# Theory Notes

## Ag. Ento. 4.2

## Principles of Integrated Pest Management

**Credit hours (1+1=2)**



## Fourth Semester

## B.Sc. (Hons.) Agriculture

**Ag. Ento. 4.2 Principles of Integrated Pest Management Credit hours (1+1=2)**

**Theory**

**Part I**

1. Insect Ecology: Introduction, Environment and its Components. Effect of abiotic factors–temperature, moisture, humidity, rainfall, light, atmospheric pressure and air currents. Effect of biotic factors – food competition, natural and environmental resistance.
2. Concepts of Balance of life in nature, biotic potential and environmental resistance and causes for outbreak of pests in agro-ecosystem

**Part-II**

3. Categories of insect pests, IPM: Introduction, history, importance, concepts, principles and tools of IPM
4. Host plant resistance, cultural control
5. Mechanical, physical, legislative control
6. Biological (parasites, predators & transgenic plant, pathogens such as bacteria, fungi and viruses) control
7. Chemical control (Importance, hazards and limitations)]
8. Classification of insecticides, toxicity of insecticides and formulations of insecticides
9. Insecticides Act 1968-Important provisions.
10. Application techniques of spray fluids.
11. Phytotoxicity of insecticides. Symptoms of poisoning, first aid and antidotes.
12. Introduction to conventional pesticides for the insect pest management.
13. Implementation and impact of IPM (IPM module for Insect pests).
14. Safety issues in pesticide uses. Political, social and legal implication of IPM.
15. Case histories of important IPM programmes.

**Part III**

1. Recent methods of pest control, repellents, antifeedants, hormones, attractants, gamma radiation, transgenic, nano technology as well as genetic control.
2. Practices, scope and limitations of IPM.

**Part IV**

1. Economic importance of insect pests.
2. Methods of detection and diagnosis of insect pest.
3. Importance of Economic threshold level.
4. Ecological management of crop environment.
5. Pest surveillance and pest forecasting.

**Practical**

- Methods of diagnosis and detection of various insect pests.
- Methods of insect pests sampling.
- Assessment of crop yield losses.
- Calculations based on economics of IPM (ICBR/ NICBR/ CBR).
- Identification of biocontrol agents,
- Crop (agro-ecosystem) dynamics of selected insect pests.
- Plan & assess preventive strategies (IPM module) and decision making.
- Crop monitoring attacked by insect pests.
- Awareness campaign at farmers’ fields.
- Pesticide formulations and calculation of spray fluid and doses.

**REFERENCE BOOKS**


1. Elements of Economic Entomology - B. V. David and T. Kumarswami
2. Integrated pest management Concepts and Approaches-G. S. Dhaliwal & Ramesh Arora
3. Textbook of Applied Entomology (Volume - I) - K. P. Srivastava
4. Agricultural pests of India and South East Asia - A. S. Atwal
5. Entomology and Pest Management - Larry P. Pedigo
6. An Outline of Entomology - G. S. Dhaliwal
7. Introduction to insect pest management. R. L. Metcalf
8. Integrated Insect Pest Management - Venugopala Rao N., Umamaheswari T., Rajendraprasad, P., Naidu V.G. and Savithri P.
9. Pesticides Application Equipments - O. S. Bindra and Harcharan Singh
10. Principles and Procedures of Plant Protection - S. B. Chatopadhyay
11. General and Applied Entomology - K. K. Nair, B. V. David and T. N. Ananthkrishnan
12. A glimpses on “Terminology of Agricultural Entomology”- S. K. Ghosh
13. Plant protection: Part 1 (Gujarati) – R. C. Patel
14. Krushi Kit Vidya: Part 1 (Gujarati)- G. A. Patel and H. K. Patel

# CHAPTER 1

- **Insect Ecology: Introduction, Environment and its Components**
- **Effect of abiotic factors–temperature, moisture, humidity, rainfall, light, atmospheric pressure and air currents.**
- **Effect of biotic factors – food competition, natural and environmental resistance.**

## Ecology

**Ecology** is 'the science of inter-relations between living organisms and their environment.

Ernst Haeckel (1869), defined ecology is the study of total relation of the animal both to its inorganic and organic environment, including above all, its favourable and unfavorable relation with those animals and plants with which it comes directly or indirectly in contact.

- **Ernst Haeckel - Father of Ecology**

E. P. 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.

**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.

**Population:** Population can be defined as 'a group of individuals or a species occurring in a given area or locality at a specific time'.

**Community:** Populations of different species live together and form a '**Community**', meaning 'all populations in the area at a specific time'.

**Ecosystem:** The complex system of biotic and abiotic factors constitutes an '**Ecosystem'**. An ecosystem is a community of living organisms in conjunction with the nonliving components of their environment, interacting as a system.

**Agro-ecosystem:** The crops, insects, other animals and the physical abiotic factors together constitute an '**Agro-ecosystem'**.

**Environment** denotes the sum total of physical and biological factors that directly influence the survival, growth, development and reproduction of organisms.

**Components of environment**

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.

## EFFECT OF ABIOTIC AND BIOTIC FACTORS ON POPULATION GROWTH

**Factors influencing population growth**

I. Abiotic factors or density independent factors.

II. Biotic factors or density dependent factors.

## [I] ABIOTIC FACTORS ON INSECT POPULATION

A. Physical factors B. Nutritional factors C. Host associated factors

**PHYSICAL FACTORS**

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

**1. TEMPERATURE**

- Insects are poikilothermic - do not have mechanism to regulate body temperature
- Upper lethal limit : 40-50 °C (even up to 60 °C survival in some stored product insects). Lower lethal limit : Below freezing point e.g. snow fleas.
- The total heat required for completion of physiological processes in life - history is a constant - **thermal constant.**
- At low temperature (winter) insect takes more days to complete a stage.
- At high temperature (summer) it takes less time to complete a stage.
- Some insects when exposed to extremes of temperature Undergo - **Aestivation** (during summer) or **Hibernation** (during winter). During this period, metabolic activities suspended. When temperature is favourable, they resume activity.

**2. MOISTURE/HUMIDITY**

- Moisture scarcity leads to dehydration and death of insects.
- Exposure to excessive moisture can be harmful to insect population by -
  i. Adversely affecting normal development and feeding activity of insects.
  ii. Encouraging disease causing pathogens on insects and thereby causing insect's mortality.
  iii. Adverse effect on its cold hardiness (capability to withstand exposure to low temp)

**Examples:** 1. High RH induces BPH in rice,
2. Low RH in rainfed groundnut crop induces leaf miner incidence

**3. RAINFALL**

- Rainfall is essential for adult emergence of cutworms and RHC
- Heavy rain reduces population of aphids, diamond back moth (DBM)
- Intermittent low rain increases BPH and thrips

**4. LIGHT**

Light is essential factor for orientation or rhythmic behaviour of insects, bioluminescence, periodicities of occurrence and periods of inactivity.

The following properties of light influence insect life

i. Intensity or illumination
ii. Quality or wavelength
iii. Duration of light hours / Photoperiod

**Photoperiodism:** The response of organisms to environmental rhythms of light and darkness. It influences the motor activity rhythms of insects such as locomotion, feeding, adult emergence, mating and oviposition and also moulting and growth in some species.

**Photoperiod**

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

- Photoperiod influences induction of diapause (a resting stage) in most of the insects e.g. Long day during embryonic development causes adult to lay diapausing eggs in *Bombyx mori*.
- Some insects are active during night - **Nocturnal**
- Some are active during the day - **Diurnal**

- Some active during dawn and dusk - **Crepuscular**

**5. Atmospheric pressure**

- A rise in atmospheric pressure generally associated with clear weather and moderately strong winds, while drop in atmospheric pressure associated with bad weather, including high winds and possible rainstorms that can results in high mortality.
- Rapid barometric changes significantly reduced the flight initiation of females.

**6. AIR CURRENT/WIND**

- Interferes with feeding, mating, oviposition
- Wind aids in dispersal of insects e.g. aphids, mites (Eriophyid mites also) disperse through wind.
- Air currents may be directly responsible for the death of insects.

**7. TOPGRAPHY**

- Mountains, valley, lakes, seas, steepness of the slope etc. act as physical barrier for spread of insects.
- Topography also affects climate of an area, thus influencing the distribution of certain insects.

**8. ADAPHIC FACTORS / SOIL TYPE**

- Wireworm, multiplies in wet clay soil with poor drainage
- White grubs and cut worm - multiply in loose soil with good drainage.
- Soil with high organic compound reduces BPH, stem borer in paddy
- In acid soils, in burrows opening at the soil surface and in surface or subterranean nests of termites tends to decrease.

**9. WATER CURRENT**

- Standing water aids in multiplication of mosquitoes
- Running water is preferred by dragonfly and caddisflies.

**10. Oxygen and $CO_2$**

- An excess of $CO_2$ in atmosphere causes growth retardation in many insects.

**[I] BIOTIC FACTORS**

**1) Competition:** Competition operates whenever population is increasing and the resources like food, mates and suitable site for oviposition or pupation are limited.

**a) Intraspecific competition:** Population of the same species competes for a resource is called intraspecific competition.

- e.g. Cannibalism in American bollworm larvae (*Helicoverpa armigera*).
- Crowding in honeybees leads to swarming

**b) Interspecific competition**. The competition occurring between members of two or more species. e.g. when flour beetles *Tribolium castaneum* and *Tribolium confusum* were grown in the same jar of flour, one species eliminates the other. Under high temperature and RH conditions *T. castaneum* eliminates *T. confusum* and vice versa under low temperature and RH conditions.

**2) Natural and environmental resistance**

Environmental resistance factors include factors that are **biotic (living)** and abiotic (non-living). Biotic factors are things like predation, parasitism, lack of food, competition with other organisms and disease.

**a) Predators and Parasites**

**Predators:** Predators are free living organisms that feed on other insects, their prey, devouring them completely and rapidly. More than one individual of prey required for predator to reach maturity. e.g. lady beetle, *Chrysoperla*, birds, amphibians, reptiles etc.

**Parasites:** An organism that is dependent on another organism throughout its all life stages. A parasite weakens or kills the host while feeding. Many parasites on a single host require only one part of one host to reach maturity. e.g. Mosquitoes, *Trichogramma spp*.

b) **Food**: Insect depends directly or indirectly on plants for food. The quantity and quality of food play an important role in insects' survival, longevity, fecundity, distribution, reproduction, speed of development etc.

i. **QUANTITY OF FOOD**
   - Short supply of food causes intranspecific and interspecific competition

ii. **QUALITY OF FOOD**
   - This depends on nutritional availability of plants

c) **Competition with other organisms**
   Population may not increase due to competition with other organisms.

d) **Disease:** Disease due to microorganisms may cause the death of organisms, hance population may reduce.

# CONCEPT OF BALANCE OF LIFE IN NATURE,
# BIOTIC POTENTIAL AND ENVIRONMENTAL RESISTANCE
# CAUSES FOR OUTBREAK OF PESTS IN AGRO-ECOSYSTEM

**Concept of balance of life in nature / Law of population growth**

**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'**.

The population size of any organism can change only by four processes; **Birth, Death, Immigration or emigration.**

**Biotic potential:** Innate capacity of an organism to reproduce and survive i.e. increase in numbers under optimal environmental conditions. It is also known as **'Maximum reproductive power'**. The biotic potential is depends on -

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

**2) Fecundity:** The more the fecundity the more will be the resultant population.

**3) Sex ratio**: Up to a limit the more the proportion of females, the more the multiplication capacity.

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

**Environmental resistance** refers to the sum total of environmental limiting factors that prevent the biotic potential from being realized.

## CAUSES FOR OUTBREAK OF PESTS IN AGRO-ECOSYSTEM

**Pest outbreak**: The increase in number of a particular pest species is termed as pest outbreak. The ecological outbreak operates through:

- Increase in rate of birth
- Decrease in rate of death
- Increase in immigration
- Decrease in emigration

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

**Reasons for outbreak:**

**i. Deforestation and bringing forest area under cultivation**

- ► This will affect the weather conditions in that locality and thus set favourable conditions for some insects to assume pest status.
- ► Pest feeding on forest trees is forced to feed on cropped area.

**ii. Destruction of natural enemies**

- ⇨ Due to excess use of insecticides, natural enemies are killed that affects the natural control mechanism and pest outbreak occurs.
- ⇨ e.g. Synthetic pyrethroid insecticides kill natural enemies. Thus, encouraged certain sucking pests to multiply to enormous proportions.

**iii. Intensive (Monoculture) and Extensive cultivation**

- When one or more related crops are raised over extensive area, limitations of food is nullify. Monoculture leads to multiplication of pests.
- If the different crops in rotation are closely related to each other or they are alternative hosts for concerned pests, pest population is likely to increase. e.g. cotton-okra: *Erias*; cotton-brinjal: whitefly.
- Extensive cultivation of susceptible crops in large area increases multiplication of insect due to no food competition. e.g. Stem borers in paddy, *Leucinodes* in brinjal, Thrips in chillies, DBM in cabbage/cauliflower in Prantij.

**iv. Introduction of new crops and high yielding improved varieties**

- Introduction of HYVs of *Hirsutum* cotton species causes pest outbreaks.
- Introduction of soyabean in Dahod district with its extensive cultivation causes the outbreak of *Prodenia* and green semilooper during *kahrif*-2008.

**v. Improved agronomic practices**

Good tilth of soil, timely irrigation, application of fertilizers improve the growth of the crop and reduce competition of food that leads build up of pest population.

- **Closer planting -** BPH, gall midge and leaf folder increases in paddy.
- **Irrigation** – With increase in irrigation facilities pest problems in many crops increased. Multiplication of brown plant hopper and gall midge increased as the level of the water in rice fields increased. Water logging enhances the multiplication of stalk borer, internode borer and whitefly in sugarcane crop.
- **Pesticides –** Large scale indiscriminate use of synthetic insecticides created problems of resurgence and pest outbreak.
- **Crop rotation –** Paddy-wheat (stem borer), Green gram – Chickpea (*Helicoverpa*), Sunflower-cotton (*Helicoverpa*) rotation cause pest outbreak.
- **Ratoon crop** favours population build up of pest. Eg. Scale, mealy bugs, whiteflies, stem borer in sugarcane. Mites in pigeonpea.
- Modification in other practices like time and manner of planting, intercropping, detrashing, harvesting time and practices etc. also aggravates insect pest problems in agriculture.

**vi. Introduction of new pest in new environment**

- A pest becomes more abundant when it is introduced into a new area. eg. FAW in maize, Apple wooly aphid *Eriosoma lanigerum* multiplied fast due to absence of specific parasitoids, *Aphelinus mali* in Nilgiri region.

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

The speeder travel has increased the chances of introduction of foreign pests into areas where they are not present earlier. e.g.

a. Diamondback moth on cauliflower (*Plutella xylostella*)
b. Potato tuber moth *Phthorimaea operculella*
c. Cottony cushion scale *Icerya purchasi* on wattle tree
d. Wooly aphid - *Eriosoma lanigerum* on apple
e. Coffee green scale, *Coccus viridis*
f. San Jose scale, *Quadraspidiotus perinicious* on fruit trees on the hills.
g. Psyllid - *Heteropsylla cubana* on subabul
h. Spiralling whitefly - *Adeyrodichus dispersus* on most of horticultural crops
i. Fall armyworm – *Spodoptera frugiperda* in maize

**viii. Large scale storage of food grains/ agril. produce**

- Large scale storage of food grains serve as reservoir for stored grain pests
- Large scale of storage of potato- potato tuber moth, *Phthorimaea operculella*

**ix. Resurgence of sucking pests**

"Tremendous increase in pest population brought about by insecticides despite good initial reduction in pest population at the time of treatment is called **resurgence**".

Sometimes application of insecticides give initial protection against sucking pests that offer physiologically favourable conditions for heavy build up of such pests. e.g.

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

**x. Biotypes of pest species**

- Development of biotypes of pest species that are able to attack resistant cultivars. e.g. Biotypes of BPH on paddy

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

The environmental factors, when they are favourable, cause pest outbreak.

# CHAPTER 3

## CATEGORIES OF INSECT PESTS
## &
## IPM: INTRODUCTION, HISTORY, IMPORTANCE, CONCEPTS, PRINCIPLES AND TOOLS OF IPM

**Pest**

"Any living organism which can cause significant and economic damage to man or man's properties" OR "Any organism that is detrimental to man and his properties"

It may be insect pest, disease producing pathogens like fungi, bacteria, viruses, mycoplasma etc., mites, rodents, bats, birds, slug & snails, weeds etc.

**INSECT PESTS**

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

**CATEGORIES OF PESTS**

**I. Based on occurrence and locality**

**Based on association with the crop**

**a.** **Regular pests:** Pests that occur more frequently on a crop having close association with particular crop. e.g. Rice stem borer, Mustard aphid, Chilli thrips

b. **Occasional pests**: Pests that occur rather infrequently and have close association with a particular crop. e.g. Rice horn caterpillar, Rice case worm

**Based on the seasonality**

c. **Seasonal pests**: Pests that occur on a crop during a particular season of the year. e.g. Red hairy caterpillar in groundnut in Saurashtra and maize in Dahod in June - July.

d. **Persistent pests**: Pests, which occur persistently on a crop almost throughout the year. e.g. Thrips on chillies

e. **Sporadic pests**: Pests, which occur in a few isolated localities during some period. Occasionally causing serious damage. e.g. Rice ear head bug, Mango shoot borer

**Based on intensity of infestations**

a. **Epidemic pests:** Pests, which occur in severe form in a region or locality at a particular season. e.g. RHC in maize in Dahod in monsoon.

**b.** **Endemic pests**: Pests, which occur regularly and confined to a particular area of locality. e.g. Mustard aphids in North Gujarat, Rice Gall midge in Madurai district

c. **Migrant pests:** These pests are highly mobile and can infest crops for short periods of time through movement. e.g. Locust

**Others**

a. **Exotic Pests*:*** Non-Native or Non-Indeginous Pests not known to occur in the state or country.

**II. Based on damage potential**

**General Equilibrium Position (GEP):** The average population density of insect over a long period of time, around which the pest population tends to fluctuate due to biotic and abiotic factors and in the absence of permanent environmental changes. It is unaffected by temporary interventions of pest control.

**Damge Boundary (DB):** The lowest level of damage which can be measured.

**Economic Injury Level (EIL):** The lowest pest population density that will cause economic damage. It is the level before which the control measures are initiated.

**Economic Threshold Level (ETL):** The population density at which control measure should be initiated against an increasing pest population to prevent economic damage. ETL is always a pest density lower than that of the EIL.

a. **Key pests**: These are the most severe damaging pests. The damage is always above the DB & EIL. GEP lies always above EIL. Human intervention may bring the population temporarily below the EIL, but it rises back rapidly and repeated sprays may be required to minimize damage. e.g. cabbage diamond back moth.
b. **Major pests**: These are pests with the population crosses EIL quite frequently and require repeated control measures to avoid economic damage. (Damage >10%). GEP lies very close to EIL or coincides with EIL e.g. Cotton jassid, Rice stem borer.
c. **Minor pests**: These are pests with population rarely crosses EIL and fluctuates around ETL. But these pests are easily control by available control measures and a single application of insecticides. (5-10% damage). GEP is usually below the EIL. These are occasional pests. e.g. Cotton stainers, Rice hispa
d. **Negligible Pest:** Population never increases high enough to cause economic injury. That cause less than 5% loss in yield, are said to be negligible pests.
e. **Potential pests**: These pests normally do not cause any economic damage. Hence, they are not pests at present but any change in the ecosystem may make them to cause economic damage (Damage > 5%). GEP always less than EIL
f. **Sporadic pests:** GEP generally below EIL Sometimes it crosses EIL and cause severe loss in some places/periods e.g. Sugarcane pyrilla, White grub, Hairy caterpillar.
g. **Secondary pests:** These pests are usually kept under adequate control by natural enemies, but can increase and produce economic losses if the natural enemies are disrupted by agricultural practices.
h. **Severe pest:** They have EIL below the GEP. Regular 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.

## IPM: Introduction, history, importance, concepts, principles and tools of IPM

After World War II the use of pesticides mushroomed, but with all the benefits of the use pesticides, it has adverse side effects on humans and in animals. During the massive use of pesticides, **Rachel Carson**, published a book ***Silent Spring*** through which she warned the people about the side effects of the use of pesticides.

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
- Deleterious effects on the environment (ecotoxicity)
- Increase of production costs, etc.
- Presence of residues in foods, feed and organisms caused widespread concern about contamination of environment.

The importance of integrated approaches to pest control was then felt and the concept of IPM evolved.

**In integrated control,** 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

**WHAT IS INTEGRATED PEST MANAGEMENT (IPM)?**

**What is IPM?**

‘**Integration’** means the harmonious use of multiple methods to control single pests as well as the impacts of multiple pests.

‘**Pests’** are any organism detrimental to humans, including invertebrate and vertebrate animals, pathogens and weeds.

‘**Management’** refers to a set of decision rules based on ecological principles and economic and social considerations. The backbone for the management of pests in an agricultural system is the concept of economic injury level (EIL).

Therefore, 'IPM' is a multidisciplinary endeavour.

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

According to Kogan (1998) "IPM is a decision support system for the selection and use of pest control tactics, singly or harmoniously coordinated into a management strategy, based on cost/benefit analysis that take into account the interests of and impacts on producers, society and the environment".

**History of IPM**

- Stern et al. (1959) systematized the integration of chemical and biological control methods. He coined the term IPM for the first time.
- Geier and Clarke (1961): The term pest management was advocated by them.
- 1976: The concept of IPM came of at the XV International Congress of Entomology.
- Metcalf (1994): He advocated judicious use of insecticides as an essential component of IPM systems based on their convenience, simplicity, effectiveness, flexibility and economy.

**Concepts of IPM**

IPM seeks to minimize the disadvantages associated with use of pesticides and maximizing socio, economic and ecological advantages**.** These are achieved through consideration of following points.

1. **Understanding the agricultural ecosystem:** An agro ecosystem is intensively manipulated by man. Agro ecosystem is a complex of food chains and food webs that interact together to produce a stable 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.
3. **Cost benefit ratio:** Based on the possibility of pest damage by predicting the pest problem and by defining ETL, emphasis should be given to cost benefit ratio.
4. **Tolerance of pest damage:** The pest free crop is neither necessary in most cases for high yields nor appropriate for insect pest management. 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.
5. **Leaving a pest residue:** 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.
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.

**Principles of IPM**

1. **Cropping system level management**: Modern IPM emphasizes the management of agricultural systems, rather than individual pests, to prevent or reduce the number and severity of pest outbreaks.
2. **Monitoring, warning and forecasting systems**
3. **Identification of pest and natural enemy**: The ability to accurately identify pests or pest damage is central to IPM, as is the ability to recognize and accurately identify a pest's important natural enemies.
4. **Life history of pest and natural enemy**: An understanding of the life history of pests and their natural enemies, as well as an understanding of the environmental conditions affecting their growth and reproduction, provide valuable information for pest management.
5. **Economic injury levels and economic (action) thresholds**: In most situations it is not necessary, desirable or even possible to eradicate a pest from an area. In IPM, acceptable pest levels are defined in terms of economic injury levels (EILs).
6. **The decision-making process**: can integrate cropping system factors to develop longer-term strategies.
7. **The combination of non-chemical methods**: that may be individually less efficient than pesticides can generate valuable synergies.
8. **Development of new biological agents and products**: offer options for the selection of products minimizing impact on health, the environment and biological regulation of pests.
9. **Reduction of pesticide use**
10. **Pesticide resistance**: Addressing the root causes of pesticide resistance is the best way to find sustainable crop protection solutions.
11. **Development of sustainable solution**: Integration of multi-season effects and trade-offs in evaluation criteria will help in development of sustainable solutions.

**Different components or tools of IPM**

1) Pest surveillance 2) Cultural methods 3) Mechanical methods 4) Physical methods

5) Biological methods (Use of parasites, predators & host plant resistance)

6) Regulatory / Legislative methods and 7) Chemical methods 8) Behavioural methods

9) Genetic / Biotechnology methods

**Why Integrated Pest Management?**

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

**Basic Requirements for successful pest management programme**

Knowledge on following points is requires for successful management of pests.

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

# 4. CULTURAL METHODS OF INSECT CONTROL AND HOST PLANT RESISTANCE (HPR)

## CULTURAL METHODS OF INSECT CONTROL

**Definition:** Cultural control is the purposeful manipulation of a cropping environment to reduce rates of pest increases and damage.

Cultural management of pests involves changes -

⇒ to make the crop less suitable for the pest

⇒ to make it suitable for natural enemies

⇒ to enhance the ability of the crop to withstand pest attack.

1. **Tillage:** Simply tilling a field may disrupt a pest's life cycle.
   e.g. Ploughing the soil up to 40 cm depth expose
   ⇒ pupae of bollworms, Gujarat hairy caterpillar and stem borers
   ⇒ adults of white grubs and
   ⇒ eggs of grasshoppers etc. to sun rays and predatory animals.
2. **Field Sanitation**: Clean cultivation is often recommended as a way to eliminate shelter and/or overwintering sites for pest populations. e.g.
   - Removing crop debris from cotton fields through allowing sheep and goats to graze cotton field after harvest, eliminates overwintering populations of pink bollworms (*Pectinophora gossypiella*).
   - Destruction of stubbles / crop residues reduces the incidence of stem borer.
   - Collection of all fallen and infested fruits of mango reduces mango fruit fly, *Bactocera dorsalis*.
3. **Removal / Destruction of alternate host:** It reduces buildup of insects in off season. Whiteflies use many broad leaf weeds as alternate host.
4. **Use of clean seed:** By using pest free healthy seeds and planting materials, possible infestation of pest can be checked. e.g. Scales and mealy bugs in sugarcane, sweet potato weevil, banana rhizome weevil.
5. **Selection of variety:** Grow pest resistant variety. e.g. Neelashan (Mango) to hoppers, Bt. cotton to *Helicoverpa armigera*, G 4 (Chilli) to thrips and mites, Pusa Purple Long (Brinjal) to FSB etc.
6. **Sowing Time:** In some crops, it is possible to create discontinuity in the pest's food supply simply by altering the time of planting by producing asynchrony between host plants and the pests. e.g. Avoidance of late sowing of pigeonpea reduces infestation of pigeonpea pod fly. Similarly, there is less infestation of aphids in timely sown mustard compared to late sown crops.
7. **Seed rate:** Adoption of appropriate seed rate ensures proper spacing and crop canopy that helps in adoption of proper spray. e.g. Use of high seed rate is recommended for shoot fly in sorghum.
8. **Plant spacing:** Spacing modifies the micro-environment of the crop, duration of crop growth and development that influence the pest population.

- Closer spacing increases the population of BPH and white backed plant hopper in paddy; whitefly in Soybean.
- Closer spacing in cotton results in bushy growth that affects penetration of light, results in vertical growth of the plant, higher RH, hinders spraying operation that favours the higher incidence of sucking pests (leaf hoppers and whitefly).
- Closer spacing decreases the population of thrips, hoppers and leaf miners in groundnut.

9. **Fertilizer management:** Application of organic manure or fertilizers in balance amount makes plant healthy that helps to minimize the pest incidence. Application of excess nitrogenous fertilizers increases susceptibility of crops against insect pests. However, application of potash reduces the incidence of insect pests.
    - Application of potash reduces virus disease transmitted by whitefly
    - Fields receiving higher dose of N-fertilizers favours incidence of the pests than crops receiving N at low level. e.g. BPH, yellow stem borer, whorl maggot, leaf folder, rice Hispa, green leaf hopper etc. in paddy; Pyrilla in sugarcane; whitefly in cotton.
10. **Irrigation management:**
    - Wireworms are controlled by flooding the field for several days or by allowing field to dry out during summer.
    - Flooding of fields –suppress cutworms, armyworms and root grubs
    - Sugarcane and wheat crops can be protected from the attack of termites by frequent light irrigations.
11. **Plant sanitation / Prunning / Thinning:** Plant sanitation is an essential prerequisite to reduce the insect population.
    - Removal of deadhearts with larvae in cereals & sugarcane reduces incidence of stem borers.
    - Picking and destruction of damaged square & bolls of cotton reduces incidence of *Helicoverpa armigera* and *Erias* spp. in cotton.
    - Picking infested shoots & fruits of brinjal reduces infestation of brinjal shoot and fruit borer; a damaged fruit of tomato, chilly reduces infestation of fruit borer.
    - Pruning of branches in Dec. -Jan. reduces citrus leaf miner.
12. **Canopy Management:** It facilitate -Light exposure, Air exposure, Pesticide exposure therefore it is beneficial.
13. **Crop rotation:** Rotating the field to a botanically different type of crop can break life cycle by starving pests that cannot adapt to a different host plant.

    In termite prone area, crops like; wheat, sugarcane, pigeonpea, chilli should be rotated with tobacco or onion.

    - Crop rotation of same group of crops i.e. cucurbits, crucifers, graminaceous, solanaceous etc. should be discouraged to reduce population of pumpkin beetles, DBM, stem borers, *Lucinodes*, respectively.

14. **Fallowing:** Fallow can reduce pest densities by starvation. If alternate host is present fallow cannot work.
15. **Trap cropping:** Trap crops are plant stands that are grown to attract insects or other organisms so that the principal crop escapes pest attack. Due to trap cropping we can keep main crop free from insecticides and this enhances natural control.

| Main crop | Trap crop | Pest |
|---|---|---|
| Cabbage, Cauliflower | Bold seeded mustard | DBM |
| Tomato | African tall marigold | Fruit borer, Leaf miner |
| Tobacco | Castor | Tobacco leaf eating caterpillar. |
| Cabbage | Tomato | DBM |
| Cotton | Okra | Spotted borer |

16. **Barrier crops**
    - The barrier can consist of a relatively tall species that is planted around the perimeter of a primary crop.
    - Living barriers include graminaceous species, like sorghum (Sorghum bicolor), Johnson grass (*Sorghum halepense*), corn (*Zea mays*) and elephant grass (*Pennisetum purpureum*).
17. **Mulching**
    - Reduces the insect's ability to find the crop.
18. **Mixed cropping /Intercropping:** Intercropping lowers the overall attractiveness of the environment, when host and non-host plants are mixed together in a single planting.
    - Tomato intercropped with cabbage reduces egg laying by DBM.
    - Intercopping of cowpea in cotton helps in colonization of coccinellids and also enhanced the parasitism of spotted bollworm.
    - Intercropping of groundnut in pearl millet reduces thrips, jassids and leaf miners.
    - Intercropping of redgram in cotton for cotton grey weevil; sunhemp in cucurbits for fruit fly; okra in cotton for spotted bollworm; soybean in groundnut for leaf miner.
19. **Hedge rows and refuge line:** Hedgerows provide benefits to enhance natural enemies. Noncropped refugia can be used to harbour beneficial organisms, especially insects and spiders. Refuge line is also useful in resistance management.
20. **Strip harvesting:** It is similar to trap cropping. Crops can be harvested in alternate strip so that insect may not move in main crop.
21. **Modify harvest schedule:** By adjusting time of harvesting, a crop can be saved from attack of the pest.
    - Timely picking of cotton avoids attack of dusky cotton bug.
    - Infestation of Sweet potato weevil reduces in timely harvest of sweet potato.
22. **Ratooning:** Avoiding rationing of pigeonpea during off season helps in reducing the carryover of pod fly and eriophyiid mite, *Aceria cajani*
23. **Border crops**

- As trap crop –Life stages
- As Banker crop –Support NE's
- As Ecofeastcrop –Sacrifice crop
- Maize around cotton field (decrease sucking pest and *H. armigera*)
- Castor in Groundnut, cotton (suppress Spodoptera)

**Advantages of cultural control**

1. No extra skill
2. No costly inputs (in most cases)
3. No special equipments
4. No toxicity or residue problem
5. Minimum effect on non target organisms
6. Ecologically sound
7. Good component in IPM
8. Minimal cost

**Limitations/Disadvantages of cultural control**

1. No complete control
2. Not always applicable
3. Usually preventive so it requires detailed advance planning (i.e. Prophylactic nature)
4. Timing decides success
5. May interfere with normal cultural operations

## HOST PLANT RESISTANCE (HPR)

**HOST PLANT RESISTANCE (HPR): Definition** "Those characters that enable a plant to avoid, tolerate or recover from attacks of insects under conditions that would cause greater injury to other plants of the same species" (Painter, R.H., 1951).

⇒ **R. H. Painter : Father of Host Plant Resistance**

**Mechanisms of Host Plant Resistance**

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

**1. Non-preference or Antixenosis:** The term 'Non-preference' refers to the response of the insect to the characteristics of the host plant, which make is unattractive to the insect for feeding, oviposition or shelter.

Kogan and Ortman (1978) proposed the term 'Antixenosis', as the term 'Non-preference' pertains to the insect and not to the host plant.

Host plant characters responsible for non-preference of the insects for shelter, oviposition, feeding, etc. are presence of morphological or chemical factor which alter insect behaviour resulting in poor establishment of the insect. e.g. Trichomes in cotton - resistant to whitefly. Wax bloom on crucifers deter diamond back moth *Plutella xylostella*.

**2. Antibiosis:** Antibiosis refers to the adverse effect of host plant on the biology (survival, development and reproduction) of the insects and their progeny due to the biochemical and biophysical factors present in it.

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. Antibiosis may be due to.

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

**Chemical factors in Antibiosis**

| Chemicals present in plants | Imparts resistance against |
|---|---|
| DIMBOA (Dihydroxy methyl benzoxazin) in maize | Against European corn borer, *Ostrinia nubilalis* |
| Gossypol (Polyphenol) in cotton | *Helicoverpa armigera* (American bollworm) |
| Sinigrin in cabbage | Aphids, *Myzus persicae* |
| Cucurbitacin in cucurbits | Cucurbit fruit flies |
| Salicylic acid in paddy | Rice stem borer |

**3. 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

e.g. Early attack by the sorghum shoot fly on main shoot induced the production of a few synchronous tillers that grow rapidly and survive to produce harvestable ear heads.

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

**1. Specificity:** Specific to the target pest. Natural enemies unaffected

**2. Cumulative effect:** Lasts for many successive generations

**3. Eco-friendly:** No pollution. No effect on man and animals

**4. Easily adoptable:** High yielding insect resistant variety easily accepted and adopted by farmers. Less cost.

**5. Effectiveness:** Res. variety increases efficacy of insecticides and natural enemies

**6. Compatibility:** HPR can be combined with all other components of IPM

**7. Decreased pesticide application:** Resistant varieties requires less frequent and low doses of insecticides

**8. Persistence:** Some varieties have durable resistance for long periods

**9. Unique situations:** HPR effective where other control measures are less effective e.g.

a. When timing of application is critical

b. Crop of low economic value

c. Pest is continuously present and is a single limiting factor

**Disadvantages/Limitations of HPR**

**1. Time consuming:** Requires 3-10 years by traditional breeding programmes to develop a research variety.

**2. Biotype development:** A biotype is a new population capable of damaging and surviving on plants previously resistant to other population of same species.

**3. Genetic limitation:** Absence of resistance genes among available germination.

# 5. MECHANICAL, PHYSICAL& LEGAL METHODS OF INSECT CONTROL

## MECHANICAL METHODS OF INSECT CONTROL

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

It includes killing or trapping pests by mechanical means or the use of barriers to prevent pests from gaining access to plants, stored products or other materials.

### I. Manual Force

i. **Hand picking of the egg masses, caterpillars etc. :**
- Egg masses of red hairy caterpillar, *Spodoptera litura* etc.
- Collection and destruction of damaged square & boll with larvae of *Helicoverpa armigera* and spotted bollworm in cotton.

ii. **Using hand nets:** Collection of grasshoppers, ear head bugs, fruit sucking moths etc.

iii. **Beating:**
- Swatting housefly and mosquito.
- Killing locusts with thorny bushes.

iv. **Sieving and winnowing:** Useful for insect pests of stored grains.
- Red flour beetle, *Tribolium castaneum* (sieving)
- Rice weevil, *Sitophilus oryzae* (winnowing)

v. **Shaking the plants :**
- Shaking neem tree to dislodge white grub's beetles**.**
- Passing rope across rice field to dislodge caseworm over standing water that is then drained out to collect the pest and suppress the population.

vi. **Hooking:** Iron hook is used against adult rhinoceros beetle to pick out of the hole.

vii. **Crushing and Swatting:** By hitting and crushing the cockroaches, bed bugs and lice like insects can be managed.

viii. **Combing:** Delousing method for Head louse

ix. **Shooting:** Shooting is relevant for noninsect pests like; monkey, pig, and bird etc. It is **restricted under prohibitory laws** for certain animals in India.

x. **Brushing and Sweeping**:
- Woollen fabrics for clothes moth, carpet beetle.
- Scale insects/mealy bugs on rose etc. can be reduced by brushing and sweeping techniques.

### II Mechanical force

i. **Entoletter:** Centrifugal force - kill insect stages - useful for storage pests.

ii. **Hopper dozer**: Kill nymphs of locusts by hording into trenches and filled with soil.

iii. **Tillage implements**: Soil borne insects, red hairy caterpillar.

iv. **Erection of bird perches:** Attracts insectivorous birds. e.g. *H. armigera* in gram

v. **Mechanical traps**:
- Heaps of plants/grasses/weeds traps red hairy caterpillar in groundnut, *Spodoptera litura* in cotton and collect and kill the trapped pests.

- ➢ Rat traps are helpful in trapping different rat species.
- ➢ Placing cut piece of banana pseudostem to attract banana pseudo stem weevil.

vi. **Use of sticky traps:** Yellow sticky trap can be used for whitefly, aphids; blue trap for thrips.

vii. **Sex Pheromone trap**: Synthetic sex pheromones are placed in traps to attract males. e.g. *Helicoverpa armigera*, *Spodoptera* litura, *Plutella xylostella*, *Leucinodes orbonalis* etc.

viii. **Air suction traps:** This trap is fixed in Godowns against stored grain pests.

**III Mechanical exclusion**

i. **Mechanical barriers:** Mechanical barriers prevent access of pests to hosts.

a. **Wrapping the fruits:** Covering fruit with brown paper bag eg. pomegranate fruit borer, *Deudorix isocrates* and citrus fruit sucking moths.

b. **Banding:** Banding (15 cm wide) with grease or slippery polythene sheets (alkathene) around trunk of mango eg. Mango mealy bug.

c. **Netting:** Putting screens on windows, doors and ventilators of green house provides protection against vector in green house.

d. **Trenching:** Digging trenches around the field helps to prevent movement of larvae from one field to another. eg. Red hairy caterpillar, *Amsacta albistriga*; armyworm, *Spodoptera mauritiana*; crawlers of locust, *Schistocera gregaria* and tobacco leaf eating caterpillar, *Spodoptera litura*.

e. **Sand barrier:** Protecting stored grains with a layer of sand on the top.

f. **Water barrier:** Ant pans for ant control.

g. **Tin barrier:** Coconut trees protected with tin band to prevent rat damage.

h. **Electric fencing**: Low voltage electric fences against rats and jackals.

i. **Paper and collar barriers:** Paper and collars are placed around small plants like tobacco and potato to protect them from cutworm infestation.

j. **Packaging:** The polymer films, laminations, and extrusions can protect packages from insect infestations.

k. **Wire-gauge screens or nylon meshes/nets:** It is used to cover seedbeds, vine yards, mango trunks to prevent the damage by insects like defoliators and borers.

l. Crushed eggshells or hydrated lime spread around plants will discourage slugs.

ii. **Clipping:**

- ➢ Clipping of leaf tips of rice seedlings containing egg masses of yellow stem borer reduces the carryover of the infestation from seedbed to main field.

iii. **Burning / Fire / Flaming:** Burning of rat, locust and grasshopper through flame thrower.

iv. **Use of reflecto-ribbon:** Due to reflection grainvorous birds remains away from field of bajara, sorghum, maize etc.

**Appliances in controlling the pests**

1. **Light traps:** Ultra Violet light is widely used in light trap. Attraction of insects through light is physical principle but attracted / trapped insects kills through mechanical devices.
2. **Pheromone trap**: Synthetic sex pheromones are placed in traps to attract males.

3. **Yellow sticky trap:** Cotton whitefly, aphids are attracted to yellow colour and trapped on the sticky material.
4. **Bait trap:** e.g. **Fishmeal trap:** This trap is used against sorghum shoot fly.
5. **Pitfall trap**: It helps to trap insects moving on the soil surface, such as ground beetles.
6. **Probe trap:** Probe trap is used to trap stored product insect.

**Advantage of mechanical control**

1. Home labour utilization
2. Low equipment cost (in most cases)
3. Ecologically safe
4. High technical skill not required.

**Limitations/Disadvantages of mechanical control**

1. Limited application
2. Rarely highly effective
3. Some mechanism require costlier equipment
4. Labour intensive

## PHYSICAL METHODS OF INSECT CONTROL

**PHYSICAL CONTROL:** It involves modification of some physical features of environment to render it unsuitable to a pest to minimize (or) prevent pest problems.

**1. Manipulation of temperature:** Extreme of temperature can cause death of any pest.

**Application of heat**

- ⇒ Sun drying the seeds to kill the eggs of stored product pests.
- ⇒ Stored grain pests can be killed by exposing them to 55 ºC for three hours.

**Solarization:** Solarization can kills dormant stages of different pests.

**Application of cold**

- ⇒ Low temperature (below 4 ºC) makes the insects inactive.
- ⇒ Cold storage (1 - 2°C for 12 - 20 days) of fruits and vegetables kills fruit flies.

**2. Manipulation of moisture**

**Flooding**

- ⇒ Alternate drying and wetting rice fields against BPH.
- ⇒ Drying grains (moisture content < 10%) prevents insect damage by stored grain pests.
- ⇒ Flooding the field for the control of cutworms, armyworm, white grubs, termites etc.

**Draining:** Draining of water from paddy field for 3-5 day is useful to control BPH and paddy case worm, *Paraponyx stagnalis*.

**3. Manipulation of light**

- ⇒ Light trapping: It is useful for monitoring of insect pests in an area.
- ⇒ The UV lamp is used to attract nocturnal insects.

**4. Manipulation of air**

- Increasing the $CO_2$ concentration in controlled atmosphere of stored grains to cause asphyxiation in stored product pests.

**5. Use of irradiation**

- Gamma irradiation from isotops like $^{60}Co$ is used to sterilize the insects in laboratory which compete with the fertile males for mating when released in natural condition.

**6. Use of Abrasive dusts**

- Applying ash over aphid infested plant parts reduce its incidence.
- Drie-Die: This is a porous finely divided silica gel causes abrasion of the insect cuticle and the loss of moisture from its body, resulting into its death. It is used against stored pests.

**7. Use of Sound:** By producing sound waves some insects/birds/rodents can be influenced.

- Ultrsonic sound waves can be used against nocturnal insects like mosquitoes and cockroaches.
- Birds and rodents that thrive on grains can be scared by producing sounds.

**8. Increase concentration of $CO_2$:** stored pests get killed due to asphyxiation.

**9. Producing alarming signals:** By producing dreadful sounds of bird's enemies, birds may go away from that area.

**10. Use of frightening devices**: eg. Birds

## LEGISLATIVE/LEGAL METHODS OF INSECT CONTROL

**Definition**: Legislative control involves the enactment of laws to regulate the entry, establishment and spread of foreign plant and animal pest in a country or area and eradication or suppression of the pests established in a limited area.

**Pests Accidentally Introduced into India**

| Sr. No. | Pests | Native Place | Year of introduction |
|---|---|---|---|
| 1 | San Jose scale of apple (*Quadraspidiotus perniciosus*) | Italy | 1879 |
| 2 | Wooly aphid of apple (*Eriosoma lanigerum*) | China | 1889 |
| 3 | Potato tuber moth (*Gnorimoschima operculella*) | Italy | 1900 |
| 4 | DBM (*Plutella xylostella*) | | 1914 |
| 5 | Cottony cushion scale (*Icerya purchasi*) | California, USA | 1926 |
| 6 | American serpentine leaf miner (*Liriomyza trifolii*) | Florida, USA | 1990 |
| 7 | Spiralling whitefly, *Aleurodicus dispersus* | Srilanka and Maldives | 1994 |
| 8 | Coconut perianth mite, *Aceria guerreronis* Keifer | Srilanka | 1998 |
| 9 | Cotton mealy bug, (*Phenacoccus solenopsis* Tinsley) | USA, via -Pakistan | 2004-05 |
| 10 | South American tomato leafminer, *Tuta absoluta* | South America | 2014 |
| 11 | Rugose spiraling whitefly, *Aleyrodicus rugioperculatus* | | 2016 |
| 12 | Fall Armyworm, *Spodoptera frugiperda* | America and South Africa | 2018 |

**Foreign Pests from which India is Free**

Mediterranean fruit fly - *Ceratitis capitata*

Codling moth of apple - *Lasperysia pomonella*

Cotton boll weevil - *Anthonomos grandis*

Grapevine phylloxera

**Quarantine:** Isolation to prevent spreading of infection

**Plant Quarantine:** The legal restriction to prevent the entrance and establishment of a plant disease or insect pest in an area where the disease or pest does not exist. In India, plant quarantine is regulated under the DIPA (Destructive Insects and Pests Act), 1914.

**PEST LEGISLATIONS**

The first Act was passed in 1906 under the Sea Customs Act of 1878 to stop the entry of Mexican cotton boll weevil.

**1914 - 'Destructive Insects and Pests Act' of India (DIPA):** 1. Prohibiting or restricting the import of plants and plant materials, insect and fungi into India. 2. Prohibiting or restricting the movement of insect or diseases and their hosts from one state to another in India.

**2020-** the *Pesticides Management Bill, 2020*, which replaced **'The Insecticides Act' 1968**

**DIFFERENT CLASSES OF QUARANTINE**

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

**Phytosanitary certificate:** The certificate issued to the consignments by the officers of the exporting state or country, as to their being free from pests, disease and weed seed is called phytosanitory certificate.

**Institute exempted from phytosanitory restrictions:**

- Indian Agricultural Research Institute (IARI), New Delhi
- Forest Research Institute, Dehra Dun
- Indian Veterinary Research Institute (IVRI), Mukteshwar
- Zoological Survey of India (ZSI)
- National Bureau of Agricultural Insect Resources (ABAIR), Banglore

2. Domestic quarantine: within different parts of country (Legislation to prevent the spread of already established pests, diseases and weeds from one part of the country to another)
3. Legislation to take up effective measures to prevent spread of established pests:
4. Legislation to prevent the adulteration and misbranding of insecticides and to determine the permissible residues in food stuff.
5. Legislation to regulate the activities of men engaged in pest control operations and the application of hazardous insecticides

**NOTE: On 12th February, *2020*, the Union Cabinet approved the *Pesticides Management Bill, 2020*, which seeks to replace the Insecticides Act, 1968, for regulating the pesticide sector by fixing prices and setting up an authority.**

## 6. BIOLOGICAL CONTROL (PARASITES, PREDATORS BACTERIA, FUNGI AND VIRUSES) AND CHEMICAL CONTROL (IMPORTANCE, HAZARDS AND LIMITATIONS)

**Biological control: Definition**

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

**History and development of biological control**

**1888 - First well planned and successful biological control attempt made by Mr. C.V. Riley** - Vedalia beetle (*Rodolia cardinalis*) was introduced from Australia to USA for cottony cushion scale, *Icerya purchasi*.

**1981 -** *Epidinocarsis lopezi* was used in a biological release programme for cassava mealy bug control under Africa-wide Biological Control Project in in Nigeria, headed by **Dr. Hans Rudolf Herren**. **Dr. Herren** was awarded the **1995 World Food Prize, for developing and implementing the world's largest biological control project** for cassava mealy bug which had almost destroyed the entire cassava crop of Africa (Nigeria).

**TECHNIQUES OF BIOLOGICAL CONTROL**

**1. IMPORTATION OR INTRODUCTION**

**Introduction/Importation**.

It is the importation of pest natural enemies from other countries, to a new environment where they do not occur naturally. Foreign exploration is conducted to identify and collect natural enemies in the country from which an exotic pest has been introduced.

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

**1898 -** First introduction of natural enemy into India**.** A coccinellid beetle, ***Cryptolaemus montrouzieri*** was imported into India from Australia and released against **coffee green scale**, ***Cocus viridis.*** Even today it is effective against mealy bugs in South India.

**1920** - A parasitoid ***Aphelinus mali*** introduced from England into at Saharanpur (Uttar Pradesh, India) to control Woolly aphid on Apple, ***Eriosoma lanigerum*.**

**1926** - The coccinellid beetle, *Rodolia cardinalis* (Origin: Australia), for cottony cushion scale, *Icerya purchasi* was introduced to India via USA (California).

**Successful Biological control of weeds**

**1795** - The first successful classical biological control was achieved in India when cochineal insect, *Dactylopius ceylonicus* was introduced from Brazil in the mistaken belief that it was the true carmine dye producing insect, *D. coccus*, controls a weed Prickly pear, *Opuntia vulgaris*.

**1921 -** The agromyzid seed fly, *Ophiomyia lantanae* was introduced from Hawaii (origin: Mexico) and released in south India for the suppression of *L. camara*.

**1982**- for *Salvinia molesta* , the weevil (*Cyrtobagous salviniae*), native to Brazil, was imported from Australia.

**1983** - A chrysomelid beetle, *Zygogramma bicolorata* was imported from Mexico for the biological suppression of congress grass, *Parthenium hysterophorus*.

For the biological suppression of water hyacinth, *Eichhornia crassipes*, exotic weevils *Neochetina eichhorniae* and *N. bruchi* (introduced from Argentina via USA)

**Transfer of parasitoids within the country**

***Epiricania melanoleuca*** is an important parasitoid of ***Pyrilla perpusilla***. The redistribution of *E. melanoleuca* for the management of sugarcane pyrilla has proved a notable success. It was introduced into **Gujarat, in 1982,** from Maharashtra and Haryana, for the control of Pyrilla on sugarcane; even after more than 35 years, it effectively suppresses the Pyrilla population in south Gujarat region.

**2. Augmentation:** It is defined as the efforts to increase population of natural enemies either by propagation and release or by environmental manipulation. Two types,

**(i) Inoculative release**: Control expected from the progeny and subsequent generations only, and not from the release itself. The release made infrequently to reestablish a species of natural enemy which is killed out by unfavourable conditions. Small numbers of a beneficial species are released in several critical locations to suppress local pest outbreaks

**(ii) Inundative release**: NE mass cultured and released to suppress pest population directly. Larger numbers are released in a single location to flood the pest population with natural enemies. e.g. *Trichogramma* sp. egg parasitoid, *Chrysoperla carnea* predator.

**3. Conservation and encouragement of indigenous NE:**

Conservation means the avoidance of measures that destroy NEs and the use of the measures that increase their longevity and reproduction or the attractiveness of an area to NEs. It is also defined as the actions that preserve and increase NE by environmental manipulation.

**Important conservation measures**

- Conservation activities might include reducing or eliminating insecticide applications to avoid killing natural enemies. e.g. Use of selective insecticides.
- Staggering harvest dates in adjacent fields or rows to insure a constant supply of hosts (prey).
- Providing shelter, over-wintering sites, or alternative food sources to improve survival of beneficial species. e.g. provide alternate host and refugia for NE.
- Avoid harmful cultural practices. e.g. avoid burning of sugarcane trashes.
- Cultivation of intercrop/varieties that favour colonization of natural enemies. e.g. sparse maize plants in groundnut/cotton harbour lady beetle.
- Provide food like pollen and nectar for adult stages of natural enemies.
- Maintenance of diversity may provide alternate hosts as a food, over wintering sites, refuges and so on.

**Parasite:** A parasite is an organism which usually much smaller than its host and a single individual usually does not kill the host.

e.g. *Epiricania melanolenca* on nymph and adults of sugarcane pyrilla.

*Trichogramma chilonis* egg parasitoid of eggs of several lepidopterans.

*Aphelinus* on aphids, mealy bugs, scale, Braconids & Icheneumonids. Braconids wasp.

**Predator:** Organism that prey the insect pests. e.g. Ladybird beetle and *Chrysoperlla* are the well known predators. Spider is the universal predator. Dragonfly, Damselfly, Preying

**Differences between predator and a parasite**

| | Predator | | Parasite |
|---|---|---|---|
| 1. | Mostly a generalized feeder | 1. | Exhibits host specialization |
| 2. | Very active in habits | 2. | Usually sluggish |
| 3. | Mouth parts are well develop | 3. | Not very well developed |
| 4. | Ovipositor not specialized | 4. | Ovipositor well developed and specialized |
| 5. | Stronger and larger than prey | 5. | Smaller than prey |

| | | | |
|---|---|---|---|
| 6. | Usually more intelligent than prey | 6. | Not clearly more intelligent than host |
| 7. | Habitat is in dependent of that of its prey | 7. | Habitat and environment is made and determined by that of the host |
| 8. | Life cycle long | 8. | Life cycle Short |
| 9. | Attack on the prey is casual and not well planned | 9. | Planning is more evident |
| 10. | Devours the prey rapidly | 10. | Kills the host slowly. |
| 11. | Attack on prey is for obtaining food for the attacking predator itself, except wasps. | 11. | It is for provision of food for the off spring |
| 12 | A single predatory may attack several hosts in a short period | 12 | A parasite completes development in a single host in most cases |

**Microbial Control:** Microbial control refers to the exploitation of disease causing organisms to reduce the pest population below the economic damage level.

**[I] Bacteria**

**i. Spore forming (Facultative, Crystelliferous): *Bacillus thuringiensis* (*B.t.*)** – is used to control larvae of many lepidoptera, larvae of Colorado potato beetle and *B.t.* '*israelensis'* is used to control mosquito larvae.

Additionally, some crops have been modified to express the insecticidal protein produced by *Bacillus thuringiensis.* They produce spores and also toxin (endotoxin). The endotoxin paralyses gut when ingested e.g. *Bacillus thuringiensis* effective against lepidopteran pests.

Commercial products : **Delfin, Dipel, Thuricide**

**ii. Spore-forming (Obligate):** e.g. ***Paenibacillus popilliae*** (Formerly, ***Bacillus popilliae***) attacking white grub of beetles, produce **'milky disease'.**

Commercial product : **'Doom'** against 'white grubs'

iii. Non-spore forming: **e.g.** *Serratia entomophila* **on grubs**

[II] Fungus

i. **Green muscardine fungus - *Metarhizium anisopliae*** attack coconut rhinoceros beetle, cuculionid and chrysomelid. Commercial product : **Metasoft**

ii. **White muscardine fungus - *Beauveria bassiana*** against lepidopteran larvae. It also controls sucking pests (aphids, whiteflies and mealy bugs) as well as orthopterans (grasshoppers, locusts, and mormon crickets). Commercial product : **Biosoft**

iii. **White halo fungus** - *Verticillium lecanii* on coffee green scale, aphids.
Commercial product : **Vertisoft**

**iv. *Hirsutella thompsonii*** - found virulent against citrus rust mite, two spotted red spider mite.

**v. *Paecilomyces lilacinus*** : It is nematophagous fungus. It controls nematodes
Commercial product **: Yorker**

**[III] Viruses**

**NPV** (Nuclear Polyhedrosis Virus) e.g. ***Ha*NPV for *Helicoverpa armigera*, *Sl*NPV for *Spodoptera litura*** Commercial product : **Elcar, Virin H, Virin S, SPOD X, Virox**

**Symptoms**

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

**[IV] Protozoa**

***Nosema locustae*** -- This microscopic protozoan is used to control grasshoppers.

***Nosema apis***—Enemy of honey bees

**[V] Nematodes**

*Steinernema carpocapsae* - This nematode serve as a vector of bacterium *Xenorhabdus nematophilus* that causes septicemia in the insect body (codling moth, *Cydia pomonella*). It is also effective against *Spodoptera litura*, paddy cutworm, *Mythimna separate* and yellow stem borer of rice, *Scirpophaga incertulas*.

Commercial product : DD-136.

**[VI] Rickettsiae:** *Rickettssiella popillae* infects the Japanese beetle causing **blue disease.**

**Biocontrol Organization:** Regional Station of Commonwealth Institute of Biological Control (CIBC) established at Bangalore in 1957. Later on it was act as Project Directorate of Biological Control (PDBC). Presently, **National Beauro of Agriculturally Important Insects (NBAII)**, Bangalore looks after Biocontrol in India. Now, **National Bureau of Agricultural Insect Resources (NBAIR).**

**Advantages of biological control in pest management**

1. It can be effective for larger area.
2. Initial cost to establish biological control station may be high but in long run it becomes cheaper.
3. Hidden pests are also controlled by the parasites eg. Stem borer are inside the stem even though they are parasitized.
4. The application of biotic agents is easy and possible even in inaccessible areas like dense forest, tall trees, ponds, rivers, lakes etc.
5. It is safe to non-target insect (beneficial).
6. Pest resistance to NE is not known.
7. Useful to reduce the use of chemical insecticides.
8. No residue problems.
9. No harmful effects on humans, livestock and other organisms.
10. Non-hazardous and eco-friendly methods.
11. It is a long lasting control i.e. biological agents will survive as long as the pest is prevalent.
12. It is self propagating and self perpetuating in nature: Once the parasites/ predators are established in the particular area/locality they multiply themselves.
13. Biological control is close to permanent.
14. Waiting period is not required for harvesting a crop after treatment with biocides.
15. The grower does not require any special treatment procedure / application equipment (sprayer, duster etc.) except for microbial preparations.
16. Biocontrol is an economically viable method. If successfully deployed and converted.
17. Biological control method can be integrated well with other methods namely cultural, physical, mechanical, chemical (except use of broad spectrum insecticides) methods and host plant resistance.

**Limitations of biological control in pest management**

1. Biological controls slow process and the exotic parasite need at least three years for proper establishment. Further farmers does not like to wait for the natural enemies they wants quick results.
2. The work of the natural enemies cannot be restricted to particular crop or area. They may migrate in nearby field.
3. If parasites have other alternative host in a locality, it may not be effective for particular pest.
4. If certain season is not favourable for the normal development of natural enemy. Replacement/changing will become necessary every year (To fill again).
5. Progress of natural enemy becomes slow if hyperparasites are present in locality.
6. Use of chemical pesticides adversely affects the population level of natural enemies.
7. It is specific in control or effective only for one pest; so far the controls of other pest farmers have to adopt other methods of insect control.
8. Not always applicable.
9. Research costs are high.
10. May be difficult or expensive to produce.
11. Level of control may not be sufficient.
12. Small farm holding is limiting factors in adopting the biocontrol programme.
13. Farmers do not easily believe that insects can help in controlling harmful insect pests.
14. The farmers are inclined to use chemical pesticides because of convenience.
15. There has been a strong feeling among the bureaucrats that biocontrol has more academic importance than practical value, hence the projects were poorly financed.

## CHEMICAL CONTROL (IMPORTANCE, HAZARDS AND LIMITATIONS)

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

**Pesticides**: Chemicals which are used to kill pests

**Insecticides**: Chemicals which are used to kill insects.

**Importance**

Chemical control have played key role in improvement of plant suffering from abnormalities but have a negative perception in public mind because pesticides are intrinsically toxic. In agricultural production, pesticides are a regular component of most systems; their development has given rise to entirely new ways of growing crops. The quantity and quality of our food and fiber production could not be maintained without substantial pesticide inputs. It is difficult to imagine a technology that would produce the amount of food and fiber and maintain the level of public health that we have today without pesticides. But their use presents a problem.

The consumption of insecticides in India is 61%, fungicide 19%, herbicide 17% and others 3%. In India, 243 g/ha pesticide is consumed which is very low as compared to Taiwan (17 kg/ha), Japan (12 kg/ha), Korea (6.6 kg/ha), Europe (3.0 kg/ha), USA (2.5 kg/ha).

The chemical insecticide came in lime light when DDT insecticidal property discovered by **Paul Muller of Switzerland in 1939**. Paul Muller awarded Nobel Prize in 1948 for discovering insecticidal property of DDT

**Advantages of Chemical Control**

1. It is often the only means of combating pests.
2. It is curative in effect.
3. It is easy to apply/adopt.
4. Farmers can apply when and where required.
5. Large area can be covered in relatively short time.
6. Broad spectrum activity: A single or combination of two insecticides in a single application may control the pest complex.
7. Depending upon crops, pests and nature of damage, a range of insecticides is available to choose from.
8. Highly effective against pests than other methods of insect control.
9. It can be used in human health programme
10. It can protect animals from illness that can be caused by parasites such as fleas.
11. Growers can get high returns on his investment in a short time.
12. It is compatible with many component of IPM.

**Limitations of Chemical Control**

1. It is non selective: May harm natural enemies (Parasites and predators) and pollinators.
2. Insecticides cause resurgence of insect pests.
3. It leads emergence of secondary pest outbreak.
4. Resistance often develops: Insects tend to become resistant to insecticides after sometime, cannot be killed.
5. It pollutes air, water and land.
6. It may cause phytotoxicity.
7. Insecticides residues in food commodities and other components of the environment affect wide variety of organisms in the food chain.
8. It upset the balance of nature, which may result in unexpected problems
9. Noncompatible with biological control method.
10. Adverse effect on animals and man himself.
11. It is dangerous to consumers, workers during and after use.
12. As it is recurring, a cost increases as control is not permanent.

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

**HAZARDS CAUSED BY PESTICIDES**

Pesticide hazard occurs at the time of **a.** Manufacturing and formulation, **b.** Application of pesticides and **c.** Consumption of treated products.

**Examples of hazards caused by pesticides**

1. In Kerala, in 1953, 108 people died due to parathion poisoning
2. 'Bhopal Gas Tragedy' in 1984 at Bhopal where the gas called Methyl isocyanate (MIC) (an intermediate involved in manufacture of carbaryl) leaked killing 5000 people and disabling 50,000 people.
3. Cases of Blindness, Cancer, Liver and Nervous system diseases where pesticides are used in high quantity.
4. Psychological symptoms like anxiety sleep disturbance, depression and severe head ache in workers involved in spraying of insecticides regularly.

## Impact of Pesticides in Agroecosystem

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

1. **Pesticide residues:** The pesticide that remains in the environment after application causes problems to humans and non-target organisms.
2. **Insecticide resistance:** Insecticide resistance is the development of an ability to tolerate a dose of insecticide, which would prove lethal (kill) to majority of the individuals of the same species.
3. **Pest Resurgence:** Tremendous increase in pest population brought about by insecticides despite good initial reduction in pest population at the time of treatment.
4. **Secondary pest outbreak:** Application of a pesticide against a major pest, kills the natural enemies of minor or secondary pest. This causes the outbreak of a secondary pest.
5. **Toxicity of non-target organisms**

## 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.

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

**Quarantine** : Isolation to prevent spreading of infection

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

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 (DIPA)” 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

**Pests Accidentally Introduced Into India**

| **Pest** | **Scientific name** |
|---|---|
| Pink bollworm | *Pectinophora gossypiella* |
| Cottony cushion scale | *Icerya purchasi* |
| Apple Wooly aphid | *Aphelinus mali* |
| San Jose scale | *Quadraspidiotus perniciosus* |
| Potato tuber moth | *Gnorimoschima operculella* |
| Potato Cyst /Golden nematode | *Globodera* sp. |
| Giant african snail | *Acatina fullica* |
| Subabul psyllid | *Heteropsylla cubana* |
| Bunchy top of banana | |
| Spiralling whitefly | *Aleurodicus dispersus* |

**Foreign Pests From Which India Is Free**

| | |
|---|---|
| Mediterranean fruitfly | *Ceratitis capitata* |
| Grapeavine phylloxera | |
| Cotton boll weevil | *Anthonomos grandis* |
| Codling moth of apple | *Lasperysia pomonella* |

PEST LEGISLATIONS

1905- Federal Insect Pest Act - first Quarantine act against San Jose scale

1912 - US Plant Quarantine Act

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

1919 - Madras Agricultural Pests and Diseases Act

1968 - The Insecticides Act

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

## CHAPTER 4
## CHEMICAL CONTROL

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

**Importance of chemical control:**

Insecticides are the most powerful tools available for use in pest management. They are highly effective, rapid in curative action, adoptable to most situations, flexible in meeting changing agronomic and ecological conditions and economical. Insecticides are the only tool for pest management that is reliable for emergency action when insect pest populations approach or exceed the economic threshold.

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

**Properties of an ideal insecticide or pesticide:**

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

**Different Classifications of Insecticides**

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

**I. Based on the origin and source of supply**

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

**B. Organic Insecticides:**

1. Insecticides of animal origin: Nereistoxin isolated from marine annelids, fish oil rosin soap from fishes etc.
2. Plant Origin insecticides or Botanical insecticides: Nicotinoids, pyrethroids, Rotenoids etc.

3. Synthetic organic insecticides: Organochlorines , Organophosphorous, Carbamate insecticides etc.,
4. Hydrocarbon oils etc.

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

**(a) Stomach poison:-** The insecticide applied on the leaves and other parts of plant when ingested act on the digestive system of the insect and bring about kill. This poison is used for chewing insects e.g. DDT, BHC, Aldrin, Toxaphene dusts, Zinc phosphide, paris green synthetic pyrethyrium.

**(b) Contact poison**:- The toxicant which brings about death of the pest species by means of contact with the cuticle. E.g. quinolphos, Monocrotophos, dichlorvos, endrin, systemic pyrethruid.

**(c) Fumigant:-** The toxicant which in its gaseous state penetrates insect body through the tracheal system and kills the pests. E.g. Alluminium phosphide, ED\CT mixture.

**Commonly used Fumigants and their doses:**

1. Aluminium phosphide, marketed as **Celphos** tablets used against field rats, groundnut bruchids etc
2. EDB Ethylene dibromide 1 lb/1000ft3 of food grains.
3. $SO_2$: By burning sulphur in godowns $SO_2$ fumes are released.

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

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

**An ideal systemic insecticide quality are**

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

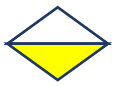
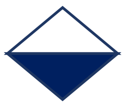
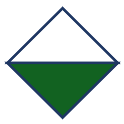
Systemic insecticides are applied as seed dressing, granular formulations, sprays etc.In the leaf, the entry of the toxicant are through stomata and cuticle. On stem the entry is through lenticels and cracks in the cuticle. In the seed it is through seed coat especially through the micropyle. Systemic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

**III. Based on mode of action:**

1. **Physical poisons**: Bring about the kill of insects by exerting a physical effect. Eg: Heavy oils, tar oils etc. which cause death by asphyxiation. Inert dusts effect loss of body moisture by their abrasiveness as in aluminium oxide or absorb moisture from the body as in charcoal.

2. **Protoplasmic poisons**: A toxicant responsible for precipitation of cell protein especially destruction of cellular protoplasm of midgut epithelium. Eg. Arsenical compounds.
3. **Respiratory poisons:** A toxicant responsible for precipitation of cell protein is said to be a protoplasmic poison e.g. Formaldehyde, Fatty acid Copper sulphite, Paris green etc.
4. **Respiratory poison**:- A chemical which inhibit cellular respiration by blocking cytochrome oxidase enzyme as with the fumigant like hydrogen cyanide, carbon monoxide EDB, ED\CT etc. is said to be a respiratory poison.
5. **Nerve poisons:** A chemical associated with solubility in tissue lipid and functions activity by blocking acetylcholinesterase enzyme in insects and warm blooded animals is called nerve poison e.g. organophosphate and carbamate insecticides, synthetic pyrethroids.
6. **Chitin inhibitors:** Chitin inhibitors interfere with process of synthesis of chitin due to which normal moulting and development is disrupted. Ex. Novaluron, Diflubenzuran, Lufenuron, Buprofezin
7. **General Poisons:**Compounds which include neurotoxic symptoms after some period and do not belong to the above categories. Eg.Chlordane, Toxaphene, aldrin

**IV. Based on toxicity:**

| Toxicity | Classification | Symbol | Oral LD50 | Dermal LD50 |
|---|---|---|---|---|
| Extremely toxic | Skull & Poison | Red  | 1-50 | 1-200 |
| Highly toxic | Poison | Yellow  | 51-500 | 201-2000 |
| Moderately toxic | Danger | Blue  | 501-5000 | 2001-20,000 |
| Less toxic | Caution | Green  | >5000 | >20,000 |

**V. Based on stage specificity:**

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

**VI. Generation wise:**

First generation - Inorganics and Botanicals
Second generation - Synthetic organics

Third generation - Recent chemicals for reproductive control, IGRs like MH & JH mimics
Fourth generation - Synthetic pyrethroids
Fifth generation - SPs, Neonicotinoids

**Toxicological terminology**

**$LD_{50}$** :Lethal dose required for killing 50% of insect and it is expressed in terms of mg/kg body weight of insect

**$LC_{50}$** : Lethal concentration required for killing 50% of insect and it is expressed on terms of percentage

**$LC_{90}$** : Lethal concentration required for killing 90% of insect and it is measured in percentage.

Thus higher the $LC_{50}$ or $LD_{90}$ vlues lesser the toxicity and vice versa

**Group of insecticides**

**3) Classification based on chemical nature:-**

Pesticides are mainly divided into two major divisions

**A) Inorganic compounds**:- Arsenic compounds, Fluorine compound, sulphar and lime sulphur, Barium carbonate, Thallium sulphite, Zinc phosphide, Aluminium phosphide.

**B) Organic compounds**:-Hydrocarbon oils e.g. petroleum oils, Tar oil etc.

**Animal origin e**.g. Nereistoxin etc.

**Plant origin** e.g. Nicotinoids, Pyrethroids, Rotenoids, Volatile oils from plants like eugenol.

**Synthetic organic compounds**

Dinitrophenols e.g. DNOC, Binapacryl etc.
Organic thiocynates e.g. Loro, Thanite etc.
Organochlorine compounds e.g. DDT, Dicofol, BHC, Endosulfan, Aldrin, heptachlor etc.
Organophosphorus compounds e.g. Dichlorvos, Quinalphos, Monocrotophos, Dimethoate, Methyl-o-demeton etc.
Carbamates e.g. carbaryl, carbofuran, Aldicarb, carbosulfan etc.
Organic sulphur compounds -Tetradifon, Aramite, chlorobenside
Other miscellaneous organic e.g. warfarin, cumarin.
Fish oil and soaps e.g. rosin fish oil soap
Synthetic pyrethroids- permethrin, cypermethrin, fenvalerate, decamethrin
Newer insecticide:-
Chloronicotinoids - Imidachloprid (gaucho), Acetamiprid (pride)

## ORGANIC COMPOUNDS OF PLANT ORIGINE

Toxicants Derived from plant are called plant origin insecticides

| | Name of compound | Plant source | Toxicity & other information |
|---|---|---|---|
| 1 | Nicotine | *Nicotiana tabacum* leaves | Nerve poison |
| 2 | Pyrethrin | *Chrysanthemum cinerariaefolium* in flowers | Natural pyrethrin |
| 3 | Rotenon | *Derris elliptica* (root) | As a Fish poison |
| 4 | Sabadilla | *Schoenocaulon otticinale* | Contact poison |
| 5 | Tephrosin | *Tephrosia vogelli* | |
| 6 | Ryania | In root of *Ryania speciosa* | |

## SYNTHETIC CHEMICALS

### A. Organochlorine compounds

| | Technical name (Insecticide) | Trade name (Formulation) | Mode of Entry Remark |
|---|---|---|---|
| 1 | DDT | DDT 5 & 10% dust | Stomach & contact |
| 2 | BHC or gamma BHC | BHC 10% dust, Lindane 0.65% | Stomach & contact |
| 3 | Aldrin | Aldrin 5 & 10% dust,30% EC | Stomach & contact |
| 4 | Endosulfan | Thiodan 35% EC | Stomach & contact |

### B. Organophosphorus compound

| | | | |
|---|---|---|---|
| 1 | Dichlorovos | DDVP 76% EC, Nuvan | Contact, Stomach, fumigation |
| 2 | Phosphamidon | Dimecron 85% EC | Contact & Stomach,systemic |
| 3 | Monocrotophos | Nuvacron 36% EC | Systemic |
| 4 | Methyl parathion | Folidol 2% Dust | Contact & Stomach |
| 5 | Fenitrothion | Sumithion, Folithion 50% EC | Contact & Stomach |
| 6 | Fenthion | Leybacid 100% EC | Contact & Stomach, systemic |
| 7 | Chlorpyriphos | Dursban or Durmet 20% EC | Contact & Stomach |
| 8 | Diazinon | Basudin 20% EC | Contact & Stomach |
| 9 | Methyl-o- demeton | Metasystox 25% EC | Systemic & contact |
| 10 | Quinalphos | Ekalux 25% EC | Contact |
| 11 | Phorate | Thimet 10% G | Systemic |
| 12 | Thiometon | Ekatin 25% EC | Systemic, Acaricides |
| 13 | Dimethoate | Rogor 30% EC | Systemic & contact |
| 14 | Formothion | Anthio25% EC | Systemic & contact |
| 15 | Profenofos | Curacron 50EC | contact & stomach. |

| | | | |
|---|---|---|---|
| 16 | Triazophos | Hostathion 40 EC | contact & stomach |
| **C. Carbamate compound** | | | |
| 1 | Carbaryl | Sevin 50% WP, Carbaryl | Contact |
| 2 | Carbofuran | Furadan 3% G | Systemic, Nematicides |
| 3 | Aldicarb | Temic 10% G | Systemic, Nematicides |
| 4 | Indoxacarb | Avaunt 14.5 SC | contact & stomach |
| 5 | Thiodicarb | Larvin 75 WP | |
| 6 | Carbosulfan | Marshal 25 EC | |
| 7 | Methomyl | Lannate, Dunet | |
| 8 | Fenobucarb | Mahakill, Knock, Merlin | |
| **D. Synthetic pyrethroid** | | | |
| 1 | Permathrin | Permasect 10 & 20% EC | Contact & stomach |
| 2 | Cypermathrin | Cyperkill, Cymbush,Ripcord 20EC | Contact |
| 3 | Fenvalate | Sumicidin 20% EC | Contact |
| 4 | Decamethrin | Decis 2.8% EC | Contact |
| 5 | Lamda cyhalothrin | Karate 5EC, Kungfoo 2.5 EC | Contact & Stomach |
| 6 | Beta cyfluthrin | Bulldock 0.25 SL | Contact & Stomach |
| 7 | Fluvalinate | Mavrik 20EC | Contact & Stomach |
| 8 | Fenpropathrin | Meothrin, Danitol and Rody | |
| 9 | Bifenthrin | Talstar | |
| **E. Neo - nicotinoids :** | | | |
| 1 | Imidacloprid | Confidor, Gaucho , Provado | Systemic |
| 2 | Acetamiprid | Pride | Systemic--sucking pests |
| 3 | Clothianidin | Dantop | |
| **F Naturalytes** | | | |
| 1 | Avermectin | *Streptomyces avermetilis* | Emamectin benzoate |
| 2 | Spinosyns | *Saccharopolyspora spinosa* | Tracer, |
| 3 | Cartap hydrochloride | Padan | Nereistoxins<br>*Lumbriconereis heteropoda* |
| **G. Chloronicotinyl Compounds** | | | |
| 1 | Thiomethoxam | Actara® and Cruiser 70WS | |
| 2 | Fipronil | Regent® | |

| | | | |
|---|---|---|---|
| 3 | Indoxacarb | Avaunt 14.5 SC | |
| 4 | Diafenthiuron | Polo 50 WP | |
| **Diamides** | | | |
| 1 | Flubendiamide | Takumi 20 WG | |
| **Quinazolines** | | | |
| 1 | Fenazaquin | Magister | |
| **Benzoylphenyl ureas (Insect growth regulators, IGRs) Chitin inhibitors** | | | |
| 1 | Lufenuron | Match 5% EC | |
| 2 | Novaluron | Remon 10% EC | |
| 3 | Buprofezin | Applaud25% EC | |
| 4 | Diflubenzuron | Dimilin25% WP | |
| | **Organosulfurs** | | |
| 1 | Proargite | Omite | |
| | **General** | | |
| 1 | Acephate | Asataf 75 % SP | |
| 2 | Dicofol | Kelthane, Dicofol 18.5% EC | |
| 3 | Thiodicarb | Laravin75%WG | |

**Technical, trade names and formulators of various pesticides (May be Duplication)**

| No. | Technical Name | Trade Name | Formulation |
|---|---|---|---|
| 1 | Abamectin | Avermectin | 1.8 % EC |
| 2 | Acephate | Asataf | 75 % SP |
| 3 | Acetamiprid | Pride | 20 % SP, |
| 4 | Aluminium phosphide | Celphos | 3g Tab |
| 5 | Betacyfluthrin | Bulldock | 25EC |
| 6 | Bifentrin | Talstar | 10% EC |
| 7 | Buprofezin | Applaud | 25% EC |
| 8 | Butacarboxim | Drawin | 50% EC |
| 9 | Carbaryl | Sevin | 10% D, 50%WP |
| 11 | Carbofuran | Furadan | 3% G |

| | | | |
|---|---|---|---|
| 12 | Carbosulfan | Marshal | 25% EC, 5%G |
| 13 | Cartap hydrochloride | Padan | 4% G, 50%SP |
| 14 | Chlorpyriphos | Dursaban, | 20% EC, 1.5% DP |
| 15 | Clothianindin | Dantop | 50% WDG |
| 16 | Cyfluthrin | Baythroid | 10% WSC, 50% WSC |
| 17 | Cypermethrin | Cymbush, Cyperkill | 10% EC, 25% EC |
| 18 | Deltamethrin/ Decamethrin | Decis | 2.8 %EC, 2.5% WP |
| 19 | Diazinon | Diazinon, Basudin, | 5% G, 10% G, 20%EC |
| 20 | Dichlorvos (DDVP) | DDVP,Vapona, Nuvan, | 76%EC |
| 21 | Difenthuron | Polo | 50%WP |
| 22 | Dicofol | Kelthane | 18.5% EC |
| 23 | Diflubenzuron | Dimilin | 25% WP |
| 24 | Dimethoate | Rogor, | 30% EC |
| 25 | Emamectin | Proclaim | 5% WG,10% SG |
| 26 | Endosulfan | Thiodan | 2% D, 4% DP, 35% EC |
| 27 | Ethion | E-Mite, Phosmite | 50% EC |
| 28 | Fenitrothion | Sumithion, | 5% D, 50% EC, |
| 29 | Fenpropethrin | Meothrin, | 30% EC |
| 30 | Fenazaquin | Magister | 10% EC |
| 31 | Fenthion | Lebaycid | 1000%EC |
| 32 | Fenvalerate | Sumicidin, | 0.4%DP, 20%EC |
| 33 | Fluvalinate | Mavrik | 25% EC |
| 34 | Formothion | Anthio | 25% EC |
| 35 | Fipronil | Regent | 5% EC |
| 36 | Imidachloprid | Gaucho, Tatamida,Confidor, Imidagold, | 70 WS,17.8 SL, 30.5 SL |
| 37 | Indoxacarb | Avaunt, Indoxa | 14.5% SC |
| 38 | Lufenuron | Match | 5% EC |
| 40 | Lambdacyhalothrin | Karate | 5% EC, 2.5% EC |
| 41 | Malathion, | Cythion, Malathion, | 5% DP, 50%EC |
| 42 | Methamidophos | Monitor, | 40% SP |
| 43 | Milbemectin | Milbeknock | 1% EC |
| 44 | Mythomyl | Lannate | 40% SP |

| | | | |
|---|---|---|---|
| 45 | Methyl-O-demeton | Metsystox | 25% EC |
| 46 | Methyl parathion | Folidol | 2% DP, 50% EC |
| 47 | Monocrotophos | Nuvacron, Monocil, | 36% SL |
| 48 | Novaluron | Remon | 10% EC |
| 49 | Permethrin | Ambush, Permasect | 25% EC, 50% EC |
| 50 | Phorate | Thimate | 10 g |
| 51 | Phosalone | Zolone | 35% EC |
| 52 | Phosphamidon | Dimecron | 40% SL |
| 54 | Profenophos | Curacron | 50% EC |
| 55 | Proparagite | Omite, Simba | 57% EC |
| 56 | Quialphos | Ekalux | 1.5 DP, 5 G, 25 EC, 20 AF |
| 57 | Spinosad | Tracer | 45% SC, 2.5%SC |
| 58 | Thiodicarb | Larvin | 75WG |
| 59 | Thiometon (morphothion) | Ekatin | 25%EC |
| 60 | Thiamethoxam | Cruiser, Actara | 70%WS, 25%WG |
| 61 | Trizophos | Hostathion | 40% EC |
| 62 | Flubendiamide | Takumi | 20 WG |
| 63 | Fenobucarb | Mahakill, Knock, Merlin | |

Toxicants Derived from plant are called plant origin insecticides

| | **Name of compound** | **Plant source** | **Toxicity & other information** |
|---|---|---|---|
| 1 | Nicotine | *Nicotiana tabacum* leaves | Nerve poison |
| 2 | Pyrethrin | *Chrysanthemum cinerariaefolium* in flowers | Natural pyrethrin |
| 3 | Rotenon | *Derris elliptica* (root) | As a Fish poison |
| 4 | Sabadilla | *Schoenocaulon otticinale* | Contact poison |
| 5 | Tephrosin | *Tephrosia vogelli* | |
| 6 | Ryania | In root of *Ryania speciosa* | |

| **Naturalytes** | | | |
|---|---|---|---|
| 1 | Avermectin | *Streptomyces avermetilis* | Emamectin benzoate |
| 2 | Spinosyns | *Saccharopolyspora spinosa* | Tracer, |
| 3 | Cartap hydrochloride | Padan | Nereistoxins |

| | | | |
|---|---|---|---|
| | | | *Lumbriconereis heteropoda* |

**Advantages of chemical control:**

1. Chemicals are powerful tools for pest management.
2. Highly effective, rapid curative action and adoptable to most situation.
3. Flexible in changing agronomic and ecological conditions.
4. It is economical.
5. Insecticides are only tools available when pest is crossing threshold levels.
6. For many of pest problems chemical control is the only acceptable solution.
7. They are easy to obtain and apply

**Limitations of chemical control:**

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

**CHITIN SYNTHESIS INHIBITORS** Chitin synthesis inhibitors disrupt molting by blocking the formation of chitin, the building block of insect exoskeleton.

| **No.** | **Name** | **Tradename** | **Formulation** |
|---|---|---|---|
| **1** | **Diflubenzuron** | Dimilin | 25 WP |
| **2** | **Flufenoxuron** | Cascade | 10 WDC |
| **3** | **Chlorfluazuron** | Atabron | 5 SC |
| **4** | **Triflumuron** | Alsystin, Baycidal Starycide | 25 WP |
| **5** | **Teflubenzuron** | Nomolt,Dart, Nemolt | 15 SC |
| **6** | **Novaluron** | Rimon | 10 EC |
| **7** | **Buprofezin** | Applaud | 25 SC, 70 WP |
| **8** | **Flufenoxuron** | Cascade, Casette, Tenope | 10%EC, 5%EC |

## CHAPTER 5

## TOXICITY OF INSECTICIDES

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**Toxicity-** is the ability of pesticides to cause harm to the human or plant health.
Human toxicity: can be caused due to the exposure of pesticides in or on the body.
Pesticide exposure means the contact of pesticides with the surface or organisms.

- Oral exposure : when swallow a pesticide
- Inhalation exposure : when breathing in a pesticide
- Ocular exposure : through the eyes
- Dermal exposure: through the skin

Pesticides cause 3 types of symptoms:

1) **Acute :** effect or illness or injuries that may appear immediately after exposure to a pesticide (usually within 24 hours). Acute symptoms of pesticides poisoning include-lack of sensation, stinging sensation, Lack of coordination, Headache, Dizziness, Tremor (Shaking), Abdominal cramps, Sweating, unclear vision, Difficulty including or respiratory depression or ,Slow heartbeat etc.
2) **Delayed or Chronic** : in chronic poisoning, the person is repeatedly exposed to toxic agent over a long period, but only a low dose enters the body each time. Chronic effects of long term pesticide exposure include: Impaired memory and concentration, Disorientation , Severe depression, Irritability, Confusion, Headache, speech difficulties, delayed reaction time , nightmares, sleep walking, Drowsiness or insomnia
3) **Allergic effect** : harmful effects that some people develop in reaction to substance that do not cause the same reaction in most of the people. Allergic effects of pesticide include:Systemic effects, such as asthama or even life-threatening shock, skin irritation, such as rash, blisters or open sores, eyes and nose irritation, such as, itchy, watery eyes and sneezing.

**PHYTOTOXICITY**

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

**1. Permanent phytotoxicity** leading to the death of the effected part or whole plant

**2. Temporary phytotoxicity** which allows the plant to recover after showing phytotoxicity

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

**Symptoms of phytotoxicity :**

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

- Poor germination of seeds

**Examples :**

| | |
|---|---|
| Organo chlorines | – Curcurbits |
| Carbaryl | – Soybean & Redgram |
| Dimethoate and Malathion | – Sorghum |
| Methyl parathion | – All Cucurbits |
| Sulphur | – Crcurbits, Apples and Tea |

CHAPTER 6
# FORMULATIONS OF INSECTICIDES

Formulation is the processing of a compound by such methods that will improve its properties of storage, handling, application, effectiveness and safety to the applicator and environment and profitability. It is the final physical condition in which insecticide is sold. A single insecticide is often sold in several different formulations.

**Types of formulations**

- **I. Solid formulations**
- **II. Liquid formulations**
- **III. Gaseous formulations**

## SOLID FORMULATIONS

1. **Dusts (D):** These are ready to use insecticides in powder form. In a dust formulation the toxicant is diluted either by mixing with or by impregnation on a suitable finely divided carrier which may be an organic flour or pulverized mineral like lime, gypsum, talc etc., or clay like attapulgite bentonite etc.The toxicant in a dust formulation ranges from 0.15 to 25% and the particle size in dust formulations is less than 100 microns and with the decrease in particle size the toxicity of the formulation increases. Dusts are easy to apply, less labour is required and water is not necessary. However if wind is there, loss of chemical occurs due to drift hence dusting should be done in calm weather and also in the early morning hours when the plant is wet with dew.
   Eg. HCH 10% dust; Endosulfan 4% D.
2. **Granules or Pelleted insecticides (G):** These are also ready to use granular or pelleted forms of insecticides. In this formulation the particle is composed of a base such as an inert material impregnated or fused with the toxicant which released from the formulation in its intact form or as it disintegrates giving controlled release. It contains 1 to 10% concentration of the toxicant. The granules are applied in water or whorls of plants or in soil. Action may be by vapour or systemic. In application of granules there is very little drift and no undue lose of chemical. Undesirable contamination is prevented. Residue problem is less since granules do not adhere to plant surface. Release of toxicant is achieved over a long period. Easy for application as water is not required for application. Less harmful for natural enemies. Eg: Carbofuran 3G, Phorate10 G, Cartap hydrochloride 4G
3. **Wettable Powders (WP)**: It is a powder formulation which is to be diluted with water and applied. It yields a stable suspension with water. The active ingredient (toxicant) ranges from 15 to 95%. It is formulated by blending the toxicant with a diluent such as attapulgite, a surface active agent and an auxiliary material. Sometimes stickers are added to improve retention on plant surface. Loss of chemical due to run off may be there and water is required for application.
   Eg: Carbaryl 50%WP, Thiodicarb 75% WP
4. **Baits:** In baits a.i is mixed with edible substance. These are always stomach poisons and are used for poison baiting which is chiefly made up of 3 components, Poison (Insecticide carbaryl), Carrier or base(Rice bran), and Attractant (Jaggery) at ratio of 1:10:1 . Poison should be strong and easily soluble. Base is the filler like rice bran with just enough water.

5. **Water Dispersible Granules (WDG):** This formulation appears as small pellets or granules. It is easier and safer to handle and mix than wettable powders. When the granules are mixed with spray water, they break apart and, with agitation, the active ingredient becomes distributed throughout the spray mixture. Ex: Thiamethoxam 25 WDG.

**LIQUID FORMULATIONS**

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

**GASEOUS FORMULATIONS**

**1. Insecticide aerosels:** The toxicant is suspended as minute particles 0.1 to 30 microns in air as fog or mist. The toxicant is dissolved in a liquified gas and if released through a small hole causes the toxicant particles to float in air with rapid evaporation of the released gas. Eg: Allethrin

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

**3. Ultra low volume concentration:** these are special formulations almost technical product as such is dissolved in a liquid solvent for micronized droplet applications without dilution. These are applied with the help of special equipment for controlled droplet applicators (CDA). Total volume dispersed dose is not exceed 1 or 2 litres per hectare by area or ground spray equipmentss.

**OTHER FORMULATIONS**

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

**Ex:** Chlorpyriphos 50% + Cypermethrin 5% EC

- Quinolphos 20% + Cypermethrin 3% EC
- Profenofos 40% + Cypermethrin 4% EC
- Profenofos 25% + Cypermethrin 5% EC
- Profenofos10% + Cypermethrin 20% EC

# CHAPTER 7
# INSECTICIDES ACT 1968

The Insecticides act of India, 1968, is an act to regulate the import, manufacture, sale, transport, distribution and use of insecticides with a view to prevent risk to human beings or animal and for matters connected there with.

The Act was passed by parliament on **September 2, 1968** and was enforced throughout the country with effect from **August 1, 1971**. The rules were framed and brought into **force on October 30 1971.**

**The objectives of insecticides act are**

- To register only safe and efficacious pesticides.
- To ensure that the farmers users get quality product for controlling the pests.
- To prescribe usage of pesticides both from ground and air, and also important precautions for their handling and use.
- To minimize health hazards from the pesticides Residue through contaminated food, water and air.
- To ensure that the pesticide industry manufacture, transport, distribute, store and sell the pesticides as per the prescribed regulations, for failing which legal action is taken.
- To ensure that the pesticides are properly tag and labelled to avoid any leakage of the hazardous pesticides in transit and to provide enough instructions for their safe handling and use.

**Some of the most important functionaries prescribed and the regulatory procedures laid down under this act are as follows:**

**A. Central bodies and Laboratories**

**I. Central insecticide Board**

This board fixes tolerance limits for insecticides residues, safety period and shelf life based on the data provided by the manufacturers and also based on research findings of the scientists in the country. It also advises Central and state government in all technical matters of insecticides.

**II. Registration committee**

Before these can be sold in India, all insecticides has to be approved and registered by this committee. Registration is done after scrutinizing and verifying the formula and their efficacy and safety to human beings and animals. In addition, the committee may also specify the precaution to be taken against poisoning by the use and handling of the particular insecticide.

**III. Other committees are**

- Pesticides environmental pollution advisory Committee, to advise the pod on all hazards emanating from the use of pesticides.
- 6 different expert panels has been constituted to finalize the approved usage of insecticides fungicides herbicides and fumigants the manufacturers of pesticides are obliged to give these usage and bio effective qualities on leaflet.

**B. Registration of insecticides**

**C. Licences for manufacture and sale**

**D. Central insecticides laboratory**

**E. State insecticides testing Laboratories**

**Salient features of the insecticides act (1968)**

Compulsory registration with CIB (Central level)

Licence for manufacture, formulation and sale at state level

Inter departmental/Ministerial/Organisational co-ordination achieved by high level Advisory Board "Central Insecticides Board" with 28 members form various fields

RC to look after registration aspects of insecticides

Enforcement by Insecticide inspectors at state/central level

Power to prohibit the import, manufacture and sale of insecticides and also confiscate stocks.

Guilty are punishable.

# CHAPTER 8
# APPLICATION TECHNIQUES OF SPRAY FLUIDS

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

1**. Dusting:** Dusting is carried out in the morning hours and during very light air stream. It can be done manually or by using dusters. Some times dust can be applied in soil for the control of soil insects. Dusting is cheaper and suited for dry land crop pest control.

**2. Spraying**: Spraying is normally carried out by mixing EC (or) WP formulations in water. There are three types of spraying.

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

**3. Granular application :** Highly toxic pesticides are handled safely in the form of granules. Granules can be applied directly on the soil or in the plant parts.

The methods of application are

a) **Broadcasting :** Granules are mixed with equal quantity of sand and broadcasted directly on the soil or in thin film of standing water. (eg.) Carbofuran 3G applied @ 1.45 kg/8 cent rice nursery in a thin film of water and impound water for 3 days.

b) **Infurrow application** : Granules are applied at the time of sowing in furrows in beds and covered with soil before irrigation. (eg.) Carbofuran 3G applied @3 g per meter row for the control of sorghum shootfly.

c) **Side dressing** : After the establishment of the plants, the granules are applied a little away from the plant (10-15 cm) in a furrow.

d) **Spot application** : Granules are applied @ 5 cm away and 5 cm deep on the sides of plant. This reduces the quantity of insecticide required.

e) **Ring application** : Granules are applied in a ring form around the trees.

f) **Root zone application** : Granules are encapsulated and placed in the root zone of the plant. (eg.) Carbofuran in rice.

g) **Leaf whorl application** : Granules are applied by mixing it with equal quantity of sand in the central whorl of crops like sorghum, maize, sugarcane to control internal borers.

h) **Pralinage :** The surface of banana sucker intended for planting is trimmed. The sucker is dipped in wet clay slurry and carbofuran 3G is sprinkled (20-40 g/sucker) to control burrowing nematode.

**4. Seed pelleting/seed dressing :** The insecticide mixed with seed before sowing (eg.) sorghum seeds are treated with chlorphyriphos 4 ml/kg in 20 ml of water and shade dried to control shootfly. The carbofuran 50 SP is directly used as dry seed dressing insecticide against sorghum shootfly.

**5. Seedling root dip:** It is followed to control early stage pests (eg.) in rice to control sucking pests and stem borer in early transplanted crop, a shallow pit lined with polythene sheet is prepared in the field. To this 0.5 kg urea in 2.5 litre of water and 100 ml chlorpyriphos in 2.5 litre of water prepared separately are poured. The solution is made upto 50 ml with water and the roots of seedlings in bundles are dipped for 20 min before transplanting.

**6. Sett treatment:** Treat the sugarcane setts in 0.05% malathion for 15 minutes to protect them from scales. Treat the sugarcane setts in 0.05% Imidacloprid 70 WS@ 175 g/ha or 7 g/l dipped for 16 minutes to protect them from termites.

**7. Trunk/stem injection:** This method is used for the control of coconut pests like black headed caterpillar, mite etc. Drill a downward slanting hole of 1.25 cm diameter to a depth of 5 cm at a light of about 1.5 m above ground level and inject 5 ml of monocrotophos 36 WSC into the stem and plug the hole with cement (or) clay mixed with a fungicide. Pseudo stem injection of banana, an injecting gun or hypodermic syringe is used for the control of banana aphid, vector of bunchy top disease.

**8. Swabbing :** Coffee white borer is controlled by swabbing the trunk and branches with HCH (BHC) 1 per cent suspension.

**9. Root feeding :** The insecticide absorbed by root, enter the plant system and control the insect.Trunk injection in coconut results in wounding of trees and root feeding is an alternate and safe chemical method to control black headed caterpillar, eriophyid mite, red palm weevil.

**11. Soil drenching :** Chemical is diluted with water and the solution is used to drench the soil to control certain subterranean pests. (eg.) BHC 50 WP is mixed with water @ 1 kg in 65 litres of water and drench the soil for the control of cotton/stem weevil and brinjal ash weevil grubs.

**12. Capsule placement :** The systemic poison could be applied in capsules to get toxic effect for a long period. (eg.) In banana to control bunchy top vector (aphid) the insecticide is filled in gelatin capsules and placed in the crown region.

**13. Baiting :** The toxicant is mixed with a bait material so as to attract the insects towards the toxicant.

a) *Spodoptera* : A bait prepared with 0.5 kg molasses, 0.5 kg carbaryl 50 WP and 5 kg of rice bran with required water (3 litres) is made into small pellets and dropped in the field in the evening hours.

b) Rats : Zinc phophide is mixed at 1:49 ratio with food like popped rice or maize or cholam or coconut pieces (or) warfarin can be mixed at 1:19 ratio with food. Ready to use cake formulation (Bromodiolone) is also available.

c) Coconut rhinoceros beetle : Castor rotten cake 5 kg is mixed with insecticide.

**14. Fumigation:** Fumigants are available in solid and liquid forms. They can be applied in the following way.(1) Soil: To control the nematode in soil, the liquid fumigants are injected by using injecting guns. (2) Storage: Liquid fumigants like Ethylene dibromide (EDB), Methyl bromide (MB), carbon tetrachloride etc. and solid fumigant like Aluminium phosphide are recommended in godowns to control stored product pest.(3) Trunk: Aluminium phosphide 7f to I tablet is inserted into the affected portion of coconut tree and plugged with cement or mud for the control of red palm weevil

**CHAPTER 9**

## INSECTICIDE POISONING, FIRST AIDS AND ANTIDOTES

**Symptoms of mild poisoning**

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

**Symptoms of moderate poisoning**

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

**Symptoms of severe poisoning**

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

**Symptoms due to Chlorinated hydrocarbons poisoning**

1. Uneasiness
2. Headache
3. Nausea
4. Vomiting
5. Dizziness and tremors
6. Convulsions
7. Respiratory arrest followed by coma
8. Leucocytosis and rise in blood pressure.

**Symptoms due to organophosphate and carbamate insecticides poisoning**

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

7. Loss of muscle coordination, speech defects; twitching of muscles; difficulty in breathing; hypertension; jerky movements; convulsions and coma indicate seriousness of poisoning.
8. Death may occur due to depressions of respiratory centre

**Zinc phosphide**

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

**Alluminium phosphide**

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

**First Aid Operations:**

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

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

**Swallowed poisoning**

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

**Inhaled poisons**

1. Carry the patient to fresh air immediately,
2. Open all doors and windows.
3. Loosen all tight clothing.
4. Apply artificial respiration if breathing has stopped or is irregular and avoid vigorous application of pressure to the chest.

5. Prevent chilling and wrap the patient in a blanket.
6. Keep the patient as quiet as possible.
7. If the patient is convulsing, keep him in bed in some dark room.
8. Do not give alcohol in any form.

**Skin contamination:**

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

**Eye contamination:**

1. Hold eye lids open
2. Wash the eyes gently with a stream of running water immediately
3. Delay of even a few second greatly increase the extent of injury
4. Continue washing until physician reaches
5. Do not use chemicals as they may increase the extent of injury.

**Antidotes:**

**General antidotes:**

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

**Specific antidotes:**

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

## CHAPTER 10

## Introduction to the conventional pesticides for the insect pests management

Much before the advent of synthetic organic insecticides need, pyrethrum, Rotenone, nicotine and number of other lesser known Botanical pesticides were used to protect agricultural crops from the ravages of insect and non insect pest in different parts of the world.

| **SN** | **Plant name** | **Product/ trade name** | **Group/mode of action** | **Targets** |
|---|---|---|---|---|
| 1 | *Lonchocarpus* spp. *Derris elliptical* | Rotenone | Insecticidal | Aphids, bean leaf beetle, cucumber beetles, leafhopper, red spider mite |
| 2 | *Chrysanthemum cinerariaefolium* | Pyrethrum/ Pyrethrins | Insecticidal | Crawling and flying insects such as cockroaches, ants, mosquitoes, termites |
| 3 | *Nicotiana tabaccum* | Nicotine | Insecticidal, antifungal | Aphids, mites, bugs, fungus, gnat, leafhoppers |
| 4 | *Azadirachta indica* | Azadirachtin/ neem oil, neem products, Bionimbecidine | Repellent, Antifeedant, Nematocide, Anti-fungal | Nematodes, sucking and chewing insects (caterpillars, aphids maize weevils) |
| 5 | Citrus trees | d-Limonene Linalool | Contact poison | Fleas, aphids, mites, paper wasp, house cricket |
| 6 | *Shoenocaulon officinale* | Sabadilla dust | Insecticidal | Bugs, blister beetles flies, caterpillars, potato leafhopper |
| 7 | *Ryania speciosa* | Ryania | Insecticidal | Caterpillars, beetles, bugs, aphids |
| 8 | *Adenium obesum (Heliotis sp)* | Chacals Baobab (Senegal) | Insecticidal | Cotton pests |

The detailed description of the above pesticide is given above in the chapter 4.

## CHAPTER 11
## IMPLEMENTATION AND IMPACT OF IPM

**IPM module of insect pests:**

**Strategies for IPM Implementation**

The IPM packages tested at several research centres vis-a-vis the farmers' practices indicate superiority of the former. IPM practices enabled reduction in the number of chemical sprays. IPM system also resulted in increase of natural enemies by three-fold, reduced the insecticide and environmental pollution (Dhaliwal and Arora, 1996).

An integrated strategy for the management of major pests and diseases is possible by

I. breeding new varieties with built-in resistance,
II. evolving efficient methods of pest control through pest surveys and monitoring, and
III. biological control of pests with the help of conservation and augmentation of natural enemies like parasites, predators and insect pathogens.

**IPM for Important Pests:**

**Rice**

| Pest | Characteristic damage | Economic thresholds | Control measures |
|---|---|---|---|
| Stem borer | Death of central shoot- Dead heart(DH), white ear(WE), Loss of tillers | 10% DH or 1 egg mass 1moth/$m^2$ | Stubble destruction, Resistant varieties like Vikas Sasyasre, Ratna. *Chemical control |
| Gall midge | Central leaf sheath modified to a Silver shoot (SS), Loss of tillers | 5% (at active tillering stage) | Early planting,Resistant varieties Phalguna, Surekha,Suraksha, *Chemical control |
| Brown plant hopper<br>Whitebacked plant hopper | Plants wilt and dry- Hopper burn | 10 insects per hill at veg. 20 insects/ hill at later stage | Resistant varieties, Alleyways formation, Draining the fileds, Judicious 'N' use, Chemical Control |
| Green leaf hopper | Vector of tungro disease, Plants wilt and dry in severe cases | 2 insects/hill in tungro endemic areas. 20-30 insects/hill in other areas | Resistant varieties, Chemical control |
| Leaf folder | Leaf damage, ill filled grain | 3 damaged leaves/ hill post active tillering stage | Judicious 'N' use, Chemical control |
| Cutworm | Defoliation and damage to rachillae | 1 leaf/hill stray incidence prior to harvesting | Flooding, Chemical control |

* need-based

**IPM - Cotton mealy bug,** *Phenacoccus solenopsis*

DAMAGE SYMPTOMS: Sucking pests feed on sap – Prefers shoots and leaves.Mature and young ones suck sap from leaves, buds, petioles, internodes.In case of severe damage, sooty mould is produced.Flowers, buds, mature bolls and even leaves fall down.Growth of the plant is retarded.Incomplete opening of the bolls and reduction in the fibre quality.In case of heavy infestations white masses of wax conceal the mealy bugs

LIFE CYCLE: Egg period: 3.5 days, Nymphal period (Male/ Female): 17.5 / 15.4 days. Fecundity cum fertility/female: 390-425 eggs. Generations/year: 10-12

MANAGEMENT STRATEGY RECOMMENDED:

- Application of methyl parathion 2% dust @ 25 kg /ha followed by deep plowing. This is most important in the field where cotton was the crop in the previous year. If irrigation facility is available, apply chlorpyriphos 20 EC @ 2 liter /ha through irrigation in case of early sown crop.
- Destruction of weed host plants, particularly Cocklebur, *Xanthium strumarium;* Indian abutilon, *Abutilon auritum*, wild *bhendi*, *Abelmoschus (Hibiscus) manihot* and Congress grass, *Parthenium hysterophorus* from the fields, field boundaries, irrigation and drainage channels, fellow land etc. This has to be carried out on cooperative and campaign base.

**MANAGEMENT STRATEGY RECOMMENDED:**

- Follow inter-culturing and weeding regularly.
- Application of methyl parathion 2% dust on field boundaries.
- In the early stage of the crop, apply recommended insecticide (as spot application) on plant infested with mealy bugs (*i.e.*, when infestation is at low level and on few plants) to prevent further multiplication of the pest.
- Foliar application of insecticides (monochrotophos @ 0.04%, methyl-o-demeton @ 0.05%, quinalphos @ 0.04%, trizophos @ 0.1 %, DDVP @ 0.075%, profenophos @ 0.05%, chlorpyrifos @ 0.05% to the extent of slight run-off. Add sticker or detergent (1 g / liter water) or power oil (1 ml / liter water). Repeat the foliar application with another insecticide after one week of first application.
- Uproot and destroy the heavily infested plants during later stage of the crop to prevent further migration and spreading of pest. Apply methyl parathion 2% dust on the spots wherein the infested plants are removed.
- Immediate disposal /burning of crop residues /cotton sticks after last picking followed by application of chlorpyriphos 20 EC @ 2 litre /ha through irrigation
- Methyl parathion 2% dust @ 25 kg /ha followed by deep ploughing.
- Follow proper crop rotation. Avoid continuous cultivation of cotton crop year after year. It is advisable not to grow the cotton crop in the field which was heavily infested with mealy bugs in the previous year.
- Searching for effective natural enemies (predators like coccinellid predator, C*ryptolaemus montrouzieri*; parasitoids like; Entomopathogenic fungus like *Beauveria bassiana* and *Verticillium lacani* etc.)

**IPM in Castor :**1. Deep ploughing in summer.2. Sow castor after 15 - August. 3. Collect & destroy egg masses of *Spodoptera*.4. Install 50-100 bird perches/ha to help birds to pick up moths/caterpillar and eat away.5. Install 5 yellow sticky traps to monitor whitefly incidence. 6. Install 7-8 pheromone traps/ha with Spodolures. 7. Install 20 Oviposition cum poison bait traps/ha(Plastic jar of 2 lit. capacity with a castor plant of 7-8 days age and a cotton wick impregnated in a mixture of Nagata 44 EC or Endosulfan 35 EC 2 ml + 250 g jaggary + 10 ml sugarcane vinegar +1 lit. water) 8. Spray SNPV 350 LE/ha in evening in700 lit. water/ha twice at 15 days' interval when small larvae of Spodoptera are found. 9. Spray neem oil based insecticide 30 ml/10 lit. or profenophos 50 EC 20 ml or quinalphos 25 EC /chlorpyriphos 20 /10 lit. water when semil-loper exceeds 4/leaf. 10. Spray neem oil based insecticide 30 ml/10 lit. or acephate 75 SP 15 g or triazophos 40 EC 25 ml or imidacloprid 18.5 EC 5 ml/10 lit. when whitefly exceeds 10 nymph/leaf.11. Spray quinalphos 25 EC 20 ml or methyl parathion 50 EC 10 ml or profenophos 50 EC 20 ml/10 lit. water against Capsule borer.

**IPM in Groundnut**

1. Install light trap after onset of first monsoon rain to attract and kill white grub beetles/moth of *Spodoptera & Helicoverpa*.2. Shake the branches of host trees of white grub & collect beetles kerosinised water to kill them.3. Prun tall host trees 9 out of 10 trees & Spray carbaryl 50 WP 40 g or quinalphos 25EC 20 ml or monocrotophos 36 WSC 12 ml/10 lit. water on host trees within 3 days of first monsoon rain on remaining tress.4. Sow sorghum/maize in groundnut in scattered manner.5. Intercrop cowpea with groundnut to reduce incidence of aphids in later crop.6. Install yellow sticky traps to monitor incidence of aphid.7. Treat groundnut seeds with 25 ml of quinalphos25 EC or chlorpyriphos 20 EC or imidacloprid 18.5 EC 5 ml + Tebuconazole 2 % DS @ 3 g/kg seeds and allow to dry under shed for 3-4 hours before sowing.8. In advance sown crop/ if untreated seeds sown apply 4 lit. of quinalphos25 EC or chlorpyriphos 20 EC by Drop by Drop method in irrigation channel or broadcast 100 kg soil impregnated with either of insecticide in standing crop when white grub damage is noticed.

**IPM in Mustard**

1. Sow GM-3 between 15- 25 October when temperature falls below 34 C. 2. Collect small larvae of mustard saw fly if less in number.3. If saw fly larvae population exceeds 2 /sq feet, spray quinalphos 25 EC 20 ml/10 lit. water.4. If aphid population exceeds 1.5 index, spray neem oil 50 ml or Growneem 1 % 50 ml or dimethoate 30 EC 10 ml/10 lit.5. For painted bug dust 2 % methyl parathion or quinalphos 1.5 % dust 25 kg/ha.

**Management of Pests of Brinjal**

Spray quinalpos 25 EC 20 ml or cypermethrin 10 EC 5 ml or carbaryl 50 WP 40 g/10 in the nursery to suppress incidence of *Leucinodes.* Install 7-8 pheromone traps with Leucilure/ha to attract and kill male moths.Spray neem seed kernel suspension 5 % or neem oil 50 ml/ 10 lit. water + 10 g soap

**To control whitefly. :** Spray neem neem oil based insecticide 30 ml or dichlorvos 76 EC 7 ml or imidcloprid 18.5 EC 5 ml. or dimethoate 30 EC 10 ml /10 lit. to control sucking pests.Spray dicofol 18. 5 EC 15 ml or propergite (Simba) 15 ml/10 lit to suppress red mite population.

**Management of Pests of Okra**

1. Remove and destroy alternate hosts like wild okra, *Hibiscus*, hollyhock etc.2. Grow Earias tolerant cultivars like Guj. Okra -1, Selection-2 Parbhani Kranti and Punjab Padmini. Sow during May to escape from heavy incidence. 3. Treat seeds with imidacloprid 7.5 g or thiomithoxam 2.8 g/kg seeds to protect okra crop from sucking pests for 30-40 days. 4.

Install 7-8 pheromone traps with Ervitlure to monitor pest incidence and kill the trapped male moth.5. Remove infested shoots, flowers and pods and destroy along with larvae inside to prevent further multiplication.6. Spray neem based Replin 1%, or Neemark 1 % 30 ml/10 lit. when the incidence is low.7. Spray methyl demeton 25 EC or dimethoate 30 EC 10 ml or imidaclprid 18.5 EC 3 ml or acetamipride 20 EC 2 g/ 10 lit. water to control aphids, leaf hopper, whitefly etc.

**To control heavy incidence of whitefly,** spray acephate 75 SP 15 g or trizophos 40 EC 25 ml.10 lit.

Spray dicofol 18.5 EC 15 ml. or anthio 25 EC 20 ml or propergite 20 ml /10 lit. water to manage **red spider mite.**

## CHAPTER 12

## SAFETY ISSUES IN USE OF PESTICIDES

Pesticides are toxic to both pests and humans. However, they need not be hazard-ous to humans and non-target animal species if suitable precautions are taken. Most pesticides will cause adverse effects if intentionally or accidentally ingested or if they are in contact with the skin for a long time. Pesticide particles may be inhaled with the air while they are being sprayed. An additional risk is the contamination of drinking-water, food or soil. Special precautions must be taken during transport, storage and handling. Spray equipment should be regularly cleaned and maintained to prevent leaks. People who work with pesticides should receive proper training in their safe use.

**Precautions**

**The label :** Pesticides should be packed and labelled according to WHO specifications (1).The label should be in English and in the local language, and should indicatethe contents, safety instructions (warnings) and possible measures in the eventof swallowing or contamination. Always keep pesticides in their original containers . Take safety measures and wear protective clothing as recommended.

**Storage and transport :** Store pesticides in a place that can be locked and is not accessible to unauthorizedpeople or children they should never be kept in a place where theymight be mistaken for food or drink. Keep them dry but away from fires and outof direct sunlight. Do not carry them in a vehicle that is also used to transport food.

**Disposal :** Left-over insecticide suspension can be disposed of safely by pouring it into aspecially dug hole in the ground or a pit latrine. It should not bedisposed of where it may enter water used for drinking or washing, fish ponds orrivers. Some insecticides, such as the pyrethroids, are very toxic to fish. Dig a holeat least 100 metres away from streams, wells and houses. In a hilly area the holeshould be on the lower side of such areas. Pour run-off water from hand washingsand spray washings into the hole, and bury containers, boxes and bottles used forpesticides in it . Close the hole as soon as possible. Cardboard, paperand cleaned plastic containers can be burned, where this is permitted, far away from houses and sources of drinking-water. For reuse of cleaned containers, see box. Pyrethroid suspensions can be poured on to dryground where they are quickly absorbed and degraded and do not cause environmental problems.Surplus solution can be used to kill insect pests such as ants and cockroaches.Pour or sponge it on to infested places (under kitchen sinks, in corners of a house).Insect breeding can be temporarily reduced by pouring the solution in and aroundlatrines or similar breeding places. Solutions of pyrethroids for the treatment ofmosquito nets and other fabrics can be used for a few days after preparation. Thesolution may also be used to treat sleeping mats or string mattresses to prevent mosquitos from biting from below. Where bedbugs are a problem, mattresses canbe treated.

**Spraying** .

- The discharge from the sprayer should be directed away from the body. Leakingequipment should be repaired and the skin should be washed after any accidentalcontamination. Persons and domestic animals must not remain indoors duringspraying. Rooms must not be sprayed if someone, e.g. a sick person, cannot bemoved out.
- Cooking utensils, food and drinking-water containers should be putoutdoors before spraying. Alternatively, they can be placed in the centre of a roomand covered with a plastic sheet.

- Hammocks, paintings and picturesmust not be sprayed. If furniture has to be sprayed on the lower side and the sidenext to a wall, care should be taken to ensure that other surfaces are not left unsprayed.
- Floors should be swept clean or washed after spraying. Inhabitantsshould avoid contact with the walls.
- Organophosphorus and carbamate compounds should not be applied for morethan 5–6 hours a day and the hands should be washed after every pump charge.
- The mouth and nose should be covered with a simple device suchas a disposable paper mask, a surgical-type disposable or washable mask, or anyclean piece of cotton.
- Long rubber gloves should be worn when treating mosquito nets, clothes, screening or tsetse traps with insecticides.
- Spray workers should wear overalls or shirts with long sleeves and trousers, abroad-brimmed hat, a turban or other headgear and sturdy shoes or boots.
- Do not eat, drink or smoke while using insecticides. Keep food in tightly closed boxes.
- Use suitable equipment for measuring out, mixing and transferring insecticide.
- Do not stir liquids or scoop pesticide with bare hands.

## CHAPTER 13

## POLITICAL AND SOCIAL IMPLICATIONS OF IPM

**Political constraints:**

- The relative low status of plant protection workers in the administrative hierarchy is a constraint to general improvement in plant protection.
- Associated with the above are the moral and financial standing of this workers.
- The continuation of pesticides subsidy by the government for political reasons and its tie up with the government provided credit for crop protection acts as a major constraint to farmers acceptance of IPM.
- Various vested interest associated with the pesticides trade also act as a political constraint on the implementation of IPM.

**Social constraints:**

- The conditioning of most farmers and farm level extension workers by the pesticide industry has created a situation where chemicals are presented as highly effective and simple to apply. This acts as a major constraint in IPM implementation.
- There appears to be a direct conflict between Industries object of more sales,and the IPM message of rational pesticides used in the eyes of farmers.
- There is a need for private industry and public sector extension Agencies to work in a more complementary manner.
- Majority of the farmer in a study in Haryana, India,express their lack of faith in IPM.
- They considered IPM practices to be risky as compared to the use of chemical pesticides.

**CHAPTER 14**

# CASE HISTORIES OF IMPORTANT IPM PROGRAMMES

## Huffaker Project

It was the first major IPM project in the USA, spanned 1972-1978 and covered six crops viz., alfalfa Citrus, cotton, pine pome and stone fruits and soyabean. The crop word selected on the basis of 3 criteria *i.e.* 1) couldn't level of insecticide use(very high in cotton and citrus and very low in soyabean) 2) potential for successful biological control (alfalfa, citrus, pome and stone fruits) 3) Representation of non agricultural system (pines). An anticipated outcome of the program was 40 – 45 percent reduction in the use of more environmentally polluting insecticide withen a 5 year period and 70 - 80% percent in 10 years. Advances were made in many aspects implementing improved IPM strategies for all system.

## Consortium for IPM

A group of scientist under the leadership of P.L. Adkisson secured funding for the second load scale large scale IPM Project in the US, called Consortium for Integrated Pest Management 1979-1985. The project focused on for major crops viz., alfalfa, Apple, cotton and soyabean. It was claimed that the average adoption of IPM for 4 crops was 66 per cent over 5.76 million ha. The main indicators of adoption were the use of Economic threshold and economic injuries levels for spray decision, use of selective pesticide or application of low dosage of broad spectrum insecticides. A significant achievement of the program was the genuine attempt to integrate weed sciences and plant pathology and the emphasis on economic assessment of IPM adoption.

## National IPM initiative

The US Department of Agriculture USDA launched national IPM initiative in 1993 the goal of which was implement IPM practices on 75 percent of the nation’s crop area by 2000. To measure the level of adoption USDA put forth PAMS concept, the acronym for prevention, avoidance, monitoring and suppression. It has been estimated that some level of IPM has been implemented on about 70% of the US crop acerage. The highest percentage of cropland under IPM was in case of cotton (86) and vegetables (86) followed by soyabean (78) other crops and pastures (63), fruits and nuts(62) and Lucrne hay (40).

## IPM in cotton

**In India,** the Indian Council of Agricultural Research, sponsored a village level IPM project to test and demonstrate the efficacy, practicability and economics of IPM in cotton in the Punjab in 1957. Initially, two or three villages were adopted for a period of 3 years after which the areas was shifted to new villages in other development blocks. In this way, a total of 15 villages in the main cotton growing districts of the state were covered during a period of 15 years. Farmers where educated regarding different insect pest problems, side effects of indiscriminate use of insecticides, cultural and mechanical practices for minimizing the incidence of insect pest and cultivation of short duration varieties. The project resulted in substantial gains. Within a period of 4 years, long duration varieties like LSS where replaced by short duration jassid -tolerant varieties. IPM Technology resulted in 73. 7 and 12. 4% reduction in number of insecticides sprays for the control of sucking pest and bollworms, respectively. In spite of reduced plant farmers obtain 23. 2 percent higher yield and 31. 7% higher net income.

A landmark in cotton IPM has been the validation of the cropping system based Holistic community approach of IPM at village Ashta (1998-2001) in Nanded dist. Of Maharashtra. the baseline information indicated less than 1 quintal average seed cotton yield per hectare in the *Helicoverpa armigera* epidemic year of 1997 when the farmers head spread more than 12-13 chemical pesticides spray rounds. All the farmers of the village were involved and the IPM approach covered 180 hectare cotton area. The offseason practices included management of *H.armigera* on pigeon pea and chickpea through use of neem seed kernel extract (NSKE) and HaNPV, field sanitation and deep plouging. In the pre sowing practices, multiplicity of cultivars avoiding by selecting only two sucking pest moderately resistant cultivars and treating the seed with Imidacloprid. the showing of entire village was completed within a week to avoid vulnerability of Crop over a long period. the IPM interventions included use of *Trichogramma chilonis* Ishii, HaNPV and NSKE. Lastly, chemical pesticides are used when needed. The average seed cotton yield in IBM was 1018 kg per hectare with an average cost benefit ratio of 1: 1. 88 compared to 649 kg per hectare seed cotton yield and 1:1. 14 C:B ratio in non IPM. The system has become self sustainable as the farmers of Ashta have themselves become decision makers and on their own have started dating many of the IPM practices.

# Recent Methods of Pest Control

## I) INSECT REPELLENTS

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

**Desirable traits of a good repellent**

a) It should be effective for a long time and on a wide range of insects.
b) Weathering effects on it should be the least.
c) Should not be toxic (or) irritating to man and animals.
d) Should leave an acceptance odour, taste and touch
e) Should be harmless to clothes.
f) Should be cheap.

**Types of repellents**

Repellents are broadly classified as Physical repellents and Chemical repellents

**1) Physical repellents**

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

**i. Contact stimuli repellents**

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

**ii. Auditory repellents**

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

**iii. Visual repellents**

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

**iv. Excitatory repellents**

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

**v. Feeding repellents**

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

**2. Chemical repellents**

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

**i. Repellents of plant origin**

The oil of citronella remained a commonly used mosquito repellent and still continues to be a constituent of a popular brand of commercial mosquito repellent, Odomos. The oil is extracted from the lemon grass, *Cymbopogon nardus* and contains citronellol, geraniol (as the main constituents), boreneol and terpenes (insmall amounts) of which the first two are regarded as the main repellents for mosquitoes. Pyrethrum is another plant product which not only acts as an insecticide but in low concentrations, also as a repellent for blood – sucking insects. Clothes impregnated with some pyrethroids have been found to afford protection against the attack of many insects vectors of diseases like *Aedes aegypi, Anopheles quardrimaculaius* etc.,

**ii. Synthetic repellents**

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

**Uses of repellents**

Repellents can find several uses such as

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

## II) INSECT ANTIFEEDANTS

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

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

**Groups of antifeedants**

**a) Triazines**

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

**b) Organotins**

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

**c) Carbamates**

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

**d) Botanical Extracts:** Antifeedants from non-host plants of the pest can be used for their control The following antifeedants are produced from plants.

**i) Pyrethrum**

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

**ii) Margosa (Neem)**

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

**iii) Apple Factor**

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

**iv) Solanum alkaloids**

Alkaloids (tomatine, solanine) extracted from some species of *Solanum* reduce feeding and survival of potato leaf hopper, *Empoasca devastans.* Besides the above, several other substances like non – essential amino acids, tannins, lignins *etc.* act as antifeedants to many insect pests.

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

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

**Advantages of Antifeedants:**

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

**Disadvantages of Antifeedants:**

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

## III) INSECT ATTRACTANTS

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

**Types of Attractants**

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

**1) Pheromones**

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

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

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

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

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

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

Sex pheromones
Aggregation pheromones
Alarm pheromones
Trail pheromones

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

**a) Sex pheromones**

A Sex pheromone released by one sex only triggers off a series of behaviour patterns in the other sex of the same species and thus facilitates mating. The male insects respond to the odorous chemical released by the female. In certain species of insects the males are known to produce the sex pheromone which attracts the females. In over 150 species of insects, females have been found to release sex pheromones and about 50 species males produce.

Ex : In the cotton boll weevil *Anthonomus grandis*

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

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

**The following sex pheromones have been isolated and identified.**

Bombycol : Silkworm, *Bombyx mori*
Gyplure : Gypsy moth, *Perthetria dispar;*
Gossyplure : Pink bollworm, *Pectionophora gossypiella*
Trimedlure : Meditarrnian fruifly, *Ceratitis capitapa*
Cuelure : Melon fly, *Bactrocera cucurbitae*
Litlure :Tobacco cutworm, *Spodoptera litura*
Helilure : Red gram pod borer, *Helicoverpa armigera*
Amlure : Chaffer beetle, *Amphimallon* sp
Looplure :Cabbage looper, *Trichoplusia ni*
Ferrolure : Coconut Red Palm Weevil , *Rhynchophorus ferrugineus*
Leucilure : Brinjal Shoot and Fruit Borer *Leucinodes orbonalis*

**Examples of male sex pheromones**

Cotton boll weevil, *Anthonomas grandis*, Coleoptera
Cabbage looper, *Trichoplusia ni*, Lepidoptera
Mediterranean fruitfly, *Ceratitis capitata*, Diptera.

**Sex pheromones in insect pest management**

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

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

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

**Merits**:

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

**Demerits**:

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

**b) Aggregation pheromones**

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

**c) Trial marking pheromone**

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

**d) Alarm pheromones**

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

**2) Natural Food lures**

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

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

**3) Oviposition Lures**

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

**4) Poison Baits**

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

**Advantages of Attractants**

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

**Disadvantages of Attractants**

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

## IV. GAMMA RADIATION AND GENETIC INSECT CONTROL

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

**A) Induced Sterility**

**i) Sterile male release technique:**

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

It is usually referred as SIT (Sterile insect technique) or SIRM (Sterile insect release method). Sterile insect release method is a genetic control method. This is also called Autocidal control since insects are used against members of their own species.

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

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

1) Rearing, Sterilization and Release (@ 9:1 sterile to fertile insects) of sterile insects to compete with the normal population.
2) Sterilizing a portion of the natural population Eg: Screw-worm (*Cochliomyia hominivorax*) a cattle pest was completely eradicated from Curacao Islands and south eastrun parts of USA by male sterilization by irradiation with gamma rays (C060).

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

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

**iii) Infecundity:** Sterile eggs by dominant lethal mutations

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

**B) Cytoplasmic Incompatibility**

Sterility is due to a cytoplasmic factor transmitted through the egg, which kills the sperm of incompatible male after its entry into the egg. Crosses between certain populations give no off-spring at all, in other cases females of one population may cross with males of another population and off-spring are produced, but the reciprocal cross is completely sterile. Recently it has been observed that in the case of some species of insects, there exist different strains with different genetic set up. When males of one such strain mate with females of another such strain, the offspring fails to develop because of incompatibility between the genes of the egg and the sperm. At an interspecific level the sperm of heterospecific males are often disadvantaged in competition with those of conspecific males.

**C) Hybrid Sterility:**

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

**D) Population Replacement:**

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

**E) Auto-Sterilization:**

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

## V) INSECT GROWTH REGULATORS (HORMONES)

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

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

**Brain hormone:** The are also called activation hormone(AH). AH is secreted by neuro secretory cells (NSC) which are neurons of central nervous system (CNS). It's role is to activate the corpora allata to produce juvenile hormone (JH).

**Juvenile hormone (JH):** Also called neotinin. It is secreted by corpora allata which are paired glands present behind insect brain. Their role is to keep the larva in juvenile condition. JH I, JH II, JH III and JH IV have been identified in different groups of insects. The concentration of JH decreases as the larva grows and reaches pupal stage. JH I, II and IV are found in larva while JH III is found in adult insects and are important for development of ovary in adult females.

**Ecdysone:** Also called Moulting hormone (MH). Ecdysone is a steroid and is secreted by Prothoracic Glands (PTG) present near prothoracic spiracles. Moulting in insects is brought about only in the presence of ecdysone. Ecdysone level decreases and is altogether absent in adult insects.

**IGRs used in Pest management**

**Ecdysoids**: These compunds are synthetic analogues of natural ecdysone. When applied in insects, kill them by formation of defective cuticle. The development processes are accelerated bypassing several normal events resulting in integument lacking scales or wax layer.

**Juvenoids (JH mimics)** : They are synthetic analogues of Juvenile Hormone (JH). They are most promising as hormonal insecticides. JH mimics were first identified by **Williams and**

**Slama** in the year 1966. They found that the paper towel kept in a glass jar used for rearing a *Pyrrhocoris* bug caused the bug to die before reaching adult stage. They named the factor from the paper as **'paper factor'** or **'juvabione'**. They found that the paper was manufactured from the wood pulp of **balsam fir tree** (*Abies balsamea*) which contained the JH mimic.

Juvenoids have **anti-metamorphic effect** on immature stages of insect. They retain *status quo* in insects (larva remains larva) and extra (super numerary) moultings take place producing intermediates which cause death of in action and they **disrupt diapauses super larva, larval-pupal and pupal-adult insects.**

**Juvenoids are larvicidal and ovicidal and inhibit embryogenesis in insects.**

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

**Anti JH or Precocenes**: they act by destroying corpora allata and preventing JH synthesis. When treated on immature stages of insect, they skip one or two larval instars and turn into tiny precocious adults. They can neither mate, nor oviposit and die soon. Eg. EMD, FMev, and PB (Piperonyl Butoxide)

**Chitin Synthesis inhibitors:** Benzoyl phenyl ureas have been found to have the ability of inhibiting chitin synthesis in vivo by blocking the activity of the enzyme chitin synthetase. Two important compounds in this category are Diflubenzuron (Dimilin) and Penfluron. The effects they produce on insects include

- ✓ Disruption of moulting
- ✓ Displacement of mandibles and labrum Adult fails to escape from pupal skin and dies Ovicidal effect.
- ✓ Chitin sysnthesis inhibitors have been registered for use in many countries and used successfully against pests of soybean, cotton, apple, fruits, vegetables, forest trees and mosquitoes and pests of stored grain.

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

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

**Advantages of Using IGRs**

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

**Disadvantages**

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

## VI) BIOTECHNOLOGY IN PEST MANAGEMENT (TRANSGENIC)

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

**Wide hybridization**: This technique involves transfer of genes from one species to other by conventional breeding. The genes for resistance are transferred from a different species. e.g. WBPH resistant gene has been transferred to *Oryza sativa* from *O.officinalis*.

**Somaclonal variability**: The variation observed in tissue culture derived progeny. e.g. Somaclonal variants of sorghum resistant to *Spodoptera litura* has been evolved.

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

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

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

**a) *Bt* endotoxin gene**:

The gram positive bacteria *Bacillus thuringiensis* produces a crystal toxin called (delta) endotoxin. The endotoxin is a stomach poison and kills the lepidopteraninsects if consumed.

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

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

**b) Protease inhibitors (PI) gene**

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

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

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

**c) Amylase inhibitor gene**

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

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

**d) Lectins genes**

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

e) **Enzyme genes**

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

**PYRAMIDING GENES**

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

The CpTi gene and pea lectin gene were cloned to produce a tranagenic tobacco.

Transgenic potato which express lectin and bean chitinase have been produced.

**Potentials/Advantages of Biotechnology in IPM**

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

# PRACTICES, SCOPE AND LIMITATIONS OF IPM

**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. An agro ecosystem is intensively manipulated by man. Agro ecosystem is a complex of food chains and food webs that interact together to produce a stable 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.

**3. Cost benefit ratio**

Based on the possibility of pest damage by predicting the pest problem and by defining ETL, emphasis should be given to cost benefit ratio.

**4. Tolerance of pest damage**

The pest free crop is neither necessary in most cases for high yields nor appropriate for insect pest management. 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.

**5. Leaving a pest residue**

Natural enemy population is gradually eliminated not only in the absence of their respective insect hosts because of the indiscriminate use of broad spectrum insecticides, which in turn 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.

**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.

**Advantage of Integrated Pest Management**:

**1. Fits better in National Economy:**

Pest control activities at present are mainly based on the application of chemical pesticides, quite a large proportion of which has to be imported. The expenditure envisaged for plant protection runs into crores of rupees even when only one or at the most two pesticide application are envisaged per crop. High yielding varieties show that many more pesticide applications are called for many crops if pest control has to depend only on the use of pesticide. Thus a time has come where Integrated Pest Management is not only advisable but also inevitable.

**2. More efficient and cheaper method:**

In IPM schedule efforts are made to utilize various methods of control including use of pesticides but some times and in some cases it is feasible to nip the trouble in the bud itself even by a mechanical campaign like destruction of egg masses of some pests or collecting the caterpillar stages. In such cases it envisages a lot of saving in the use of pesticides, this means saving of money and saving of foreign exchange and also the destruction of the pest before it has been able to inflict damage.

**3. Avoid upsetting the balance of nature:**

Chemical control has often been reported to upset the balance of nature at times leading to upsurge of new type of pest problem which did not exist before. The seriousness of mites in many parts of the world has occurred by the use of DDT. It is confidently expected that such adverse side effects will be much less as a result of integrated pest management schedule.

**4. Minimises residue hazards of pesticides:**

It is obvious that in an IPM schedule the use of pesticides will be considerably reduced, hence the pesticide residue hazards will also get automatically minimised.

**Limitations of IPM:**

- An IPM programme 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 an alternate plan for when these problems arise.

## Part IV

### I . Economic importance of insect pests

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**A. Beneficial Insects:**
Insects which produce honey, wax, lac, dyes and silk are commercially beneficial. Some insects are very helpful in destroying injurious insects.

**1. Commercial Products:**
*Apis*, the honeybees produce millions of tons of honey every year, it also gives bees wax from its combs.

Benefits of bees are cosmopolitan, not only in producing honey and wax, but also in bringing about cross-pollination of many fruits and flowers without which these plants could not exist.

*Tachardia*, the lac insect secretes commercial lac produced from integumentary glands as a protective covering by females, shellac is made from lac in India.

*Dactylopius*, the cochineal insect of Mexico is found on cacti, dried bodies of females of this scale insect are used for making cochineal dyes.

*Bombyx* and *Eupterote* are silk moths, they are reared in India, China, Japan and Europe, their larvae called silk worms spin cocoon of raw silk, the silk fibre is reeled off and used for making silk. In Asiatic countries over 25 million kilograms of silk are produced annually.

**2. Useful Predaceous Insects:** Some insects are predaceous, they feed upon and destroy a large number of injurious insects. *Stagomantis*, a mantis is voracious, it feeds on flies, grasshoppers and caterpillars, some of which are injurious to crops. The larvae and adults of *Chilomenes*, a lady-bird beetle, feed on aphids which infect cotton plants. Ladybird bettle, destroys scale insects which are pests of fruit trees trees. *Epicauta* is a blister beetle, it deposits eggs where locusts occur, the larvae on hatching enter egg capsules of locusts and eat up masses of eggs. *Calasoma*, a ground beetle preys upon many kinds of lepidopterous larvae which destroy cereals and cotton.
**3. Beneficial Parasitic Insects:** Some insects parasitise injurious insects, they usually lay eggs in the bodies of larvae and adults of harmful insects; the young on hatching from eggs finally kill their hosts. The larvae of *Tachina* and related flies are parasites of injurious lepidopterous larvae, such as army-worms which are injurious to cereals.
Larvae of hymenopteran flies and carnivorous wasps devour aphids in large numbers. Chalcids and ichneumon flies are parasitic, laying eggs in cocoon and larvae of phytophagous Lepidoptera. *Apanteles*, a hymenopteran fly lays eggs in army-worms and boll worms, the parasitic larvae gnaw their way through the skin of the host.

**4. Scavengers:** Some insects are scavengers, they eat up dead animal and vegetable matter, thus, they prevent decay. Some ants and larvae of some flies can devour entire animal carcasses.
**B. Injurious Insects:**
Compared with beneficial insects the number of injurious insects is very large.

**1. Disease Transmitting Insects:** Many types of white fly, aphids, jassids, mosquitoes, flies, fleas, lice and bugs transmit diseases to plant, man and domestic animals.
**2. Household Insects:** Human food is spoiled by cockroaches, ants, flies and weevils. Clothes moths, lay eggs on warm clothes, the larvae on hatching eat and destroy clothes, they also feed on furs, carpets and dry fruits. Carpet beetle is a scavenger eating decaying animal matter, but its larvae destroy carpets and preserved biological specimens.
*Tenebrio* is the mealworm beetle, its larvae are mealworms, they eat meal, flour and stored grains, such as rice. *Lepisma*, the silver fish and *Liposcelis*, the book louse live in and destroy

books and old manuscripts. Termites, the white ants cause untold destruction of books, carpets, furniture and wood-work of buildings.

**3. Injurious to Domestic Animals:** *Glossina*, the tsetse fly transmits *Trypanosoma brucei* which causes nagana in horses. *Tabanus* and *Stomoxys*, the blood sucking flies inject *Trypanosoma evansi* into horses and cattle which causes surra in India.

*Gasterophilus*, the bot-fly lays eggs on hair of horse, the larvae enter the stomach in large numbers. *Melophagus*, the sheep tick and *Hippobosca*, the forest fly of cattle and horses suck blood of their hosts and often cause haemorrhage.

**4. Injurious to Crops:** Many insects damage forest trees, growing farm crops, fruits and stored grain, the damage they cause annually runs into millions of rupees. The number of such insects is innumerable, they are mostly Lepidoptera, Coleoptera, Diptera and Hemiptera. Euproctis, the brown tail moth and Lymantria, the gipsy moth are serious pests of shade and foliage trees, their larvae are a menace and destroy forest trees.

**Many moths, caterpillars and beetle cause a great deal of damage to stored grains:** two beetles *Tenebrio* and *Tribolium* have similar habits and are commonly found in stores and granaries, the former is found in all stages in meal, flour and stored goods, its larvae are known as meal worms. *Tribolium* eats stored wheat and grain. *Calandra*, a weevil bores through grains of rice and other stored grain in India.

## II. Methods of diagnosis and detection of various insect pests

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Insect and non-insect pests cause a particular type of damage to the plant parts often characteristic to particular pests. The pest mostly insect not present on the site of damage makes it difficult to know the casual organism. Sometimes, the symptoms of damage caused by insects may closely resemble to those resulted due to pathogens or due to nutritional disorders. So, practical experience makes familiar about the correct diagnosis on the basis of visual symptoms of damage to take appropriate control measures.

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It is very important to know and study about the symptoms of damage by various phytophagous insect pests for proper, effective and economic management. Insect-pests found to be cause injury to plant either directly or indirectly to secure food, their development and further generations. Insect-pests attack on various parts of plant *viz.*, root, stem, bark, leaf, bud, flower and fruit. Based on the nature and symptoms of damage, insect-pests can be classified into different groups as mentioned below.

**Root and Tuber Damage**

**Root Damage :** Larvae feed on root/ root nodules or the nymphs and adults suck the cell sap form the roots resulting in stunted growth/ poor tillering/drying of plants in isolated patches.

**Wilting and drying:** Wilting and drying of plants in patches. Leaves of affected plants turn pale, droop down and ultimately wither off. Cut end of affected stem of collapsed plant swells, a characteristic diagnostic symptom. Root grub, *Holotrichia* spp, *Anomala* spp

**Poor tillering:** Affected plant tillering is very poor. Affected plant turns yellow and stunted. Rice root weevil

**Tunnels on pseudo stem:** Insects can be make tunnels on pseudo stem and plants break down at tunneled portion. Plants bear few fruits and suckers, Circular holes with black rotten tissue of rhizome plugged with excreta. Banana Rhizome weevil

**Wilting and death of plants:** In the wheat and sorghum field, infected plants are wilting and in severe infestation condition it becomes completely drying and then death. Damaged tubers in potato, when uproot plant inside stem filled up with soil and mud.

Bored hole on stem at or just below the ground level, mature and developing pods are filled with mud in Groundnut. Earthen sheeting at the base of plant, mud filled galleries in shoots, drying of shoots in Sugarcane.

Mud galleries on tree trunk, if earthen sheet is removed eaten bark of trees is visible, Death of young plants and dry up in Mango. Mud galleries on tree trunk, bark and stem are eaten below the mud galleries, Nursery and transplanted fields show wilting of central shoot and stunted growth in coconut. Termite

Wilting and Drying of plants and presence of large number of ants at the base of ragi tillers. Ragi root aphid

**Root knots:** On the roots of tomato, chilli, okra, *etc* vegetables crop roots show knots. Root knot nematode, *Meloidogyne incognita*

**Tuber Damage :**Grubs bore the tubers and veins by making tunnel and feed on the internal content. As a result of feeding, thickening and malformation of veins and discoloration, cracking or wilting of damaged veins is noticed. An infested tuber is tunnels and attacked tubers become spongy, brownish to blackish in appearance. Potato tuber moth, Sweet potato weevil

**Stem Damage :**Larvae enter into the stem/ tillers and feed on inert green matter. As a result, damaged part is wilted, dried and exhibited symptoms like dead heart/ white ear. Damaged part is cut off from the main plant and affected part wilts, dries up and exhibits symptoms like dead heart/white ear/bunchy top. Stem borers of paddy, millets, sugarcane and brinjal *etc*

**Ringing and girdling of stem bark :** Grape vine stem girdler, *Sthenias grisator,* Amaranthus stem weevil, *Hypolixus truncatulus*, Coccinia gall fly, *Neolasioptera cephalandrae*

**Galls on stem:**Insect feeding inside the stem, the plant shows a characteristic swelling and gall which hinders the growth of plant.Tobacco stem borer, cotton stem weevil

**SHOOT DAMAGE** : Larvae attack tender shoots and bore inside during the vegetative stage of the crop growth and cause wilting, drooping of terminal plant part which later dries up. Shoot borers of brinjal, bhendi, cotton, castor, shoot fly of sorghum and black gram stem fly.

**LEAF DAMAGE**

**Mines in leaf :** Larvae mine leaves/leaflets between the epidermal layers and feed on green matter, resulting in the appearance of translucent white patches/ zig-zag galleries on leaves. Leaf miner of ground nut, chickpea, rice hispa

**Serpentine mines:** Thread like. American serpentine leaf miner, *Liriomyza trifoli*

Linear or serpentine mines: Thread like. Citrus leaf miner, *Phyllocnistis citrella*

Blotch mines: Blight. Patch like. Blotch leaf miner, *Acrocercops syngramma*

Punctures on leaf - Leaves show punctures made by insects for feeding or oviposition . Bean flies, *Ophiomyia phaseoli*

**Defoliator:** Larvae feed on the leaves completely by scraping the chlorophyll content of leaves; leaving only midrib/veins or cause numerous holes. *e. g*., castor semilooper, red headed hairy caterpillar, Bihar hairy caterpillar, tobacco caterpillar

**Leaf webber:** Larvae web leaves/ leaflets by means of silken threads and feed inside the webbed leaves and the chlorophyll content. Often faecal pellets/ frass are found within the web. *e.g*: leaf Webbers on Ground nut.

**Leaf webbing :** Few leaves are webbed together and the larva feeds in between the leaves by scraping . Pumpkin caterpillar, Diaphania indica.

**Terminal leaf webbing:** The terminal tender leaves are webbed together and larvae and pupal stages occur in the webbed leaves. Larvae feed by scraping the surface. Sapota leaf webber, *Nephopteryx eugraphilla*

**Leaf folder:** Larvae fold leaves from tip to base/ longitudinally/ margin to margin edge which producing appearance of a fold/ roll. *e.g.* rice leaf folder, cotton leaf folder.

**Galls on leaf:**Larvae feeding inside the leaf/ flower bud stimulate excessive growth of cells at the affected portion and disturb normal growth which results in malformation of plant parts called as gall formation. Due to insect feeding on the leaves, the plant reaction results in gall formation like warts, *etc.* Mango gall fly, *Procantarina mattesiana*

**Out growths on leaves:** The damage makes the plant to produce felt lie out growths e.g: Jasmine mite, Aceria *jasmini*

**Leaf feeding:**

**Scraping**: Early instar larvae feed by scraping the surface of leaves leaving papery patches. Larvae of *Spodoptera litura*

**Papery windows**: Ladder like papery windows caused by the feeding of adult beetles. Brinjal epilachna beetle, *Henosepilachna vigintioctopunctata*

**Holes:**

- ❖ Small round holes result due to the feeding of small adult beetles on leaves. White spotted flea beetle, *Monolepta signata*
- ❖ Medium round symmetrical holes on leaves by the larval stages. Pea nut defoliator *Helicoverpa armigera*
- ❖ Irregular bigger holes on the leaves caused by the larval stages of many lepidopteran insects. Slug caterpillar, *Latoia lepida*, Hairy caterpillar, *Euproctis fraterna*

**Skolemization** of leaves by completely feeding on leaf lamina, leaving only the veins by larval stages . Castor semilooper, Achoea janata

**Free feeding:** Completely the lamina and veins eaten away by the voracious feeder or in severe cases by the larvae . Lemon butterfly, *Papilio demoleus*.

**Nibbling:** The leaves from margins in to small U shaped cuttings is done by adult beetles. Grey weevil, *Myllocerus viridanus*

**Cutting the leaves** in to big semicircular shape is done by adult bees. Leaf cutting bee, *Megachile anthracina*

**Crinkled leaves** are due to sucking of cell sap by nymphs and adult insects. Aphids

**Cupping /curling** of leaves with result due to sucking of insects. Thrips

**Pod/ capsule borers/ boll worm:** During the reproductive stage of crop, larva enter into the pod, capsule, boll and feed on the seed/lint exhibiting symptoms like webbed condition of pods/bolls or web few pods/capsules with frass and excreta or holes of different sizes and shapes.
*e. g.*, spotted pod borer, capsule borers of castor and red gram pod fly, tobacco caterpillar, gram caterpillar, pink boll worm *etc*.
**Tree Damage :**Yellowing of trees, withering of leaves, drying of twigs or complete drying of tree. Sometimes gummy material oozes from the affected portion on the tree trunk. Tree borers of mango, cashew, coconut red palm weevil

**Bark Damage:** Galleries of frassy web on the stem and near bark/angles of branches, Silken ribbon plastered on stem. Bark eating caterpillars of citrus, mango, guava, casuarina and jack

**FRUIT DAMAGE**

Spots on outer surface indicate the oviposition punctures of insects on fruits *e.g.*, Mango fruit fly, Ber fruit fly. Corky layer on fruit surface is caused by laceration of cells Grape vine thrips, Bore holes plugged with excreta on the fruits are done by larvae Bhendi shoot and fruit borer, *Earias vittella.* Bore holes without excreta and sometimes, larva is seen outside Tomato fruit borer, *Helicoverpa armigera.* Spots on outer surface indicate the oviposition punctures of insects on fruits. Mango fruit fly, *Bactocera dorsalis*, Ber fruit fly, *Carpomyia vesuviana* and cucurbit fruit fly *Bactocera cucurbitae*

**SEED DAMAGE: (STORED GRAIN PESTS)**

**Seed feeder (stored grain pests):**Larvae feed on stored seeds either as internal/external feeders/by webbing the food particles. *e.g.* rice weevil, red rust flour beetle, rice moth etc.

**Sap feeder:**

**a. From grain:** Nymphs and adults suck juice from developing ovaries/ milky grains resulting in the formation of shrivelled/chaffy grains *e.g.* rice gundhy bug, sorghum ear head bug, sorghum midge.

**b. From tender plant parts:** Nymphs and adults suck the cell sap from the base of the plant/leaves/ tender terminal plant parts/ flowers, thereby affect the vigour and growth of the plants. Different insects exhibit different symptoms. In case of severe infestation, sooty mould develops on the plant parts covered with honey dew excreted by insects while feeding. *e.g.* paddy brown plant hopper, white backed plant hopper, paddy leafhopper, cotton aphid.

All these insect pests causing damage to different parts of plant and based on the symptoms of damage the name was given. This will helpful for identifying the insect pest damage during field visit.

**Example:** Rice weevil, red rust flour beetle, rice moth

**DIAGNOSIS BY LOCATING SIGNS ON/NEAR PLANTS**

**Diagnosis by locating signs:** Black ants, *Componotus compressus* movement on plant parts, honey dew secretion on plant parts; Sooty mould development on plant parts. All the above indicate the presence of Homopteran insects . Mealy bug *Planococcus lilacenus*, Aphid , *Aphis craccivora*, Whitefly, *Bemisia tabaci*

**Excreta of Insects:**Black spots are found due to drying of excreta on leaves by thrips. Presence of excreta indicate usually the lepidopteran larvae

**Scale covering**: The stem, leaves *etc* are covered heavily by the scale covering

**Exuviae of insects**: Moulted skins of leafhoppers, aphids *etc* present usually on lower surface of leaves BPH moulted skins at base of plant and floating in water.

Black spots are found due to drying of excreta on leaves by thrips

## III. Importance of Economic Threshold Level

**Economic Threshold Level (ETL) :** The density at which control measures should be applied to prevent an increasing pest population from reaching the economic injury level. OR An increasingly damaging population can occur as a result of an increase in density-no. of individual or an increase in bio-mass-size of individuals. OR The economic threshold always represents a pest density lower than that of the economic injury level to allow the initiation of control measures so that they can take effect before the pest density exceeds the ETL.

**Factors Influencing ETL and EIL**

**a. Market value of crop Primary factors** :When crop value increases, EIL decreases and vice-versa.

**b. Management costs:** Management of injury per insect - When management costs increase, EIL also increases

**c. Degree of injury per insect** Secondary factors: Insects damaging leaves or reproductive parts have different EIL (Lower EIL for Rep. part damages). If insects are vectors of disease EIL is very low even 1 or 2 insects if found management to be taken. If insects found on fruits - Marketability reduced - EIL very low
**d. Crop susceptibility to injury**: If crop can tolerate the injury and give good yield. EIL can be fixed at a higher value. When crop is older, it can withstand high pest population - EIL can be high

**How Thresholds are Developed?**

Thresholds, mainly thresholds used by commercial growers, can be developed from the following factors:

1. Amount of physical damage related to various pest densities; How large thepest population can grow before it causes a certain level of damage.

2. Monetary value and production costs of the crop at various levels of physical damage

3. Monetary loss associated with various levels of physical damage.

4. Amount of physical damage that can be prevented by the control measure.

5. Monetary value of the portion the crop that can be saved by the control measure.

6. Monetary cost of the control measure.

7. History of the field.

8. Determining the danger of the pest at different stages of the crops development.

9. The pest distribution.

10. How much aesthetic or economic damage can be tolerated.

11. Establish a treatment level that keeps the pest population small enough so it does not cause an unacceptable level of damage.

12. Ultimate destination of the crop, what the standard of the end consumer is.

13. Ability to control the pest rapidly and effectively

**Importance of Thresholds**

1. The main importance is for decision making on scheduling of control and

control methods

2. To establish the optimal amount of control which can be used to minimize risk of economic damage and environmental hazards

**What factors are important when determining ET**?

- Lifecycle of your pest
- Time required for your control action to take effect
- Environmental conditions

## IV ECOLOGICAL MANAGEMENT OF THE CROP ENVIRONMENT / ECOFRIENDLY IPM

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

**Indigenous/Traditional technologies in IPM**

The following are some examples of traditional technologies in IPM

i. **Cultural methods**: (a) Farm level (b) Community level, which were originally practiced by farmers.

ii. **Physical and mechanical methods** originally followed by farmers e.g. Use of storage bins, treatment of stored grain with vegetable oil etc.,

iii. **Farmers' wisdom on pest control tactics as follows** (a) Use of chilli mash and garlic juice spray against rice earhead bug. Many other similar techniques are followed by farmers. (b) Use of ak (*Calotropis*) for termite control. Research has to be done to prove their usefulness in IPM.

**I. Cultural methods/Practices:**

**Purpose:** To make the environment less favourable for pest and/ or favourable for its natural enemies. To reduce or avoid pest damage

**Ecological base management:** "Since cultural control manipulations are based on habitat management and component of the agro-ecosystem in which the pest thrive, this approach has also been called as Ecological management or environmental control"

**Cultural practices include:**

❖ **Planting time:**

- **Asynchrony** between host plant and pest
- **Synchronizing** insect-pests and their N.E.
- **Crop production** with available alternate host plants
- **Delayed planting-** Castor semilooper
- **Early planting -** Sorghum shoofly, Rice gall midge, and leaf folder, Mustard aphid, Sugarcane borer, *Helicoverpa* in chickpea

❖ **Seed rate and plant spacing:**

- High seed rate – Sorghum shoot fly

➢ **Closer spacing** – Increase the incidence of -WBPH, BPH, gall midge, folder in Rice, Jassid, whitefly, bollworms in Cotton, Whitefly in Soybean, Borers in Sugarcane

➢ **Closer spacing** – lower incidence of- GLH, rice hispa, whorl maggot in Rice, Thrips, jassids, miners in Groundnut, Aphids in chickpea

❖ **Tillage:**

- Type and timing of tillage
- Influence the soil environment and
- Affect the survival of insect-pests or N.E.
- Pupation in soil
- Egg laying in soil

- Hibernating site-E.g. fruit flies, GHC, *Helicoverpa*, armyworm, G.H., sugarcane shoot borer (light earthing up.)

❖ **Intercropping:**Cotton with black gram, green gram, cowpea etc -Divert the population of sucking pests and *Helicoverpa*. Cotton with groundnut, cowpea, soyabean, instead of monoculture of cotton. Groundnut with bajra -Reduces thrips, jassid, leafminers. Chickpea with wheat, barley, linseed, mustard, safflower -Reduce the population of *Helicoverpa* as compare to sole crop of chickpea

❖ **Trap Cropping:** Planting small areas of a crop or other plants on the boarders or even in the main crop may serve as a trap crop for some insect-pests. Attractiveness of trap crop may be enhanced by use of
Insect-pheromones, plant kairomones or insect food supplements.

Cotton---Castor or African yellow flower marigold, Tobacco---Castor , Citrus---Tomato, Cabbage---Mustard, Tomato- Marigold- for *Helicoverpa*

❖ **Crop rotation:** Effective against the pests that have narrow host range and dispersal capacity. Cotton followed by ragi, maize, rice, groundnut, soybean- Reduce the incidence of insect-pests

❖ **Nutrient management:**

- ➢ High rate of N -Increase the incidence of WBPH, BPH, GLH, stem borer, folder in rice.
- ➢ K2O & P2O5-Lower incidence of many insect-pests
- ➢ Deficiency of N2-Increase w.fly in sugarcane

❖ **Water management:** Flooding of fields-Cutworms, army worms, termite, white grubs. Water logged condition- Build up sugarcane whiteflies

❖ **Sanitation:** Destroying or removing of crop residues- To eliminate pest overwintering sites & reduce the spreading

❖ **Harvesting practices:** Selective harvesting => Suppressing the insect population & Strip harvesting => Conserving their N. E

**II Mechanical Methods:**

❖ **Manual devices:** The reduction or suppression of insect population by means of manual devices. **Hand picking:**Hand-picking and destruction of large sized, conspicuous immature or mature stages of insect e.g. *Spodoptera*, GHCP, Rice yellow stem borer, sugarcane borers, sorghum borer

**B. Exclusion by screens and barriers:**

- **Deep trenches**: digging of 30-60 cm wide and 60 cm deep trenches or eracting 30 cm height tin sheet barriers around field- to prevent the moving bands of locust, Hairy C. P. armyworms
- **Barrier crop:** Grow 2-3 lines of bajra around <u>Groundnut</u> to prevent the spreading of thrips
- **Wrapping:** fruits wrapped in paper bags or cloths or
- Straw- E.g. fruitfly, fruit sucking moth, Anar butterfly

- **Bands:** sticky and slippery bands at the base end of tree trunk- to prevent mealy bug nymphs from climbing.
- **Trapping and suction devices:**
- **Devices**: Mechanical clevices are used for collecting insects - Light-traps, Sticky traps/ yellow sticky traps, Pheromone traps, Methyl eugenol traps, Black tulsi trap
- **Clipping, pruning and crushing:**
- **Effective**: against scale, mealybug, gallmidges- To check the multiplication of insects. Clipping of tips of rice seedling- rice stem borer
- **Flaming and burning:**Locust, GH, armyworm, GHCP

- **Washing, cleaning and soaking:** Soft bodied insect/ small insects

**III. Physical methods:**

- Use of certain physical forces to eradicate the insect population
- Heat, cold, humidity, sound, energy in the form of light traps and light regulation
- **Hot and cold treatment:**
- Sun heat- seed expose
- Hot water or hot air treatment. E.g. s.cane scale, mealybug
- Flame thrower- locust, hopper, adults
- Cold storage- fruitfly, potato tuber moth
- Empty godown, hot air treatment (50-55 °C)
- Cold application (5-10°C) - development checked
- **Moisture:** Well dried grains (below 8% moisture) - dev. Inhibited
- **Light-traps:** Attracting and mass killing of several species of moths/ beetles. Monitoring E.g. GHCP, whitegrub, s.cane root borer
- **Sound:** Affect the insect- physiological activities, mating Behaviour
- **Protective packaging:** Wooden boxes, Hard board boxes, Small iron tins

**IV. Biological control:**

**Biological control** is a process in which one species population lowers the numbers of another species by mechanisms such as predation, parasitism, pathogenesis or competition.

**Microbial Control:** when microbial organisms or their (toxins) are employed by man for the control insect, animals and plants a particular area is referred as Microbial Control . It includes (i) Viral pathogens, (ii) Fungal Pathogens, (iii) Bacterial Pathogens, (iv) Nematodes

**V. Botanical pesticides :**

- Neem, *Azadiracta indica* A Juss
- Dharek, *Melia azedaracta*.
- Pyrethrum, *Chrysanthemum cinerariaefolium*
- Rotenone, Derris elliptica
- Nicotine, Nicotiana tobacum
- Ryanodine, Ryani speciosa
- Pellitorine, Anacyclus pyrethrum
- Quassin, Quassia amara
- Sabadilla, Sabadilla officinarum
- Pongamia, P. pinnata (Karanja)
- Custard apple, Annona squamosa

## V. Methods of Pest Surveillance and Forecasting

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

**Pest Monitoring-** Monitoring phytophagous insects and their natural enemies is a fundamental tool in IPM - for taking management decision

Monitoring - estimation of changes in insect distribution and abundance

- information about insects, life history
- influence of biotic and abiotic factors on pest population

**Concepts of Pest Management:** is primarily to reduce the plant protection bill, which is achieved by adopting need-based insecticide application based on economic threshold (ET).

**Possible:** Such decision making is possible when the Surveillance Programme is effectively implemented.

❖ **Objectives of Pest Surveillance**

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

❖ **Types of Pest Surveillance:**

1. Rapid Roving Survey
2. Fixed Plot Survey

**1. Rapid Roving Survey:**

- ✓ Assessment of pest population/damage from randomly selected spots representing larger area. Large area surveyed in short period. Provides information on pest level over large area. Roving survey is undertaken in villages by Govt. agencies. This is a quick survey methods and field are visited randomly once during the week. Minimum 4 places are selected for observation every 10 km's.

**2. Fixed Plot Survey:**

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

**Monitoring can be done by:** Surveying with the help of diff. types of traps –

- ✓ Light trap
- ✓ Pheromone trap
- ✓ Water trap
- ✓ Sticky trap etc.

**After detection:** After detecting the arrival of entrance of pest in an ecosystem, the most imp. Technique is the **Surveillance and forecasting** of the pest species.

**Basic component of pest Surveillance:**

1. Determination of the level of incidence of pest species.
2. Determination of what loss the incidence will cause
3. Determination of the economic benefits or other benefits, the control will provide.
   The above information would be of immense use in pest control strategy.

**Forecasting:**
**Complex:** surveillance activities connected with pest forecasting are complex.
**Require**: forecasting pest incidence often requires systematically recorded specific field data in an elaborated manner over considerable period of time which can be easily retrieved and analysed.
**Useful**: Advance knowledge of probable pest infestation or outbreak would be very useful not only to plan the cropping pattern in such a way as to minimize the damage but also to get best advantage of pest control measure.
**Forecasting serves:**

1. To predict the forth coming infestation level of pest
2. To find out the critical stage at which the application of insecticide should be made for maximum protection.

**Forecasting of pest infestation must be related to the economic threshold of pest and can be made through:**

1. Population Studies (Quantitative studies)
2. Studies on the pest life history
3. Field studies of the effects of climate on the pest and environment

1. **Population studies:** This can be done by proper survey and sampling method. Such survey is to be carried out for several years and seasons. The seasonal count should be related with climatic factors.
2. **Studies on the pest life history:** The possible numbers of the generation and behaviour of the diff. larval instars under controlled condition in the insectory. Fecundity and length of life cycle both in the field and in the laboratory can be related to the range of environment factors.
3. **Field studies of the effect of climate:**
   - Climatic factor usually affects the **pest number** and **its N. E** directly or indirectly.
   - **The spread** of pest from area to area largely determined by **wind currents**. Therefore, a nation-wide surveillance Centre are to be more helpful for system occurrence of insect pest and disease.

**Methods of Pest Forecasting can be classified into 3 categories:**

**1)** Forecasting based on observation of environment factors.
**2)** Forecasting based on observation of climatic area.
**3)** Prediction from empirical observation.
**1)** **Forecasting based on observation of environment factors.**
   - **Biotic and abiotic:** Among the various biotic and abiotic environmental factors, **temperature** and **humidity** are the most important and used for forecasting.

**2) Forecasting based on observations of Climatic area:**

**Areas:** The areas where there is a probability of occurrence of pest species can also be forecasted.

**Factor:** In this method the biotic factor as well as topographic or climatic factors are most important combination of temperature and rainfall, Temperature and atmospheric humidity and in soil – inhabitant, insect-pest, the combination of soil-temperature and soil- moisture are most important.

**Geographical distribution zones:**

**i) Zone of normal abundance:** Pest is persistent occurrence i.e. some detectable pests can always be found on a regular basis. Such areas may be termed as endemic areas**.**

**ii) Zone of occasional abundance:** Pest occurs throughout the year but population is maintained at **low level** as **climatic factors** are not **favourable.** Under certain condition, there may be **upsurge of population** of insects.

**iii) Zone of possible abundance:** Pest does not occur normally. Migration of pest from the adjoining area and occurrence can be detected. If climatic conditions permit, the pest may assume a high level of population, thus causing outbreak.

**3) Prediction from empirical (experiential) observation:**

**Predicted:** The population can be predicted by taking into consideration the population counts of previous year and regular meteorological observations are gathered and Nation-wide forecasting information is published once a month by plant protection Division. This is helpful only in the static pests only.

**Limitation of forecasting:**

- ✓ Still it is not standard
- ✓ Time consuming and labour intensive
- ✓ Continuous evaluation is required for its validity due to changing in the agro – ecosystem.
- ✓ Faulty forecasting may led to disastrous consequences.

However, some sort of monitoring is primary requisite in the modern concepts of insect control.

**In India:** Central plant protection and quarantine established a nation-wide centre for the key pest.

**In Gujarat :** SAUs, Department of Entomology/ Pathology, sub centres, and Department of Agriculture → joint venture for survey & forecasting of major insect pest and diseases of major crops.