DEPARTMENT OF PLANT PROTECTION

M.Sc. Ag. (Entomology) CBCS II Semester

Core Course- IV: INSECT ECOLOGY

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.

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:

60^0C - Maximum Fatal Temperature

Zone of Fatal High Temperatur

50^0C - Zone of Inactivity due to High Temperature

35^0C - Maximum Effective Temperature (Threshold of Development), Upper vital limit

Zone of Optimum/Normal/Effective Temperature

10^0C - Minimum Effective Temperature (Threshold of Development), Developmental zero

Zone of Inactivity due to Low Temperature

-5^0C

Zone of Fatal Low Temperature

-14^0C - Minimum Fatal Temperature

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,Sitophilussp 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 beneficiensparasitoid 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 No. 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, $Qn = 1 - (1/s)^n / fn$.

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 pernicioususon 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 albistrigaon 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 nontarget 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.

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 albais 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.

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.

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

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 550C 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.

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 18th 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

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.

LECTURE NO. 12 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.

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 controllingOpuntia 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.