: 0.93 mg/kg

5. Methomyl:

It is a systemic with contact and stomach insecticide and nematicide. It is very effective against a wide variety of pests particularly army worms, cabbage semilooper, Okra stem fly, fruit borers, leaf defoliators, cotton boll worms, etc.

Formulations: 90 WP,12.5 EC, 40 SP

Trade names: Lannate, Dunnate

LD_{50} value: 30 mg/kg

LECTURE NO. 16

SYNTHETIC PYRETHROIDS AND INSECTICIDES OF OTHER GROUPS

Synthetic pyrethroids have got the properties of plant derivative pyrethrum as insecticides but areconsiderably more stable in light and air. Allethrin was first synthetic analogue of pyrethroids.

They act on tiny channel through which sodium is pumped to cause excitation of neurons and prevent the sodium channels from closing,resulting in continual nerve trans mission , tremors and eventually death.

The synthetic pyrethroids have extremely high insecticidal activity at extremely low doses and are bio-degradable in nature. Their activity is most pronounced against lepidopterous pests and they are very effective against beetle, leaf miner and bugs. They are very effective against eggs, larval and adult stages of insects. They have antifeedant and repellent properties. They are not readily washed off from the plants by rain due to lipophilic characters.

These synthetic pyrethroids are very less toxic to mammals and having a quick knock down activity to insects, the lower toxicity to mammals and increase safety for the user. Very low application rate of synthetic pyrethroids as compared to conventional insecticides brings reduced environmental pollution.

Limitations

- A major limitation of synthetic pyrethroids is that these are generally not effective as soil insecticide.
- Even at low dosages kill non target species
- Synthetic pyrethroids cause resurgence of several groups of insect pests especially whiteflies and aphids.
- Rapid development of resistance to synthetic pyrethroids in many insect species. This may be due to high selection pressure exerted by high mortality caused by synthetic pyrethroids
- Synthetic pyrethroids are poor acaricides

First generation: First generation pyrethroids are considered to be of low toxicity to people and other mammals because they are rapidly broken down in the body. First generation pyrethroids decompose quickly in sunlight and air and thus pose little risk in the environment but all pyrethroids are toxic to aquatic animals.

1) Allethrin

It is contact, stomach and respiratory action and bring quick knock down of flies and mosquitoes when applied in combination with Piperonyl butoxide.

Trade name: Pynamin

LD_{50} value: rats 572-1100 mg/Kg for rats and Dermal LD_{50} >2000 mg/kg

Second generation: Second generation pyrethroids are not acutely toxic to people or other mammals.These pyrethroids decompose rapidly in sunlight. They thus pose little threat to the environment, but for the same reason they are not suitable for agricultural use.

2) **Resmethrin**

. Approximately 20 times more effective than pyrethrum in housefly knock down, and is not synergized to any appreciable extent with pyrethrum synergists.

Trade name: NRDC – 104, SBP-1382, and FMC – 17370

LD_{50} value Dermal LD_{50} 2000-3000 mg/kg

3) **Bioresmethrin**

It is stereoisomer of resmethrin. Appeared in 1967.50 times more effective than pyrethrum against normal (susceptible to insects) houseflies, and also not synergized with pyrethrum synergists. Both resmethrin & Bioresmethrin decompose fairly rapidly on exposure to air & sunlight, so never developed for agricultural use.

Trade name: NRDC-107,FMC –18739, and RU-1148

LD_{50}: 8,600 mg/kg (oral) and 10,000 mg/kg (dermal).

4) **Bioallethrin** (d-trans –allethrin) introduced in 1969. More potent than allethrin and readily synergized, but it is not as effective as resmethrin.

Third generation: Third generation pyrethroids do not decompose in sunlight and contain some of the most powerful insecticides known.

Third generation pyrethoids are not highly toxic to people or other mammals mainly because they decompose rapidly in the body.

5) Fenvalerate:

It is contact insecticide and of broad spectrum in nature. It is stable in sunlight and has longer residual toxicity.

Formulations: 20 EC

Trade names: Fenvel, Bilfen, Belmark, Sumicidin, Pydrin

LD_{50} value: 300-630 mg/kg

6) **Permethrin:**

Contact insecticide, light stable, but poor knock down. First agricultural pyrethroids- because of their exceptional insecticidal activity (0.11 kg a.i/ha) and their photo stability.

Formulations: 25 EC and 5% smoke generation

Trade names: Ambush , pounce , pramex

LD_{50} value: Acute oral LD_{50} : 7000 mg/kg, Dermal LD_{50}: >5100 mg/kg

Fourth generation: Offer the most resistance to exposure to sunlight and air and, therefore, are more persistent. This group is more toxic to people than other pyrethroids and therefore requires more care in use. More stable in the environment.

7) λ **cyhalothrin**

Non-systemic insecticide with contact and stomach action, and repellent properties.gives rapid knockdown and long residual activity. It is an insecticide and acaricide used to control a wide range of pests.

Formulations: 2.5 EC, 5% EC

Trade names: Kung-Fu,Reeva, Charge, Excaliber, Grenade, Hallmark, Karate, Matador, Samurai and Sentinel.

LD_{50} value: 56 mg/kg

8) Cyfluthrin

It is a non-systemic contact and stomach poison,with rapid knock down effect. It is for control of chewing and sucking insects on crops. Cyfluthrin is also used in public health situations and for structural pest control.

Formulations: 5 EC, 10% EC

Trade names: Contur, Laser, Responsar, Tempo

LD_{50} value: 869 - 1271 mg/kg

9) Cypermethrin

It is stomach and contact insecticide. It is very effective against different types of pests on various crops.

Formulations: 10 EC, 25 EC

Trade names: Cyper guard, Ripcord, Cymbush and Cyper kill

LD_{50} value: ha Oral LD_{50} 303-4123 MG /KG, dermal more than 2400mg/kg

10) Fenpropathrin

It is contact insecticide and of broad spectrum in nature.It is extremely toxic to fish, wildlife.and aquatic organisms. It have acaricidal and miticidal property.

Formulations: 2.4 EC, 10 or 20% EC.

Trade names: Danitol, Rody and Meothrin

LD_{50} value:54 mg/kg

11) Flucythrinate

Flucythrinate is a synthetic pyrethroid used to control insect pests in apples, cabbage, field corn, head lettuce and pears, and to control Heliothis spp. in cotton.

Trade names: AASTAR, AC 222705, Cybolt, Fuching Jujr, OMS 2007, and Pay-Off.

LD50 value: 81 mg/kg .dermal LD50 in rabbits of greater than 1000 mg/kg

12) Decamethrin (Deltamethrin)

It is more potent than any other insecticide. It has also proved effective even against insects resistant to conventional insecticides.It is contact and stomach insecticide.

Formulations: 2.8 EC, 2.5% WP

Trade names: Decis, Decaguard, Deltex

LD_{50} value:135mg/kg

13) Fluvalinate

It is a insecticide and acaricide with stomach and contact activity in target insects. It is used as a broad spectrum insecticide.

Formulations: 25 EC

Trade names: Klartan, Mavrik, Mavrik Aqua Flow, Spur and Yardex

LD_{50} value: 1,050 to 1,110 mg/kg

14) Fenfluthrin: It is a very potent recent synthetic pyrethroid against a various groups of insects and mites. Highly toxic to *Daphnia* (Aquatic Invertebrate)

Trade Names: Bayticol, Bayvarol, Baynac

INSECTICIDES OF OTHER GROUPS

Fixed oils are the less aromatic oils derived from plants. Oils generally work by clogging the respiratory openings of the insect, causing suffocation. Oils are usually emulsified with water for application.Ex: Neem oil, Citronella Oil ,Garlic oil etc. Neem oil is extracted from the tropical neem tree, *Azadirachta indica*, contains insecticidal properties that are composed of a complex mixture of biologically active compounds. Its various active ingredients act as repellents, feeding inhibitors, egg laying deterrents, growth retardants, sterilants and direct toxins. Neem oil has very low toxicity to mammals. The advantages of oil applications are many, like they are inexpensive, usually result in good coverage, are simple to mix, and are safe to warm-blooded animals. Some disadvantages of use include phytotoxicity, instability in storage, and ineffectiveness against certain pests.

NOVEL INSECTICIDES

Neonicotinoids

They represent a novel and distinct chemical class of insecticides with remarkable chemical and biological properties. Similar to nicotines in activity partially to structure. Imidacloprid and other neonicotinoids interact with acetyl choline binding site of nicotinic Ach receptor which cause excitation and eventually paralysis leading to death of insects. These are selective and safe to non target organisms.

1) Imidacloprid:

Systemic insecticide with translaminar activity and with contact and stomach action. Used as a seed dressing, soil application and foliar application against sucking insects including leaf hoppers, plant hoppers, aphids, thrips and whitefly, also effective against soil insects, termites. It is highly toxic to birds.

Formulations: 17.8 SL ,70 WS

Trade names: Confidor, Gaucho, Admire, Merit, Premier, Stalone. Tatamida, Maratho , Provado LD_{50} value: 450 mg/kg

2) Acetamiprid: It is a systemic insecticide with contact and stomach action. Used as a soil and foliar application against homoptera especially aphid and leafhoppers. Thysonaptera and Lepidoptera.

Formulations: 20 SP

Trade names: Pride, Assail Intruder, Profil, Supreme

LD_{50} value:>2000 mg/kg

3) Thiomethoxam :

Contact and stomach poison with translaminar and systemic movement used as a seed treatment and foliar application against sucking insects . It has very strong effect on viral transmitting insects.

Formulations: 25 WG, 70 WS

Trade names: Actara, Cruiser, Crux, Flagship, Meridian, Adage, Rinova

LD_{50} value: 1563 mg/kg

4) Clothianidin: It is systemic and translaminar in action It shows inhibitory action on oviposition and feeding.

Formulations: 50 WG

Trade names: Dantop, Celeso

LD_{50} value: >5000 mg/kg

5) Thiacloprid: Used as a foliar spray against sucking pests such as aphids, thrips, whitefly, beetles and leaf miner. It act as an acute and stomach poison.

Formulations: 36 WG, 70 WG

Trade names: Calypso, Bariard, Alanto

LD_{50} value: 500mg/kg

Phenyl pyrazoles (Fiproles):

1) Fipronil

GABA receptors is the target site for fipronil. Blockage of GABA gated chloride channel reduces neuronal inhibition which leads to hyper exitation of the central nervous system, convulsions and death of an target pest.

Broad spectrum systemic insecticide with contact and stomach poison activity. Used as a foliar application against stem borer, leaf miner, hoppers, root worm and mites

Formulations: 0.3 G, 5 SC

Trade names: Regent, Front line,Tremidor, Zoom, Icon Tempo, Bilgran

LECTURE NO. 17

MACROCYCLIC LACTONES

Macrocyclic lactones

1. Spinosyns - Spinosad

The extract of the fermentation broth that contains spinosad is produced by the microorganism, *Saccharopolyspora spinosa.* The primary components are spinosyn A and spinosyn D.

Spinosad kills insects by causing rapid excitation by activation of nicotinic acetylcholine receptors of the insect nervous system, leading to involuntary muscle contractions, prostration with tremors, and paralysis. It also effects GABA receptor functioning.

Spinosad is a contact and stomach poison with some translaminar movement in leaf tissue.

Formulations: 45 SC, 2.5 WSC

Trade names: Tracer, Spintor, Precise, Success, Naturalyte, Laser, Credence Caribstar, Boomerang, and Conserve

LD_{50} value: 3738 mg/kg

2. Avermectins:

Avermectins form a new class of compounds having nematicidal, miticidal and insecticidal activity. These are produced by the soil microorganism *Streptomyces avermitilis*. Avermectins activate the GABA gated chloride channel, causing an inhibitory effect, which, when excessive, results in the insect's death. This channel normally blocks reactions in some nerves, preventing excess stimulation of CNS.

Emamectin benzoate and abamectin are the two major compounds in this group. .contact and stomach poisons. These are used as bait, foliar application against Homoptera, Diptera, Coleoptera, Lepidoptera and mites

Emamectin benzoate: It is non systemic insecticide which penetrates by translaminar movement and effective against Lepidopterous pests It has low toxicity to non target organisms and environment.

Formulations: EC 5, SG 5

Trade names: Proclaim

LD_{50} value: 300 mg/kg.

Abamectin:

It is a broad spectrum insecticide acting on mites of Tetranychidae, Eeriophyidae and Tarsonemidae. It is also effective against tobacco hornworm, diamondback moth, tobacco budworm, serpentine leaf miner and less potent against certain Homoptera (aphids) and Lepidoptera. It is less toxic to beneficial arthropods

Formulations: EC 1.8

Trade names: Avid, Agrimec, Vertimec, Argi-mek, Affirm and Avert

3. Oxadiazines

Indoxacarb:

The active ingredient indoxacarb works by inhibiting sodium ion entry into nerve cells, resulting in paralysis and death of targeted pests.

Indoxacarb is a stomach poison with slight contact action. Indoxacarb affects insects from direct exposure and through ingestion of treated foliage/fruit. Once indoxacarb is absorbed or ingested, feeding cessation occurs almost immediately. It kills by binding to a site on sodium channels and blocking the flow of sodium ions into nerve cells. The result is impaired nerve function, feeding cessation, paralysis, and death.

Formulations: SC 14.5, WDG 30

Trade names: Avaunt, Steward.Torando

4. Thio-Urea Derivatives

Diafenthiuron is new types of thiourea derivative which acts specially on sucking pests such as mites, whiteflies and aphids. Diafenthiuron is photochemically converted within a few hours in sunlight to its carbodimiide derivative which is much more powerful acaricide/insecticide than diafenthiuron. It is a inhibitor of oxidative phosphorylation, via distruption of ATP formation (inhibitor of ATP synthase).

It acts as Acaricide cum-insecticide as a foliar sprays against mites, sucking pests, lepidopteran insect pests

Formulations: 50 WP

Trade names: Polo

LD_{50} value: 2068 mg/kg.

5. Pyridine Azomethines

Pymetrozine is a new insecticide highly active and specific against sucking insect pests. Pymetrozine is the only representative of the pyridine azomethine. It has high degree of selectivity, low mammalian toxicity and safety to birds, fish and non-target arthropods.

When the insertion of the stylets of sucking insects into the pymetrozine treated plant tissues, stylets are almost immediately blocked. The sucking insects die by starvation a few days later (feeding depressant)

Formulations: 50 WDG

Trade names: Full fill, Chess

LD_{50} value: 5693 mg/kg

6. Pyrroles

Pyrroles are oxidative phosphorylation inhibitors. It works by uncoupleing oxidative phosphorylation from electron transport process in mitochondria.(Oxidative phosphorylation is the process through which ATP is synthesized in plants and animals). It interferes with formation of ATP which is essential for muscle contraction.

1. Chlorfenapyr: It is a miticide and insecticide. Chlorfenapyr has broad spectrum of activity against many species of Coleoptera, Lepidoptera, Acarina and Thysanoptera. It is mainly stomach poison and has contact action also.

Formulations: SC 3

Trade names: Pirate ,Pylon

LD_{50} value: 626 mg/kg

Formamidines

Formamidines are represented by Chlordimeform and Amitraz with very unique actions for the control of phytophagous mites, ticks and certain insects (Lepidoptera and Hemiptera) by acting as agonists of octapamine receptors octapamine act as neurotransmitter,neuromodulator and is involved in energy metabolism and stress responses.

1. Chlordimeform: It has marked translaminar and systemic activity. It shows a strong repellent-antifeedant action on both lepidopterous larvae and mites. It has good ovicidal activity. Non toxic to non target organisms except predaceous mites.

Formulations: 50 SP, 4 EC

Trade names: Galecron, Fundal, Fundal, Spike

LD_{50} value: 340 mg/kg

2. Amitraz:It is a non systemic insecticide and acaricide with contact and respiratory action It is used to control red spider mites, leaf miners, scale insects, and aphids.

Formulations: 50 SP, 20 EC

Trade names: Acarac, Amitraze,Baam

LD_{50} value: 523- 800 mg/kg

Ketoenols

Ketoenols act as insecticide and acaricides against against all developmental stages and is a valuable new tool in the resistance management. They arehttp://www.alanwood.net/pesticides/class_insecticides.html - tetronic_acid_insecticides tetronic acid insecticides with acaricidal action. Their mode of action is to inhibit lipogenesis in treated insects, resulting in decreased lipid contents, growth inhibition of younger insects, and reduced ability of adult insects to reproduce.

1. Spiromesifen:

Spiromesifen is effective against whitefly, spider mites and psyllids. It is is particularly active against juvenile stages. However, it also strongly affects fecundity of mite (and whitefly adults by transovariole effects.

Formulations: 2 SC, 4 F

Trade names: Oberon, Forbid

LD_{50} value: >2000 mg/kg

2. Spirodiclofen:

Spirodiclofen is a selective, non-systemic foliar insecticide and acaricide. It is effective against mites and sanjose scales.

Formulations: 2 SC,

Trade names: Envidor

LD_{50} value: >2500 mg/kg

3. Spirotetramat:

Spirotetramat is effective against aphids, whiteflies, scales, mealybugs, psylla, phylloxera, thrips, and mites on crops like citrus, vegetables, grapes, potato, other tuberous crops, livestock commodities, and greenhouses/nurseries.

Formulations: SC 14.5, SC 22.4

Trade names: Movento, Ultor

LD_{50} value: >2000 mg/kg

Diamides

1.Chlorantraniliprole

Chlorantraniliprole is a novel anthranilic diamide insecticide, efficacious for control of lepidopteran insect pests as well as some species in the orders Coleoptera, Diptera and Hemiptera. It is active on chewing pest insects primarily by ingestion and secondarily by contact. It exhibits larvicidal activity as an orally ingested toxicant by targeting and disrupting the $Ca\ 2^{+}$ balance . Chlorantraniliprole activates ryanodine receptors via stimulation of the release of calcium stores from the sarcoplasmic reticulum of muscle cells (i.e for chewing insect pests) causing impaired regulation,paralysis and ultimately death of sensitive species. It has low mammalian toxicity.

Chlorantraniliprole can be used as foliar spray on insect pests of fruits and vegetable crops@ 10 to 60 g/ha. Trade names: Coragen 200SC and Altacor 35 WG

2.Cyantraniliprole

Cyantraniliprole is another diamide efficacious against a cross spectrum of chewing and sucking pests. It works as toxicant in ingestion orally and has systemic activity. It targets and disrupts $Ca\ 2^{+}$ balance in nervous system. It is formulated as OD (Oil Dispersion) and SC (Suspension Concentrate) and generally applied @ 10-100 g a.i/ha

Trade name : Cyazypyr

3. Flubendiamide: It is a new lepidoperan insecticide. Acts by ingestion and disrupts Ca^{2+} balance in the nervous system resulting in rapid cessation of feeding and extended residual control of important lepidopteran pests.

Formulations: 240 WG, 480 SC

Trade names: Fame, Belt

LECTURE NO.18

CHITIN SYNTHESIS INHIBITORS, INSECT HORMONE MIMICS, AGONISTS AND RECENT METHODS OF PEST CONTROL

Chitin synthesis inhibitors disrupt molting by blocking the formation of chitin, the building block of insect exoskeleton. Without the ability to synthesize chitin, molting is incomplete, resulting in malformed insects that soon die. It suppresses egg-laying and causes egg sterility in treated adults through secondary hormonal activity.

S. No	Name & Mode of action	Tradename &Formulation	LD_{50} mg/kg
1	**Diflubenzuron:** Stomach and contact poison that acts by inhibiting chitin synthesis so it interferes with formation of cuticle.	Dimilin 25 WP	4640
2	**Flufenoxuron :** Broad spectrum Insect and mite growth regulator with contact and stomach action.	Cascade 10 WDC	3000
3	**Chlorfluazuron:** Chlorfluazuron is used in subterranean termite baiting stations.	Atabron 5 SC	8500
4	**Triflumuron:** Broad spectrum Insect growth regulator	Alsystin , Baycidal Starycide25 WP	>5000
5	**Teflubenzuron:** It is effective against Lepidoptera, Coleoptera, Diptera, Hymenoptera Aleyrodidae, and Psyllidae	Nomolt,Dart, Nemolt 15 SC	2250
6	**Novaluron:** It acts mainly by ingestion, but has shown some contact activity. It does not have ovicidal activity, but a high percentage of mortality of first instars hatching from eggs laid on sprayed foliage occurs.	Rimon 10 EC	5000
7	**Buprofezin:** Contact and stomach, persistent chitin	Applaud	2198

	synthesis inhibitor with miticidal action. Effective against specifically on Homopteran pests.	25 SC, 70 WP	
8	**Flufenoxuron:** Contact and stomach, inhibits chitin synthesis in nymphal mites and lepidopteran larvae. Compatible with α-Cypermethrin.	Cascade Casette Tenope 10%EC, 5%EC	>3000

Juvenile Hormone (JH)Mimics

The possibility that JH analogs may have potential as insect control was first recognized by Williams (1965). The compounds showing JH activity, 'Juvenoids'. Four types of JHs (JH= 0, I, II, and III) are known with their structural variations.JH-0 is known from the eggs of *Manduca sexta* only.JH-I & JH-II are from all lepidopterans and are said to be morphogenetic in action *i.e* to retain the larval characters.JH-III present in all insect orders and are said to be gonado tropic *i.e.* for stimulating the ovaries to mature in the female.

The so called 'Paper factor' (Karel Slama & C.M. Williams , 1966) against the bug *Pyrrhocoris apterus* (Heteroptera) was subsequently traced to be balsam fir trees, *Abis balsamea* from the wood pulp of which the paper towels were manufactured and scientifically named 'Juvabione'. These findings opened up the flood gates for JH research chemists to get busy in synthesizing JH mimics (Juvenoids).

Mode of Action:

i) Antimorphic effect: Do not allow Metamorphosis to take palace there by forcing larva to continue as a larva. There fore if the Juvenoids are provided exogenously the larvae will undergo an extra larval moult (change in to super larva) or moult in to defective intermediate forms which may suffer from a failure to successfully moult, feed or mate.

ii) Larvicidal effect

iii) Ovicidal effect.

iv) Diapause disrupting effect

v) Embryogenesis inhibiting effect.

Juvenoids acts as ovicides when applied directly on eggs and indirectly on ovipositing females. They block embryogenic development of blastokinesis stage. When applied before hatching, they show morphogentic effect at the time of metamorphosis. They inhibit ecdysone synthesis by effecting prothorasic glands. If applied to the last instar larvae, they could prevent pupa from entering in to diapause. They could terminate pupal diapause by activating the inactive PTG of diopausing pupa.

Juvenoids:

i) Juvabione (Fernesol - extracted from excreta of *Tenebrio* sp)
ii) Methoprene (Altosid)
iii) Hydroprene (Gentrol, Altozar)
iv) Kinoprene (Enstar)

Anti JH orJH Agonists or Precocenes: Anti-juvenile hormones found in plants that induce reversible precocious metamorphosis and sterilization in insects by suppressing the function of the corpora allata gland

Precocenes are the compounds which would antagonize the JH activity and dearrange the insect development. These compounds induce the precocious metamorphosis of immature insects. Precocenes affect insect diapause, reproduction and behaviour. These compounds first extracted from the plant *Ageratum houstonium.* It contains two simple chromene compounds precocene –I and II.

1) Fenoxycarb (Insegar 50 % WP, Award,Comply Logic, Torus, Pictyl and Varikill) @ 0.025 %
2) Pyriproxyfen (Tiger 10 % EC, Distance, Esteem, Archer Knack, Sumilarv and Admiral) @ 0.0125 %

Ecdysone or Moulting Hormone (MH) Agonists

MH contains two hormones, α -Ecdysone and β - Ecdysone. The α - ecdysone is a prohormone produced by PTG which is converted into β - ecdysone in the peripheral tissues of the gland and is also called 20-Hydroxy Ecdysone, which actually brings about molting in insects and is the true MH.

Synthetic analogues of ecdysones are called ecdysoids .After absorption into haemolymph it binds the ecdysone receptor proteins which initiates moulting process .The normal moulting process is disrupted. Larvae is prevented from shedding of old cuticle and it will die due to dehydration and starvation.

a) Tebufenozide (Mimic, Confirm and Romdan)
b) Halofenozide (Mach)
c) Methoxyfenozide (Prodigy)

Recent Methods of Pest Control

I) Insect Repellents: Chemicals which cause insects to move away from their source are referred to as repellents (or) Chemically that prevent insect damage to plants (or) animals by rendering them unattractive, unpalatable (or) offensive are called repellents.

Desirable traits of a good repellent

a) It should be effective for a long time and on a wide range of insects.
b) Weathering effects on it should be the least.
c) Should not be toxic (or) irritating to man and animals.

d) Should leave an acceptance odour, taste and touch
e) Should be harmless to clothes.
f) Should be cheap.

Types of repellents

Repellents are broadly classified as Physical repellents and Chemical repellents

1) Physical repellents

These produce repellence by physical means and are of the following kinds.

i. Contact stimuli repellents

These are substances (Such as dusts, granules, water, oils, leaf hairs, spines and waxes) that influence the surface texture of the plants to produce a disagreeable effect on the tactile sense of the insects.

ii. Auditory repellents

Theses employ sound to ward off insects. For instance, an amplified sound has been found effective in repelling mosquitoes, pyralid moths and files.

iii. Visual repellents

White light normally attracts insects but the yellow colour light is the least attractive and to some extent acts as a visual repellent to insects.

iv. Excitatory repellents

Chemicals such as pyrethrum, DDT, BHC etc., which excite the insect's tarsi by stimulating the sensory nerves and force them to leave the treated surface.

v. Feeding repellents

Substances that inhibit feeding in insects are called feeding repellents (or) Antifeedent.

2. Chemical repellents

These are chemicals that affect tactile, olfactory (or) gustatory receptors of insects and could be plant origin (or) synthetic as follows.

i. Repellents of plant origin

The oil of citronella remained a commonly used mosquito repellent and still continues to be a constituent of a popular brand of commercial mosquito repellent, Odomos. The oil is extracted from the lemon grass, *Cymbopogon nardus* and contains citronellol, geraniol (as the main constituents), boreneol and terpenes (insmall amounts) of which the first two are regarded as the main repellents for mosquitoes.

Pyrethrum is another plant product which not only acts as an insecticide but in low concentrations, also as a repellent for blood – sucking insects. Clothes impregnated with some pyrethroids have been found to afford protection against the attack of many insects vectors of diseases like *Aedes aegypi, Anopheles quardrimaculaius* etc.,

ii. Synthetic repellents

Diethyl toluamide, protects the bearer against mosquitoes, ticks, fleas and biting files. The others Bordeaux mixture, Dimethyl pthalate, and Indalone acts as . repellents for insects**.**

Uses of repellents

Repellents can find several uses such as

1. They can be used on the body in some formulation to ward off insects.
2. They can be used as fumigants in an enclosed area of insects.
3. They can be used as dusts and sprays on domestic animal to protect them from noxious biting and blood – sucking insects.
4. They can be used to drive insects from their natural breeding grounds to areas treated with an insecticide (or) a chemosterilant to kill (or) sterilize them.

Insect Antifeedants

Antifeedant is a chemical that inhibits feeding but does not kill the insect directly; the insect often may remain on the treated plant material and possibly may die of starvation. These are also caused as "Feeding deterrents"

There are three main sites for the sense of taste in insects located in the mouth, on the tarsi and on the antennae. Insect feeding deterrents may be perceived either by stimulation of specialized receptors (or) by distortion of the normal function of neurons which perceive phagostimulating compounds. Since the sugars are very important components of an insects sustained feeding, the inhibition of its receptors is an effective antifeedant action

Groups of antifeedants

a) Triazines

Acetanilide.is an odourless and tasteless solid and not phytotoxic and inhibits feeding of most chewing surface feeders such as caterpillars, beetles and cockroaches.

b) Organotins

Triphenyl tin acetate (Brestan) was one of the earliest organotins that was found to have an antifeedant effect on the foliage – feeding insects such as the cotton leaf worm, colorado potato beetle, larvae of potato tuber moth, *Agrotis ipsilon* and grasshoppers.

c) Carbamates

Several thiocarbamates inhibit the feeding of Mexican beetle, Colorado potato beetle and japanese beetle. The carbamate, arprocarb (Propoxur) is systemic antifeedant against the boll weevil, *Anthonomus grandis*.

d) Botanical Extracts

i) Pyrethrum

From the flowers of *Chrysanthemum cinerariaefolium*, is not only insecticide but in small doses also acts as an antifeedant for the biting fly, *Glossina.*

ii) Margosa (Neem)

First reported by Pradhan *et al.* in 1962, the extracts of the leaves and fruits of neem trees (*Azadirachta indica,* family Meliaceae) act as very effective antifeedants against a large number of insects, particularly the desert locusts, *Schistocerca gregaria*, which is a very destructive polyphagous insect.

iii) Apple Factor

An Apple of the genus, *Malus* yields phenolic substance, phlorizin which stimulates probing in the apple feeding aphids (*Aphis poni*) but acts as a feeding deterrent for the non- apple feeding aphids (*Myzus persicae*).

iv)Solanum alkaloids

Alkaloids (tomatine, solanine) extracted from some species of *Solanum* reduce feeding and survival of potato leaf hopper, *Empoasca devastans.*

Besides the above, several other substances like non – essential amino acids, tannins, lignins *etc.* act as antifeedants to many insect pests.

Advantages of Antifeedants:

1. Antifeedants affect only the phytophagous insects and so do not harm the beneficial parasitoids, predators and pollinators.
2. As the pest is not immediately killed by antifeedent, its parasites and predators continue to feed on it, thrive, and keep it under control.
3. Antifeedants produce no phytotoxicity (or) pollution.

Disadvantages of Antifeedants:

1. Only the chewing type of insects are effected by antifeedants, the sucking pests remain unaffected.
2. New growths of plant are not protected.
3. As the insects are not immediately killed, they could move to untreated parts (or) other plants and damage them.
4. Antifeedants are not effective enough to become a sole control measure. They could only be promising when included in the integrated control schemes.

Insect Attractants

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

Types of Attractants

1. Pheromones
2. Natural food lures
3. Oviposition lures
4. Poison baits

1) Pheromones

In 1959 Karlson and Butenandt coined the term pheromone. For a Chemical that is secreted into the external environment by an animal and that elicits a specific response in a receiving individual of the same species. It is also referred to as "ectohormone". Depending on their mode of action pheromones are divided into two general classes.

i) One which gives a releaser effect – an immediate and reversible behavioural change is produced in the receiving animal.

ii) One which gives a primer effect - a chain of physiological changes is triggered off in the receiving animal. Eg : Gustatory stimulation, controlling caste determination and reproductive control in social Hymenoptera (Ants and Bees), Isoptera (Termites).

Behaviour – releasing pheromones are typically odorous and act directly on the central nervous system of the receiving animal. Eg: Alarm, trail following, aggregation for mating, feeding (or) oviposition, The pheromones that promote aggregation are sex pheromones and aggregation pheromones.

a) Sex pheromones

A Sex pheromone released by one sex only triggers off a series of behaviour patterns in the other sex of the same species and thus facilitates mating. The male insects respond to the odorous chemical released by the female. In certain species of insects the males are known to produce the sex pheromone which attracts the females. Ex : In the cotton boll weevil *Anthonomus grandis*

The sex pheromones are specific in their biological activity, the males responding only to a specific pheromone of the female of the same species, and their reactions are directed towards the air currents carrying the odour. The time of release of the pheromones by the females and response by male to them appears to be specific for each species. Effective distances for sex pheromones depend on the threshold concentration for male stimulation and release rate from the female.

The following sex pheromones have been isolated and identified.

Bombycol : Silkworm, *Bombyx mori*

Gyplure : Gypsy moth, *Perthetria dispar;*

Gossyplure : Pink bollworm, *Pectionophora gossypiella*

Trimedlure : Meditarrnian fruifly, *Ceratitis capitapa*

Cuelure : Melon fly, *Bactroceracucurbitae*

Litlure :Tobacco cutworm, *Spodoptera litura*

Helilure : Red gram pod borer, *Helicoverpa. armigera*

Amlure : Chaffer beetle, *Amphimallon* sp

Looplure :Cabbage looper ,*Trichoplusia ni*

Ferrolure : Coconut Red Palm Weevil , *Rhynchophorus ferrugineus*

Leucilure : Brinjal Shoot and Fruit Borer *Leucinodes orbonalis*

Sex pheromones in insect pest management

1) Monitoring of insect pests: Traps baited with synthetic sex pheromones is useful in estimating population and detecting early stages of pests. Four pheromone traps per acre is recommended.

2) Mass-trapping: (Male annihilation technique): Large number of pheromones baited traps can be used in the fields to capture male moths of newly emerged and reduce the number of males for mating.

3) Control of pest by mating disruption: By permeating the atmosphere with higher concentration of the pheromone the opposite sex is rendered confused and unable to locate their mates.

Merits:

1. The pheromones are species specific.
2. They are safe to natural enemies and environment.
3. They require in small doses.
4. They are economical and compatible with other components of IPM.

Demerits:

1. Synthetic pheromones are available only for a few pest spec ies.
2. Replacement of pheromone lures at regular interval is required for good catch of moths.
3. Pheromone traps attracts only target pest even when crop is attracted by many other pests.
4. Pheromone reception and dispersal are not understood even for most important pests.

b) Aggregation pheromones

The pheromone released by one sex only elicits response in both sexes of a species. In scolytid (or) bark beetles the males secrete the pheromone into the hind gut which gets incorporated in to the faceal pellets and through them attracts flying males and females towards the galleries. In *Trigoderma granaria* mixture of fatty acid esters and methyl and oleate function as aggregation pheromones.

c) Trial marking pheromone

At low concentrations mostly used by foraging ants and white ants. In ants *Formica rupa,* formic acid while termites,*Zootermopsis nevadensis* hexanoic acid functions as the trial marking pheromone.

d) Alarm pheromones

These substances are elaborated by mandibular glands, sting appartus, anal glands which typically results in fight or aggression. *Dolichoderine* ants – release a fruity odour by the worker that results in a erratic behavour of workers, when this is discharged into mandibles onto an intruding insects that becomes marked as agreessor.

Natural Food lures

These are Chemicals present in plant and animal hosts that attract (lure) insects for feeding. They stimulate olfactory receptors and may be

1. A floral scent in case of the nectar feeding insects
2. Essential oils for the phytophagous insects.
3. Decomposing products for the scavenger
4. Carbon dioxide, lactic acid and water for the blood sucking insects.

Oviposition Lures

These are chemicals that govern the selection of suitable sites for oviposition by the adult female for example, P-methyl acetophenone attracts adult female rice stem borers to oviposit.

Poison Baits

Poison baits are a mixture of food lures and insecticides. The effort is made to make the bait more attractive to insects than their natural food and also a smaller quantity should be able to attract the largest number of insects. Baits are used when for some reason spraying (or) dusting of insecticides is not practicable. For instance, when insects live hidden under the soil, inside the fruits and vegetables (or) for household insects like ants, cockroaches and houseflies.

Advantages of Attractants

1. Attractants do not kill the insects and, therefore, do not disrupt the ecosystem (or) food chain.
2. They are specific for some insects and so do not affect the non-targets.
3. They can be used to mass trap the insects to be subsequently killed by insecticides.
4. Since they are not long lasting, they do not cause environmental pollution.
5. They can be employed to misguide the insects to wrong host plants, wrong mating partners (or) wrong oviposition sites where by their number will go down by starvation (or) by producing unfertilized eggs.

Disadvantages of Attractants

1. Insects can always find untreated hosts, so their number may not be affected.
2. The attractants can not be relied as a sole control measure – can only be used in integrated control programmes.

Genetic Insect Control

The basic principle in genetic control of insects is to utilize factors which will lead to reproductive failure. Genetic control of insects is not limited to the use of insects sterilized by radiation or chemicals but also include cytoplasmic incompatibility, induced sterility, hybrid sterility etc.

A) Induced Sterility

i) Sterile male release technique:

When a sterile male mates with normal female there will be no progeny. If adequate number of vigorous and competitive sterile males is introduced systematically into natural population the population will soon cease to exist.

This theory of Male Sterile Technique was conceived by E F Knipling as early as 1937 and was published in 1955. He suggested two procedures,

1) Rearing, Sterilization and Release (@ 9:1 sterile to fertile insects) of sterile insects to compete with the normal population.
2) Sterilizing a portion of the natural population

Eg: Screw-worm (*Cochliomyia hominivorax*) a cattle pest was completely eradicated from Curacao Islands and south eastrun parts of USA by male sterilization by irradiation with gamma rays ($C0^{60}$).

Limitation: Applicable only to species, where the female mates only once in its lifetime.

ii) Aspermia: Inactivation of sperms. In some cases, as in mosquitoes the sperm of the incompatible male is blocked before is could fuse with the nucleus of the egg of native female. This principle was employed in eradicating *Culux pipensquinquifasciatu*s in Rangoon. The possibility is, the incompatible strain could be identified, multiplied in large numbers and released in infested areas for eradicating the pests.

iii)Infecundity: Sterile eggs by dominant lethal mutations

iv)Use of non-mutagenic chemicals: To induce sterility by preventing mating by developing monogamous females, inhibition of spermato/oogenesis or by sperm inactivation

B) Cytoplasmic Incompatibility

Sterility is due to a cytoplasmic factor transmitted through the egg, which kills the sperm of incompatible male after its entry into the egg. Crosses between certain populations give no off-spring at all, in other cases females of one population may cross with males of another population and off-spring are produced, but the reciprocal cross is completely sterile.

Recently it has been observed that in the case of some species of insects, there exist different strains with different genetic set up. When males of one such strain mate with females of another such strain, the offspring fails to develop because of incompatibility between the genes of the egg and the sperm. At an interspecific level the sperm of heterospecific males are often disadvantaged in competition with those of conspecific males.

C) Hybrid Sterility:

In some insect cross-types or races which produce fertile females but sterile males among progeny. These sterile hybrids are excellent material for use in insect control. These sterile males are more vigorous and competitive than the sterile males produced after radiation or chemosterilization.

D) Population Replacement:

The ability of disease transmission of vectors *ie* replacement of specific vector populations can as well be changed by genetic methods.

E) Auto-Sterilization:

Sterilization of native insects in their natural environment by using chemosterilants along with the species specific attatractants / lures/ bait traps. Through this both the sexes can be sterilized, and also negate the reproductive ability of those insects which have escaped the lure/bait treatment.

LECTURE NO. 19

RODENTICIDES AND ACARICIDES

Rodenticides

Compounds, which kill the rodents by their chemical action, are known as rodenticides. Rodents belong to order Rodentia, class Mammalia and phylum Vertebrata. Rodents such as rats, mice, gophers and ground squirrels spread diseases like plague, rat bite fever and leptospiral jaundice in human beings. They damage the standing crops and cause substantial loss during storage of the produce.

Characteristics of ideal rodenticide:

1. Toxic action should be slow so as to allow the animal to consume a lethal dose.
2. Palatable and odourless.
3. Bait shyness must be avoided.
4. Poison is specific to species to be controlled.
5. Manner of death not be cruel and make surviving population suspicious.
6. Susceptibility should be age, sex or strain dependent.
7. No danger of secondary poisoning through animals eating poisoned rodents.
8. Consumption of chemical should not lead to development of resistance.
9. Chemical mixed with bait be stable under various environmental conditions.
10. For easy removal of corpses, animal should preferably die in the open space.

Zinc phosphide: A grayish black powder with strongly disagreeable odour

When zinc phosphide is ingested, it reacts with stomach acids and causes poisonous phosphine gas to be released. This leads to nausea, vomiting, pulmonary edema, and eventual death. Zinc phosphide, acute stomach poison is used as a bait at 2% strength, mixed with popcorn, rice, dry fish, onions etc., Pre baiting is essential as rats exhibit bait shyness to this. In paddy fields, two rounds of baiting before and after sowing nursery and another two rounds in planted crop are required. About 500 g of poison is needed per hectare.

Formulation: 80% powder

Trade name: Zintox

$LD_{50:}$ 46 mg/kg

Aluminium phosphide:

Aluminum phosphide is an inorganic phosphide used to control insects and rodents in a variety of settings. It is mainly used as an indoor fumigant at crop transport, storage or processing facilities for both food and non-food crops It may also be used as an outdoor fumigant for burrowing rodent control, or in baits for rodent control in crops. Aluminum Phosphide is available in pellet and tablet form. Under optimum moisture conditions, it liberates ‘Phosphine’ gas, which is highly toxic. ¼ to ½ of a 3 g tablet is put in a live-burrow; a little water is added if necessary and the burrow closed with mud. Repeat the operation if the burrow remains closed. Also used to fumigate the godowns @ 1tab/ ton / 5 days and also@ 1 or ½ tab/tree against red palm weevil.

Formulation: Tablets (3g)

Trade name: Celphos, Fumitoxin, Phostoxin, and Quic k Phos.

$LD_{50:}$ 11.5 mg/kg

Anti-Coagulant Rodenticides:

Anticoagulants are defined as chronic single-dose or multiple-dose rodenticides, acting by effectively blocking of the vitamin K cycle, resulting in inability to produce essential blood-clotting factors

Bromodiolone:It act by depressing the hepatic vitamin K dependent synthesis of substances essential to blood clotting.A single dose anticoagulant rodenticide from Coumarin group The technical material (97% pure) is an odourless, yellow-white powder.

Bromadiolone is vitamin K antagonist. The main site of its action is the liver, where several of the blood coagulation precursors under vitamin K dependent post translation processing take place before they are converted into the respective procoagulant zymogens. The point of action appears to be the inhibition of K_1 epoxide reductase..

Formulation: Solids

Trade names: Roban, Moosh moosh, Bromard; Bromatrol; Bromone^R; Bromorat Deadline; Hurex

$LD_{50:}$ 1-3 mg/kg

Acaricides:

The substances exercising toxic effects on mites are specifically called as miticides or may be generalized as 'Acaricides'. Most of the organophosphatic insecticides are also effective acaricides, whereas, most of the organochlorines (except dicofol) are ineffective against mites. Thus, use of organochlorines in situations where mites are present, may aid in the increase of mite population substantially by killing their natural enemies.

The following are some of the specific acaricides:

i) **Sulphur:** It is a fungicide and acaricide. It is formulated as a fine dust (80–90%) to which about 10% inert material is added to prevent 'balling'. Flowability of the dust is increased by adding 3% tricalcium phosphate. The finer the dust the more effective it will be. Also available as a Wettable Powder (50%).

ii) **Dicofol:** It is a hydroxylated product of DDT. It is non-systemic acaricide effective against all stages of mites. It has long residual action. and low mammalian toxicity.

Formulation: 18 EC

Trade names: Kelthane, Hifol

LD_{50}: 850 mg/kg

iii) **Tetradifon:**Persistent acaricide, kills all stages of mites except adults.

Formulation: 20 EC

Trade names: Tedion

LD_{50}: >5000 mg/kg

iv) **Propargite**: It is non-systemic acaricide, used for control of mites on fruits,grain, vegetables, nut and crops. It is highly toxic to fish

Formulation: 57 EW

Trade names: Comite, Omite

LD_{50}: >5000 mg/kg

LECTURE NO.20

APPLICATION TECHNIQUES OF SPRAY FLUIDS

The pesticide application plays important role in pest management. The main purpose of pesticide application technique is to cover the target species and safety to the non target organisms and the environment. The complete knowledge of pest is essential for correct time of application. Most of the pesticides are applied as sprays. Spraying is classified on the basis of the droplet size of the spray as

	Spray Type	Droplet size
1.	Very Coarse spray	> 500 μ
2.	Coarse spray	400 μ – 500 μ
3.	Medium spray	250 μ – 400 μ
4.	Fine spray	100 μ – 250 μ
5.	Mist	50 μ – 100 μ
6.	Fog	5 μ – 50 μ
7.	Aerosol	0.1 μ – 5 μ

On the basis of Volume of spray fluid per unit area, Spraying is classified as

1. **High volume spraying (HVS) or Full Cover spraying or conventional spraying:**Pesticide is diluted with water and droplet size is larger. Spray fluid requirement is 500 – 1000 lit/ha in case of field crops (1500 – 2000 lit/ha – Orchard crops).

Advantages :

1. Meant for chewing insects.
2. Drift is very less

Disadvantages :

1. Less area is covered
2. More water is required
3. More time , labour and cost of application due to labour cost

2. **Low volume spray (LVS):** The low volume sprays are 8-25 times more concentrated than high volume spraying. Spray fluid requirement ranges from 12-125 lit/ha. The droplet size is 70 – 150 μ.

Advantages :

1. Less time and less cost are involved in transport of water and hence the cost of application is minimized
2. More area is covered (6 – 8 acres in a day)
3. Control of pests is in time

Disadvantages :

1. Loss of chemical due to the drift
2. Application of LVS is preferred when wind velocity is less than 8 km/hour.

3. **Ultra low volume spray (ULVS):** ULV sprayer or air craft with special nozzles require 0.5 - 5.6 lit/hac with droplet size of 20 – 70 μ.

Advantages:

1. Very less time is required
2. No water requirement
3. Labour cost is less
4. Larger area covered (8 hac/day).

Disadvantages:

1. Drift is more
2. More hazardous
3. Special foundations are needed
4. High cost

4. Aerial spraying: Aerial Air crafts has been employed for application of agricultural and public health pesticides. It is used for spraying, dusting and application of baits. However, Spray formulations are more suitable than dusts because of wind speed should not be more than > 5 KMPH. It has to be done at low heights and in the early hours of the days to ensure uniform deposition of dust particles.

Advantages:

1. Large area covered
2. Locusts, cut worms, army worms could be checked before much damage is done.
3. Cost of application is cheap per unit area.
4. Inaccessible areas are also can be protected.

Disadvantages :

1. Drift is more
2. Undersurface of leaves is not fully covered
3. Depend on weather conditions
4. Preplanning and collaboration with other agencies is required
5. Pollution is more

Phytotoxicity: The application of pesticides or insecticides on plants is intended to control the pests without causing adverse or harmful effects to plants. It is common to see some adverse insecticides in fields which is called phytotoxicity

It is of two kinds

1. Permanent phytotoxicity leading to the death of the effected part or whole plant
2. Temporary phytotoxicity which allows the plant to recover after showing phytotoxicity

Most insecticides are not phytotoxcity at ordinary/ recommended concentrations but show temporary / permanent phytotoxcity when applied indiscriminately at much higher concentrations.

Eg: Now many farmers are applying insecticides formulations as ULV sprays which are meant for application as higher volume sprays. Some times the solvents/diluents used may also cause phytotoxcity

However, some plants/crops are highly sensitive to certain insecticides and show phytotoxicity when applied.

So thorough knowledge of phytotoxicity of chemicals and dosages at which they are to be applied is essential for plant protection people.

Symptoms of phytotoxicity

- Chlorosis or yellowing of leaves
- Bronzing of leaves
- Necrosis of complete plant or parts of it
- Scorching
- Deformation and curling of leaves
- White spots on leaves
- Burning effects on leaves
- Premature falling of leaves
- Mottled leaves
- Poor germination of seeds

Examples :

Organo chlorines – Curcurbits

Carbaryl – Soybean & Redgram

Dimethoate and Malathion – Sorghum

Methyl parathion – All Cucurbits

Sulphur- Crcurbits, Apples and Tea

Advantages of chemical control:

1. Chemicals are powerful tools for pest management.
2. Highly effective, rapid curative action and adoptable to most situation.
3. Flexible in changing agronomic and ecological conditions.
4. It is economical.

5. Insecticides are only tools available when pest is crossing threshold levels.
6. For many of pest problems chemical control is the only acceptable solution.
7. They are easy to obtain and apply

Limitations of chemical control:

1. Harmful to non target organisms.
2. Many pesticides bring about the secondary infestation of non target pests and resurgence of target pests.
3. Other beneficial insects like pollinators, honeybees, weed killers may also be killed.
4. There is a risk to man and livestock.
5. Some pesticides may cause phytotoxicity.
6. Some insecticides leave residues which cause environmental pollution.
7. Some insects may develop resistance to insecticides.
8. Some insecticides accumulate in body tissue become dangerous even without any prior indications.
9. Some insecticides have a tendency to be passed over from one food source to another food source.

Safe use of Insecticides:

1. Mixing and loading operations are the most hazardous because they generally result in possibilities of exposure i.e. spills
2. Read label carrying out the necessary calculations for the required dilution of the insecticide
3. Obtain proper equipment, including protective clothing, etc
4. Never work alone while handling highly hazardous insecticides
5. Mix insecticides outside or in a well ventilated area. Never position any part of the body directly over the seal while opening .Always stand upwind when mixing or loading the insecticides
6. Clean up spilled insecticide immediately from skin, clothing etc.
7. Persons engaged in handling, mixing or applying insecticides should not smoke, eat or drink while working.
8. Do not use mouth to siphon an insecticide from the container.
9. Avoid drift.
10. Guard against drift of insecticides on to near by crops, field, fish pond, stream or livestock
11. Do not spray when it is windy .
12. Do not spray or dust when it is likely to rain.
13. Do not use poor quality or leaky equipment
14. Take the most needed parts/tools to the field (site of application)
15. Never allow the children to apply insecticides
16. Do not blow out the clogged nozzles with the mouth

17. Cleanliness and maintenance of insecticide application equipments and keep separate sprayers for herbicides
18. Do not eat, drink or smoke during application operation and later do these only after washing hands and face thoroughly

19. Never leave insecticides and equipments unattended in the field
20. The insecticides should always be stored in their original containers and kept in a locked cup board where they are out of reach of the children and the domestic animals
21. These should be kept away from food or feed stuffs and medicines
22. Instructions found on the labels should be carefully read and strictly followed.
23. The empty containers, after the use of the insecticide, should be destroyed and should not be put into some other use.
24. Persons engaged in handling insecticides should undergo regular medicinal check-up.
25. In case of any suspected poisoning due to insecticides, the nearest physician should be called immediately.

INSECTICIDE POISONING AND ANTIDOTES

Symptoms of mild poisoning

1. Headache
2. A feeling Of Sickness (nausea)
3. Dizziness
4. Fatigue
5. Irritation of the Skin, Eyes, Nose And Throat,
6. Perspiration
7. Loss of Appetite

Symptoms of moderate poisoning

1. Vomiting,
2. Blurred vision,
3. Stomach cramps,
4. Rapid pulse,
5. Difficulty in breathing, constricted pupils of the eyes,
6. Excessive precipitation,
7. Trembling and twitching of muscles, fatigue and nervous distress headache,

Symptoms of severe poisoning

1. Convulsions
2. Respiratory failure
3. Loss of consciousness
4. Loss of pulse

Symptoms due to Chlorinated hydrocarbons poisoning

1. Uneasiness
2. Headache
3. Nausea

4. Vomiting
5. Dizziness and tremors
6. Convulsions
7. Respiratory arrest followed by coma
8. Leucocytosis and rise in blood pressure.

Symptoms due to organophosphate and carbamate insecticides poisoning

1. Headache, giddiness, vertigo, weakness, excessive mucous discharge from nose and sense of tightness are symptoms of inhaled exposures.
2. Nausea followed by vomiting, abdominal contraction, diarrhea and salivations are symptoms of ingestion.
3. Loss of muscle coordination, speech defects; twitching of muscles; difficulty in breathing; hypertension; jerky movements; convulsions and coma indicate seriousness of poisoning.
4. Death may occur due to depressions of respiratory centre
5. Headache, giddiness, vertigo, weakness, excessive mucous discharge from nose and sense of tightness are symptoms of inhaled exposures.
6. Nausea followed by vomiting, abdominal contraction, diarrhea and salivations are symptoms of ingestion.
7. Loss of muscle coordination, speech defects; twitching of muscles; difficulty in breathing; hypertension; jerky movements; convulsions and coma indicate seriousness of poisoning.
8. Death may occur due to depressions of respiratory centre

Zinc phosphide

1. Nausea
2. Vomiting
3. Diarrhea
4. Severe abdominal pain followed by symptom free period of eight hours or longer

Alluminium phosphide

1. Headache
2. Giddiness
3. Nausea
4. Diarrhea and mental confusion
5. If treatment is delayed, coma, loss of reflexes may develop and death may occur from respiratory or circulatory collapse

First Aid Operations:

Many accidental pesticide deaths are caused by eating or drinking the chemical. Some applicators die or are injured when they breathe pesticide vapors or get pesticides on their skin. Repeated exposure to small amounts of some pesticides can cause sudden, severe illness. All pesticide handlers should know and thoroughly understand first aid treatment for pesticide poisoning. Call local emergency response provider and local emergency medical facility immediately and

1. Remove patient to fresh air
2. Loosen all knots of clothes and change overalls.
3. Flush eyes with copious cold water till irritation subsides
4. Wash the patient thoroughly with plenty of soap and water.
5. Keep the patient calm, comfortable and warm.
6. In case of accidental ingestion ,induce vomiting by administering a glass of warm water mixed with two spoons of common salt or putting the forefinger at the base of plate.
7. Show label leaflet of pesticide for identification
8. If breathing is stopped provide artificial breathing.

Swallowed poisoning

1. Remove poison from the patient's stomach immediately byinducing vomiting.
2. Give common salt 15 g in a glass of warm water as anemetic and repeat until vomit fluids is clear.
3. Gently stroking or touching the throat with the finger or the blunt end of a spoon will aid in inducing vomiting when the stomach is full of fluid.
4. If the patient is already vomiting, do not give emetic butgive large amounts of warm water and then follow the specific directions suggested

Inhaled poisons

1. Carry the patient to fresh air immediately,
2. Open all doors and windows.
3. Loosen all tight clothing.
4. Apply artificial respiration if breathing has stopped or is irregular and avoid vigorous application of pressure to the chest.
5. Prevent chilling and wrap the patient in a blanket.
6. Keep the patient as quiet as possible.
7. If the patient is convulsing, keep him in bed in some dark room.
8. Do not give alcohol in any form.

Skin contamination:

1. Drench the skin with water.
2. Apply a stream of water on the skin while removing clothing.
3. Rapid washing is most important for reducing the extent of injury

Eye contamination:

1. Hold eye lids open
2. Wash the eyes gently with a stream of running water immediately
3. Delay of even a few second greatly increase the extent of injury

4. Continue washing until physician reaches
5. Do not use chemicals as they may increase the extent of injury.

Antidotes:

General antidotes:

1. Remove poison by inducing vomiting
2. Universal Antidote: It is a mixture of 7 g of activated charcoal, 3.5 g of magnesium oxide and 3.5 g of tannic acid in half a glass of warm water may be used to absorb or neutralize poisons. Except in cases of poisoning by corrosive substances, it should be fallowed by gastric lavage.
3. Removal of stomach contents (Gastric lavage.)
4. Demulcents : After removal of stomach contents as completely as possible, give one of the following:
    1. Raw egg white mixed with water
    2. Gelatine 9 g to 18 g dissolved in 570 ml of warm water
    3. Butter
    4. Cream
    5. Milk or Mashed potato

Specific antidotes:

1. Atropine is the usual antidote for organophosphate and carbamate poisoning. It can be given orally and in severe cases, injections are given. Repeated injections may be required.
2. 2 PAM: It is injected intravenously as an antidote in organophosphate poisoning. It should not be used in case of carbamate poisoning
3. Calcium gluconate is recommended as an antidote for some organochlorine insecticides
4. Vitamin K is the preferred antidote for anticoagulant poisoning such as warfarin.
5. Dimercaprol (BAL) is recommended for arsenic poison

INSECT RESISTANCE TO INSECTICIDES

The development of an ability in a strain of insects to tolerate a dose of an insecticide toxicant, which would prove lethal to majority of individuals in a normal population of the same species. The Division Entomology, IARI, New Delhi was the first to report insecticide resistance (IR) in the Singhara beetle, *Galerucella birmanica* in India . At present there are many insects have developed resistance to insecticides.

Resistance is of three types:

a. Simple resistance: Where resistance to only one insecticide and not to related ones

b. Cross resistance: Where an insect resistance to one insecticide and is also resistance to the related ones
c. Multiple resistance: Resistance to insecticides belong to more than one group of insecticides

There are three phases in development of resistance:

1. Resistance insects are very low in a population and insecticides gives a satisfactory control
2. With continuous use of the same insecticide or related ones, frequency of resistant individuals increases in leading to occasional crop failures.
3. Large increase of resistant individuals in a population and becomes ineffective.

Mechanisms of Resistance:

A. Physiological mechanism

a. Detoxification: Resistance to insecticide is due to the ability of insects to detoxify (degrade) toxicants by enzymes, mixed function oxidases (MFO). These detoxifying enzymes are more in resistant strains (R) than in susceptible (S)strains. These non-toxic break down products can be excreted or stored in the body without any harm to the insects
b. Cuticular penetration: Insecticides penetration through cuticle is slow in 'R' strains than in 'S' strains because of bristles, thick pulvilli etc
c. Increased storage: The ability of storing in the non sensitive tissues like fat body variable in 'R' and 'S' strains.
d. Increased excretion: 'R' strains detoxify and excrete insecticides faster than 'S' strains.
e. Penetration into target organs: A ChE is present only in ganglia, so a toxicant must enter the ganglia to inhibit AChE slow in 'R', fast in case of 'S'

B. Behavioural mechanisms:

a. Avoidance of treated areas: 'R' strains do not prefer treated surfaces.
b. Decreased period of contact: 'R' insects fly away from treated surface so contact period with treated area is less.

INSECT RESURGENCE

It refers to an abnormal increase in pest population or damage following insecticide application often for exceeding the EIL's. Pest resurgence mostly noticed in Homoptera, Lepidoptera and phytophagous mites. Resurgence occurs due to insecticides in two ways

1. They induce resistance in insects so that after an initial decline, they start growing in numbers again.

2. Insecticides not only kill the pests but also the natural enemies , thus natural control over the pests is minimized leading to their resurgence

A well-known example in rice cultivation is the resurgence of brown plant hopper (BPH). If no pesticides are used, BPH is kept under control by its natural enemies (mirid bugs, ladybird beetles, spiders and various pathogens). Pesticides kill the beneficials and create a situation where populations of BPH can multiply rapidly and thus become a man made pest

Insecticide(s)	Resurgence of insect species
Quinalphos , phorate , Carbaryl	
Deltamethrin, methyl parathion	
Monocrotophos,	- BPH
Synthetic pyrethroids	- Aphids, whiteflies, mite in cotton
Carbaryl	- Mites on mango and brinjal

INSECTICIDE RESIDUES

The very small quantity of insecticide that can remain in a crop after harvesting or storage and makes its way into food chain is called insecticide residues.Some insecticides continue to remain toxic for long periods after application this period of activity is called persistence or residual action

Pyrethrum and rotenone are less persistent (12 hrs) while Organochlorines are most persistent. Longer residual toxicity is desirable for pest control , it is not desirable from safety point of view to man ad his animals.

Maximum Residue Limits (MRLs) (Residue Tolerance Level)

The amount of the residue of the toxicant that can be permitted to be present in / on the produce used by man and his animals is called tolerance limits. It is expressed in ppm. The residues should not exceed than the tolerance limits when offered for consumption. It is measure of safety against the harmful effects of pesticide

Endosulfan - cabbage, brinjal, tomato	2.00 ppm
Malathion - cabbage, brinjal tomato	8.00 ppm

When pesticide residues persist more than their prescribed MRL , in fruits and vegetables, washing the contaminated fruits and vegetables could dislodge the residues to the extent of 20-25 % with water, 20-35 % with dilute solutions of salt, 40-60 % with detergent solutions and 40-100 % by peeling the fruit skin , processing and cooking.

Waiting period:

The waiting period must be observed between the time of pesticide application and harvest of produce so that toxicants are metabolized into non toxic level

Acceptable Daily In take (ADI):

It is the amount of a chemical in food and water that can be ingested on daily basis over a life time without appreciable risk. It is expressed as mg per kg body weight per day.

Insecticides Act, 1968:

The Government of India passed an Insecticide Act in 1968to regulate the import, manufacture, sale, transport, distribution and use of insecticides with a view to prevent risk to human beings or animals. All the provisions of the Insecticides Act was brought into force with effect from 1st August, 1971. In the Act and the Rules framed there under, there is compulsory registration of the pesticides at the Central level and licence for their manufacture, formulation and sale are dealt with at the State level.

With the enforcement of the Insecticides Act in the country pesticides of very high quality are made available to the farmers and general public for house-hold use, for protecting the agricultural crops from the ravages of their pests, humans from diseases and nuisance caused by public health pests and the health hazards involved in their use have been minimised to a great extent. For the effective enforcement of the Insecticides Act, the following bodies have been constituted at the Central level.

Central Insecticide Board: The Government has constituted Central Insecticides Board under the Chairmanship of Director General of Health Services with 29 members from different speciality and government organisations.

Functions:

1. To advise the Central and state Governments on technical matters on technical matters arising out of administration
2. To specify the uses of the classification of insecticides on the basis of their toxicity
3. To advise tolerance limits for insecticides, residues and an establishment of minimum intervals between the application of insecticides and harvest in respect of various commodities
4. To specify the shelf-life of insecticides

Registration committee

Registration Committee consisting of a Chairman and other five persons who shall be members of the Board. The main objective the committee is to register insecticide after scrutinizing their formulae and verifying claims made by the importer or the manufacturer, as the case may be, as regards their efficacy and safety to human being and animals. The function of the registration committee is to specify the precautions to be taken against poisoning through the use or handling of insecticides. For import and manufacture of insecticides, registration certificate is essential and a separate certificate for each insecticide.

Types of registration

A) Provisional registration: Provisional registration for 2 years for data Generation but not for commercialisation

B) Regular or full registration: is done when committee satisfy on the data produce.

C) Repeat registration: Registration for already registered product for a subsequent applicant. Data requirement is less.

Central Insecticide Laboratory:

1. To analyze samples of insecticides and submission of certificates of analysis to the concerned authority;
2. To analyze samples of materials for insecticide residues
3. To carry out such investigations as may be necessary for the purpose of ensuring the conditions of registration of insecticides;
4. To determine the efficacy and toxicity of insecticides

Lecture - 21

History of nematology, economic importance in Agriculture-Classification of Nematihelmenthes – General characters of plant parasitic nematodes

History of nematology:

The guinea worm, *Dracunculus medinensis* and round worms, *Ascaris lumbricoides* were known to Egyptians as early as 1553-1500 B.C as parasites of man.

William Shakesphere mentioned about plant parasitic nematodes in 1594 in his book" **Loves Labours Lost"** where he wrote the line " Sowed the ear cockle nematodes and called them "Vibrios".

In 1743, Needham discovered the Ear cockle nematode, *Vibrio tritici* (*Anguina tritici*) as the causal agent of "Cockles" in Wheat.

Later in 1858, Berkely reported root knot nematode from the roots of green house cucumber.

In 1857, Khun reported "Vibrios" *Anguillula dipsaci*, *Ditylenchus dipsaci* infesting the heads of teasel, *Dipsacus fullonum*.

In 1859, Schacht reported the sugarbeet cyst nematode, which was named as *Heterodera sachachtii* in 1871 from Germeny

In 1884 - **De Man** - Taxonomic monograph of soil and fresh water nematodes and

De Maris formula for measurement .

1891 - Ritzemaboss - First report of foliar nematode,

Aphelenchoides frageriae on strawberry.

1889-1937 -Flipjer - Manual of Agril. Helminthology.

1910 - Helminthological society of Washington

1953 - Mc Beth - Nematological property of DBCP

(DiBromo chloro picrin)

1957 - Hewitt, Raski & Goheen - Transmission of fan leaf virus of grapes by *Xiphinema index.*

These discoveries are considered to be the milestones of Nematology.

Important events in the field of Nematology is furnished below.

1837-1915 – **Bastian H.C,** published a monograph of "Anguillidae" in 1866 which marked the beginning of science of Nematology.

He was considered as "**Father of Nematology**".

1871 - **Kuhn** experimented with CS_2 as fumigant for control of sugarbeet Nematodes, *Heterodera schachtii*

1913 - **N.A.Cobb** published

"contributions to a science of Nematology"

lab manual "For estimating the nematodes population of soil" and

developed Sieving method for nematode extraction from soil.

He was considered as Father of American Nematology.

1941 - Discovery of potato cyst nematode, *Globodera rostochiensis* in Long Islands, USA.

1943 - **Carter** - Discovered the nematicidal properties of DD (dichloropropane-dichloropropene)

1945 - **Christie** discovered the nematicidal properties of EDB (ethylene dibromide)

1950 – **B.C. Chitwood** and **M.B. Chitwood** – publication of book "An introduction to nematology".

1955 – Founded European society of Nematologists

1956 – Publication of First Journal for plant parasitic nematodes "**Nematologica**".

1970 - Edward, J.C.& Misra,S.L.- First text book on Nematology, " An introduction to plant Nematology"

History of Nemotology in India:

"1901 - **Barber** reported - first ever report of a plant parasitic nematode from India "root-knot nematode infecting tea in south India"

1913 - **Butler** reported **Urfa disease** of rice from Bengal

1917 - Hutchinson - First report of Tundu disease of wheat, *Anguina tritici.*

1919 - **Milne** recorded seed gall nematode of wheat in Punjab

1926-34. **Ayyr** discovered root-knot nematode on vegetables and other crops in south India

1936 - **Dastur** reported **White tip** disease of rice caused by

Aphelenchoides besseyi

1956 - Thirumala Rao - First report of root-knot nematode on citrus.

1958 - **Vasudeva** reported **Molya disease** of wheat and barley in Rajasthan

1959 - Prasad Mathur and Sehgal - First report of *Heterodera avenae*

1959-61 - **Siddiqi** discovered plant parasitic nematodes from Uttar Pradesh including citrus nematode on citrus

1961 - **Jones** reported Golden nematode of potato from Nilagiri hills in Tamil nadu

1966 - **Nair, Das and Menon** reported burrowing nematode, *Radopholus similis* on banana in Kerala

1966 - Establishment of **Division of Nematology** at Indian Agricultural Research Institute, New Delhi

1969 - Founded Nematological society of India .

First All-India Nematology symposium held at the IARI, New Delhi

1971 - Commencement of publication of Indian Journal of Nematology

1977 - Establishment of All-India Co-ordinated Research Project on Nematode pests of crops and their control at New Delhi

1979 – All India nematology workshop and symposium at OUAT, Bhubaneswar

1986 – National conference on Nematology at IARI, New Delhi

1992 – Silver jubilee celebration of division of Nematology, IARI, New Delhi

2001 – Centenary celebration of Nematology held at Division of Nematology, IARI, New Delhi.

Economic importance of Nematodes in Agriculture

The science that deals with study of nematodes is known as Nematology.

The branch of nematology that deals with animal parasites is known as **Helminthology**.

The branch of nematology that deals with plant parasites is known as **Phytonematology.**

Nematodes occur in soil and water and are ubiquitous in nature. In agricultural soils, plant parasitic species are known to occur to a depth of at least 17 feet. One gram of soil has 101 nematodes. There are about 30,000 described species, of which 50% are marine,25% free living (found in soil and water), 15% are animal parasites and 10% are **plant parasitic**. Some are **entomopathogenic** with insect killing ability through parasitism.Eg: *Heterorabditis* sp and *Steinernematidis* sp

Plant parasitic nematodes present in soil are the most difficult pest problems encountered in our country. The damage of nematodes to a crop may be to roots, stems, crowns, leaves, buds or developing seeds. The degree of damage depends upon the crop/ cultivar, nematode species, level of soil infestation and environment. Damage result in affecting plant growth resulting in low yields and poor quality.

Annual loss due to namatodes in the world has been estimated to the tune of 1000 billion dollars . Annual loss due to seed gall nematode *Anguina tritici* responsible for Ear Cockle Disease in North India is about 10000 tonnes of Wheat costing more than 70 million rupees. The golden cyst nematode of potato *Globodera rostochinensis* is a serious problem in about 3050 hectares in Nilgiri Hills and 200 hectares in Kodaikanal hills. The annual loss to Indian Coffee due to root lesion nematode *Pratylenchus coffeae* is estimated to be about 40 million rupees. AICRP on nematodes has reported an yield loss in vegetables varying from 6 to 90 %.

The groundnut yield in Rayalaseema particularly in Chittor district has been significantly reduced due to” Kalahasti Melody” for which nematodes are responsible.

Classification of Nematihelmenthis :

The nematodes have bee placed with in the kingdom –Animalia , sub-kingdom-Invertebrata and phylum – Nematihelmenthis

The concept that nematodes belong to phylum Nemata or Nematoda was first proposed by N.A.Cobb (1919) and later supported by Maggenti (1971 & 1981).

Nematodes are cylindrical, bilaterally symmetrical, unsegmented, pseudo coelomic (body cavity without epithelium), triploblastic (ie having three germ layers) , microscopic organisms with well developed digestive, excretory and reproductive systems and no respiratory and circulatory systems.

The word 'Nematode" is derived from the Greek word, '**nema**' means threads and '**oides'** means resembling or like.

Nematodes are called as either eel worms or nemas or round worms .

Phylum Nematoda is divided in to two classes viz.,

Secernentea (Phasmida) and

Adenophorea (Aphasmida)

Characters of nematodae classes

Character	**Secernentea**	**Adenophorea**
Orders	Tylenchida, Aphelenchida	Dorylaimida
Habitat	Exclusively terrestrial, rarely fresh water or marine	Marine, fresh water and terrestrial
Amphids open on	Head near lip region	Behind head ie post labial
Oesophagous divided in to	Procarpus, isthmus and glandular terminal bulb with or without median bulb	It is cylindrical with an enlarged glandular base
Caudal glands (Three elongated cells in or near the tail)	absent	present
Male tail	Have caudal alae (bursa)	Lack bursa but possess genital papillae
Excretory system	Possess a transverse duct with lateral canals	Lacks lateral canals and excretory duct ends in a cell

Class **Secernentea** is divided in to three sub classes namely

Rhabditia - Entomopathogenic nematodes

Diplogasteria – Entomopathogenic and plant parasitic nematodes

Tylenchia (Spirulia)- Parasitic on birds, Ascaris and Fish

Class **Adenophorea** is divided in to two sub classes namely

Chromadoria -

Enopila –

Orders under different sub classes:

Rhabditia	**Diplogasteria**	**Tylenchia (Spirulia)**	**Chromadoria**	**Enopila**

Rhabditida	Diplogastrida	Tylenchida	Araiolamida	Enoplida
Oxiurida	Drylonematida	Aphelenchida	Menohysterida	Dorylaimida
Stronglida			Desmodarina	Monochida
			Chromodorina	Mermithida
			Desmoscolaicida	

Plant parasitic nematodes belong to three orders namely

Tylenchida, Dorylaimida and Aphelenchida

Characters of Plant parasitic nematode orders:

Character	**Tylenchida**	**Aphelenchida**	**Dorylaimida**
Stoma	Has protrusible stomato stylet	--	Is with mural tooth/an axial spear called as odanto or onchio stylet
Oesophagus	Has three parts	Dorsal oesophagal gland opens with in median bulb of oesophagus	Two parts- anterior part slender , posterior part expanded with 3 to 5 gland nuclei
Caudal alae	Not provided by ribs	Males with out caudal alae except Aphelencha and Metaaphelencha	
Cuticle	With distinct annulation		
Median bulb		Angular and occupy entire body diameter	
Amphids			Variable in size

The plant parasitic nematodes are classified it two groups based on plant part damaged.

I. **Above ground feeders:**

1. Seed gall nematodes (*Anguina tritici*)

2.Leaf and bud nematode (*Aphelenchoides* spp.)

3. Stem and bunematode (*Ditylenchus* sp.)

II.**Below ground feeders :**

Based on mode of feeding , they can be divided in to three groups

i) Endoparasites

a) Sedentery:

Root knot nematode (*Meloidogyne* spp)

Cyst forming nematodes (Heterodera and Globodera)

b) Migratory:

Lesion nematode (*Pratylenchus* sp)

Burrowing nematode (Radopholus similis)

Rice root nematode (*Hirschmaniella* sp)

ii) Semi Endoparasites :

a) Sedentery:

Citrus nematode: (*Tylenchulus semipenetrans*)

Reniform nematode (*Rotylenchulus reniformis*)

b) Migratory:

Spiral nematode (*Helicotylenchus*, *Rotylenchus*)

Lance nematode (*Hoplolaimus* sp.)

Stunt nematode (*Tylenchorynchus*, *Microlinus*)

iii) Ectoparasites :

a) Sedentery:

Ring nematode (*Criconema* sp, *Cricuneroides* sp)

Shead nematode (*Hemicriconemoides* sp , *Hemicycliophora* sp)

Pin nematode (*Pratylenchus* sp)

b) Migratory:

Needle nematode (*Longidorus* sp)

Dagger nematode (*Xiphinema* sp)

Stubby nematode (*Trichodorus* sp)

General Characters of Plant Parasitic Nematodes :

Nematodes are cylindrical , bilaterally symmetrical , unsegmented, pseudo coelomic (body cavity without epithelium), triploblastic (ie having three germ layers) , microscopic organisms with well developed digestive, excretory and reproductive systems and no respiratory and circulatory systems.

In general nematodes are **dioecious** (males and females are separate).

For sucking the food material from the plant parts the plant parasitic nematodes possess protrusible piercing **sphere/ stylet** (ie Stomato stylet (Axial holosphere) in Tylenchida and Aphelenchida , **Odonto stylet** in Dorylaimida , **Onchio stylet** (Solid stylet) in Trichodorida).

All Plant Parasitic Nematodes prefer sandy loam soils. Due to their microscopic nature and passive mode of life, their role in Agricultural Production remained underestimated.

Lecture - 22

Different Functional Systems of Nematodes

Morphology

Body shape & size

Sexual dimorphism occur in some members of Tylenchida, where females become swollen and males are vermiform.

Eg. *Anguina, Meloidogyne, Heterodera, Rotylenchulus* and *Tylenchulus* etc.

Size vary from 0.2mm (*Pratylenchus*) to about 11mm (*Paralongidorus maximus*) averaging about 1.0mm in length. Width range from 0.01 to 0.5mm. The nematode parasitising whale fish is about 27 feet long.

Body Posture:

Nematode, when relaxed by gentle heat, remain straight (*Pratylenchus)*,

Slightly curved ventrally (*Hoplolaimus),* curved dorsally into 'C' shape(*Dorsalla)* Curved into 'e' shape (*Tylenchorhynchus)* or spiral (*Helicotylenchus).*

Body is not segmented. However, body appears segmented as annulations of cuticle as in *Criconema.* Body show radial symmetry in the anterior region and asymmetry in intestine, excretory and reproductive systems.

Body at the anterior region has **mouth**, **lips** and **stoma** forming the head position. Behind the head and base of Oesophagous is the neck, from anus and extending to the posterior extremity is the tail.

Body longitudinally can be divided into four zones, ventral side having the natural openings i.e. excretory, anus and vulva. Side opposite to ventral is dorsal.

Head or lip region:

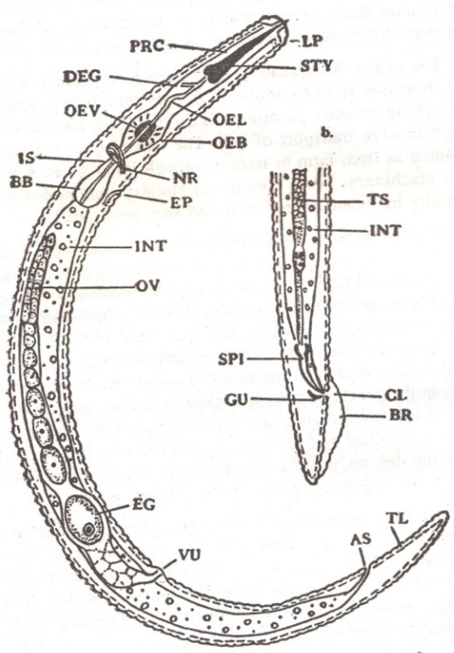
In some nematodes (*Ecphyadiphora)* head in merged with body or it may be truncates (*Duotylenchus*)or it may be distinctly set off (*Dolichodorus)*.

Around the lip region, number of **annules** formed by transverse striae are present. However, longitudinal striations are also found in lip region of *Hoplolaimes* that gives **tick like** appearance.

Tail:

Present in male, female and larva. Tail vary in shape and size. Sometimes it may be different in larva and adult or it may be present in larva but reduced or absent in adult as in *Heterodera* and *Globodera.*

Tail is a **locomotory** organ useful for **swimming** in aquatic nematodes. Other structures present at tail region include **caudal alae**, **bursa** and **genital papillae** that help in reproduction. Tail tip may be filiform, conoid, hooked short bluntly conoid, hemi-spheroid or clavate type.



A typical female nematode, b. Posterior portion of a male nematode, AS, Anus; BB, basal bulb; BR, Bursa; CL, Cloaca; DEG, dorsal oesophageal gland opening; EG, egg; EP, excretory pore; GV, Gubernaculum; INT, intestine; IS, isthmus; LP,lip; NR,nerve ring; OEB,median oesophageal bulb; OEL, oesophageal lumen; OEV, oesophageal valve, OV, ovary, PRC, procorpus, SPI, spicule, STY, Stylet, TL,Tail; TS, testis, VU, vulva.

General structure of Nematode:

Body is tubular and divided into three regions

1. Outer body tube or body wall.

2. Inner body tube or alimentary canal.

3. Body cavity or Pseudocoelom in which excretory, nervous and reproductive system are present.

1. Outer body tube:

Consists of three layers; the cuticle, epidermis(hypodermis) and somatic muscle layer.

Cuticle: is the outermost layer non cellular secreted by epidermal cells derived from ectoderm serves as exoskeleton and protect the inner soft body tissues.

Cuticle has three layers

1. Outer cortical - has keratin and collagen disulphide group – give resistance nature.
2. Matrix - Consists of protein resembling collagen. It is not metabolically active layer.
3. Fibre Layer - protect nematode from environment.

Hypodermis / Epidermis : It lies between cuticle and somatic layer. It is responsible for formation of cuticle. In higher nematodes it is rich in lipids and glycogen which serve as source of reserve energy .

Somatic muscle layer:

These are arranged longitudinally beneath the hypodermis in the interchordal zones.

Based on arrangement the following types of cells are present

1. Holomyarian - Have 2 muscle cell in each zone.
2. Meromyarian - 2 or 5 muscle cells in each zone.
3. Polymyarian - More than 5 muscle cells per zone

Based shape of cells they are grouped in to –

1. Platymyarian - flat type of muscle cell
2. Coclomyarian - 'U' shaped cell muscle fibre are adjacent and perpendicular to epidermis
3. Circomyarian` - Muscle fibre completely surround the cytoplasm

Nematode muscles are unusual, in that muscle sends branches to nerves rather than nerves send branches to muscle.

<u>Inner body tube or digestive system:</u>

It is divided in to **stomodeum** (foregut), **mesenteron** (Midgut) and **proctodeum** (Hindgut). Foregut and hindgut are **lined with cuticle**. Proctodeum is small and includes the **rectum** in females and **cloaca** in males, Midgut is **endodermal** in origin.

Stomodeum: It includes mouth and lips, the stoma and the oesophagus. Six lips surround the mouth.

Mouth cavity is called **stoma or buccal cavity** forming the feeding apparatus.

In the order Tylenchida, stoma has protrusible hollow stylet, formed by the fusion of stomal walls, hence called **stomatostylet.**

In the order, Dorylaimida, stylet is formed from oesophagial wall, hence called **Odontostylet**

It is a replaceable stylet, it is also called **Odontostyle or Ononio stylet**

Phaynx or Oesophagus : It is found between stoma_and intestine. Serves to pump food from stoma into intestine. Oesophagus may be simple consisting of cylindrical muscular tube as in Monenchida.

In Dorylaimida, it is bottle shaped and with narrow anterior and broad posterior part.

In Tylenchida, cylindrical oesophagus has 3 parts i.e. **corpus**, **isthumus** and **basal bulb**. Corpus is further divided into anterior cylindrical **procorpus** and swollen **metacarpus.**

Mesenteron : It is divided into 3 distinct regions (1) anterior ventricular region,

(2) mid intestinal region and (3) posterior or pro rectal region. Inside, plasma membrane is thrown in to finger like projection called **microvilli ,** which are **secretary and absorptive** in nature.

Proctodeum : Rectum is a narrow tube connecting intestine in the slit like anus in females and cloaca in males.

In Dorylaimida, a distinct region known as **prerectum** is found between intestine and rectum.

In some nematodes, rectal glands which are 3 in females and 6 in males are present, which are responsible for production of gelatinous matrix in which eggs are laid.

Body Cavity:

Body cavity is devoid of **mesoderma**l lining,hence, it is called **pseudocoelom**.. Externally it has somatic muscle cells and internally cells of alimentary canal. Pseudocoelom is filled with fluid which is rich in proteins and bathes all internal organs and functions as part of the **turgor pressure** system on the exoskeleton.

The pseudocoelom is also linked with a network of fenestrated membrane that support visceral organs.

Excretory system:

Different types of excretory systems are found in Nematodes, **Vonlinstow**, 1909 classified nematodes into **4** groups based on excretory system viz:

1. Secerentes 2. Resorbents 3. Pleuromyarli 4. Adenophori.

Now secerentes are synonymous to resorbants; Pleuromyarli with Adenophori.

Morphologically excretory system is of two types

(1) **Renette type** has large cell in the pseudo coelomic cavity known as renette or ventral gland, which is connected to the excretory pore by a duct Eg. Adenophorea

(2) **Tubular** or **Canalicular** type : Eg. Secernentea

Tubular type that may be

(a) simple H shaped (Oxyuroid type)
(b) Rhabditoid type
(c) Ascaridid type 3 Nuclei (Invented U shape)
(d) Asymmetrical type or uni nucleate system.

In tylenchida, the terminal duct points the lateral canal and there are (2) nuclei,

The excretory system also plays important role in osmoregulation, in addition to excretion so it is called as excretory secretory sytem.

Reproductive system:

Nematodes are **dioceous or amphigonus** having separate males and females within a species. Generally males are less in number than females or may be absent completely, indicating reproduction by hermaphroditism or parthenogenesis.

Hermaphroditism: -an individual function both as male and female. It may be

1. **Syngonic Hermaphroditism:** gonads first produce sperms that are stored and fertilize eggs produced later .

Eg. *Caeonoshabditis briggsae*.

2. **Digonic Hermaphroditism** : Both sperms and ova are produced simultaneously by different parts of same gonad.

Eg. *Helicotylenchus sp.*

Parthenogenesis: If males are not found or less in number , eggs can reproduce without fertilization.

Eg. *Meloidogyne, Heterodera, Tylenchulus*.

Intersexes are found in some genera like *Meloidogyne_* and *Ditylenchus* – it is an individual that show blending of both male and female characters usually females showing male characters of pseudo coelomic fluid. The nervous, excretory and reproductive system are present in pseudocoelom.

Male reproductive system:

Nematode may consists of one or two testes ,If it is only one testes – it is called **monarchic,** Two testes – **diarchic.**

In diarchic forms testes may be outstretched i.e directed opposite to each other except in *Meloidogyne* where they are in parallel position. Males have testes, seminal vesicle and vasa difference.

Male nematodes have a pair of **copulatory spicules** which are lodged in the spicular pouches formed as out growths of dorsal wall of the rectum.

Spicules are tubular structures covered by sclerotized cuticle. It functions to open the vulva for transfer of sperms during copulation.

Spicule is divided into 3 parts:

1. Head known as **capitulum.**
2. Shaft known as **corpus or calomus**.
3. The blade or **lamina** that tapers to tip.

Gubernaculum : Sclerotized plate like structure located dorsal to the spicules.

Eg. *Tylenchorhynehus , Ditylenchus.*

Sexual dimorphism is very common among females of ***Meloidogyne ,*** where they are swollen and males are slender, worm like

<u>Female Reproductive</u> :**system**

The female has a single ovary, it is called as **monodelphic**. If at anterior to vulva, monodelphix or **prodelphic ,** posterior **– opisthodelphic**, two ovaries – **didelphic;** among the two, if one is towards anterior other is towards posterior end of the body, it is called **didelphic**, **amphidelphic**. However, in *Meloidogyne* and *Heterodera* , both the gonads are directed towards the anterior end of the body with reflexed ovaries, it is called didelphic, prodelphic.

Female reproductive system consists of an ovary, oviduct, uterus, vagina and vulva,

Eggs have outer protein layer, chitinous layer, a vitelline or lipid membrane

Gelatinous matrix is secreted by rectal glands in which eggs are deposited. If eggs are laid outside the body – it is called **exotoky.**

Eggs deposited with the body of female – **endotoky**

Nervous system:

It is not well studied in nematodes particularly in Tylenchida due to its small size. The central nervous system has nerve ring, associated ganglia and the ventral nerve. The nerve ring is broad, flat present around the oesophagus.

In Tylenchida, it encircles the middle part of the oesophagm.

In Dorylaimida, it is present around the narrow anterior part of oesophagus.

Ventral nerve is a chain of ganglia. The first and largest ganglia is known as

Retro – vesicular ganglia

Sensory organs

Amphids : lateral pair of sensory organs or chemoreceptors present in the cephalic region of the nematode. They are larger in males than females.

Phasmids: Paired lateral sense organs usually one on each side of tail.

Deirids: paired papillae present in the oesophageal mid region of the body opposite to the excretory pore. Do not open outside Also called as **Cervical papillae** function as mechanoreceptors.

Hemizonids and Hemizonion : Highly refractive biconvex structure forming a semi-circle on the ventral side of the body and ending at the lateral fields.

Hemizonion is a small nerve commisure.

Cephalids: Highly refractive band like structure present in the cuticle dorsally.

Caudalids: small nerve commissure in caudal region slightly posterior to anus.

Lecture - 23

Biology and Ecology of nematodes-types of parasitism-complex diseases caused by nematodes:

Biology :

The plant parasitic nematodes have 6 stages in their life cycle. They are

1. Egg ,
2. First stage larva/juvenile (J_1)
3. Second stage larva/juvenile (J_2), 4. Third stage larva/juvenile (J_3)
5. Fourth stage larva/juvenile (J_4) and 6. Adult

The first stage juvenile undergo molting with in the egg after hatching and second stage juveniles will be released into the soil, which is the infective stage. Larva or juvenile undergo moulting thrice and then develops into adult.

The female lays eggs in the soil or plant tissue either singly or in masses that hatch into larvae which are almost similar to adults in appearance. The first moulting usually occurs before hatching when the larvae is within the egg shell. The larva undergoes series of four moults. The period of growth between moults are called juvenile stages.

The first larval stage is ended by the first moult, the 2nd stage by second moult. After 4th moult the adult is formed. In case of *Xiphinema index* the larvae emerge from the egg before the first moult. The larval cuticle is shed after each moult.

The average number of eggs laid by nematode may be 200-500. The total lifecycle will be completed in 20-40 days.

NATURE OF DAMAGE:

Majority of phytophagous nematodes are polyphagous infecting wide range of hosts among which a few may be more favourable than others. These nematodes feed on plant tissues by sucking sap from the host cell with the oral stylet that is used as a hypodermic needle to puncture the host cell. Nematodes usually cause damage by

Mechanical injury – by penetration and movement through plant tissues causing cellular changes like necrosis – death of cells and causes some

Physiological changes in the host by interruption in uptake of nutrients and water from roots as vascular bundles get damaged.

Provide avenue for **entry of other microorganisms**

Interaction with other **disease causing organisms**

Transmission of disease causing organisms and

Increase susceptibility to **environment stress**

Classification of Nematodes (based on plant part damaged).

I. **Above ground feeders:**

1. Seed gall nematodes (*Anguina tritici*)

2.Leaf and bud nematode (*Aphelenchoides* spp.)

3. Stem and bunematode (*Ditylenchus* sp.)

II.**Below ground feeders :**

Based on mode of feeding , they can be divided in to three groups

i) Endoparasites: remain inside the host and feed

a) **Sedentery:** enter in to the root and settle at one place for feeding

Root knot nematode (*Meloidogyne* spp)

Cyst forming nematodes (Heterodera and Globodera)

b) **Migratory:** enter in to the root system and feed from cells as they migrate

Lesion nematode (*Pratylenchus* sp)

Burrowing nematode (Radopholus similis)

Rice root nematode (*Hirschmaniella* sp)

ii) Semi Endoparasites : half of the body remain outside and half inside the plant tissue

a) **Sedentery:** only anterior portion will be inserted in to plant tissue and settle at one feeding site.

Citrus nematode: (*Tylenchulus semipenetrans*)

Reniform nematode (*Rotylenchulus reniformis*)

b) **Migratory:** only anterior portion will be inserted in to plant tissue and move from one site to other feeding site

Spiral nematode (*Helicotylenchus*, *Rotylenchus*)

Lance nematode (*Hoplolaimus* sp.)

Stunt nematode (*Tylenchorynchus*, *Microlinus*)

iii) Ectoparasites : nematode remain outside the host and suck the sap

a) **Sedentery:** remain outside the host throughout its life and settle at place for feeding

Ring nematode (*Criconema* sp, *Cricuneroides* sp)

Shead nematode (*Hemicriconemoides* sp, *Hemicycliophora* sp)

Pin nematode (*Pratylenchus* sp)

b) **Migratory:** remain outside and move from one feeding site to the other

Needle nematode (*Longidorus* sp), Dagger nematode (*Xiphinema* sp)

Stubby nematode (*Trichodorus* sp)

Symptoms of nematode infection:

Nematode infected plant lack vigour and have reduced ability to withstand drought and adverse conditions. Various types of symptoms due to nematode infection are furnished below

A. Above ground symptoms:

1. **Distorted and abnormal growth**: *Anguina tritici* larvae feed on the growing point of wheat seedlings without killing it. The affected plant show twisted and crinkled leaves. *Aphelenchoides* spp. associated with straw berry disease known as 'spring crimp' & 'summer crimp' , here the leaves become crinckled abnormally dark in colour & brittle.
2. **Leaf galls:** some spps of *Anguina* produces galls on leaf surface.
   Eg: *A. tumifaciens* produces galls on *Cynodon transvalenses & A. graminis* on *Festuca ovina* & *F. rubra.*

3. **Seed galls:** Eg: *A. tritici* on wheat. The nematode larvae feed on floral primodia & seeds gall become green & soft in initial stage & later on turned into black –brown hard structure. and *A.agrostis* on *Agrostis tenuis*.

4. **Stem galls:** A number of spp of *Anguina* forms galls on *Cyanodon transvalensis.* These galls may be greenish or reddish in colour.

5. **Necrosis & discolouration of foliage & stem:** Discolouration of stem & foliage may range from light to dark shades & these symptoms are not very specific. Eg: *Aphelenchoides ritzembosi* causes interveinal discolouration in Chrysanthemum & strawberry and a similar symptom is produced by *Ditylenchus dipsaci* on aster leaves. On coconut, *Rhadinaphelenchus cocophilus* produces a band of necrotic tissues in the lower part of the stem & which turns reddish in colour due to death of cells.

6. **Lesion & spots:** The foliar nematodes causes destruction of leaf parenchyma which may appear in the form of spots or lesions. The spots first appear on the lower side of leaf surface as small yellowish areas, which later turned to brown & finally black in colour. These spots may coalesce together & the entire leaf is destroyed.

Eg: *Aphelenchoides ritzembosi* on chrysanthemum *& A. fragariae* on Begonia.

7. **Devitalised buds:** This type of symptom may result in killing buds or growing points & stopping further growth of the affected tissues. *A.besseyi & A. fragariae* may cause this type of injury on strawberry.

B. Below ground symptoms:

Nematode produces a wide range of symptoms on under ground parts of the plants which may be specific or non specific types.

1. **Root galls & cysts:** Galling of roots is the most characteristic symptom produced by root knot nematodes. Small root galls can be produced by *Hemicycliophora arenaria* on citrus, by *Xiphinema diversicaudatum* on roses. The size & number of galls may vary with host crops & nematode spp. . In cyst nematodes the presence of white to brown cyst projecting on root surface is seen.

2. **Root proliferation:** Some spp of nematodes do not cause generally decay of roots. But due to injury plants grow more roots in cluster, especially behind the damaged portion. *Heteroderous sp., Globodera rostochinensis , Trichodorous christei & Meloidogyne* sp. produce such type of symptoms.

3. **Lesions & necrosis:** Typical lesions are produced by the lesion nematodes, *Pratylenchus sp.,* burrowing nematode, *Radopholus similis* & rice root nematode, *Hirschmaniella sp*. Ectoparasitic nematodes may cause superficial discolouration & injury due to killing of cells over large area. Eg: *Xiphinema sp., Tylenchulus semipenitrans & Aphelenchoides sp.*

4. **Devitalised root tips:** Many nematodes penetrate roots just behind the root tip resulting in stoppage of further growth & a situation arises when the root system appears to be composed of cluster of stubby roots. Eg : *Trichodorous* & *Belomolaimus sp*. Sudden halt in growth of lateral roots just as they are emerging from main roots.

5. **Root rots:** Many nematodes parasitizing fleshy roots serve to initiate & increases the activity of many other micro organisms. Once the nematodes have started the damage of root system, other secondary micro organisms enter through the injuries causing extensive tissue destruction. Eg : Infection of potato by *Ditylenchus destructor*.

Association of nematodes (as vectors) with other plant pathogens:

A. Nematode- bacterium Association :

1. Tundu Disease/Yellow slime/ear rot of wheat :

Nematode, *Anguina tritici* acts as a vector carrying the bacterium *Corynebacterium tritici* causing above disease.

2. Bacterial wilt in Cotton:

Nematode , Ditylenchus dipsaci

3. Bacterial wilt in potato and tomato:

Nematode , *Helicotylenchus naunm* transmits the bacteria *Pseudomonas solanacearum*

B. Nematode –Virus Association :

1. Tomato Mosaic viral Disease:

Transmitted by nematode *Meloidogyne javanica*

2. Tomato Leaf curl viral Disease :

Transmitted by nematode *Meloidogyne incognita*

3. Cow pea mosaic viral Disease :

Transmitted by nematode *Meloidogyne incognita*

4. Fan leaf disease of Grape (NEPO) :

Transmitted by nematode *Xiphinema index*

NEPO : Nematode Transmitted Polyhedra Viruses

NETU: Nematode Transmitted Tubular Viruses

C. Nematode –Fungus Association :

1. Wilt Diseases :

Nematode , *Meloidogyne incognita* predisposes plants like cotton, tomato, tobacco, chickpea to the attack of wilt causing fungi ie., *Fusarium, Phytophthora, Pythium, Rhizoctonia, Sclerotium, Verticilium* sp etc.

2. Root Decay in Citrus:

Citrus root nematode aggravate the above disease by transmission of *Fusarium solani*

3. Wilt in Maize :

Haplolaimus indicus (Lance nematode) & *Fusarium moniliformae* show maximum wilt symptoms in Maize.

Lecture - 24

Different types of nematodes

1. Seed gall nematode: *Anguina tritici*

Host Range: Wheat

First plant parasitic nematode identified . Nematode larvae revived even after 28 years of storage.

- Obligate plant parasites with obese body.
- Female spiral in form and immobile.
- Males usually shorter than females.
- Infective stage: **juvenile stage (J2).**
- The juveniles moult thrice in quick succession within 3-5 days after invasion of flower primordia and change into adult males and females.

Symptoms:

- Nematode infected seedlings show slight enlargement of basal portion of the stem after about 20-25 days of germination.
- Leaves emerging from the seedling are twisted and crinkled, often folded with their tips held near the growing point.
- Infested plants generally show profuse tillering.
- Glumes may be loosely arranged and **galls** replace the seeds.
- Conversion of all or few grains in the ear into **cockles**.

2. Stem and bulb nematode: *Ditylenchus sp.*

Host Range: Paddy , potato, mushroom (*D.myceliophagus*) and Onion

Important pest during storage.

- Rarely striated head, lip region is without dovious annuls.
- Oesophageal glands may overlap intestine slightly.
- Female with monodelphic, prodelphic ovary.
- Male with one testis.
- Infective stage - **juvenile stage (J4)**

- **Symptoms:**
- The leaves may become slightly thinner and more flaccid and sometimes chlorosis may be observed.
- The chlorotic portion of leaves becomes brown to dark brown.
- Twisting of leaf and leaf sheath.
- Panicles do not emerge and are enclosed completely within the flag leaf sheath.

3. Leaf and bud nematode: *Aphelenchoid sp.*

Host Range: Rice, mushroom ,strawberry and chrysanthemum

- Cuticle is marked by fine transverse striae.
- Lip region is not striated.
- Spear is with thickening at the base but without well developed knobs
- Female with single ovary out stretched. Vulva posterior,
- The nematode is carried beneath the hull of the rice kernel in quiescent, immature, usually preadult stage.
- These nematodes do not survive in the soil after harvesting and are not transmitted through seeds.
- Infective stage - **juvenile stage (J2)**

Symptoms:

- White tip of seedlings.
- Initially the seedling growth is stunted and germination is delayed.
- Turning of 3-5cm of leaf tip into pale yellow to white colour at the tillering stage.
- The emerged panicles are generally short and flower becomes sterile.
- Glumes of affected spikelets are white and do not change in shape and size.

4.Red ring nematode: *Rhadinaphelenchus cocophilus*

Host Range: Coconut

Very slender body, massive sclerotization of the labial arches, elongated medium bulb , wide vulvar flap, curved vagina, speculum form and sclerotized spade like extension of male tail.

- Transfer of nematodes is purely mechanical through palm weevil *Rhynchophorus palmarum*

Symptoms:

- Yellowing and browning of the leaves begin at the base of the tree and progress upward till the leaves die, break and hang down.
- A cross section shows 1-2 inches **red ring** that extends from the base of the trunk to a height of 4 feet or more.
- Infested roots show discoloured tissues.

5.Root knot nematode: *Meloidogyne sp.*

Polyphagous

Host Range:Tomato, brinjal, bhendi, chilli, cowpea, greengram and tobacco

Female:

- The cuticle is transcuscent and glistening giving the white , pearly appearance to the nematode.
- the posterior end of the females possess distinctive arrangements of striae about the vulva- anus areas(perineal area).
- The excretory pore is infront of the muscular bulb of the oesophagus and close behind the stylet base.

Male:

- Vermiform, having blunt tail and slightly tapering neck region.
- Spicules simple, curved and gubernaculum is small.
- Caudal alae absent.

Symptoms:

- The infected plants usually exhibit yellowing of foliage, reduced unthrifty growth, smaller foliage, poor and fewer fruits and a tendency to wilt during warmer parts of the day.
- Poor emergence and death of young seedlings .
- Early poor fruiting for a relatively shorter period .
- Wilting and drying of crop in the field in patches.
- Presence of **galls or knots** on roots is the important diagnostic symptom

6. Cyst nematode: *Heterodera sp. and Globodera sp.*

Host Range: Wheat, Barley. Rie, Oats, Pulses and Potato etc

- **Heterodera:**
- the mature cyst is **lemon shaped** with a short neck and terminal cone
- Male vermiform, stylet and oesophagus well developed, tail end twisted, spicules robust with out bursa.
- **Infective stage :** juvenile stage(J2)

Globodera:

The mature cyst **spheroidal** (round) with a short projecting neck, terminal region not forming a cone.

- Vulval fenestra circumfenstrate, no anal fenestra.

Infective stage : juvenile stage(J2)

Symptoms of potato cyst nematode:

- The disease usually occurs in patches under severe infection
- Stunted growth, general necrosis, in severe infection
- The newly formed tubers are few in no. and considerably reduced in size.

Symptoms of *Heterodera avenae*:

The effected fields usually give patchy appearance during initial stages of infection.

- Stunted growth, general necrosis, in severe infection, there may not be any grain formation.
- Infected roots are short, with multiple branches giving a bunchy appearance.

7. Root lesion nematode(*Pratylenchus sp.)*

The head is relitively broad and continuos with body. Tail blunty rounded.

Symptoms:

In infected plants exhibit thin stem, leaves are small ,chlorotic ,crinkled and diseased plants are stunted ,become prematurely old.

The roots of diseased plants show discreate elliptical lesions in the intial stage which are yellow, brown or black in colour.

The infected plants can be easily pulled out from the ground.

The wounds caused by nematode are invaded by secondary pathogens like fungi and bacteria.

8. Rice root nematode*(Hirschmanniella sp*.)

It is migratory, endoparasitic aquatic nematode. Spear shape well developed.Tail is abruptly conoid with a mucro at the terminous.

Sympotoms:

Damage to roots, retardation of growth ,stunting of plants chlorosis and reduction in tillers can be observed .

In case of severe infection, flowering is delayed by about 12 to 15 days resulting in late maturation of crop.

Infected root exhibits necrosis and browning and too much vaculation in the cortex.

9. Burrowing nematode(R*adopholus sp*.)

Host Range: Wheat, Barley. Rie, Oats, Pulses and Potato etc

Both adult female and male are vermiform .In female, the lip region rounded, marked by striae.

Tail is concoid to blunt with rounded terminus.in adult males, lip region is subspherical with or without striae.

Infective stage: Juvenile (J3) and adult Female

Symptoms:

Spreading decline of citrus: (*R.citrophilus)*

Infection results in stunted plants with sparce foliage, small fruits and retarded terminal growth.

Trees possess large number of drying branches. Typical lesions are found on new roots

Root and rhizome rot banana:

Leaf chlorosis, dwarfing, thin pseudostem, small bunches and premature lodging of plants occur due to nematode infection.

Yellow disease of pepper:

Infection results in increase in the number of yellow leaves , arrests growth of veins, leading to severe die back and death of the plants

10. False root knot nematode (*Nacobbus sp.)*

Female body is swollen and irregularly shaped . While male is typical filiform with short tail enveloped by a narrow bursa.

Large galls frequently contains no living female and only masses of darkened tissues are found . Cell wall collapses and enlarged cells are formed due to coalesion of adjacent cells .

11. Citrus nematode (*Tylenchulus semipenetrans*)

Females long with variable saccate body, stylet short , blunt tail.

Male: Slender, vermiform, stylet and oesophagus degenerated

Symptoms:

Infection results in reduced terminal growth, chlorosis and shedding of leaves, dieback of branches, and reduction in size and number of fruits. Infected fibrous roots show irregular thickening and exhibit extensive necrosis which give them a rust brown colour.

12. Reniform nematode (*Rotylenchulus sp.)*

It is kidney shaped. Female irregular shaped, reniform, tail concoid with rounded terminus. In case of male tail is pointed; spicules are curved.

Infective Stage: Immature Female

Symptoms: Stunted growth of plants, premature decay and loss of secondary roots

Cotton: Browning and necrosis of epidermal cells are found on infected roots.

Castor: Infection results in reduction in growth, shedding of leaves, early flowers malformation and discolouration of seeds ultimately leading to dieback symptoms

Vegetables: Infection destroys the epidermal cells causing necrosis and browning of surrounding cells.

13. Lance nematode *(Hoplolaimus sp*.):

Yellowish in colour spear robust with prominent tulip shaped knobs. Vulva near middle of body, tail with rounded terminus

Symptoms:

H.indicus stunting of upper internodes ;drooping of leaves ;withering leaf tips the infected roots exhibit gallaries. young lateral roots developed reddish brown it is important in inducing the wilt fungi *fusarium monoliformae* .

14. Spiral nematodes *(Helicotylenchus sp.and Rotylenchus sp*.)

Spiral or helical shape, pore like tiny phasmids.

Rotylenchus is migratory ectoparasite of roots

Helicotylenchus dihystera: Roots attacked by the nematode are blunt, malformed and much reduced in volume

15. Sheath nematode (H*emicycliophora sp.)*

Ovary is prodelphic and outstretched tail elongated, pointed and rounded. Inmales spicules are variously shaped, almoststright, slightlycurved, sicklelike. Due to feeding on root tips, galls are caused growth of hoots stop

16. Pin nematode (P*ratylenchus sp.):*

Usually they lie immobile in semi circularposition. Head is conical or rounded .tail is conical to various shaped point.

Though the nematode have long styletsbut generally feed only upon epidermal tissues or roothairs.

17. Dagger nematode(*xiphinema sp*.)

Long, sword like stylet and given the common name “dagger nematodes” stylet very long hypodermal needle like. Tail short rounded to filiform.

X. index is a vector for NEPO virus transmitting the **fan leaf virus of grape**

18. Needle nematode*(Longidorus sp.):*

Longidorus are known to transmit polyhedral viruses.

Eg*: L. elongates* transmits **raspberry ring spot viruses** and

L. attenuates transmits **tobacco black ring viruses**.

19.Stubby root nematodes (*Trichodorus and Paratrichodorus*):

Stylet with hair like mural tooth.

The nematodes with blunt rounded tails and thick cuticle. Transmit soil borne plant viruses

Feeding is confined to root tips causing ,stunted growth of roots hence, the name “stubby root” It is a vector of NETU virus.

Lecture - 25

Integrated Nematode Management – Host plant resistance-cultural, mechanical methods

Several species of nematodes cause damage to crops. One or more of them occur in soil and cause damage. Careful integration of all available and suitable techniques is necessary for reducing the economic loss due to nematodes.

In the management of nematode problem, prevention is always better than control where nematode problems may be observed throughout the cultivated area and can spread either through plant or soil.

Preventing spread of nematodes can be done by

1. Use of certified planting material
2. Use soil less graving media in green houses
3. Clean the equipment from soil before moving between the fields
4. Prevent animal movement from infested field to uninfested.
5. Removal of weeds from the field.

MANAGEMENT:

HOST PLANT RESISTANCE:

Nematode resistant varieties:

Rice - TKM-9 - *Hirshemanielia oryzae*

RNR-877, WGL-47969, Badami, neel,

Palghar-1, KAU 28-1-1,bhanja - *M. graminicola*

Barley - DL 349,DL-375,DL-379, Raj kiran, BP-263, BP-264 - *H. avenae*

Tomato – nematex, PAU-15, SL-120 – *M.incognita*

Atkins HIsarlaht – *M.javanica*

LP3 - *M. javanica*

N 10- M.incognita

NDTR-1 - *M. arenaria*

Potato – kuifri swarna- *G. rostochinensis*

Pea- Co-50, A-70, B-58- *M. incognita*

Chickpea- selection no 501- *M. incognita*

Ground nut – Ambali 4018- *M. javanica*

Virginia runner group Ah-18- *M. arenaria*

TMV-10, Jb-182, DS-99- *M. arenaria*

Coffee- *C. robusta – M. incognita*

C. Arabica- M. javanica

Grape- Hur, Calcutta- *M. incognita*

Cultural practices:

a) **Crop rotation:** effective against nematodes that show a strong food preference

   Eg: cereals followed by vegetables and *vice versa* reduces *Heterodera avenae* and *Meloidogyne incognita*

b) **Crop root destruction:** After the crop season uproot the roots and destroy or burn on the soil surface.

   Eg: *Hoplolaimus, Helicotylenchus, Xiphinema longidorus, Tylenchorhynchus sp.*

c) **Flooding and fallowing:** Due to flooding , oxygen content of soil is decreased and nematodes are killed by asphyxiation.

d) **Healthy plnating material:** Use of nematode free planting material to avoid further spread especially in the case of Onion, garlic, flower buds (*D. dipsavi*) Strawberry and chrysanthemum (*Aphelenchoides)*, citrus (*T. semipenetrans*) and Banana (*R. similis*).

e) **Summer ploughing:** Two to three deep ploughings during hot summer months suppresses weeds, insects, soil fungi along with nematodes.

f) **Solarisation of soil:** Exposure of soil covered with polythene cover during April- June will effectively reduce nematode population in soil.

g) **Application of organic amendments or green manuring:** soil application of oil cakes of Neem, Pongamia, Mahua, Castor etc. has (with nematicidal action) @15 tonnes per ha reduce nematodes in soil.

h) **Adjustment of sowing/ planting dates or season.** As nematode activity depends upon the soil temperature that vary with the season. Planting at unfavourable temperature or moisture condition of soil affect the nematode activity.

i) **Growing trap crops/antagonistic crops.** Trap crops should be grown in nematode infested soil where the second stage juveniles of nematodes enter in to the root but unable to reproduce affecting their population.

Eg: Crotolaria, Chrysanthimum, cowpea, sweet potato cv. Shree Bhadra can be used as trap crops.

Antagonistic crops are those which affect the nematode development in soil due to the chemicals released by them with nematicidal activity

Eg: *Tagetes erecta, T. patula,* mustard neem – release ferthinyl and bithinyl compounds

marigold – isothiocyanate

Pangola grass – Pyrocatechol compounds

Allelopathic cover crops: produce allelochemicals that function as nematode-antagonistic compounds such as triterpenoids, phenolics, glycosides, alkaloids

Eg: oil radish as a green manure reduce *Trichodorus* and *Pratylelchus* in potato

Rape seed and mustard in straw berry fields

j) **Sanitation:** Removal of weeds, destruction of crop residues and disinfestation of farm equipment

k) Nutrition and general care of plants:

Proper nutrition and timely irrigation should be provided to maintain the health of the plants.

Mechanical Methods:

Sieving : Simple sieving or winnowing or floatation in plain water or brine (5-10% salt solution) avoid nematodes in infested wheat seed with *Anguiana tritici*

Lecture - 26

Integrated nematode management- Physical- biological- quarantine- chemical methods

Physical methods:

a) **Barriers:** Plastic bags of 100 cm^3 should be placed on boards while rising seedlings to avoid infestation from soil due to small breaks

b) **Heat and solarisation :** Sending steam through pipes in glass houses and seed beds and bins .

c) **Hot water treatment:** Dipping of seeds, tubers, bulbs, suckers, rhizomes, rooted cuttings and often planting material in hot water at 50^0c will help in reducing the nematodes

d) **Use of nematode free stock:** Helps to reduce the infection by wheat gall nematode, stem nematode in garlic and onion seed, flower bulbs, leaf nematode in strawberry and chrysanthemum,Citrus nematode in citrus seedlings

e) **Irradiation;** Expose potato infected with *Globodera* to 20,000 gamma rays affect the eggs.

Biological control:

1. **Nematophagous fungi :**

A) Endoparasitic fungi – *Nematophthora*

2. **Predaceous fungi** :

Eg: *Arthrobotrys conoids*

Oligospora
Dactylella doedycoides
Dactylaria candida

3. **Oppurtunistic fungi-** Colonize nematodes

Eg: *Paecilomyces lilacinus*

Verticillium or Pochorria clamydosporus

Hirsutella sps

4. **Mycorrhiza**

Eg: *Glorris fasiciculatum*

5. Bacteria:

Eg: Pastenria penetrans - *Pseudomonas flourescens*

Parasitic protozoa - *Duboscquia penetrans*

Predaceous nematodes - *Mononchus,Diplogaster vorax, Aphelenchoides*

Quarantine methods*:*

It is originated from Latin word **quarantum** meaning **forty** , originally it was applied to the period of detention for ships arriving from the countries having epidemic diseases .Later on the term was also applied to regulatory methods aimed at keeping out the exotic pests and pathogens associated with plants.

Plant quarantine regulations in India :

The Destructive Insects and Pests Act (DIP Act) was enacted in1914 to regulate the import of certain plant or plant materials from other countries (International Quarantine) and from one state to other within the country(Domestic Quarantine) **Eg:** Domestic quarantine is in vogue in Tamil Nadu against Goldent Cyst Nematode - *Globodera rostochiensis and G pallida* due to the enactment of Madras Agricultural pests and Diseases Act 1919

Chemicals / Nematicides:

Nematicides which are in commercial use may be grouped in to two types namely

a) Fumigants (Compounds belonging to halogenated hydrogen and isothiocyanate group) and

b) Non Fumigants (include organophosphates and carbamates)

Halogenated Hydrogen Group:

DD Mixture (1-3 Dichloro propene and 1-2 , Dichloro propane in 2:1 ratio)

Used @ 400-500 lts per ha as pre platn soil fumigant .

EDB (Ethylene Dibromide)

Chloropicrin

Methylbromide

Organophosphates and Carbamates:

Parathion , Phorate , Carbofuran and Methomyl

Factors affecting the efficacy of Nematicides:

The following factors influence the efficacy of soil nematicides

1.**Temperature:**Chemcials with boiling point between 150-200 ^{O}c are more effective at soil temperature of 27 ^{O}c or more, and almo ineffective at 10 ^{O}c.

2.**Soil Moisture:** In sandy loam or clay loam soils moisture content prolongs gas retention and retards diffusion

3.**Soil Type:** Heavy clay soils are unsuitable for fumigation owing to absorption on the increased active surface area of the soil particles and blocking of pore spaces by soil moisture.

4.**Compactness of Soil :** Fumigant gas tends to move upwards in most porous top layers of the soil henc, soils must be cultivated deeply before treatment.

5.**Sorption capacity of Soil:** The chemicals are absorbed more in dry soil than moist soils**.**

Lecture - 27

Mites –Importance of mites –morphology and biology of mites

Importance of Mites : Mites are very tiny creatures capable of infesting and causing severe loss to a variety of **agricultural and horticultural crops** particularly under dry situations.

In addition to direct damage to crops they also cause in direct damage by acting as **vectors** of important viral diseases .

Some of the mites harbour in carpets, sofa etc furniture in the houses and cause **serious allergies** in human beings.

Some of the mites even cause loss to the **stored produce**

Not only they cause damage to crops they are also harmful to **productive insects** like honeybees acting as parasites.

On the other side, some of the mites (predatory mites) are very useful in **biological control** of some insect pests and mites.

Phytophagous mites:

The mites that feed on plants are called **phytophagous** mites which mainly belong to families namely

Eriophyidae (Erenium or gall or itch or rust mites), Tetranychidae (spider mites),

Tenuipalpidae (Broad mites) and

Tarsonemidae (False spider mites).

Mites as Vectors:

Some of the eriophid mites act as vectors of some important viral diseases

Eg: *Aceria cajani* transmit redgram sterility mosaic disease

Aceria tulipae transmit wheat streak mosaic disease

Mites as Parasites :

Ecto Parasite on honey bee : *Tropilaelaps clariae*

Varroa jacobsoni

Endo Parasite*:* *Acarapis woodi(Tarsonemidae)*

(Tracheal mite on honey bee)

Locustacarus buchneri (Poapolidae) on bumble bees

Predatoy Mites: (Phytoseiids)

Phytoseilus persimilis

Amblyseius fallacies

House Dust Mite: ***Dermatophagoides farina***

Stored grain mite*:* ***Acarus siro***

Mites belong to the class, Arachnida and Order Acarina. They are found in a variety of habitats ie., aquatic (lakes or ponds) or terrestrial (plants, mammals, on birds and insects).

Mites can be distinguished from their insect relatives by the presence of two body regions (cephalothorax and abdomen, in some these two are fused), four pairs of legs(only two pairs in Eriophyidae) , sucking mouth parts and lack of antennae and wings

Mites possess chelicerae as mouth parts which are needle like useful for sucking sap from plants. Adults vary in body shape and possess 2 or 4 pairs of legs. The life cycle consists of an egg, larva , proto nymph, deuto nymph, trito nymph and adult stages. Oval shaped eggs are laid on leaves. Incubation Period is 6-13 days. The no.of nymphal instars vary among the families.

Example: Eriophyid mite has only 2 nymphal instars and Tetranychid mite has 3 nymphal instars. The nymphs are active and nymphal period vary from 1-3 weeks. The total life cycle in summer extend from 3-6 weeks .

MORPHOLOGY:

Body is vermiform, divided into cephalothorax and abdomen in family Eriophyidae . It contains 2 pairs of legs.

In Tetranychidae, body is divided into **Gnathosoma** and **Idiosoma**. Gnathosoma contains mouth parts like Chelicerae and Pedipalpi that cover the mouth cavity.Above the mouth cavity there is a **capitulum or tectum** dorsally. Gnathosoma consists of 3 segments where the second segment has chelicerae and 3rd segment has pedipalpi. The Idiosoma is further divided into **Podosoma** and **Opisthosoma**. Podosoma has legs that is further divided into **Propodosoma** and **Metapodosoma**. Propodosoma has 2 pairs of legs and Metapodosoma has 2 pairs of legs. Opisthosoma is the posterior part of the body having anal opening.

Eyes may be present or absent. In some mites if eyes are absent body surface act as photo sensitive organ.

Mouthparts are Chelicerae , 3 segmented, modified into stylet like piercing organs.

Pedipalpi are present on dorso-ventral surface of Gnathosoma resembling the legs. These are modified as piercing or grasping organs.

Legs may be 2 or 4 pairs. Each leg consists of coxa, trochanter, femur, Genu, tibia and tarsus

Differences between Eriophyid and Tetranychid mites

Character	**Eriophyid mite**	**Tetranychid mite**
Size	Very minute	Bigger
Body	Vermiform	Flat or oval
Segmentation	Body is divisible into Cephalothorax and long tapering abdomen	Body unsegmented and not divided into cephalothorax and abdomen
Legs	2 pairs of legs(situated near the anterior end of the body) both in the adult and nymphal stages	4 pairs of legs in the adult and also nymphal stages. The larva (1st nymphal stage) has only 3 pairs of legs (mites living enclosed with in plant tissues have vestigial legs)
Life Cycle	2 nymphal instars (protonymph and duetonymph) which are almost similar to adults	3 nymphal stages(protonymph, duetonymph, tritonymph) and an adult stage.
Symptoms	Gall formation is the main symptom	Formation of the red spot is the main symptom
Examples	Eg: Gall mite, blister mite, rust mite & bud mite	Eg: spider mite

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Lecture - 28

Mites –Classification- characters of important families Tetranychidae, Tenuipalpidae, Tarsonemidae, Eriophidae- host range

Family: Tetranychidae(spider mites)

Characters:

1. Body colour is red, green, yellow, brown etc.
2. Body is 0.2-0.8 mm long
3. Body is flat, oval.
4. Body is not divided into divisions
5. Not segmented.
6. Body of male tapers posteriorly
7. Chelicerae are fused to form a stylopore and the movable segment of chelicerae forms a flagellate stylet.
8. Threre is no mitotic division in larval stage.
9. Most of the species are having narrow host range
10. Palpal thumb claws are present.

Life cycle includes

Egg,
Larva (3 pairs of legs),

Protonymph (4 pairs of legs),

Deutonymph(4 pairs of legs),

Tritonymph(4 pairs of legs) and

Adults (4 pairs of legs)

Examples:

1. Red spider mite on okra, cotton, citrus, tomato, grape, papaya, jasmine, pumpkin. *Tetranychus macfarlan*i(telarius) results in Browning of leaves, fruits and hairy out growth on both.
2. Jowar mite (greyish green colour): *Oligonychus indicus*, lower side of leaf becomes wet, red spots appear in patches on leaf.
3. Vegetable mite, *Tetranychus cucurbitae*

Family:Tenuipalpidae (false spider mites)

Characters:

1. Same as Tetranychidae, but without thumb claws.
2. Three types of setae namely hysterosomal, dorsocentral and mediolateral are present.
3. The true tarsal claw is hooked or pad like and with tenent hairs.

Examples:

Citrus flat mite *Brevipalpus lewisi*

Brevipalpus californicus- It causes serious injury to a wide variety of ornamental and agricultural crops.

Lecture - 29

Mites –Classification- characters of important families Tetranychidae, Tenupalpidae, Tarsonemidae, Eriophidae- host range

Family: Tarsonemidae (Broad mites)

Characters:

1. Body is elliptical (ovoid)
2. Body measures 0.1-0.3 mm long
3. Body is divided in to three parts Capitulum, Propodosoma and Prohysterosoma (the later two parts together known as Idiosoma)
4. Mouth parts are contained in a distinct capsular head known as Capitulum
5. Females are bigger than males.
6. Body colour is opaque white, light green, pinkish
7. Adult integument is hard and shiny.
8. Few hairs, spines are present on body.
9. Chelicerae are needle like
10. Egg – larvae – adult

Examples:

Yellow mite on chilli- *Palyphagotarsonymus latus*

Paddy panicle mite - *Stenotarsonemus spinki*

Family: Eriophyidae (Blister, rust, gall mites)

Characters:

1. Body is minute measuring 0.08 – 0.2 mm long.
2. Body is 2 types:
    a) Elongate (vermiform), worm like, soft body
    b) Wedge shaped, hard body
3. Body is segmented
4. Body is divided into cephalothorax and tapering abdomen.
5. Abdomen is finely striated with long setae.

6. Two pairs of legs on anterior end of body (in all the life stages)
7. Pedipalpi or chelicerae are capable of making some independent movements and form a telescope or fold base. No thrusting stylopore.
8. Egg, Protonymph (2 pairs of legs),Deuteronymph (2 pairs of legs)

   Adult (2 pairs of legs)

   Examples:

   1. Citrus rust mite- *Phyllocoptruta oleivora*

      (Pinkish brown blotches on fruits).

   2. Jasmine mite- *Aceria jasmini*
   3. Mango gall mite- *Aceria mangiferae*
   4. coconut mite- *Eriophyes guerreronis*

Nature and symptoms of Mite damage :

Both nymphs and adults suck sap from plant parts like leaves, terminal or axillary shoots, fruits etc with their needle like chelicerae .

They cause symptoms like

1) Formation of white blotches on leaves in vegetables
2) Characteristic red spots that enlarge and coalese making whole leaf reddish
3) Drying of leaves and stems in sugarcane
4) Formation of galls on leaves in pongamia
5) Production of felt like growth on leaves in jasmine
6) Formation of crowded buds ,crumpled shoots in mango
7) Formation of pinkish blotches on fruits of citrus
8) Curling of leaves upwards in chillies
9) Formation of warts and longitudinal tissues on nuts of coconut
10) Act as vectors by transmitting viral diseases
11) Spin delicate webs on the lower surface of the leaf and live inside the web and suck sap from leaves

Mites of Agricultural Importance :

1. Jowar mite : *Oligonychus indicus* - Tetranychidae
2. Red spider mite : *Tetranychus neocaledonicus*
   T. telarius - Tetranychidae
3. Citrus rust mite :*Phyllocoptruta oleivora* – Eriophyidae
4. Citrus leaf mite : *Eutetranychus banski* - Tetranychidae
5. Sugarcane mite : *Schizotetranychus andropogonii* Tetranychidae
6. Coconut eriophyid mite :Aceria guerreronis
7. Jasmine mite (felt mite) : *Aceria jasmini* – Eriophyidae
8. Sweet potato rust mite :*Oxpleurites convolvuli* –Eriophyidae
9. scarlet mite of tea :*Brevipalpus anstralis* – Tetranychidae
10. Chilli mite :*Tarsonemus transluscens*
    Polyphagotarsonemus latus - Termipalpidae
11. Sugarcane mite :*Tarsonemus spinipes*
12. Coffee mites :*Oligonychus coffeae* –Tetranychidae

Management of mites:

1. Removal of alternate hosts in the field .
2. Spraying of sulphur @ 3 gm/ Dimethoate 30 EC @ 2 ml/lt/
   Methyldemeton 25 EC @ 2 ml /lt / kelthane (Dicofol) 5 ml /lt /
   Ethion @ 1 ml/lt
3. Fungal pathogen, *Hirsutella thompsoni* reported to be effective against coconut eriophid mite
4. Predaceous insects on mites
   Ex. *Scolothrips indicus*
   Scymnus gracilis

Lecture - 30

Rodents

Rodents are of two type namely Commensel rodents and Field rodents

COMMENSEL RODENTS

Family: Muridae; Order: Rodentia; Class : Mammalia

House mouse - *Mus musculus*

House rat or black rat – *Rattus rattus*

Common Indian field mouse - *Mus musculus booduga*

Brown rat - *Rattus norvegicus*;

1. House mouse (*Mus musculus*)

It is quick, tends to nibble and run rather than stay longer at food source. They can pass through a hole slightly less than 1.25 cm. They live mostly in houses. They produce 6-10 litter per year with 6-10 young ones per litter. They can climb easily and also can swim when necessary. They are distributed all over India and are omnivorous. Total length including tail is 8-22 cm with pointed snout. They are brownish grey above and whitish to light grey on belly.

2. House rat (*Rattus rattus*)

Lives in close association with human beings. Excellent climber and good swimmer. 4-6 litters / year and tail length 31-43 cm with pointed snout. Dark brownish above (dorsal) and dirty white on belly.

3. Common Indian field mouse (*Mus musculus booduga*)

The body of Indian field mouse is about 5 to 8 cm long with 5 cm long tail. It is brown in color with a white belly. It burrows in field bunds causing extensive damage to bunds and wastage of water. It produces 3 to 9 young ones per litter.

4. Brown rat or Norway rat (*Rattus norvegicus*)

Closely associated with the activity of man. Good climber and swimmer. Prefers wet or damp locations. Do not close the burrow openings. Length from nose to tail 35-41 cm with blunt snout. Brownish above, white on belly.

The above three species are known as **commensal** rodents. They contaminate 20 times the material actually they eat. A rat winates 15-25 ml/day and 25-150 pellet droppings per day / rat. They regularly shed hairs @ 100-200 hair fragments per day/rat. They bite some times human beings. They spread disease. They are social animal. They share same food source and common run way. They live closely to one another. They are most active at dusk and during calm period.

Rats become conditioned to eating a particular food and are suspicious in nature. Taste the food cautiously and develop bait shyness. House mouse is not suspicious of new food. Eagerly tastes all. In single night mice tastes and feed on many different foods, hence difficult to get them to take a lethal dose of poisoned bait. Mice readily accept water baits.

Management of commensal rodents

Killing rats by sticks

Trapping the rats using traps.

Snap neck trap kills the rat instantly.

Live catch traps trap the rats alive Eg. Single rat trap, wonder trap.

Chemicals

Chemicals are of two types

Acute poison: That are used in single dose

Anticoagulants : That are used in multiple doses

1. Acute poison

Zinc phosphide: To be used only in fields not in houses

Commonly used acute rodenticide in India

Recommended at 2.5% technical grade in bait material

Broken cereal could be used as bait material with vegetable oil as binding medium

Pre-baiting is compulsory for effective results

95% flour + 1 to 2% Zinc phosphide + 2% groundnut oil + 1% sugar

Prebaiting 2-3 days without Zinc phosphide and then bait is mixed with zinc Phosphide

2. Anticoagulants

1st generation anticoagulants

Warfarin, Fumarin, Toumarin, Recumin

These poisons are lethal when consumed for several days. They prevent blood clotting and break cell wall of blood capillaries leading to **haemorrhage**. Rats normally die in aerated areas. House rat and house mouse die after 2-5 days of continuous feeding.

Solid base – Rodafarin C

1 part of Rodafarin C + 1 part of granulated sugar + 1 part of vegetable oil + 17 parts of crushed grian or corn meal

Liquid base –Rodafarin C

Antidote- Vitamin k-1

2nd generation anticoagulants

Bromadiolone is only registered

Recommended @ 0.005% ai in cereal baits to be used in pulsed baiting technique (Exposing the bait at weekly interval)

Fumigants :

Aluminium phosphide (CP) solid.

Ethelen dibromide (EDB)

Ethelene dichloride carbontetrachloride (EDCT)

Natural enemies

Cats, dogs, owl, hawks and snakes

Field rodents

1. Soft furred field rat or grass rat (*Millardia meltada*)

It occurs in irrigated fields but observed in pastures also. It is nocturnal and lives in simple burrows. It breeds through out the year with litter size of 2-10 young ones. It is small and slender. Adult weight is 100 gm. Total length including tail is 19-29 cm, tail length is 9-14 cm either equal or little shorter than head and body, moderately to poorly haired. The tail is dark above and pale below.

2. Indian Mole Rat or Lesser Bandicoot Rat (*Bandicota bengalensis*)

It is an excellent swimmer, often living in flooded rice fields and bunds. Also occurs in the wheat crop fields and godowns. It is nocturnal and fossorial. They hoard large amounts of food in its burrows. Breeds commonly twice a year with 8-10 young ones in each litter.

Adult weight is 325 gm. Length from nose to tip of tail is 36-48 cm. Tail is18-20 cm; less than or some times equal to length of head and body together, 160-170 rings clearly seen on scaly tail. Ear 2.5 to 2.6 cm in length, thick and opaque. Snout – short, stumpy, pig like. Fur and colour – thick, short and harsh, spines present, dark brown, pale brown or reddish above.

Nature and Symptoms of damage

Rodents attack rice at all stages of growth from planting to harvest and if there is opportunity, even they will continue to attack the grain in store. Freshly sown seed may be dug up and the seed eaten. On young rice plants, rodents attack the heart of the stem discarding the leaves. The rodents make the rice stems fall by gnawing 5-15 cm above ground level. Some rodent species may store grain in their burrows. Large rodents, besides feeding on the crop may cause serious damage to the bunds.

Management of Rodents:

Rodent management should be taken up on community basis well before sowing of the crop. The rodent burrows should be marked and the burrow opening is closed with moist soil. The burrows opened out on the next day are active burrows. Then pre baiting has to be done on the 1st and 3rd day. On 5th day 2% zinc phosphide is added and baits distributed in the field. 70-80% kill of rodent population can be secured by the operation.

The remaining population can be controlled by fumigating the burrows. On 6th day in those reopened burrows, aluminium phosphide @ 1.5 gm/ should be placed in the active burrow and this will take care of residue rodent population.

Lecture - 31

Other non insect pests

1. Important birds causing damage to agricultural crops

A number of birds feed upon grains from earheads of field crops; fruits and vegetables. They actually consume very little quantity but often cause more damage than what they actually eat.

Major bird species affecting different crops are as follows

1. Crow *Corvus* spp. – Damage wheat, cobs of maize, ripe fruits of fig, mulberry
2. The parrot *Psittacula cyanocephalus* cuts and feeds on maize, jowar, bajra, what, barley grains and fruits such as guava, fig, mango, pomegranate etc., (both semi ripened and ripened fruits are cut and eat leading to fruit drop)
3. The house sparrow – *Passer domesticus* damages the earheads of jowar, maize, bajra and soft and fleshy fruits such as mulberry and fig
4. The blue rock pigeon *Columba livia* eats maize, pulses and groundnut
5. The yellow throated sparrow causes havey damage to wheat and barley

Many species of birds are found throughout India, out of which some birds are considered harmful to agricultural crops. Some of them are as following:
(i) **Crow:** (*Corvus Splendens* Vieillot): Crows cause considerable damage to ripe fruits in orchards and also ripening grains of maize and fruits. The crows are particularly attracted to the grains when they are exposed on a cob. They may prove a menace to the successful growth of field crops as well as harvest of fruits. They are often seen in flocks in maize and other fields.
(ii) **Sparrow :** (*Passer domesticus*): The flocks of sparrows is a great menace to various field crops like Jowar, bajra, wheat, maize, etc. mainly in the seed setting stage. They also threaten mulberry and many other small sized juicy fruits and fruit buds.They visit the ripening fruit fields, particularly those of wheat in the spring season, and cause much damage both by feeding and causing the grains to shed.

Damage by House sparrows

House sparrows consume grains in fields and in storage. They do not move long distances into grain fields, preferring to stay close to the shelter of hedge rows. Localized damage can be considerable since sparrows often feed in large numbers over a small area. Sparrows damage crops by pecking seeds, seedlings, buds, flowers, vegetables, and maturing fruits. They interfere with the production of livestock, particularly poultry by consuming and contaminating feed. In grain storage facilities, fecal contamination probably results in as much monetary loss as does the actual consumption of grain.

(iii) **Parrot:** (*Psittacula* spp.): About eight species of parrots have been recorded in India. Out of these species, Large Indian parakeet (*P. eupatria*) is very common in Maharashtra. This species causes heavy damage to orchards by eating fruits and also spoiling the fruits by cutting it with beak. The parakeets are among the most wasteful a destructive birds. They gnaw at and cut into bits all sorts of near-ripe fruits such as guava, ber, mango, plums, peaches, etc. In sunflower when the seeds are soft the parrots cause extensive damage by feeding on the seed thus reducing the yield

Management of Birds

Various methods are employed which include covering by nets, using scaring devices, reducing their population by shooting, trapping and use of chemicals.

(a) Trapping the birds in nets or catching them with the help of sticky substance '**Lassa**'.

(b) A piece of Chapatti dipped in 0.04% parathion and placed on the top of roof is a good bait for crows.

(c) Parrots and sparrows are repelled by spraying 0.6% **thiurun**' on wheat crops at milk stage.

(d) Scaring devices using mechanical, acoustic and visual means are normally employed, i.e. Beating of drums to produce sounds is still in vogue in many parts of the country particularly during harvesting.

(e) Fire crackers placed at regular intervals along a cotton rope. The rope burns from one end and ignites the crackers at regular interval which produce sounds and scare away the birds.

(f) Loud sounds due to the burning of **acetylene gas** produced at intervals are utilized to scare away birds and small animals.

(g) Birds may be scared by display of scare crows, dead birds and visually attractive flags etc.

2. Crab damage

The rice **field crab** *Paratelphusa hydrodromus* (Decapoda; Crustacea). The crab has an oval body with an abdomen tucked beneath the thoracic region. Crabs live in holes made in the sides of field bunds, irrigation channels and field corners, where water does not stand. The holes are protected by heaping soil around their openings. Crabs multiply mainly during dry period, April to June. A single female lays about 200 eggs which are carried by the mother in a pouch like abdominal flap on her ventral side.

Crab Damage :

Young seedlings in nurseries and newly transplanted fields are damaged. The seedlings are cut at ground level in to small bits which are carried to the holes for feeding. In older plants, outer sheaths are cut open and the tender inner portions are consumed. In an attacked field, bits of leaves and stems can be seen floating in water. In severely affected fields patches of damage can be seen. Crabs are active mostly after dusk and at nights. In addition to damage to plants, the carb holes made in bunds lead to braches and water losses.

Management:

1. They are naturally controlled by rats and **pond heron** *Ardeloa grayi*.

2. They can be trapped in wide-mouthed pots buried with their rim at about the water level; inside the pots, moistened rice bran in lumps are kept as bait.

3. Poison baiting with warfarin 0.0025 per cent in popped rice mixed with fried onions and fish can be used

4. Fumigation with cyno gas though effective is costly

3. Snail damage

The giant African snail – *Achatina fulica*, which is a foreign pest got introduced in India and is now wide spread.

Slugs and snails are legless creatures that glide along on a path of mucus. This mucus dries out and can be seen in the daytime as a shiny trail over leaves, fruit and soil. The detection of these "**slime trails**" may be the only way of determining their presence, as slugs and snails generally feed at night. When trails and damage are observed, the slugs and snails can often be found on the ground near the injured plants, hiding under decaying plant debris, stones, clods of soil, or logs.

They feed on the lower leaves of many plants especially in the areas between the veins. Immature slugs and snails damage plants by rasping away the surface tissue, while adults eat holes through the leaves, nip off tender shoots or cause complete destruction of seedlings. Damaged leaves break, due to wind and shed or in the case of grass and corn, split lengthwise. Litter heaps, compost piles, drain pipes, greenhouses, well walls and uncultivated areas with dense plant growth, provide ideal sites in which the gray garden slug, gray field slug and snails are capable of overwintering in all developmental stages.

Management:

1. During rainy season, moist gunny sacks or leaves can be heaped near the cropped area and the snails collected near them can be killed on following day.
2. Among chemicals, metaldehyde is the most effective molluscicide which are available as 5 % pellets.

Lecture - 32

House hold and live stock insect pests

Domestic insect pest

1. Ants

House ants viz., *Monomorium criniceps* (small brown ant) and *M. destructor* (small red ant) is a problem in household carrying bits and pieces of food material. They cause annoyance and also sting people causing disturbances.

They can be controlled by keeping the house clean and tidy. Chemical control can be done with dusting of carbaryl 10 per cent (not advisable if infants live in the houses)

2. Termites

Termites feed on wood, paper, wood products, dried plant and animal products etc.,

To prevent infestation by subterranean termites, avoid construction of any wood material 40 cm from ground surface. A thin sheet of metal or good concrete between foundation and timber of the house will prevent infestation. Termite proofing of wood can be done by pressure impregnation with coal tar, zinc chloride, chlorpyrifos etc., Soil termite attack can be controlled by spraying of chlorpyrifos 20 EC @ 50 ml/ liter of water.

3. Silver fish *Ctenolepisma* spp. (Lepismatidae; Thysanura)

This insect is found commonly in neglected places on walls, starched clothes, fabrics, bindings of books, papers on which paste or glue is used. The insect is wingless, 8-13 mm long, silvery greenish grey or brownish, lives in warm places and avoids light.

This insect can be controlled by application of propoxur (Baygon) 0.5 %.

4.Cockroach *Periplanata Americana*; German cockroach *Periplanata germanica* (Blattidae; Dictyoptera)

Well known insect in all households. They are active in nights mostly in places which are damp and dark and avoid light. They cause nuisance in the household with their foul smelling excreta. The female cockroach produces ootheca containing 14 to 16 eggs and about 15 to 90 oothecae may be laid by a female.

These insects can be controlled by application of propoxur (Baygon) 0.5 %.

Aerosols containing propoxur 0.75 % + cyfluthrin 0.025%

5. Cricket *Gryllus* spp. (Gryllidae; Orthoptera)

These insects live in cracks and crevices in the houses and causes annoyance by making chirping noise at nights. With proper ventilation and lighting, these insects can be controlled.

6. Powder post beetles

The furniture beetle *Sinoxylon sudanicum* (Bostrychidae; Coleoptera) and other species Anobiidae, Bostrychidae etc destroy wood items in households. The grubs of these insects cut the hard and dry wood and tunnels downwards until the wood becomes powdered. Small shot holes can be seen externally on affected wood.

These insects can be controlled by painting the wood with varnish, paint, tar etc., of fumigation with methyl bromide can be done.

7. Carpet beetle *Anthrena pimpinella* (Dermistidae; Coleoptera); Cloth moths *Trichophaga abruptella* (Tinaeidae; Lepidoptera)

The larva and adults of the beetle and the moth, bite holes in fabrics like wigs, clothing, interior padding of furniture etc., which contains wool, fur, feathers and hairs. They also attack cotton goods, insect specimens, dried meat etc.,

These insects can be controlled by cleaning the household premises regularly and also fumigation with naphthalene balls or paradichloro benzene crystals.

Veterinary Entomology

Cattle Pests:

1. The horse fly *Tanbanus striatus* (Tabanidae; Diptera)

It resembles the housefly but is larger and stouter, has three rows of white spots on the abdomen and prominent compound eyes. The fly breeds in marshy places. Eggs are black, elongate and are laid on aquatic plants. The grubs are carnivorous and feed on small aquatic organisms. The female fly pierces the skin of the animal and sucks the blood, causing wounds.

2. The stable fly *Stomoxys calcitrans* (Muscidae; Diptera)

This fly is cosmopolitan and is smaller than housefly, long proboscis and presence of seven spots on the abdomen. It breeds in moist straw, grass and other material in the cattle shed. Both male and female sucks the blood from the animals.

3. The cattle fly *Hippobosca maculate* (Hippoboscidae; Diptera)

It is a flat fly with a leathery thick-set body and strong tarsal claws. It can be always seen on cattle clinging mostly at sides of the neck region. It feeds on the blood contneously and produces seed-like puparia direcly without egg and grub stage.

All the above three flies can be controlled by use fenitrothion 50% EC @ 10 ml/liter of water or deltamethrin 2.8% EC @ 2ml/liter of water. The animals can be sprayed individually taking care to treat the tip and under portion of tail; inside the ear and folds of legs. The animals should not be washed immediately. Spraying may be repeated at an interval of 4 to 5 weeks.

4. The blood sucking fly *Siphona exigua* (Muscidae; Diptera)

It is a common blood-sucking fly in India, which attacks cattle, buffalo and dog. It is attracted by the odour, warmth and sweat of its host.

5. The eye fly *Siphunculina funicola* (Chloropidae; Diptera)

They are shining black in colour and cling in clusters. They hover in front of the eyes and feed on upon the secretions from the eye.

II. Fowl

1. The shaft louse *Menopon gallinae* (Menoponidae; Mallophaga)

It is a permanent ectoparasite of fowl found on their feather feeding by nibbling on the dry scales of the skin and chewing the feathers.The louse spends its entire life cycle on the host bird itself. Badly infested birds can be seen rubbing their bodies in soil or ash pits to get rid of the louse.

2. The body or vent louse *Menacanthus stramineus* (Menoponidae; Mallophaga)

It is one of the common ectoparasite of poultry. It congregates on the skin just below the vent and in case of severe infestation can be seen on ventral side of wings.

3. The chicken flea *Echidnophaga gallinacean* (Tungidae; Siphonaptera)

The flea infests the face, comb, wattles and area around the eyes of fowl in clusters. It is a minute, flat, dark brown insect remaining attached to the host with its head embedded in to the skin.

Control of poultry lice and chicken flea can be done by spraying fenitrothion 0.25 % on batches of 10-12 birds at a time. The spray should be repeated at an interval of three months.

III. Sheep and goat

1. The head maggot of sheep *Oestrus ovis* (Oestridae; Diptera)

This larviparous fly deposits the maggots in the nostrils of sheep. The maggots move to frontal sinuses resulting in constant nasal discharge and sometimes obstruction of air passage.

2. The sheep ked *Melophagus ovinus* (Hippoboscidae; Diptera)

It is a wingless, leathery, hairy fly which attacks the sheep. The female glues its larvae to the wool of sheep. The adults live among the wool and suck blood causing intense irritation prompting the sheep to bite the area thus damaging the wool. Spraying with 0.01% diazinon or deltamethrin will eliminate this insect.

3. The biting louse *Bovicola caprae* (Trichodectidae; Mallophaga)

Commonly occurs in goats and sheep (*B. ovis*). Dips containing 0.01 % diazinon or deltamethrin 2.8% EC @ 3 ml/liter of water.
