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PRINCIPLES OF INTEGRATED PEST AND DISEASE MANAGEMENT (ASPP3204-1+1)

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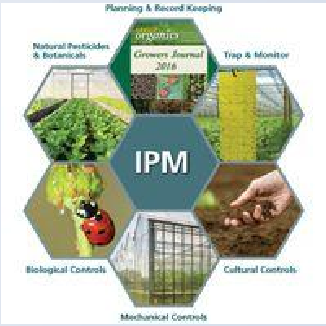
- What is Pest and Category of pest
- Integrated Disease and Pest Management
- Clultural, Physical and Mechanical
- Biological and Microbial
- Chemical Methods



Shaping Lives... Empowering Communities...

INDEX

LECTURE NO. 1

PEST - DEFINITION, CATEGORIES, CAUSES FOR OUTBREAK, LOSSES CAUSED BY PESTS

PEST - Any organism that cause significant and economic damage to crops, stored produced and animals”.

- A pest is any organism which occurs in large numbers and conflict with man’s welfare, convenience and profit
- A pest is an organism which harms man or his property significantly or is likely to do so (Woods, 1976)
- Pests are organisms which impose burdens on human population by causing
  (i) Injury to crop plants, forests and ornamentals
  (ii) Annoyance, injury and death to humans and domesticated animals
  (iii) Destruction or value depreciation of stored products.
- Pests include insects, nematodes, mites, snails, slugs, etc. and vertebrates like rats, birds, etc.

Depending upon the importance, pests may be agricultural, forest, household, medical and veterinary pests.

Parameters of insect population levels

General equilibrium position (GEP)

The average density of a population over a long period of time, around which the pest population tends to fluctuate due to biotic and abiotic factors and in the absence of permanent environmental changes.

Economic threshold level (ETL)

Population density at which control measure should be implemented to prevent an increasing pest population from reaching the ETL. It is also known as Action Thresold.

ETL= EIL - Daily reproductive rate of insects

Economic injury level (EIL)

The lowest population density that will cause economic damage.

Damage boundary (DB)

The lowest level of damage which can be measured. ETL is always less than EIL. Provides sufficient time for control measures.

CATEGORIES OF PESTS

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

a. **Regular pests**: **Regular pest**: Occur most frequently (regularly) in a crop and have close association with that particular crop. Eg: Chilli Thrips *Scirtothrips dorsalis* , brinjal shoot and fruit borer, *Leucinodes orbonalis,* Rice stem borer.
b. **Occasional pests**: Here a close association with a particular crop is absent and they occur infrequently. Eg: Rice case worm, *Nymphula depuctalis* castor slug caterpillar, *Parasa lepida* , mango stem borer, *Batocera rufamaculata*
c. **Seasonal pests**: Occur mostly during a particular part of the year, and usually the incidence is governed by climatic conditions. Eg: Red hairy caterpillar on groundnut-June - July, Rice grasshoppers –June-July
d. **Persistent pests**: Occur on a crop almost throughout the year. Eg. Thrips on chillies.
e. **Sporadic pests**: Pests, which occur in a few isolated localities Eg. Rice ear head bug.

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

a. **Epidemic pests**: Occur in a severe form in a region or locality at a particular season or time only. Eg: Rice hispa, *Dicladispa armigera*, rice leaf roller, *Cnaphalocrocis medinalis*

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

III. Pests are classified as follows based on damage potential

a. **Key pests**: These are the most severely damaging pests. The GEP is always above the EIL. Human intervention may bring the population temporarily below the EIL, but it rises back rapidly and repeated interventions (sprays) may be required to minimize damage. These are persistent pests. The environment must be changed to bring GEP below EIL. Ex.Cotton bollworm, Diamond backmoth

b. **Major pests**: These are pests with the population crosses EIL quite frequently. Economic damage can be prevented by timely and repeated sprays 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 amenable to available control measures and a single application of insecticides is usually enough to prevent economic damage (5-10% damage).

d. Potential pests: These pests normally do not cause any economic damage. Any change in the ecosystem may make them to cause economic damage .

e. Sporadic pests : GEP generally below EIL The population of these pests is usually negligible but in certain years under favorable environmental conditions, they appear in a virtually epidemic form crossing many times over DB and EIL. Under these conditions, the pest has to be controlled by undertaking suitable management strategies. These pests are highly sensitive to abiotic conditions and once the favorable season is over, only a residual population survives.

Ex: White grub, hairy caterpillars, cut worm, grass hoppers

LECTURE NO. 2

INTEGRATED PEST MANAGEMENT

History of Integrated Pest Management

- Michelbacher and Bacon (1952) coined the term "integrated control"
- Stern *et al*. (1959) defined integrated control as "applied pest control which combines and integrates biological and chemical control"
- Geier (1966) coined the term "pest management"
- Council on Environmental Quality (CEQ, 1972) gave the term "Integrated Pest Management"
- In 1989, IPM Task Force was established and in 1990. IPM Working Group (IPMWG) was constituted to strengthen implementation of IPM at international level.
- In 1997, Smith and Adkisson were awarded the World Food Prize for pioneering work on implementation of IPM.

Definition IPM by Food and Agricultural Organization (FAO, 1967)

Integrated Pest Management (IPM) is a pest management system that, in the context of associated environment and population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains pest populations at levels below those causing economic injury.

In IPM three aspects are emphasized, i.e

i. Multiple control tactics used in a compatible manner
ii. The populations maintained below levels that cause economic damage
iii. Socio economic and eco-friendly to the environment

IPM definition by Luckmann and Metcalf (1994)

IPM is defined as the intelligent selection and use of pest control tactics that will ensure favourable economical, ecological and sociological consequences.

Need for Pest Management (or) Why Pest Management

1. Development of resistance in insects against insecticides e.g. OP and synthetic pyrethroid resistance in *Helicoverpa armigera*.
2. Out break 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.
7. Human and animal health hazards.

Why Pest Management

1) Collapse of control system:

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

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

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

A) Subsistence phase

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

B) Exploitation phase

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

C) Crisis phase

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

i) Pest resurgence
ii) Pest resistance to insecticides
iii) Change of pest status
iv) Increase of production costs, etc.

D) Disaster phase

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

E) Integrated control phase

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

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

3) Environmental contamination

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

Concepts of IPM

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

1. Understanding the agricultural ecosystem

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

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

2. Planning of agricultural ecosystem

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

3. Cost benefit ratio

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

4. Tolerance of pest damage

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

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

The terms used to express the levels of pest population are

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

b) Economic Threshold Level (ETL): It is the index for making pest management decisions. ETL is defined as the population density at which control measures should be applied to prevent increasing pest population from reaching the economic injury level. Relationship between EIL and ETL can be expressed as when no action is taken at ETL the population reaches or exceeds EIL.

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

c) General equilibrium position (GEP)

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

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 inturn also eliminate natural enemies. Therefore, it is an important concept of pest management, to leave a permanent pest residue below economic threshold level, so that natural enemies will survive.

6. Timing of treatments

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

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

7. Public understanding and acceptance

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

Limitations of IPM: An IPM program requires a higher degree of management: Making the decision not to use pesticides on a routine or regular basis requires advanced planning and therefore a higher degree of management. This planning includes attention to field histories to anticipate what the pest problems might be, selecting crop varieties which are resistant or tolerant to pest damage, choosing tillage systems that will suppress anticipated pest damage while giving the crop the greatest yield potential. IPM can be more labour intensive, consistent, timely and accurate field scouting takes time. Without this information,intelligent management decision cannot make. Success of IPM programmes can be weather dependant. Therefore good IPM planners will have a alternate plan for when these problems arise.

Aims of IPM

- Reduce the use of synthetic organic pesticides
- That are environmentally sound
- Pest minimal risk of human health
- Re-useable return on investment
- Provide consumable safe food

Principles of IPM

- Identification of key pests and beneficial organisms
- Defining the management unit, the Agro-ecosystem
- Development of management strategy
- Establishment of Economic thresholds (loss & risks)
- Development of assessment techniques
- Evolving description of predictive pest models

Pest management strategies:

The application of pest management concepts begins with the development of a strategy. In pest management, we aim to reduce pest status. Because the pest status is determined by both the insect and the crop, our management programme may emphasized modification of either or both of these. The various strategies are

1. **Do nothing strategy:** When pest densities are below ETL, "do nothing" strategy is followed. Considerable sampling is required to assure that 'no action' is appropriate and significant pest suppression is likely to occur as a result of natural environmental factors.
2. **Reduce number strategy:** When the general equilibrium position (GEP) is low compared to ETL (problems are not severe), the best strategy would be to dampen population peaks. On the other hand, when GEP is lying very close to or above the ETL, the appropriate method is to reduce the environmental carrying capacity (eg. Crop rotation) or to reduce the inherited reproductive and or survival potentials of population (sterile insect technique or application of chemicals that disrupt the mating activity). Tactics used in this strategy may be the release of natural enemies, application of insecticide, growing of resistant cultivars, and adaptation of ecological modification and use of IGR.
3. **Reduce crop-susceptibility strategy**: This is one of the most effective and environmentally desirable strategies available. For this we rely on changes made in the host plant that makes it less susceptible to the pest. This includes planting resistant/tolerant crop varieties and the crop environment manipulation (time of sowing, fertilization etc.)

4. **Combined strategies**: This is the most desirable strategy when feasible. As such adoption of multiple strategies and tactics is a basic principle in developing insect pest management programme.

Requirements for successful pest management programme

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

LECTURE NO. 3

PEST SURVEILLANCE AND FORECASTING

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

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

Advantages

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

Pest surveillance comprises of three basic components

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

Objectivesof pest surveillance

- 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

Components of pest surveillance

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

Survey : Regular survey activity is necessary for successful surveillance programmes. An insect pest survey is 'a detailed collection of insect population information at a particular time in a given area'. These surveys are both qualitative and quantitative.

The **qualitative surveys** aim at the pest detection, employed with newly introduced pests and often precedes quantitative survey. The **quantitative surveys** attempt to define numerically the abundance of an insect population in time and space. It is useful to predict future population trends and to assess damage potentials.

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

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

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

Scientific surveillance methodologies:

The methodology consists of fixed plot surveys, roving surveys and monitoring through light pheromone and sticky traps.

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

e.g. 1 sq.m. plots randomly selected from 5 spots in one acre of crop area in case of rice. From each plot 10 plant 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.

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

- 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

Sampling Techniques

- **Absolute sampling -** To count all the pests occurring in a plot
- **Relative sampling** - To measure pest in terms of some values which can be compared over time and space e.g. Light trap catch, Pheromone trap

Methods of sampling

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

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

c. Netting - Use of sweep net for hoppers, odonates, grasshopper

d. Norcotised collection - Quick moving insects anaesthesised and counter

e. Trapping - Light trap - Phototropic insects
Pheromone trap - Species specific
Sticky trap - Sucking insects
Bait trap - Sorghum shootfly - Fishmeal trap
Emergence trap - For soil insects

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

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

- Population or damage assessed from the crop
- Compared with ETL and EIL
- When pest level crosses ETL, control measure has to be taken to prevent pest from reducing EIL.

Indices in pest surveillance

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

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

EIL can be calculated using following formula

EIL= C/VIDK

where,

EIL = Economic injury level in insects/production (or) insects/ha

C = Cost of management activity per unit of production (Rs./ha)

V = Market value per unit of yield or product (Rs./tonne)

I = Crop injury per insect (Per cent defoliation/insect)

D = Damage or yield loss per unit of injury (Tonne loss/% defoliation)

K = Proportionate reduction in injury from pesticide use

Worked examples of EIL

Calculate EIL in terms of pest population/ha with following figures

C = Management cost per unit area = Rs.3,000/- per ha

V = Market value in Rs./unit product = Rs.1,000/tonne

I = Crop injury/pest density = 1% defoliation/100 insects

D = Loss caused by unit injury = 0.05 tonne loss/1% defoliation

K = Proportionate reduction in injury by pesticide application = 0.8 (80% control)

EIL= C/VIDK= 3000/1000x 0.01x0.05x0.8= 7500 insects/ha

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

Factors affecting the ETL:

1. Crop value / market value
2. Management costs

Primary factor

3. Degree of injury per insect
4. Crop susceptibility to injury

Secondary factor

1. Market value of crop: When crop value increases, EIL decreases and vice-versa

2. Management of injury per insect: When management costs increase, EIL also increases

3. Degree of injury per insect

- o Insects damaging leaves or reproductive parts have different EIL (Lower EIL for Rep. part damages)
- o If insects are vectors of disease EIL is very low even 1 or 2 insects if found - management to be taken
- o If insects found on fruits - Marketability reduced - EIL very low

4. 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

Tertiary factors

Weather, soil factors, biotic factors and human social environment

These tertiary factors cause change in secondary factors thereby affect the ETL and EIL.

FORECASTING

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

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

Forecasting service serves

(I) To predict the forthcoming infestation level of the pest, which knowledge in essential in justifying the use of control measures

(II) To find out the critical stage at which the applications of insecticides would afford maximum protection.

(III) The pest surveillance programmes are highly useful in forecasting of the pests.

The forecasts may be of two types viz.,

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

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

Forecasting is made through

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

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

LECTURE NO. 4

TOOLS OR COMPONENTS OF INTEGRATED PEST MANAGEMENT

i. **Cultural method** or use of agronomic practices
ii. **Host plant resistance** - Antixenosis, antibiosis, tolerance
iii. **Mechanical methods of pest control**
   1. Hand destruction
   2. Exclusion by screens, barriers
   3. Trapping, suction devices, collecting machine
   4. Crushing and grinding

iv**. Physical methods**
   1. Heat
   2. Cold
   3. Energy - light trap, irradiation, light regulation
   4. Sound

v. **Biological methods**
   1. Protection and encouragement of NE
   2. Introduction, artificial increase and colonizing specific parasitoids and predators
   3. Pathogens on insects like virus, bacteria, fungi and protozoa
   4. Use of botanicals like neem, pongam, etc.

vi**. Chemical methods**
   1. Attractants
   2. Repellents
   3. Insecticides - OC, OP, carbamates, pyrethroids, etc.
   4. Insect growth inhibitors
   5. Chemosterilants

vii**. Behavioural methods**
   1. Pheromones
   2. Allelochemics

viii. **Genetic/biotechnology method**
   - Release of genetically incompatible/sterile pests
   - Transgenic plant

ix. **Regulatory/legal method**
   - Plant/animal quarantine
   - Eradication and suppression programme

The mistake of the past in pest management

1. We have been guilty of introducing susceptible varieties into an established population of pest.
2. The second great error in strategy has been to resort to intensive agriculture where monoculture is practiced in large areas.
3. The scientists have compounded these errors of strategy by manipulating genes, so heterogeneity of populations is lost. Thus, exposing the uniform population to enormous hazard of attack from pest.
4. Breeding of crops for resistance increases this hazard. When resistance is bred into a crop, a single gene change in the parasite (in pathogen) can render an uniformly resistant variety, uniformly susceptible *i.e*, breaking down of resistance takes place.
5. There are some soil management practices that have intensified pest problems. An excess of nitrogen is most favorable to insect pest attack. Intensive cultivation of

crops and failure to restore organic material creates a hazardous condition by depleting the abundance and diversity of beneficial soil micro-organisms.

Constrains (demerits) in IPM have been listed by IPM task force as follows:

i. Institutional constraint

IPM requires interdisciplinary approach to solve pest problem. Lack of coordination among different institution is a constraint. Research programme based on farmer's need - is lacking.

ii. Informational constraint

Lack of information on IPM among farmers and extension worker. Lack of training on IPM.

iii. Sociological constraint

Some farmers feel it is risky to adopt IPM compared to use of pesticides alone. Our farmers are habituated to using more pesticides.

iv. Economic constraint

Lack of funds for training farmers and extension workers on the use of IPM.

v. Political constraint

- Vested interest associated with pesticide trade
- Pesticide subsidy by Government

vi. Technological constrants: Although IPM technologies have been synthesized for almost every crop, these have validated only fw crops.

LECTURE NO. 5

HOST PLANT RESISTANCE

Plant species, which are fed upon by an insect are called ‘ host plants’. The inability of insect to attack a non-host plant is termed ‘immunity’. Relative amount of heritable qualities possessed by the plant which influence the ultimate degree of damage done by the insect is called ‘Host plant resistance’ to insect attack.

Lesser damage than average damage is taken as resistance while more damage than average damage constitutes susceptibility. A resistant variety produces higher yield than susceptible variety when both are subjected to the same extent of infestation by same insect at the same time. Resistance is a relative term only compared with less resistance or susceptibility. Absolute resistance or Immunity refers to the inability of a specific pest to consume or injure a particular variety under any known-conditions. Immune varieties are rare.

Definition

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

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

Painter (1951) :Defined plant resistance as “relative amount of heritable qualities possessed by the plant which influence the ultimate degree of damage done by the insects”.

The ability of a variety to produce a larger crop of good quality than other varieties, under conditions of similar insect population levels and other environmental factors."

History of host plant resistance

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

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

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

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

Types of resistance

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

Ecological Resistance or Pseudo Resistance or Apparent Resistance

Ecological resistance relies more on environmental conditions than on genetics. Certain crop varieties may overcome the most susceptible stage rapidly and thus avoid insect damage. Early maturing crop cultivars have been used in agriculture as an effective pest management strategy. However, plants that evade insect attack by this mechanism are likely to be damaged if the pest populations build-up early.

Pseudoresistance may be one or combination of the following:

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

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

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

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

Eg: Application of potassium fertilizers.

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

Genetic Resistance

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

Genetic resistance may be grouped based on,

A. Number of genes

- **Monogenic resistance:**When resistance is controlled by a single gene, it is called monogenic resistance
- **Oligogenic resistance**: When resistance is governed by a few genes, it is called oligogenic resistance.
- **Polygenic resistance**: When resistance is governed by many genes, it is called polygenic resistance. This is also termed as horizontal resistance.

B. Major or minor genes

- **Major gene resistance**: The resistance is controlled by one or few major genes. Major genes have a strong effect and these can be identified easily. This is also called Vertical resistance.
- **Minor gene resistance**: The resistance is controlled by a number of minor genes, each contributing a small effect. It is called minor gene resistance. This is also referred to as horizontal resistance.

C. Biotype reaction

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

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

D. Miscellaneous categories

i. **Cross resistance** - When a variety with resistance to a particular pest, may confer resistance to another pest

ii. **Multiple resistance**- Ability of a variety to resist variety of environmental stresses like insect, diseases, nematodes, etc.,

Characterisation of Resistance: There are four major characteristics by which resistance can be assessed

- Resistance is heritable and controlled by one or more major genes
- Resistance is relative and can be measured only by comparing with a susceptible cultivar of the same species.
- Resistance is measurable and its magnitude can be determined quantitatively and qualitatively.
- Resistance is variable and can be modified by abiotic and biotic components of the environment.

Host Plant Selection Process by an Insect

Host plant selection is a process by which an insect detects a resource providing plant within an environment of large population of diversified plant species. The process of host plant selection involves a sequence of five steps

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

2. Host finding: After locating habitat the insect pest makes a purposeful search to locate its appropriate host plantfor its establishment. The essential visual or olfactory mechanisms help the contact**.** Once the pest reaches orcontacts the host plants, tactile and olfactory sensory organs arrest further movement causing the insects to remain on the plant.

3. **Host recognition**: Although larvae are with sensorial receptors for host recognition, this phase is usually taken care of by ovipositing female adult. It is usually done with the help of specific volatile from the plants.

Eg:-Onion maggots,*Delia sp* attracted to its host by the odour of propryl disulphide.

Cabbage maggot fly,*Delia brassica* get attracted by crucifer due to presence of few glucocyanolides.

4. Host acceptance: Various chemicals present in the host species actually govern the feeding process of insects. These chemicals responsible for initial biting, swallowing and continuation feeding. Eg: Presence of phagostimulants like *morin* in mulberry *Morus alba*is key in continuation of feeding of silkworm *Bombyx mori.*

5. **Host suitability**: The nutritional value in terms of sugars, proteins, lipids and vitamins or absence of deleterious toxic compounds determines the suitability of the host for the pest in relation to the development of larvae, longevity and feeding.

Mechanisms of Host Plant Resistance

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

1. Non-preference (Antixenosis) 2. Antibiosis 3. Tolerance

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

Non-preference or Antixenosis:

The term ‘Non-preference’referes to the responce of the insect to the charecteristics of the host plant, which make is unattractive to the insect for feeding, oviposition or shelter.Kogan and Ortman (1978) proposed the term ‘Antigenosis’, as the term ‘Non-preference’ pertains to the insect and not to the host plant. Some plants are not choosen by insects for food shelter or oviposition because of either the absence of desirable characters in that plant like texture, hairyness taste, flavour, or presence of undesirable characters. Such plants are less damaged by that pest and the phenomenon is called non preference.

Antixenosis is the ability of a variety to repel insects, causing a reduction in oviposition or feeding.

Antixenosis can be chemical or morphological. Some chemicals are volatile: they are released from plants into the air and are sensed by insects before they land. Other repellent chemicals are sensed or tasted by insects after they contact the plant or feed on it. Morphological features that can cause antixenosis include leaf hairiness and stem hardness.

Antixenosis is generally measured by testing insect behavior, for example comparing the number of insects landing on or laying eggs on different test varieties.

Eg. Hairy varieties of soybean and cotton are not preffered by leafhoppers for oviposition
Open panicle of sorghum supports less *Helicoverpa armigera*
Wax bloom on crucifers deter diamondback moth *Plutella xylostella*

Antibiosis:

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

Hundreds of chemicals that are toxic to insects have been identified from different species and cultivars of plants. Well-known examples include nicotine from tobacco and gossypol from cotton. Antibiosis may also be caused by large amounts of indigestible polymers such as lignin, which can reduce the nutritional value of the plant and increase the toughness of leaves and stems.

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

Tolerance:

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

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

6. Compensation by growth of neibhouring plants

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

Tolerance is difficult to measure in experiments, because yield or plant growth must be compared while insect numbers or biomass are kept constant on all test varieties. Unlike antixenosis and antibiosis, tolerance does not affect the behavior or health of insects feeding on the plant.

LECTURE NO. 6

Cultural method of Pest Management

Cultural practices include all the crop production and management techniques which are utilized by the farmers to maximize their crop productivity and/or farm income. It includes decisions on crops/varieties to be grown, time and fertilizers and irrigation, harvesting times and procedures, and even off-season operations in fallow/cropped fields.

The manipulation of these practices for reducing or avoiding pest damage to crops is known as cultural control. Cultural practice which do not allow the favourable conditions for life cycle, growth and breeding of the pests. Since cultural control manipulations are based on habitat management and require a through understanding of different components of the agroecosystem in which the pest thrive, their approach has also been called as ecological management or environmental control. The purpose of cultural control practices is to make the environment less favourable for the pest and/or more favourable for its natural enemies. Procedure in this category mainly aim at reducing pest density by reducing the average availability of food, shelter and habitable space.

The first reference on the use of cultural control practices in India is found in the book "The Agricultural Pests of India and of Eastern and Southern Asia" by Balfour in 1887. Maxwell-Lefroy in his book "The Indian Insect Pests" published in 1906, suggested some other practices like mixed cropping, use of trap crop, hoeing etc. Ayyar(1938) in his book "Handbook of Economic Entomology for South India" gave the pride of place to various cultural control practices.

STRATEGIES ON WHICH CULTURAL PRACTICES ARE BASED:

- Usually food sources or physical factors of the crop environment are made unfavourable for insects through manipulating production practices.
- To use this approach weak links in the insect seasonal cycle are identified and exploited. Red hairy caterpillar summer ploughing is done to expose the pupal stage for natural predation.
- Reduce pest survival on the crop by enhancing its natural enemies, or by altering the crop's susceptibility to the pest.
- This approach is a preventive tactic that anticipate problems before they occur and attempts to avoid or minimize their impact. Therefore, timing is critical to the success of most cultural practices.
- It serve as a baseline procedure that is compatible and can be integrated with many other pest management tactics.
- Several cultural practices give good control when adopted at community level. E.g Bonfire to attract moths of Red hairy caterpillar.
- Cultural practices are often pest, crop and region specific. Care should be exercised in transferring tactic to a region with markedly different agro-ecological conditions.

Cultural practices:

1) Tillage or proper preparatory cultivation: Several insects which live or hide in the soil get exposed to sun as well as predators like birds etc due to proper preparatory cultivation/ploughing. Eg. Red hairy caterpillar, white grubs, cut worms etc.

Raking and hoeing of the soil around melon plants, mango and other fruit trees serve to destroy pupae of fruit flies.

2) Growing resistant varieties: It is well known that some crops are less attacked by pests because they have more natural resistance than others. They have some special characteristic like acidity or tasteless of cell sap, early maturity, hard bark etc., which helps in building their resistance. Certain varieties resist pest attack.

Eg: IR 36, IR 64 and MTU–5249 resistance to paddy BPH, IR 36, Phalguna,Shakti, Surekha variety to gall midge, TKM -6, Ratna, IR 26 for stem borer.

3). **Seed rate**: Adoption of appropriate seed rate ensures proper stand, spacing and crop canopy that helps in adaptation of proper spray technology and checks the unwanted growth of crop. Use of high seed rate is recommended in those crops where removal of infested plants is helpful in minimizing the incidence of insect pests, viz. maize borer in maize, and sorghum shoot fly in sorghum.

4) Planting time: The manipulation of planting time help to minimize pest damage by producing asynchrony between host plant and the pest or synchronizing insect pests with the natural enemies or crop production with available alternate host plants of the pest. Early planting has been found to reduce gall midge and leaf folder damage in rice, shoot fly and head bug damage in sorghum and millet, white grub damage in groundnut and mustard aphid damage in mustard. Timely and synchronous planting has been found to reduce bollworm damage in cotton and stem borer damage in sugarcane.

5) Plant spacing: In entomology point of view plant spacing may influence the population and damage of many insect pests by modifying the micro-environment of the crop or affecting health, vigour and strength of the crop plants. Closer spacing has been reported to increase the incidence of planthoppers, BPH, WBPH and leffolder etc. The closer spacing in cotton results in increase the relative humidity that favour higher incidence of sucking pets and bollworm. Closer spacing in groundnut lowered the incidence of thrips, jassids and lafminers and also increased parasitism in the latter.

6) Fertility Management: High levels of nitrogen fertilizers significantly increase the incidence of most of the insect pests including yellow stem borer, leaffolder, gall midge, BPH, WBPH, Hispa , Whorl maggot etc. in rice crop. In cotton also it result in greater attack of leaf folder, white fly and bollworms. Reduction in the incidence of GLH, BPH and WBPH in rice, aphids and thrips in chilies has been reported by the application of potash. Potassium increase the silica content in the leaf due to which cell-wall of parenchyma and tissues containing epidermal sclerenchyma become hard and unfavourable for pest attack.

7) Water management:

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

- The incidence of gall midge was less in continuous flooding.
- For cutworms like paddy swarming caterpillar (*Spodoptera mauritinana and S. exiqua)* and ragi cutworm, by flooding the fields the caterpillars float and leave the plants.
- The irrigation in sugarcane and wheat crop protects from white ants.

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

- Draining the rice fields for 3-4 days during infestation controls BPH and whorl maggot.
- Alternate drying and wetting at 10 days interval starting from 35 DAT reduces the BPH and WBPH.

8) Sanitation

Clean cultivation/ weed management: Removal of weeds which act as alternate hosts reduce insect pests.

- Paddy gall fly *Orseolia oryzae* breeds on grasses such as *Panicum* sp., *Cynodon* etc.
- Fruit sucking moth spend their life on alternate host before attacking on main host crops.
- Mealy bug infestation in cotton is reduce by removal of weed which is alternate host for mealy bugs

Systematic cutting/prunning and removal of infested parts: Keeps down subsequent infestation.

- Removal of sugarcane shoots affected by borers,
- Cutting and removal of infested parts of brinjal attacked by *Leucinodes orbonalis*
- Prunning of dried branches of citrus eliminates scales and stem borer.
- Clipping of tips of rice seedlings before transplanting eliminate the egg masses of stem borer.
- Clipping of leaf lets in coconut reduces the black headed caterpillar.

9). Trap cropping: Growing of susceptible or preferred plants by important pests near a major crop to act as a trap and later it is destroyed or treated with insecticides. Trap crop may also attract natural enemies thus enhancing natural control. The trap crop can be from the same or different family group, than that of the main crop, as long as it is more attractive to the pest. There are two types of planting the trap crops, border trap cropping and row intercropping.Boarder trap cropping is the planting of trap crop completely surrounding the main cash crop. It prevents a pst attack that comes from all sides of the field.Row intercropping is the planting of the trap crop in alternating rows within the main crop.

Trap crop	Main crop	Pest control
Mustard	Cabbage	Dimondback moth
Marigold	Tomato	Tomato fruit borer, Nematodes, Snails
Cow pea	Groundnut	Leaf minor, Tobacco caterpillar
Castor	Tobacco	Tobacco caterpillar, gram pod borer
Cucumber	Tomato	White fly and mite
Okra	Cotton	Bollworm, Jassid
Chich pea	Cotton	*Heliothis* sp.
Cow pea and Maize	cotton	Aphids, increase growth of crysopa, lady bird beetles, syrphid fly
Sudan grass	Corn	Stem borer
Onion and garlic	Carrot	Carrot root fly and thrips

Advantage of trap cropping:

- It lessens the use of pesticide
- Lowers the pesticide cost
- Preserves the indigenous natural enemies
- Improve the crop quality
- Additional yield from trap crop.

Tips for successful trap cropping:

- Select trap crop that is more attractive to the pests than the main crops.
- Monitor the plants regularly.
- Immidiately control the pests that are found in the trap crop. Destroy the trap crops once the pest population is high, otherwise they will serve as the breeding ground and pests will attack the rest of the field.
- Be ready to sacrifice trap crop as an early crop and destroy them once pest population is high.

10). Intercropping: Tomato intercropped with cabbage has been reported to inhibit or reduce egg laying by Dimondback moth. The intercrop of cowpea, maize etc in cotton helped in the colonization of coccinellids and also enhanced the parasitism of spotted bollworm.Okra intercrop with cotton increased the population build up of jassids, whitefly, spotted bollworms and Americal bollworm. Intercropping of groundnut with pearlmillet reduced the incidence of thrips, jassids and leafminer where as the same with sunflower and castor increased the incidence of thrips and jassids, respectively.

11) **Changes in the system of cultivation:**

- Change of banana from perennial to annual crop reduced the infestation of banana rhizome weevil *Cosmopolitus sordidus* in addition to giving increased yields.
- Avoiding ratoon redgram crop during offseason helps in reducing the carry over of pod fly *Melangromyza obtusa* and eriophyid mite *Aceria cajani*

12**) Crop rotation:** Crop provides food for insect-pests and if the food is abundant all round the year, such pests flourish and multiply rapidly. Lady's finger followed by cotton will suffer from increased infestation of pests. Hence if a non-host crop is grown after a host crop, it reduces the pest population. The pest problem of monoculture can be control by adopting crop-rotation cultivation. Ex.

- Cereals followed by pulses reduce pest incidence.
- Cotton should be rotated with non hosts like ragi, maize, rice to minimize the incidence of insect pests.
- Groundnut with non leguminous crops is recommended for minimizing the leaf miner incidence.

13) **Harvesting practices** involving crop maturity, time of harvest or cutting practices, selective harvesting and strip harvesting can be of considerable assistance in suppressing a variety of insect pests and/or conserving their natural enemies.

Physical control

Definition: Modification of physical factors in the environment to minimize or prevent pests problems is called physical control.

Insect require definite range of physical condition and any deviation from such range are lethal to the survival and other life activities of insects.

Physical methods in pest management:

1. **Manipulation of temperature**: Insect activity and metabolic rate are influenced by temperature. Optimum range of temperature is vital for normal insect activity.
    - Sun drying the seeds to kill the eggs and hidden stages of stored product pests.
    - Exposure of cotton seeds to sun heat in thin layer for 2-3 days in April-May helps in killing larvae of pink bollworm.
    - Treatment of sugarcane setts with heat energy units either as hot water or hot air treatment kill te scale insects carried over through setts.
    - Hot water treatment of paddy seeds at 50-55 ^{0}C for 15 minutes to control rice white tip nematodes.
    - Use of flame throwers against locusts.
    - Use of burning torch against hairy caterpillar.
    - Cold storage of fruits and vegetables at 1-2 ^{0}C for 10-12 days to kill fruit flies.
    - Low lethal temperature: Cold storage of potatoes - potato tuber moth
2. **Manipulation of moisture**:
    - Alternate drying and wetting of rice fields to manage rice Brown plant hopper..
    - Drying of seeds below 10% moisture level affect insect development(rice weevil, pulse beetle)
3. **Manipulation of light**: Behavioural orientation is influenced by light
    - Mating frequency reduction (eg. Bihar hairy caterpillar)
    - Reduce fertility (eg. Indian meal moth)
    - Dipause disruption in all dipausing insects
    - Use of light trap to attract positively phototropic insects
4. **Manipulation of air**: Increasing of Carbon dioxide concentration in control atmosphere of stored grain to cause asphyxiation in stored product pests.
5. **Use of irradiation**: Gamma irradiation from Co^{60} is used to sterilise the insects in laboratory. Cattle screw worm, *Cochliomyia hominivorax* was controlled in Curacao island by E.F. Knipling using this technique.
6. **Use of abrasive dust:**

    Activated clay: Causes injury to the insects wax layer, resulting in loss of moisture leading to death. It is used against stored product pests.

    Dri-die: This is porous finely divided silica gel used against stored insects.
7. **Radiant energies**: Radiant energies (solar) energies which have been tried in the control of insect pests are

1	Radio frequencies	Energies of longer wave length
2	Infra red light	

3	UV and visible light	producing heating effects
4	X- ray	Energies of shorter wave length producing chemical effects
5	Gamma ray	

These radiations can be used mostly for pests of stored grain and their products. Most of above energies have not been commercially feasible on account of their high costs.

1. **Radio-frequencies**: High frequencies radio waves generate temperature of 80 ^{0}C in grains to kill grannary weevils and confused flour beetles in 15-20 seconds.
2. **Infrared**: Kill insects by heating.
3. **Visible and ultraviolet (UV):** man is able to see the colours violet to red(380-779nm wave lengths) of the solar spectrum. The insect responsive range lies between UV to red (253-700 nm). In general UV to blue-green (350-560 nm) region of the spectrum is the most effective in attracting insects while red, orange and yellow are not attractive. For this reason, yellow colour in particular is used to repel insects and UV lamp is used to attract nocturnal insects.

   Visible light can be used 3 ways to control pests.

   a. BY producing photo taxis- Positive (to attract) or negative (to repel)
   b. By inducing dipause by altering photo period. The field can be flood light to extend the day length and to prevent the onset of dipause in insects and finally perish in adverse weather.
   c. By modifying behaviour: Exposure of apple plants to artificial light interfered with egg laying of the codling moths.
4. **Ionising radiation**: X-ray and gamma ray are ionising radiation which provides prospects of controlling stored grain pests.
5. **Use of sound energy**
   - Acoustical device (Bird scarer/acetylene exploders) produces sudden loud sound which frighten birds.
   - Fire crackers also used to make loud sound to scatter away squirrel, foxes, rats, mice, deer, etc.

LECTURE NO. 8

Mechanical Methods

Defination: The reduction or suppression of insects population by means of manual devices or machines is referred as mechanical control.

Use of mechanical devices and manual forces for the destruction or exclusion of pests is known as mechanical method of pest control.

1. **Collection and destruction**: Different life stages of the insects are killed by manual or mechanical forces.
   a. **Manual forces:**
      - The egg masses of rice stem borer, *Spodoptera*, Red hairy caterpillar can be picked up and destroy.
      - Hand picking of caterpillar *i.e*, 1st and 2nd instar larvae of *Spodoptera*, bihar hairy caterpillar, red hairy caterpillar etc.
      - Destruction of infested cane stalks harbouring larvae of gurudaspur borer and plassy borer in gregarious phase
      - Collection and destruction of fallen infested fruits is effective against fruit flies and fruit borers.
      - Manual removal of pink bollworm attacked rosette flowers, wither and dropping terminal infested by spotted bollworm.
      - Prunning and destruction of infested shoots and flower parts is effective in checking the multiplication of scales, mealy bug, aphids etc.
      - Passing rope across rice fields to dislodge case worm over the standing water which is then drain out.
      - Hooking with iron hook to remove adult Rhinocerous beetle.
      - Sieving and winnowing the red flour beetle (sieving) and rice weevil(winnowing)
      - Clipping and destruction of aphid infested twig of mustard helps in the management of mustard aphids

   b. **Mechanical force:**
      - Entoletor: In entoletor centrifugal force is used to break infested kernals and kill stages of storage pests.
      - Tillage implements: Use to expose the soil born insects eg: red hairy caterpillar
      - Mechanical traps: Rat trap
      - Screw crow
      - Use of sting slot
      - Drumming
      - Use of insect collection net

Preventive barriers (Mechanical exclusion): Use of mechanical barriers to prevents access of pests to host

a. Wrapping the fruits: Covering with polythene bag against pomegranate fruit borer
b. Banding: Banding with grease or polythene sheet on the trunk of mango to prevent insect pests from climbing to the tree top so as to destroy inflorescence or to descent back to soil to lay eggs by mealy bug.

c. Netting: Use for mosquitoes and vector control in green houses.
d. Trenching: For trapping of marching larvae of red hairy caterpillar, locusts, army worms digging 30-60 cm wide and 50 cm deep trenches.
e. Tin barrier: Tin bands are fixed over coconut palms to prevent damage by rats.
f. Electric fencing: Putting fences around crop fields in the normal ways or charged with low voltage electricity will key away animal pests like rats, jackles, monkey etc.

Trapping:

- **Light trap**: These are used to attract nocturnal insects which are strongly phototaxic. It serves many purposes like monitoring initial infestation, seasonal incidence, pest / weather relationship, pest intensity, pest survey, trapping and killing.
- **Sticky trap**: Cotton white fly, aphids and thrips prefer yellow colour. Yellow colour is painted on tin boxes and sticky material like castor oil or grease is smeared on the surface. Those insects are attracted to yellow colour and trapped on the sticky materials.
- **Bait trap:** In bait trap attractants are placed to attract the insects and kill those using insecticides.
- **Fish meal trap**: Used against sorghum shoot fly
- **Pit fall trap:** Trap insects moving about on the soil surface, such as ground beetle, collembolan etc.
- **Pheromone trap**: Synthetic sex pheromones are placed in traps to attract mostly males.
- **Probe trap**: The trap can be inserted in to the stored grain. Rice weevil, *Rhizopertha*, *Tribolium* can be effectively traps.

Advantage:

- Home labour utilization
- Low cost equipment
- High technical skill not required in adoption
- No residue problem and side effect

Dis advantage:

- Required repeated use so labour intensive
- It is practice in small scale ie. Kitchen garden

LECTURE NO. 9

BIOLOGICAL CONTROL

The successful management of a pest by means of another living organism (parasitoids, predators and pathogens) that is encouraged and disseminated by man is called biological control. In such programme the natural enemies are introduced, encouraged, multiplied by artificial means and disseminated by man with his own efforts instead of leaving it to nature. The term biological control was first used by Smith in 1919 to signify the use of natural enemies to control insect pests.

Natural Control: The maintainance of population numbers within certain upper and lower limits by the action of a combination of abiotic and biotic factors as well as the characteristic of the species under consideration is called natural control.

History and development of biological control and classical examples of biological control

First use of insect predators was in 900AD, when Chinese citrus growers used red ant (*Oecophylla smaragdina*) on the citrus trees to control citrus leaf chewing insects.

Year 1762 - 'Mynah' bird (*Gracula religiosa*) imported from India to Mauritius to control red locust (*Nomadacris septemfasciata*).

1770 - Bamboo runways between citrus trees for ants to control caterpillars.

1888 - First well planned and successful biological control attempt made

During 1888 citrus industry in California (USA) seriously threatened by cottony cushion scale, *Icerya purdian.* Chemical treatments not known at that time. Mr. C.V. Riley, a prominent entomologist suggested that the scale inset originated from Australia and natural enemy for the scale from Australia should be introduced into USA.Mr. Albert Koebele was sent to Australia. He found a beetle called Vedalia (*Rodolia cardinalis*) attacking and feeding on seeds. Vedalia beetle (*Rodolia cardinalis*) was imported in November 1888 into USA and allowed on scale infested trees. Within a year spectacular control of scale insect achieved. Even till date this beetle controls the scale insect.

1898 - First introduction of natural enemy into India

1898 - 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 mealybugs in South India.

1920 - A parasitoid *Aphelinus mali* introduced from England into India to control Woolly aphid on Apple, *Eriosoma lanigerum*.

In 1960, a tachinid, *Spogossia bezziana* was introduced from Srilanka into India for control of Coconut black headed caterpillar.

Techniques in biological control:

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

1. **Introduction or classical biological control:** It is the deliberate introduction and establishment of natural enemies to a new locality where they did not occur or originate naturally. When natural enemies are successfully established, it usually continues to control the pest population.
   Pest – Cotton cushion scale, *Icerya purchesi*
   Predator-nVedalia beetle, *Rodolia cardinalis*
2. **Augmentation**: It is defined as the effort to increase population of natural enemies either by propagation and release or by environmental manipulation. It is the rearing and

releasing of natural enemies to supplement the numbers of naturally occurring natural enemies. There are two approaches to augmentation.

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

b. Inundative releases: It involves mass multiplication and periodic release of natural enemies when pest populations approach damaging levels. Natural enemies are not expected to reproduce and increase in numbers. Control is achieved through the released individuals and additional releases are only made when pest populations approach damaging levels. In this case large numbrs of natural enemies are released to obtain rapid pest suppressions.

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

Important conservation measures are

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

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

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

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

Eg: Braconid wasps

Qualities of a Successful Parasitoid in Biological Control Programme

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

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

SUCCESSFUL / CLASSICAL EXAMPLES OF BIOLOGICAL CONTROL

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

Parasites can be grouped as furnished below

1. Depending upon the nature of host,

i. Zoophagous - that attack animals (cattle pests)
ii. Phytophagous - that attack plants (crop pests)
iii. Entomophagous - that attack insects (parasites)
iv. Entomophagous insects - parasitoids

II. Based on the specialization of the site of parasitisation

1. **Ectoparasites:** they attack its host from the outside of the body of the host. The mother parasite lays its eggs on the body of the host and after the eggs are hatched the larvae feed on the host by remaining outside only. Head louse; *Epiricania melanolenca, Epipyrops* sp. Sugarcane fly.
2. **Endoparasites :**they enters the body of the host and feeds from inside. The mother parasite either lays its eggs inside the tissues of the host or on the food material of the host to gain entry inside.

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

III. Specialization based on the stage of the host

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

TAMGESTT

i. Egg parasite : *Trichogramma australicum*
ii. Early larval parasite – *Apanteles taragama*
iii. Mid larval parasite – *(Micro*) *Bracon hebtor*
iv. Prepupal parasite – *Gonizus nephantidis*
v. Prepupal parasite – *Elasmus nephantidis*
vi. Pupal parasite –*Stomatoceros sulcatiscutellum*
Trichospilus pupivora, Testrastichus israeli,

IV. Depending upon the duration of attack

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

2. Permanent parasite :

Which spends all the stages of its life on the same host.Eg**.** Head louse

V. Depending upon degree of parasitization

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

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

VI. Depending upon the food habits

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

Kinds of Parasitism

1. **Simple parasitism :**Irrespective of number of eggs laid the parasitoid attacks the host only once. Eg. *Apanteles taragamae* on the larvae of *Opisina arenosella, Goniozus nephantids*
2. **Super parasitism :**phenomenon of parasitization of an individual host by more larvae of single species that can mature in the host. Eg. *Apanteles glomeratus* on *Pieris brassica, Trichospilus pupivora* on *Opisina arenosella*.
3. **Multiple parasitism :**Phenomenon of simultaneous parasitization of host individual by two or more different species of primary parasites at the same time. Eg:*Trichogramma, Telenomous and Tetrastichus* attack eggs of paddy stem borer *Scirpophaga incertulas*.
   Super parasitism and multiple parasitisms are generally regarded as undesirable situations since much reproductive capacity is wasted
4. **Hyper parasitism:** When a parasite itself is parasitized by another parasite. Eg. *Goniozus nephantidis* is parasitized by *Tetrastichus israeli,* Most of the Bethylids and Braconids are hyper parasites.

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

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

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

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

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

Predators and Predatism

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

Insect predator qualities

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

Eg. Preying mantids and Robber flies

Predatism

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

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

Differences Between predator and a parasite

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

Predators

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

Non-insect predators

Arachnids - Spiders, Scorpions, mites

Fishes - *Gambusia affinis* on mosquito larvae
Amphibians - Frogs and toads (insectivorous)
Birds - Ducks, owls (on rats), king crow, mynah (on larvae of *Helicoverpa*)
Reptiles - Lizards, snakes (rats)

Biological control of weeds with insects

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

A successful weed killer

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

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

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

Biotic agents used for control of weeds

Weed	Sc. Name	Biotic agent	Origin
Terrestrial weed			
Prickly pear	*Opuntia dillent*	*Dactylopius opuntiae*(Dactylopidae: Hemiptera)	USA
Congress grass or carrot weed	*Parthenium hysterophorus*	*Zygogramma bicolorata*(Chrysomelidae: Coleoptera)	Maxico
Lantana Weed	*Lantana camera*	*Ophiomyia lantanae* (Tortricidae: Lepidoptera) *Teleonemia scrupulosa*(Tingidae, Hemiptera)	Mexico
Siam weed	*Chromolaena odorata*	*Pareuchaetes pseudoinsulata* (Arctiidae: Lepidoptera)	West Indies
Crofton weed	*Eupatorium adenophorum*	*Procecidochares utilis* (Trypetidae;Diptera)	Mexico
Aquatic weed			
Water fern	*Salvinia molesta*	*Crylobagus singularis* (Curculionidae: Coleoptera)	Australia

Water hyacinth	*Eucharnia crassipes*	*Neochetina eichorniae* (Curculionidae: Coleoptera)	USA

Advantages of Biological control

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

Disadvantages:

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

LECTURE NO. 10

CHEMICAL CONTROL

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

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

Importance of chemical control:

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

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

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

General Properties of Insecticides

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

Toxicity terms used to express the effect on mammals

Acute toxicity	Toxic effect produced by a single dose of a toxicant
Chronic toxicity	Toxic effects produced by the accumulation of small amounts of the toxicant over a long period of time
Oral toxicity	Toxic effect produced by consumption of pesticide orally
Dermal toxicity	Toxic effect produced when insecticide enters through skin
Inhalation toxicity	Toxic effect produced when poisonous fumes of insecticide are inhaled (fumigants)

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:

i. Insecticides of animal origin: Nereistoxin isolated from marine annelids, fish oil rosin soap from fishes etc.
ii. Plant Origin insecticides or Botanical insecticides: Nicotinoids, pyrethroids, Rotenoids etc.
iii. Synthetic organic insecticides: Organochlorines , Organophosphorous, Carbamate insecticides etc.,

iv. Hydrocarbon oils: Coal tar oil, mineral oils etc

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

a. Contact poisons: These insecticides are capable of gaining entry into the insect body either through spiracles and trachea or through the cuticle and kill them. Eg.Phoalone and HCH.

b. Stomach poisons: The poison or toxicant which enter the body of the insect through its food and kill it. Eg: *Bacillus thuringiensis*, trizophos, quinalphos

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

Commonly used Fumigants and their doses:

i. Aluminium phosphide, marketed as Celphos tablets used against field rats, groundnut bruchids etc
ii. Carbon disulphide 8-20 lbs/1000ft3 of food grains
iii. EDCT (Ethylene Dichloride Carbon Tetrachloride) 20-30 lbs/1000cft of food grains
iv. EDB Ethylene dibromide 1 lb/1000ft3 of food grains.
v. SO2: By burning sulphur in godowns SO2 fumes are released.

d. Systemic insecticides

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

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

An ideal systemic insecticide quality are

- Should have high intrinsic pesticidal activity
- 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.
- The toxicant or its metabolites should be stable for sufficiently long period to exercise residual effect.
- Sufficiently soluble in water for translocation through vascular system
- 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:

- **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.
- **Protoplasmic poisons**: The poisons or toxicants which kill the insect by destruction of cellular protoplasm of the mid gut epithelium cells. Eg. Arsenical compounds, mercury, copper

- **Respiratory poisons:** The poisons or toxicants which block cellular respiration and inhibits the respiratory enzymes. Ex. Hydrogen cyanide (HCN), carbon monoxide, rotenone etc.
- **Nerve poisons:** The poisons or toxicants which block Acetyl cholinesterase (AChE) and effect the nervous system leading to death of the inscts. Eg. Organophosphorous, carbamates.
- **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

- **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 (Based on LD50):

Category of insecticides	Symbol	Oral LD50	Dermal LD50	Colour of the label
Extremely toxic	Skull & Pioson	1-50	1-200	Red
Highly toxic Pioson	Poison	51-500	201-2000	Yellow
Moderately toxic	Danger	501-5000	2001-20,000	Blue
Less toxic	Caution	>5000	>20,000	Green

V. **Based on stage specificity:**

i. Ovicides
ii. Larvicides
iii. Pupicides
iv. Adulticides

VI. **Generation wise:**

Sl. No.	**Generation**	**Category of insecticide**
1	**First generation**	Inorganics and Botanicals
2	**Second generation**	Synthetic organics
3	**Third Generation**	IGRs like MH & JH mimics
4	**Fourth Generation**	**Anti JH,** Synthetic pyrethroids

Toxicity evaluation of insecticides

LD 50 (Lethal Dose):

In 1952 Finney has given the computation methods. It is the amount of toxicant required to kill 50% of the test population and is expressed in terms of milligrams of the substance of toxicant per kilogram body weight (mg/kg) of the test animal (usually rat, when treated orally). As the test animals usually rat and some times rabbit it is also referred to as the mammalian toxicity. This forms the general criteria for acute toxicity and is also known acute oral LD50.

In case of insects the LD50 **(Median Lethal Dose)** value is expressed in terms of micrograms of the toxicant per one gram body weight of the insect.

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

The amount of toxicant required to be placed on the skin to cause death of 50% of test population is known as acute dermal LD50. It must be understood that higher the LD50.value lesser is the toxic nature of the chemical and vice - versa.

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

LC 50 (Median Lethal concentration): Defined as the concentration of insecticide required to kill 50% of the given organism or insect. This is used when the exact dose per insect is not known, but the concentration is known. It is usually determined by potters tower and probit analysis.

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

ED50/ EC50 (Effective Dose/Concentration 50): Chemicals that gives desirable effects in 50% of test animals. These terms are used to express the effectiveness of insect growth regulators (IGR)

LT 50 (Mediam Lethal time 50): LT_{50} is defined as the time required to kill 50% of the population at a certain dose or concentration. LT_{50} expressed in hours or minutes. LT_{50} is used in field studies and also for testing insect viruses (NPV).

KD50/ KT50 (Median Knoc down Dose /Time 50): Dose / Time required for 50% of population having knockdown effect. KD_{50} and KT_{50} are used for evaluating synthetic pyrethroids against insects.

Bioassay of insecticides

Study of response of individual or group of organisms exposed to the toxicant is called ‘Bioassay’ or Any quantitative procedure used to determine the relationship between the amount (dose or concentration) of an insecticide administered and the magnitude of response in a living organism. Potter spraying tower apparatus is required for studying the biological effects of contact poisons on organisms. This air operated spraying apparatus applies an even deposit of spray over a circular area of 9 cm diameter. Suitable for studying the biological effects of chemicals, both when applied as direct spray on organisms or as a residual film. Bioassays are used for screening of potential insecticides, for determination of valuesLD50 and LC 50. Estimation of residues, and quality testing of formulated insecticides

LECTURE NO. 11

Formulations of Insecticides

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

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

1. **Dusts (D):** These are ready to use insecticides in powder form. In a dust formulation the toxicant is diluted either by mixing with or by impregnation on a suitable finely divided carrier which may be an organic flour or pulverized mineral like lime, gypsum, talc etc., or clay like attapulgite bentonite etc.The toxicant in a dust formulation ranges from 0.15 to 25% and the particle size in dust formulations is less than 100 microns and with the decrease in particle size the toxicity of the formulation increases. Dusts are easy to apply, less labour is required and water is not necessary. However if wind is there, loss of chemical occurs due to drift hence dusting should be done in calm weather and also in the early morning hours when the plant is wet with dew.Eg. HCH 10% dust; Endosulfan 4% D.
2. **Granules or Pelleted insecticides(G):** These are also ready to use granular or pelleted forms of insecticides. In this formulation the particle is composed of a base such as an inert material impregnated or fused with the toxicant which released from the formulation in its intact form or as it disintegrates giving controlled release. The particle size ranges from 0.25 to 2.38 mm, or 250 to 1250 microns and contains 1 to 10% concentration of the toxicant. The granules are applied in water or whorls of plants or in soil. Action may be by vapour or systemic. In application of granules there is very little drift and no undue lose of chemical. Undesirable contamination is prevented. Residue problem is less since granules do not adhere to plant surface. Release of toxicant is achieved over a long period. Easy for application as water is not required for application. Less harmful for natural enemies.Eg: Carbofuran 3G, Phorate10 G, Cartap hydrochloride 4G
3. **Wettable Powders (WP)**: It is a powder formulation which is to be diluted with water and applied. It yields a stable suspension with water. The active ingredient (toxicant) ranges from 15 to 95%. It is formulated by blending the toxicant with a diluent such as attapulgite, a surface active agent and an auxiliary material. Sometimes stickers are added to improve retention on plant surface. Loss of chemical due to run off may be there and water is required for application. Eg: Carbaryl 50%WP, Thiodicarb 75% WP
4. **Emulsifiable Concentrates(EC):** Here the formulation contains the toxicant, a solvent for the toxicant and an emulsifying agent. It is a clear solution and it yields an emulsion of oil-in water type, when diluted with water. The active ingredient (toxicant) ranges from 2.5 to 100 %.When sprayed the solvent evaporates quickly leaving a deposit of toxicant from which water also evaporates. The emulsifying agents are alkaline soaps, organic amines alginates, Carbohydrates, gums, lipids, proteins etc. Eg: Endosulfan 35EC, Profenophos 50EC
5. **Soluble Powder or Water Soluble Powder (SP or WSP)**: It is a powder formulation readily soluble in water. Addition of surfactants improves the wetting power of the spray fluid. Sometimes an anti-caking agent is added which prevents formation of lumps in storage. This formulation usually contains a high concentration of toxicant and therefore convenient to store and transport. Eg: Acephate 75 SP.

6. **Suspension Concentrate (SC):** Active ingredient is absorbed on to a filler which is then suspended in a liquid matrix (water).It is not dusty and easier to disperse in water. Eg: Imidacloprid 50 SC
7. **Flowables (F):** When an active ingredient is insoluble in either water or organic solvents, a flowable formulation is developed. The toxicant is milled with a solid carrier such as inert clay and subsequently dispensed in a small quantity of water. Prior to application it has to be diluted with water. Flowables do not usually clog nozzles and require only moderate agitation.**Ex;**Methoxyfenozid*e(* Intrepid 2F)
8. **Water Dispersible Granules (WDG):**This formulation appears as small pellets or granules. It is easier and safer to handle and mix than wettable powders. When the granules are mixed with spray water, they break apart and, with agitation, the active ingredient becomes distributed throughout the spray mixture.Ex: Thiamethoxam 25 WDG
9. **Solutions:** Many of the synthetic organic insecticides are water insoluble but soluble in organic solvents like amyl acetate, kerosene, xylene, pine oil, ethylene dichloride etc., which themselves possesses some insecticidal properties of their own. Some toxicants are dissolved in organic solvents and used directly for the control of household pests. Eg. Baygon
10. **Concentrated insecticide liquids:** The technical grade of the toxicant at highly concentrated level is dissolved in non-volatile solvents. Emulsifier is not added. Generally applied from high altitudes in extremely fine droplets without being diluted with water at ultra volume rates. There is greater residual toxicity and less loss through evaporation. Active ingredient ranges from 80-100%. Eg: Malathion, Bifenthrin,Fenitrothion.
11. **Insecticide aerosels:** The toxicant is suspended as minute particles 0.1 to 30 microns in air as fog or mist. The toxicant is dissolved in a liquified gas and if released through a small hole causes the toxicant particles to float in air with rapid evaporation of the released gas. Eg: Allethrin
12. **Fumigants:** A chemical compound which is volatile at ordinary temperature and sufficiently toxic is known as fumigant. Most fumigants are liquids held in cans or tanks and quite often they are mixtures of two or more gases. Advantage of using fumigant is that the places not easily accessible to other chemicals can be easily reached due to penetration and dispersal effect of the gas. Eg; Aluminium phosphide
13. **Microencapsulation**: Microencapsulated formulations consist of dry and liquid pesticide particles enclosed in tiny plastic capsules which are mixed in water and sprayed. After spraying, the capsule slowly releases the pesticide. The encapsulation process can prolong the active life of the pesticide by providing timed release of the active ingredient. Ex: Lambda-cyhalothrin
14. **Insecticide Mixtures:** Insecticide mixtures involve combinations of two or more insecticides in the right concentration into a single spray solution. Insecticide mixtures are widely used to deal with the array of arthropod pests encountered in greenhouse and field production systems due to the savings in labor costs. Furthermore, the use of pesticide mixtures may result in synergism or potentiation (enhanced efficacy) and the mitigation of resistance. However, antagonism (reduction in efficacy) may also occur due to mixing two (or more) pesticides together. Judicious use of pesticide mixtures or those that may be integrated with biological control agents is especially important because parasitoids and predators (and even microbials such as beneficial bacteria and fungi) can suppress arthropod pest populations irrespective of the arthropod pests' resistance traits or mechanisms.

    Ex:Chlorpyriphos16% + Alphacypermethrin 1% EC

    Chlorpyriphos 50% + Cypermethrin 5% EC

Quinolphos 20% + Cypermethrin 3% EC
Profenofos 40% + Cypermethrin 4% EC
Profenofos25% + Cypermethrin 5% EC
Profenofos10% + Cypermethrin 20% EC
Cypermethrin 20% + Permethrin 10% EC

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

PESTICIDE APPLICATION METHODS

The desired effect of a pesticide can be obtained only if it si 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 Volume	**Spray fluid (litre per acre)**	**Droplet size**	**Area covered per day**	**Equipment used**
a) High volume spraying	200-400	150	2.5 ac	Knapsack, Rocker sprayers
b) Low volume spraying	40-60	70-150	5.6 ac	Power sprayer, Mist blower
c) Ultra low volume spraying	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
   - **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.
   - **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.
   - **Side dressing :** After the establishment of the plants, the granules are applied a little away from the plant (10-15 cm) in a furrow.
   - **Spot application :** Granules are applied @ 5 cm away and 5 cm deep on the sides of plant. This reduces the quantity of insecticide required.
   - **Ring application :** Granules are applied in a ring form around the trees.
   - **Root zone application :** Granules are encapsulated and placed in the root zone of the plant. (eg.) Carbofuran in rice.
   - **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.
   - **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. **Padding :** Stem borers of mango, silk cotton and cashew can be controlled by this method. Bark of infested tree (5 x 5 cm) is removed on three sides leaving bottom as a flap. Small quantity of absorbant cotton is placed in the exposed area and 5-10 ml of Monocrotophos 36 WSP is added using ink filler. Close the flap and cover with clay mixed with fungicide.

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

10. Root feeding : 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. Monocrotophos 10 ml and equal quantity of water are taken in a polythene bag and cut the end (slant cut at 45) of a growing root tip (dull white root) is placed inside the insecticide solution and the bag is tied with root. The insecticide absorbed by root, enter the plant system and control the insect.

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.

1**2. 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.

- **Soil :** To control the nematode in soil, the liquid fumigants are injected by using injecting gun.
- **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.

- **Trunk** : Aluminium phosphide ½ to 1 tablet is inserted into the affected portion of coconut tree and plugged with cement or mud for the control of red palm weevil

LECTURE NO. 12
INORGANIC INSECTICIDES

Arsenic compounds:

In an arsenical compound, the total arsenic content and the water soluble arsenic content are of importance, the water solubility of arsenic may result in entering the foliage and causing burning injury to plants, and hence water insoluble compounds are preferred for insect control. Arsenates are more stable and safe for application on plants then arsenites. Arsenites are mainly used in poison baits since they are phytotoxic. However arsenates are less toxic to insects then arsenites. In insects arsenates cause regurgitation, torpor (sluggishness) and quiescence. Disintegration of epithelial cells of the midgut and clumping of the chromatin of the nuclei are the effects noticed in poisoned insects. Slow decrease in oxygen consumption is also evident and kill of the insect is primarily due to the inhibition of respiratory enzymes. Water soluble arsenic causes wilting followed by browning and shriveling of the tissue.

1. **Calcium arsenate:** It was first used by about 1906 as an insecticide. It is a white flocculent power, formulated as a dust of 25 to 30% metallic arsenic equivalent. Dosage – Calcium arsenate at 0.675 to 1.350 kg with equal quantity of slaked lime in 450 litres of water. LD50.for mammals oral – 35 to 100. Being a stomach poison it was mainly used for control of leaf eating insects.

2. **Lead arsenate:** It was first used as in insecticide in 1892 for the control of gypsy moth. It is a stomach poison with little contact action LD50.for rat oral 10-100, dermal 2400 mg/kg. . It is rarely used as dust. 450 g to 1800 g of load arsenate is diluted with 200-240 litres of water. An equal quantity of hydrated lime is some time added to prevent phytotoxicity to tender foliage. In baits it is used at 450 or900 g in 1200 g to 45000 g of carrier such as wheat bran or rice husk respectively.

3. Arsenite: Paris green:It is a double salt of copper acetate and copper arsenite. It was first used in 1867 for the control of Colorado potato beetle, *Leptinotarsa decemlineata*. It is now used as bait for the control of slugs. LD50for rat oral- 22 mg/kg.Very good against termites.

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

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

Other inorganic compounds

1. **Sulphur:** It is primarily fungicide and acaricide. Formulated as fine dust (90 to 95% a.i with 10% inert material. It is also formulated as wettable powders. Effectiveness increases with fineness of sulphur particles.

2. **Lime sulphur:** Aqueous solution of calcium polysulphide. It is prepared by sulphur solution in calcium hydroxide suspension, preferably under pressure in the absence of air and is used against scales, mites, aphids besides powdery mildew.

Properties

- Affect nervous system causing excitement at lower doses and paralysis at higher concentration.
- Not phytoloxic
- Leave no harmful side effects.
- Mighly toxic to mammals.

- Disappear rapidly from the treated surface.So can be used safely before harvest of the produce.

Insecticides of plant origin (Botanical Pesticides)

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

In nature more than, 2400 plant species are reported to have pesticidal properties. The important families having pesticidal properties are

Plant family	No. of plant having pesticidal property
Meliaceae	> 500
Myrtaceae	72
Asteraceae	70
Euphorbiaceae	65
Leguminosae	60
Fabaceae	55

1) Neem (*Azadirachta indica)*

Perennial tree distributed in tropical, subtropical, semi-arid and arid zones. It posses medicinal, insecticidal, insect repellent, antifeedant, growth regulatory, nematicidal and antifungal properties. Neem seed extract and oil contains a number of components such as Azadirachtin, salannin, nimbin, epinimbin nimbidin that gives insecticidal, insect repellent, ovicidal, Antifeedant and growth regulator characters. Azadiractitin disrupts moulting by antagonizing the insect hormone ecdysone.Azadiractitin Acute oral LD50 for rat is 5000mg/kg, Acute dermal for rabbit is >2000mg/kg.

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

Prepartion of Neem Cake Suspension

Soak one kilogram of neem cake in 5 liters of water for 2 days and filter It through muslin cloth. Dissolve 200 g of soft soap in the filtrate and make upto 10 L of water before spraying. This controls tobacco cutworm, leaf miners of citrus, groundnut, tomato and beans etc. Dried powder of neem leaves are used against stored grain insect pests. Leaf extracts showed insecticidal property against,*Plutella xylostella*,*Aproaerema modicella; Spodoptera litura etc.* Desert locust *Schistocerca gregaria* avoids feeding on neem leaves. Neem leaves are found as attractants to white grub *Holotrichia* adults. Neem seed/ kernel extract showed insecticidal properties against a number of sucking pest. Neem oil can be used against storage insect pests @ 1 to 2% and field insects @ (0.2 -0.4%, 1 to 2% 5% or 10% neem oil). Neem products are safer to honey bees, parasitoids, predators.

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

2) Nicotine: Nicotine is found in the leaves of *Nicotiana tabacum* and *N.rustica*from 2% to 14%.Nicotine sulphate has been mainly used as a contact insecticide with marked fumigant action in the control of sucking insect's*viz*., aphids, thrips, psyllids, leafminers and jassids. Nicotine sulphate is more stable and less volatile. It is a nerve poison being highly toxic when absorbed through the cuticle taken in through the tracheae or when ingested. It affects the ganglian blocking conduction at higher levels. Nicotine sulphate containing 40% alkaloid, is safer and is more convenient to use and the free alkaloid is liberated by the addition of soap lime or ammonium hydroxide to the spray solution. Dust formulation of nicotine sulphate releases nicotine in the presence of moisture. It is also used in aerosols. Tobacco decoction, useful for controlling aphids, Thrips etc. can be prepared by boiling 1kg of tobacco waste in 10lts of water for 30 minutes or steep it in cold water for a day. Then make it up to 30 litres and add about 90gm of soap. Addition of soap improves wetting, spreading and killing properties. Nicotine does not leave any harmful residue on treated surface. LD50for rat oral- 50-60 mg/kg.

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

It is oxidized to non-insecticidal compound in the presence of light and air and hence rotenone residues are difficult to find after 5 to 10 days in normal sunlight. Insects poisoned with rotenone show a steady decline in oxygen consumption followed by paralysis and deaths. It is very specific being highly toxic to fishes and to most insect species but almost harmless to warm blooded animals except pigs LD50.to white rat oral-130 to 1500. Dust or spray containing 0.5 to 1.0 per cent and 0.001 to 0.002
percentrotenone are used commercially.

4) Plumbagin:

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

The elucidation of structure of plumbagin and its synthesis in 1936 led to detailed studies. More recently, its IGR properties *viz.*, inhibition of chitin synthetase and ecdysteroid titres have been demonstrated (Kubo et al., 1982) The cold alcoholic extract (5%) of roots of *P. zeylanica* L was toxic to *Euproctis fraterna* larvae as contact spray. Contact toxicity of 5% petroleum ether extracts of *P. zeylanica* root against *Spodoptera litura* Fab., *Dystercus koenigii*Fab.,*Dipaphis erysimi* Kalt, *Dactynops carthami* H.R.L, *Coccinella septumpunctata* L was also reported.

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

Two acids – Chrysanthemic acid and Pyrethric acid

Three alcohols – Pyretholone, Cinerolone and Jasmolone

Active principles/Esters

Pyrethrin I = Pyrethrolone + Chrysanthemc acid

Pyrethrin II = Pyrethrolone + Pyrethric acid

Cinerin I = Cynerolone + Chrysanthemc acid

Cinerin II = Cynerolone + Pyrethric acid

Jasmolin II = Jasmolone + Pyrethric acid

Pyrethrum powder is prepared by grinding the flowers. The powder mixed with a diluent such as talc or clay is known as pyrethrum dust. It is prepared just before use. Otherwise it gets deteriorated rapidly. It is also used as emulsions, solutions, and aerosoles. Pyrethrum is unstable to light, air moisture and alkali. The residues deteriorate very rapidly after application. Pyrethrins are powerful contact insecticides but appear to be poor stomach poisons. A characteristic action of Pyrethroid is the rapid paralysis or ‘knock down’ effect and substantial recovery that follow it. This recovery is due to rapid enzymatic detoxification in the insect. To bring about mortality equivalent to knock down effect three times increase in dosage may be required. Compounds such as piperonyl butoxide, propyl isome and sulfoxide are known to inhibit the detoxication enzyme and increase the toxicities of pyrethroids. These synergists are used at 10 parts to 100 part of pyrethroid. LD50. for white rat oral-200 dermal for rat-1800. Pyrocon E 2/22 (1 part of pyrethrin + 10 parts of piperonyl butoxide) is used for the control of coconut red palm weevil. In household sprays and as a repellent against external parasites of livestock pyrethrum is useful. It is also mixed with grains in storage to protect from stored grain pests. Its use alone or in combination with piperonyl butoxide as food packages has been permitted by the food and Drug Administration in the U.S.A. and no other chemical has been approved.

Properties

i. Highly unstable in light, moisture and air.
ii. Have no residual effect.
iii. Paralyse by more contact.
iv. Gains entry through spiracle and cuticle.
v. Act on central nervous system.
vi. Having rapid knock down effect.
vii. Practically no mammalian toxicity.
viii. Good insecticides against household and cattle pests

Sabadilla:

- It is a alkaloid found in seeds of tropical lily Schoenocaulon officinale (fam: Liliaceae)
- The alkaloid mainly, cevadine and veratridine act as nerve poisions
- It is a primarily contact poision.
- It is harmful to pollinator, honey bees

Ryanodine:

- It is a alkaloid derived from woody stems of South American shrub, Ryania speciosa (Fam; Flacourtaceae)
- Activity: It acts as muscular poison by blocking the conversion of ADP to ATP in strated muscle.
- It acts as slow acting stomach poision and causes insects to stop feeding after they eat it.
- It is reportedly effective against thrips and worms.
- It is used as dust (20-40%)

LECTURE NO. 14

SYNTHETIC ORGANIC INSECTICIDES

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

1. DDT: DDT was first synthesized in 1874 by Othmar Zeidler. In 1939 a Swiss entomologist, Paul Muller, found its insecticidal property for the first time. This discovery brought the `Nobel Prize' for medicine to Paul Muller in 1948 for the life saving discovery. Dichloro Diphenyl Trichloroethane (DDT) is stomach and contact insecticide. It has got long residual action. It is also non-phytotoxic except to cucurbits. It is not much effective against phytophagous mites. Due to low cost of DDT and effectiveness against a variety of insects particularly against house flies and mosquitoes, it is much popularized but due to long residual life and accumulation, it is banned in several countries. The acute oral LD50 for rats is 113-118 mg/kg. It does affect the nervous system preventing normal transmission of nerve impulses. DDT causes a violent excitatory neurotoxic system in most insects which are having uncoordinated movement and DDT Jitters (tremor of the entire body).

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

II) Cyclodines

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

The outstanding characteristic of the cyclodienes is their longer stability in the soil, resulting in more control of soil inhabiting insect pests. Some of the compound belonging to this group are chlordane (1945), aldrin and dieldrin (1948), heptachlor (1949), endrin (1951), mirex (1954), endosulfan (1956) and chlordecone 1958). Among them aldrin, chlordane and heptachlor were often in use for termite control as they are most effective, long lasting and economical insecticides but now banned by GOI.

1) Aldrin

It is persistent and non-systemic soil insecticide. It is usually recommended for the control of termites throughout India. Two German chemists Otto Paul Hermann Diels and Kurt Alder first documented the Diels-Aldernovel reaction in 1928 for which they were awarded the Nobel Prize in Chemistry in 1950 for their work Formulations: EC 30%, Granule 5% and Dusts 5%

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

LD50 value: 67 mg/kg

2) Dieldrin

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

Formulations: Dust 2%

Trade names: Quintox, Alvit
LD50 value: 46 mg/kg

3) Heptachlor

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

Formulations: EC 20%, and Dust 5%
LD50 value: 100-162 mg/kg

4) Endosulfan:

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

Formulations: EC 35%, Granule 4% and Dusts 4%
Trade names: Thiodan, Endocel, Endodhan, Endotaf
LD50 value: 80-110 mg/kg

III) Organophosphates

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

1) Malathion

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

Formulations: EC 50 and Dusts 40
Trade names: Cythion and Himala
LD50 value: 2800 mg/kg

2) Methyl parathion:

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

Formulations: EC 50 and Dusts 2
Trade names: Folidal, Metacid, Paratox, Dhanumar
LD50 value: 13 mg/kg

3) Diazinon:

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

Formulations: EC 20 and 5G
Trade names: Basudin
LD50 value: 300-850 mg/kg .

4) Dichlorvos (Dimethyl Dichloro Vinyl Phosphate - DDVP)

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

Formulations: EC 76 and 5G
Trade names: nuvan, vapona, Doom, Divap

LD50 value: 56 – 108 mg/kg.

5) Fenitrothion:

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

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

Trade names: Sumithion, Folithion

LD50 value: 50 – 250 mg/kg.

6) Quinolphos:

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

Formulations: EC 25 and 5 G

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

LD50 value: 62–137 mg/kg.

7) Phosolone:

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

Formulations: EC 35

Trade names: Zolone

LD50 value: 135 mg/kg

8) Chlorpyriphos:

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

Formulations: EC 20

Trade names: Dursban, Chloroban, Durmet, Radar

LD50 value: 135-163 mg/kg

9) Phosphomidon:

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

Formulations: 40 SL

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

LD50 value: 17-30 mg/kg

10) Monocrotophos:

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

Formulations: 36 SL

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

LD50 value: 14-23 mg/kg

11) Methyl demeton:

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

Formulations: 25 EC

Trade names: Metasystox and Dhanusyatax

LD50 value: 57-106 mg/kg

12) Dimethoate:

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

Formulations: 30 EC

Trade names: Rogor, Celgor, Novogor, Tara 909, roxion
LD50 value: 320-380 mg/kg

13) Triazophos:

It has insecticidal, acaricidal and nematicidal properties with trnalaminar action. It is very effective against variety of pests particularly Lepidoptera larvae on fruits and vegetables.
Formulations: 40 EC
Trade names: Hostathion, Trizocel, Truzo, Suthation
LD50 value: mg/kg

14) Profenophos:

It is a broad spectrum non-systemic insecticide.It is recommended against pest of vegetables. It is highly toxic to birds and fish.
Formulations: 50 EC
Trade names: Curacron, Celcron, Bolero, Carina, Proven
LD50 value: 358 mg/kg

15) Acephate:

It is a systemic andcontact poison.It has low toxicity and safe to environment.
Formulations: 75 SP
Trade names: Arthane, Starthane, Orthene
LD50 value: 866-945 mg/kg

16) Phorate:

It is a systemic granular insecticide and also possesses acaricidal properties. It is very effective against sucking insects and also against maize borers, cut worms, white grubs etc.
Formulations: 10 G
Trade names: Thimet
LD50 value: 1.6 – 3.7 mg/kg

CARBAMATES

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

1. Carbaryl:

Carbaryl is a contact and stomach insecticide. It is most popular insecticide because it is effective against a wide range of insects and possesses very low mammalian toxicity. It is compatible with many pesticides except Bordeaux mixture lime sulphur and urea. It is not effective against mites.
Formulations: WP 50%, Granule 4% and Dusts 5%
Trade names: Sevin.
LD50 value: 400 mg/kg

2. Propoxur(Arprocarb)

It is a broad spectrum, contact and stomach poison with good knock down properties. It is effective in controlling house hold pests such as cockroaches, crickets, flies etc. It has long residual action.
Formulations: 20% EC, 50% WP
Trade names: Baygon, Bla ttamen, Saphaer
LD50 value: 90-128 mg/kg

3. Carbofuran.

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

Formulation: 3G,48F

Trade names: Furadan

LD50 value: 8-14 mg/kg

4. Carbosulfan.

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

Formulation: 25 DS

Trade name: Marshal

5. Thiodicarb

It is a insecticide with ovicidal properties, and molluscicide.

Formulation: 75 WP

Trade name: Larvin

6. Aldicarb

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

Formulation: 10 G

Trade names: Temik

LD50 value: 0.93 mg/kg

5. Methomyl:

It is a systemic with contact and stomach insecticide and nematicide. It is very effective against a wide variety of pests particularly army worms, cabbage semilooper, Okra stem fly, fruit borers, leaf defoliators, cotton boll worms, etc. It is insecticide belonging to carbamate groups that has ovicidal action against lepidopteran pests (*Helicoverpa armigera).*

Formulations: 90 WP,12.5 EC, 40 SP

Trade names: Lannate, Dunnate

LD50 value: 30 mg/kg

SYNTHETIC PYRETHROIDS AND INSECTICIDES OF OTHER GROUPS

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

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

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

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

Limitations

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

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

1) Allethrin

It is contact, stomach and respiratory action and bring quick knock down of flies and mosquitoes when applied in combina tion with Piperonyl butoxide. These are lipophlic compounds. In 1949, the first synthetic pyrethrum analougue allethrin commercially introduced.

Trade name: Pynamin

LD50 value: rats 572-1100 mg/Kg for rats and Dermal LD50 >2000 mg/kg

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

2) **Resmethrin**

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

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

LD50 value Dermal LD50 2000-3000 mg/kg

3) **Bioresmethrin**

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

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

LD50: 8,600 mg/kg (oral) and 10,000 mg/kg (dermal).

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

Third generation: Third generation pyrethroids do not decompose in sunlight and contain some of the most powerful insecticides known. Third generation pyrethoids are not highly toxic to people or other mammals mainly because they decompose rapidly in the body.

5) Fenvalerate:

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

Formulations: 20 EC

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

LD50 value: 300-630 mg/kg

6) **Permethrin:**

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

Formulations: 25 EC and 5% smoke generation
Trade names: Ambush , pounce , pramex
LD50 value: Acute oral LD50 : 7000 mg/kg, Dermal LD50: >5100 mg/kg
119

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

7) **Cyhalothrin**

Non-systemic insecticide with contact and stomach action, and repellent properties.gives rapid knockdown and long residual activity. It is an insecticide and acaricide used to control a wide range of pests.
Formulations: 2.5 EC, 5% EC
Trade names: Kung-Fu,Reeva, Charge, Excaliber, Grenade, Hallmark, Karate,
Matador, Samurai and Sentinel.
LD50 value: 56 mg/kg

8) Cyfluthrin

It is a non-systemic contact and stomach poison,with rapid knock down effect. It is for control of chewing and sucking insects on crops. Cyfluthrin is also used in public health situations and for structural pest control.
Formulations: 5 EC, 10% EC
Trade names: Contur, Laser, Responsar, Tempo
LD50 value: 869 - 1271 mg/kg

9) Cypermethrin

It is stomach and contact insecticide. It is very effective against different types of pests on various crops.
Formulations: 10 EC, 25 EC
Trade names: Cyper guard, Ripcord, Cymbush and Cyper kill
LD50 value: ha Oral LD50 303-4123 MG /KG, dermal more than 2400mg/kg

10) Fenpropathrin

It is contact insecticide and of broad spectrum in nature.It is extremely toxic to fish, wildlife.and aquatic organisms. It have acaricidal and miticidal property.
Formulations: 2.4 EC, 10 or 20% EC.
Trade names: Danitol, Rody and Meothrin
LD50 value:54 mg/kg

11) Flucythrinate

Flucythrinate is a synthetic pyrethroid used to control insect pests in apples, cabbage, field corn, head lettuce and pears, and to control Heliothis spp. in cotton.
Trade names: AASTAR, AC 222705, Cybolt, Fuching Jujr, OMS 2007, and Pay-Off.
LD50 value: 81 mg/kg .dermal LD50 in rabbits of greater than 1000 mg/kg

12) Decamethrin (Deltamethrin)

It is more potent than any other insecticide. It has also proved effective even against insects resistant to conventional insecticides.It is contact and stomach insecticide.
Formulations: 2.8 EC, 2.5% WP
Trade names: Decis, Decaguard, Deltex
LD50 value:135mg/kg

13) Fluvalinate

It is a insecticide and acaricide with stomach and contact activity in target insects. It is used as a broad spectrum insecticide.
Formulations: 25 EC
Trade names: Klartan, Mavrik, Mavrik Aqua Flow, Spur and Yardex

LD50 value: 1,050 to 1,110 mg/kg

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

Trade Names: Bayticol, Bayvarol, Baynac

INSECTICIDES OF OTHER GROUPS

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

LECTURE NO. 15

NOVEL INSECTICIDES

Neonicotinoids

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

1) Imidacloprid:

It is the first commercial insecticide of this group which inhibits nicotinic acetylcholine by binding with nicotinic acetylcholine receptor (nAChR).Systemic insecticide with translaminar activity. Imidacloprid has good xylem mobility and formulated for use as seed treatment, soil and foliar application and effective against sucking insects including leaf hoppers, plant hoppers, aphids, thrips and whitefly, also effective against soil insects, termites.. It is highly toxic to birds.

Formulations: 17.8 SL ,70 WS

Trade names: Confidor (foliar application), Gaucho (seed treatment), Admire, Merit, Premier, Stalone. Tatamida, Maratho , Provado (termite control)

LD50 value: 450 mg/kg

2) Acetamiprid: It is a systemic insecticide. The mode of action is same as imidacloprid and it is a broadspectrum insecticide used for control of pests of vegetables, fruit trees, tea etc. Used as a soil and foliar application against homoptera especially aphid and leafhoppers.

Formulations: 20 SP

Trade names: Pride, Assail Intruder, Profil, Supreme

LD50 value:>2000 mg/kg

3) Thiomethoxam :

It is a broad spectrum insecticide acting against stem borers, hoppers, jassids, whiteflies, aphids, mosquito bug, psyllids and used in crops viz., rice, cotton, wheat, mustard, okra, mango, potato, tea and citrus etc.Contact and stomach poison with translaminar and systemic movement used both as a seed treatment and foliar application against sucking insects . It has very strong effect on viral transmitting insects.

Formulations: 25 WG (foliar spray) , 70 WS (Seed treatment)

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

LD50 value: 1563 mg/kg

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

Formulations: 50 WG

Trade names: Dantop, Celeso

LD50 value: >5000 mg/kg

5) Thiacloprid: It affects transmission of nerve impulse.Used as a foliar spray against sucking pests such as aphids, thrips, whitefly and leaf miner.

Formulations: 36 WG, 70 WG

Trade names: Calypso, Bariard, Alanto

LD50 value: 500mg/kg

6. Dinotefuran: It is third generation nicotinyl group of insecticides acting against sucking pests like hoppers, jassids and aphids of different crops. It is highly systemic compound. Commercially available formulation is Dinotefuran 20% SG in the name of **Osheen** and **Token.**

7. Flonicamid: It has systemic as well as translaminar activity which gives long term control. Flonicamid rapidly inhabits the feeding behavior of aphids. Excellent activity against major species of aphids. It offers good persistence gives long time protection from the pest. It is also moderately effective against whiteflies, plant hoppers, plant bugs and mealy bugs of cotton, potato vegetables and fruit crops. It is available with the brand name **Ulala** with flonicamid 50% WG in the market.

2. Phenyl pyrazoles (Fiproles):

1) Fipronil

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

Broad spectrum systemic insecticide with contact and stomach poison activity. It is found effective against stem borer, gall midge, DBM, thrips, shoe borers, root borer and can be used in crops viz., sugarcane, cruciferous crops cotton and rice.

Formulations: 0.3% GR, 5% SC

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

3. Oxadiazines

Indoxacarb:

The active ingredient indoxacarb works by inhibiting sodium ion entry into nerve cells, resulting in paralysis and death of targeted pests. Indoxacarb is a stomach poison with slight contact action. Indoxacarb affects insects from direct exposure and through ingestion of treated foliage/fruit. Once indoxacarb is absorbed or ingested, feeding cessation occurs almost immediately. It kills by binding to a site on sodium channels and blocking the flow of sodium ions into nerve cells. The result is impaired nerve function, feeding cessation, paralysis, and death. used to control for variety of lepidoptera pests, specially against american boll worm, *Helicoverpa armigera* and diamond back moth (DBM), *Plutellla xylostella.*

Formulations: 14.5% SC, WDG 30%, 15.8% EC

Trade names: Avaunt, Steward.Torando

4. Thio-Urea Derivatives

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

Formulations: 50 WP

Trade names: Polo

LD50 value: 2068 mg/kg.

5. Pyridine Azomethines

Pymetrozine is a new insecticide highly active and specific against sucking insect pests (whiteflies, hoppers and aphids) and can be applied both as foliar and soil application.. Pymetrozine is the only representative of the pyridine azomethine. It has high degree of selectivity, low mammalian toxicity and safety to birds, fish and non-target arthropods. When the insertion of the stylets of sucking insects into the pymetrozine treated plant tissues, stylets are almost immediately blocked. The sucking insects die by starvation a few days later (feeding depressant)

Formulations: 50 WDG

Trade names: Full fill, Chess
LD50 value: 5693 mg/kg

6. Halogenatd Pyrroles

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

1. Chlorfenapyr: It is a miticide and insecticide. Chlorfenapyr has broad spectrum of activity against many species of Coleoptera, Lepidoptera, Acarina and Thysanoptera. It is mainly stomach poison and has contact action also. It is found effective against DBM in cabbage and cauliflower and also against mites in *chilli*

Formulations: SC 3
Trade names: Pirate ,Pylon
LD50 value: 626 mg/kg

7. Diamide Group

Flubendiamide and Chlorantraniliprole are two insecticides of this group. Flubendiamide a novel class of insecticide having a unique chemical structure used against broad spectrum of lepidopterous insects. Ryanodine receptors are intracellular Ca^{2+} channels specialized for the rapid and massive release of Ca^{2+} from intra cellular stores, which is an essential step in the muscle contraction process. It has been recently registered in India under different formulations such as **20**% WG registered trade name as Takumi® & 39.35% SC with registered trade name as Fame® which act on insect pests of rice (stem borer, leaf folder) and cotton *(H. armigera* and spotted bollworm)

The other new class of chemistry of this group is Chlorantraniliprole, to be specific it belongs to anthranilidin diamides controlling almost all economically important Lepidoptera and other species. It has high larvicial potency and long lasting activity with new mode of action and safe to non target insects (parasitoids, predators and pollinators). It is also used to control insects which are found resistant to other insecticides and fits into IPM programs. It binds to insect ryanodine receptors in muscle cells causing the channel to open and release Ca^{2+} ions from internal stores into cytoplasm and because of depletion of calcium it causes paralysis and death. It is registered in India in 2009 and available in different formulations as 18.5% SC and 0.4% GR and targets stem borer, leaf folder (Rice), DBM (Cabbage), *H. armigera*, *S. litura*, *Earias* spp (Cotton), Termites, early shoot bore, top borer in sugarcane and yellow stem borer, leaf folder in rice, respectively. It is marketed as Coragen and Ferterra.

8. Ouinazoline Group

Acaricide, Fenazaquin belongs to quinazoline group. It inhibits mitochondrial electron transport chain by binding with complex I at co-enzymes site Q. In India, it is registered as Fenazaquin 10% EC and sold as Magister which proved to be effective against mites in tea and chilli.

9. Formamidines

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

1. Chlordimeform: It has marked translaminar and systemic activity. It shows a strong repellent-antifeedant action on both lepidopterous larvae and mites. It has good ovicidal

activity. Non toxic to non target organisms except predaceous mites.
Formulations: 50 SP, 4 EC
Trade names: Galecron, Fundal, Fundal, Spike
LD50 value: 340 mg/kg

2. Amitraz:It is a non systemic insecticide and acaricide with contact and respiratory action It is used to control red spider mites, leaf miners, scale insects, and aphids.
Formulations: 50 SP, 20 EC
Trade names: Acarac, Amitraze,Baam
LD50 value: 523- 800 mg/kg

10. Ketoenols (Tetronic Acid Derivatives)

Ketoenols act as insecticide and acaricides against against all developmental stages and is a valuable new tool in the resistance management.They are tetronic acid insecticides with acaricidal action. Their mode of action is to inhibit lipogenesis in treated insects, resulting in decreased lipid contents, growth inhibition of younger insects, and reduced ability of adult insects to reproduce.

1. Spiromesifen:
Spiromesifen is effective against whitefly, spider mites and psyllids. It is is particularly active against juvenile stages. However, it also strongly affects fecundity of mite (and whitefly adults by transovariole effects.
Formulations: 2 SC, 4 F
Trade names: Oberon, Forbid
LD50 value: >2000 mg/kg

2. Spirodiclofen:
Spirodiclofen is a selective, non-systemic foliar insecticide and acaricide. It is effective against mites and sanjose scales.
Formulations: 2 SC,
Trade names: Envidor
LD50 value: >2500 mg/kg

3. Spirotetramat:
Spirotetramat is effective against aphids, whiteflies, scales, mealybugs, psylla, phylloxera, thrips, and mites on crops like citrus, vegetables, grapes, potato, other tuberous crops, livestock commodities, and greenhouses/nurseries.
Formulations: SC 14.5, SC 22.4
Trade names: Movento, Ultor
LD50 value: >2000 mg/kg

11. Sulfite Ester Group

Propargite an acaricide belongs to this group. It kills mites through inhibition of oxidative phosphorylation i.e this compound act as disruptors of ATP formation. It is highly effective against phytophagous mites viz., red spider mite, pink mite, purple mite, scarlet mite in tea, yellow mite in chilli and European red mite & two spotted mite in apple and available in liquid formulation as 57% EC in market as **Omite**.

12. Carbazate Acaricide

It is selective acaricide that controls spider mite. These compounds are neuroactive but it's exact mode of action is unclear. It paralyses the mites suggesting that it may act on nervous system of mites. In the market it is available by trade name Bifenazate with Trade name **Floramite**.

13. Pyridazinones Acaricide

This class of acaricide is very effective against red spider mites and two spotted mites. It inhabits mitochondrial electron transport. It affects respiratory chain also. In the market it is available with active in gradient Fenpyroximate with trade name **Mitigate**.

Insect Growth Regulators

A. Benzoyl Urea

The insecticides of this group are Novaluron and Lufenuron. Novaluron is new Insect Growth Regulator. It is powerful toxicant for controlling lepidopteran larvae. It acts by both ingestion as well as contact. It has got translaminar effect. It is quiet safe for beneficial insects and natural parasites and predators. It is available with the name of
Rimon and **Signa** in the market**.**

B. Thiadiazines

This is Chitin synthesis inhibitor. It prevents proper formation of exoskeleton after molting. It is effective against homoperean insects such as hoppers, Jassids and white fly. In the market Buprofezin active ingredient available with trade name **Applaud.**

MACROCYCLIC LACTONES (New Insecticides from Microorganisms)

1. Spinosyns - Spinosad

The extract of the fermentation broth that contains spinosad is produced by the microorganism, *Saccharopolyspora spinosa.* The primary components are spinosyn A and spinosyn D. Spinosad kills insects by causing rapid excitation by activation of nicotinic acetylcholine receptors of the insect nervous system, leading to involuntary muscle contractions, prostration with tremors, and paralysis. It also effects GABA receptor functioning. Spinosad is a contact and stomach poison with some translaminar movement in leaf tissue. Effective againt stem borer, leaf folder (Rice), DBM (Cabbage), *H. armigera, S. litura, Earias* spp (Cotton), Termites, early shoot borer, top borer in sugarcane and yellow stem borer, leaf folder in rice, respectively.

Formulations: 45 SC, 2.5 WSC

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

LD50 value: 3738 mg/kg

2. Avermectins:

Avermectins form a new class of compounds having nematicidal, miticidal and insecticidal activity. These are produced by the soil microorganism *Streptomyces avermitilis*. Avermectins activate the GABA gated chloride channel, causing an inhibitory effect, which, when excessive, results in the insect's death. This channel normally blocks reactions in some nerves, preventing excess stimulation of CNS. Emamectin benzoate and abamectin are the two major compounds in this group. .contact and stomach poisons. These are used as bait, foliar application against Homoptera, Diptera, Coleoptera, Lepidoptera and mites

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

Formulations: EC 5, SG 5

Trade names: Proclaim

LD50 value: 300 mg/kg.

Abamectin:

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

Formulations: EC 1.8

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

LECTURE NO. 16

Legislative / Legal / Regulatory Methods of Pest Control

Definition

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

Foreign pests introduced into India

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

List of Insects introduced into India

Common Name	Scientific Name	Crop	Country from where introduced
Cottony cushion scale	*Icerya purchasi*	Citrus	Australia
San Jose scale	*Aspiodiotus perniciosus*	Apple	China
Wooly aphid	*Erisoma lanigera*	Apple	Europe
Serperntive leaf miner	*Liriomyza trifolii*	Chrysanthemum	
Coffee berry borer	*Hypothenemus hampei*	Coffee	
Spiralling whitefly	*Alerodicus disperses*	Guava	Sri Lanka
Dimond back moth	*Plutella xylostella*	Cabbag	
Potato tuber moth	*Pthorimaea operculella*	Potato	
Subabul psyllid	*Heteropsylla cubani*	Subabul	Sri Lanka

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

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

The first Quarantine Act in USA came into operation in 1905. While Govt. of India passed an Act in 1914 entitled “Destructive Insect and Pests Act of 1914” to prevent the introduction of any insect, fungus or other pests into our country. This was later supplemented by a more comprehensive act in 1917. Madras State enacted " Madras Agricultural Pests and Diseases Act 1919" , which was the first state Act in India.The insect which enterd India before the enforcement of quarantine measures is cottny cushion scale.

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

i. Legislation to prevent the introduction of new pests and weeds etc from foreign countries (International quarantine)
ii. Legislation to prevent the spread of already established pests, diseases and weeds from one part of the country to another (Domestic quarantine)
iii. Legislation to enforce upon the farmers regarding the application of effective control measures to prevent damage by already established pests.

iv. Legislation to prevent the adulteration and misbranding of insecticides and determine their permissible residue tolerance levels in food stuffs and
v. Legislation to regulate the activities of men engaged in pest control operations and application of hazardous insecticides

1) Legislation to prevent the introduction of foreign pests:

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

The Directorate of Plant Protection Quarantine and Storage (DPPQS) was established in Faridababd in 1946. Prior to which customs authorities did the enfo rcement of quarantine laws. From 1949, DPPQS deals with the commercial import of consignments of grains, plants and plant products for consumption through its network of 35 Plant Quarantine Stations spread across the country including seaports, airports and land frontiers These operate under the provisions made under the "Destructive Insect and Pests Act of 1914". Further Government of India has approved NBPGR, New Delhi for quarantine processing of all germplasm including transgenic planting material under exchange for research purposes, Forest Research Institute (FRI) Dehadradun for forest plants and Botanical Survey of India (BSI), Kolkatta for ornamental plants to enforce quarantine laws.

The importation of plant material from foreign countries has to be done only through any of these ports.The consignment should also be accompanied with the certificate issued by the Officers of agriculture department of the exporting country so as confirm that the consignments are pest free. This certificate is called as 'Phytosanitory certificate'. Import of plants by post or air is not permitted, except by experts for scientific purpose. Import of potatoes from areas known to be infected with wart disease or golden cyst nematode is totally prohibited in to our country.

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

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

The Madras Government enacted the Madras Agricultural Pests and Diseases act in 1919 and was the first state to enact such laws in our country. This act was passed to prevent the spread of pests or diseases or weeds form one part of the state to another. Cottony cushiony scale when localized in Nilgiris and Kodiakanal none of the alternate host plants were permitted to get transported from these areas. Quarantine stations were opened at Mettupalayam and Gudalur of Nilgiris and at Shenbegmur station of Kodaikanal in 1943 and were closed subsequently.

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

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

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

To avoid malpractices and supply of substandard chemicals, the pesticide products are to be standardized through the Indian Standards Institute. Such products carry **ISI mark** and are expected to confirm the level of *a.i* (Active ingredient) The Insecticide Act, 1968 has been enforced on 2nd September, 1968 by the Government of India to regulate the import, manufacture, sale, transport and distribution and use of insecticides. The government of India also constituted the Central Insecticide Board (CIB) to advise the state and central governments as per this act. The insecticide rules of 1971 framed under the Insecticides Act 1968 had come in to force in 1971.

5) Legislation to regulate the activities of men engaged in pest control operations: They have to take certain precautionary measures to avoid pesticide poisoning and undergo regular medical checkup.**Invasive Alien Species (IAS):** is a species outside of its native range whose introduction and or spread threatens biodiversity.

……………………………………………………………………………………………

Pest Risk Analysis (PRA): It is a process of investigation, evaluation of information and decision making with respect to a certain pest, that start once it is known or determined that this pest is a quarantine pest. It is done to protect the country's agriculture from damages that can be causd by harmful (quarantine) pests which can be brought in along with imported commodities.

LECTURE NO.17

INSECT GROWTH REGULATORS (Hormonal Control)

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.

Insect growth and development are controlled by three principal hormones namely

1. **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).
2. **Juvenile hormone (JH):** Also called neotinin. It is a terpene secreted by corpora allata which are paired glands present behind insect brain. Wigglesworth (1936) showed that JH inhibits metamorphosis and stimulates ovarian development. Their role is to keep the larva in juvenile condition. JH 0, JH I, JH II and JH III have been identified in different groups of insects. The concentration of JH decreases as the larva grows and reaches pupal stage. JH 0, I and II are found in larva while JH III is found in adult insects and are important for development of ovary in adult females.
3. **Ecdysone or 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. Ecdysone is not the active moulting hormone. Various tissues, including fat body convert ecdysone to 20-hydroxyecodysone, the active form of moulting hormone. The cells of the epidermis respond to 20-hydroxyedysone with initiation of the process of moulting. Cholesterol acts as the precursor for ecdysone synthesis.

IGRs used in Pest management

Ecdysone or Moulting Hormone (MH) Agonists:

MH contains two hormones, α -Ecdysone and ß - Ecdysone. The α- ecdysone is a prohormone produced by PTG which is converted into ß - ecdysone in the peripheral tissues of the gland and is also called 20-Hydroxy Ecdysone, which actually brings about molting in insects and is the true MH. Synthetic analogues of ecdysones are called ecdysoids .After absorption into haemolymph it binds the ecdysone receptor proteins which initiates moulting process.

When applied in insects, kill them by formation of defective cuticle. The normal moulting process is disrupted. The development processes are accelerated by passing several normal events resulting in integument lacking scales or wax layer. Thus, larvae will die due to dehydration and starvation.

Example: Tebufenozide (Mimic, Confirm and Romdan), Halofenozide (Mach), Methoxyfenozide (Prodigy)

The ecdysterone isolated from the mature stem of *Diploclisia glaucescens* showd insecticidal activity against the groundnut aphid.

b) **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.

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

Mode of Action:

i) Antimorphic effect: Do not allow Metamorphosis to take palace there by forcing larva to continue as a larva. They retain *status quo* in insects (larva remains larva).There fore if the Juvenoids are provided exogenously the larvae will undergo an extra larval moult (change in to super larva) or moult in to defective intermediate forms (larval-pupal and pupal-adult) which may suffer from a failure to successfully moult, feed or mate and ultimately which cause death of insects.

ii) Larvicidal effect

iii) Ovicidal effect.

iv) Diapause disrupting effect

v) Embryogenesis inhibiting effect.

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

Juvenoids Ex:

- Juvabione (Fernesol - extracted from excreta of *Tenebrio* sp)
- Methoprene (Altosid): first commercial product used for control mosquitoe.
- Hydroprene (Gentrol, Altozar)
- Kinoprene (Enstar)

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

c) **Anti JH or JH Agonists or Precocenes**: They act by destroying corpora allata and preventing JH synthesis. These compounds induce the precocious metamorphosis of immature insects.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. These compounds first extracted from the plant *Ageratum houstonium.* It contains two simple chromene compounds precocene –I and II.

- Fenoxycarb (Insegar 50 % WP, Award, Comply Logic, Torus, Pictyl and Varikill) @ 0.025 %. It is registered for the control of several fruit pests such as grape moths, plum moth and codling moth.Target pest are Blatellidae, Coccoidae, Culicidae, Lepidoptera, Psyllidae, ants.
- Pyriproxyfen (Tiger 10 % EC, Distance, Esteem, Archer Knack, Sumilarv and Admiral) @ 0.0125 %. It has proveed effective against a number of ucking pests including whitefly, red scale and cottony cushion scale.Target pest are Blatellidae, Coccoidae, Diptera and Siphonaptera.

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

The effects they produce on insects include

• Disruption of moulting

- Failure to feed due to 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.

Advantages : Low mamalion toxicity, environmentally compatible

IGRS from Neem : Leaf and seed extracts of neem which contains azadirachtin as the active ingredient, when applied topically causes growth inhibition, 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

- Juvinoids affect only the last larval instar so that the earlier instars could continue to cause damage
- Slow mode of action
- Since they are chemicals possibility of build-up of resistance
- Unstable in the environment

CHAPTER 10
Safe use of pesticides

Pesticides are toxic to both pests and humans. However, they need not be hazardous 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 indicate the contents, safety instructions (warnings) and possible measures in the event of swallowing or contamination. Always keep pesticides in their original containers (Figs. 10.1 and 10.2). 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 unauthorized people or children (Fig. 10.3); they should never be kept in a place where they might be mistaken for food or drink. Keep them dry but away from fires and out of 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 a specially dug hole in the ground or a pit latrine (Fig. 10.4). It should not be disposed of where it may enter water used for drinking or washing, fish ponds or rivers. Some insecticides, such as the pyrethroids, are very toxic to fish. Dig a hole at least 100 metres away from streams, wells and houses. In a hilly area the hole should be on the lower side of such areas. Pour run-off water from hand washings and spray washings into the hole, and bury containers, boxes and bottles used for pesticides in it (Fig. 10.5). Close the hole as soon as possible. Cardboard, paper and cleaned plastic containers can be burned (Fig. 10.6), where this is permitted, far away from houses and sources of drinking-water. For reuse of cleaned

Fig. 10.1
Types of pesticide container (adapted from *2*).

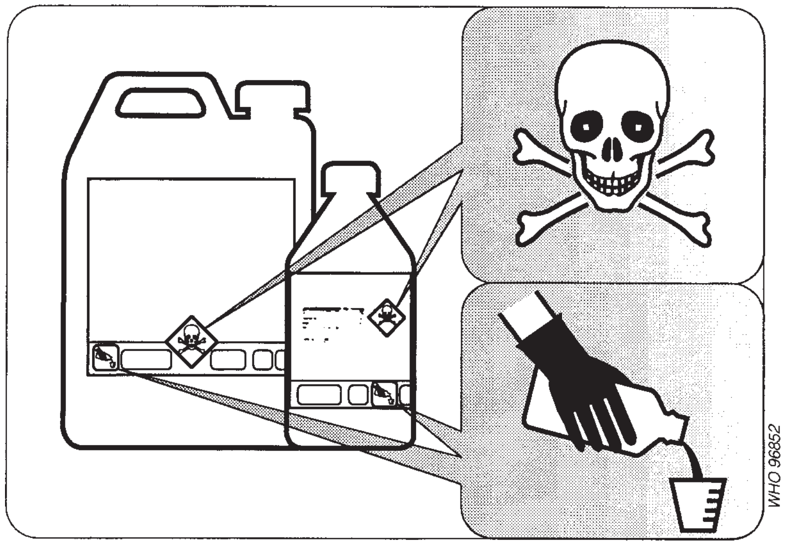


Fig. 10.2
Look for warning symbols, pictograms and colour coding on labels (adapted from *2*).

containers, see box (p. 388). Pyrethroid suspensions can be poured on to dry ground 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 around latrines or similar breeding places. Solutions of pyrethroids for the treatment of mosquito nets and other fabrics can be used for a few days after preparation. The solution may also be used to treat sleeping mats or string mattresses to prevent

Fig. 10.3
Keep pesticides out of reach of children (adapted from *3*).

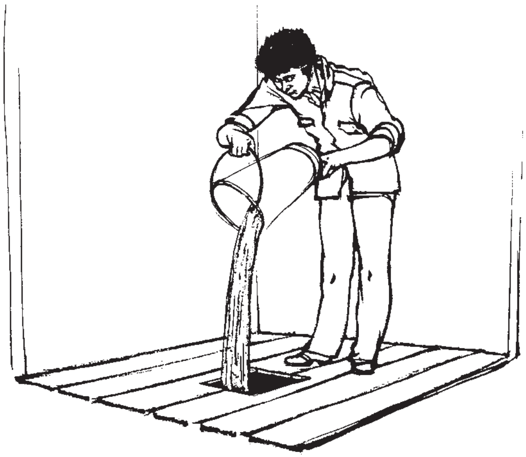


Fig. 10.4
Surplus insecticide solution can be disposed of safely by pouring it into a pit latrine or a specially dug hole in the ground.

Fig. 10.5
Packages to be buried must be made unusable and reduced in bulk as much as possible (adapted from *4*).

Fig. 10.6
Clean paper and cardboard and cleaned plastic containers (not PVC) may be burnt (adapted from *4*).

mosquitos from biting from below. Where bedbugs are a problem, mattresses can be treated.

Cleaning used pesticide containers

The reuse of pesticide containers is risky and not recommended. However, some pesticide containers may be considered too valuable to be thrown away after use. Whether containers are suitable for cleaning and reuse depends on the material they are made of and what they contained. The label should provide instructions on possibilities for reuse and cleaning procedures.

Containers that have held pesticide formulations classified as highly hazardous or extremely hazardous must not be reused. Under certain conditions, containers of pesticide formulations classified as slightly hazardous or unlikely to present acute hazard in normal use can be reused for purposes other than the storage of food, drink or animal feed. Containers made of materials such as polyethylene that preferentially absorb pesticide should not be reused if they have held pesticides in which the active ingredient is classified as moderately, highly or extremely hazardous, regardless of the formulation.

Pesticide containers should be rinsed as soon as they are empty, completely filled with water, and allowed to stand for 24 hours. They should then be emptied, and the process repeated twice.

General hygiene

Do not eat, drink or smoke while using insecticides. Keep food in tightly closed boxes. Use suitable equipment for measuring out, mixing and transferring insec-

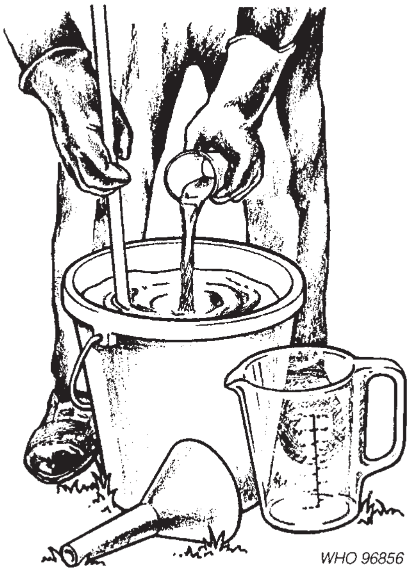


Fig. 10.7
Use suitable equipment for measuring out and mixing insecticides (adapted from *2*).

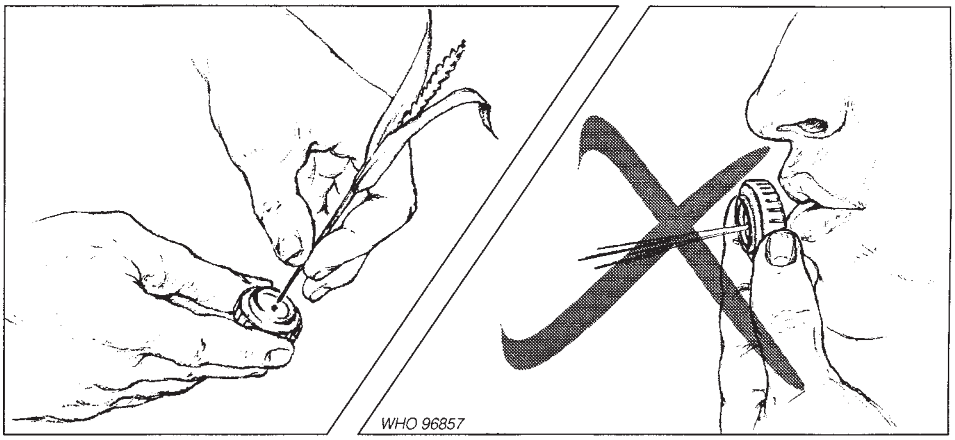


Fig. 10.8
Clean blocked nozzles with a soft probe (adapted from *2*).

ticides (Fig. 10.7). Do not stir liquids or scoop pesticide with bare hands. Use the pressure-release valve of the pump or a soft probe to clear blockages in the nozzle (Fig. 10.8; see also Chapter 9, p. 379). Wash the hands and face with soap and water each time the pump has been refilled. Eat and drink only after washing the hands and face (Fig. 10.9). Take a shower or bath at the end of the day.

Protective clothing

Spraying indoors

Spray workers should wear overalls or shirts with long sleeves and trousers, a broad-brimmed hat, a turban or other headgear and sturdy shoes or boots. Sandals are unsuitable. The mouth and nose should be covered with a simple device such as a disposable paper mask, a surgical-type disposable or washable mask, or any clean piece of cotton. The cotton should be changed if it becomes wet. The clothing should be of cotton for ease of washing and drying. It should cover the body without leaving any openings. In hot and humid climates the wearing of additional protective clothing may be uncomfortable, and pesticides should therefore be applied during the cooler hours of the day.

Mixing

People who mix and pack insecticides in bags must take special precautions (see Chapter 9, p. 373). In addition to the protective clothing described above, it is recommended that gloves, an apron and eye protection such as a face shield or goggles be worn (Figs. 10.10 and 10.11). Face shields provide protection for the whole face and are cooler to wear. The mouth and nose should be covered, as

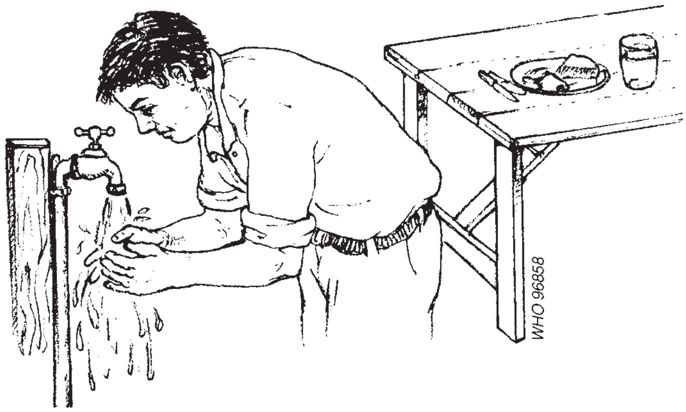


Fig. 10.9
Wash the hands and face before eating or drinking (adapted from *2*).

Fig. 10.10
Wear gloves when handling concentrates.

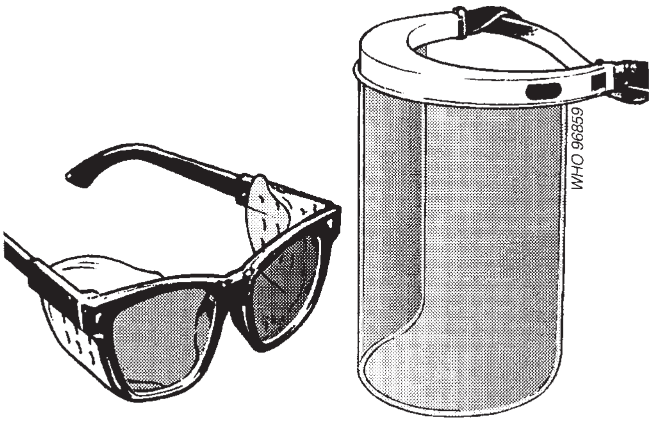


Fig. 10.11
Protective equipment for the eyes and face (adapted from *2*).

recommended for indoor spraying. Care should be taken not to touch any part of the body with gloves while handling pesticides.

Impregnation of fabrics

Long rubber gloves should be worn when treating mosquito nets, clothes, screening or tsetse traps with insecticides.

Under certain circumstances extra protection may be required, e.g. from vapour, dust or spray of hazardous products. Such additional protective items should be indicated on the product label and may include aprons, boots, face masks, overalls and hats.

Maintenance

Clothing should be kept in a good state of repair and should be inspected regularly for tears or worn areas through which skin contamination might occur. Protective clothing and equipment should be washed daily with soap, separately from other clothing. Gloves need special attention and should be replaced when there is any sign of wear and tear. After use, gloves should be rinsed with water before they are taken off. At the end of each working day they should be washed inside and outside.

Safe techniques

Spraying

The discharge from the sprayer should be directed away from the body. Leaking equipment should be repaired and the skin should be washed after any accidental contamination. Persons and domestic animals must not remain indoors during spraying. Rooms must not be sprayed if someone, e.g. a sick person, cannot be moved out. Cooking utensils, food and drinking-water containers should be put outdoors before spraying. Alternatively, they can be placed in the centre of a room and covered with a plastic sheet (Fig. 10.12). Hammocks, paintings and pictures must not be sprayed. If furniture has to be sprayed on the lower side and the side next to a wall, care should be taken to ensure that other surfaces are not left

Fig. 10.12
Furniture and food should be covered with a plastic sheet or placed outdoors before a house is sprayed.

unsprayed. Floors should be swept clean or washed after spraying. Inhabitants should avoid contact with the walls. Clothes and equipment should be washed daily.

Organophosphorus and carbamate compounds should not be applied for more than 5–6 hours a day and the hands should be washed after every pump charge. Blood cholinesterase activity of spray personnel should be checked weekly if fenitrothion or old stocks of malathion are used (see box).

Monitoring exposure to organophosphorus compounds

Commercial field kits are available for monitoring blood cholinesterase activity. Low levels suggest overexposure to an organophosphorus insecticide. Such assays should be performed weekly for all persons handling these products. Persons with unduly low cholinesterase activity should stop working with insecticides until it has returned to normal.

Impregnation of fabrics

Gloves should be worn when handling the insecticide concentrate and preparing the insecticide mixture. Care should be taken to avoid splashing insecticide into the eyes. A wide, shallow bowl should be used (Fig. 10.13), and the room should be well-ventilated to avoid fumes being inhaled.

Fig. 10.13
Wear long rubber gloves and use a wide, shallow bowl when impregnating fabrics.

Emergency measures

Signs and symptoms of poisoning

Poisonings due to pesticides are usually acute and result from extensive skin contact or ingestion. Signs and symptoms vary with the type of pesticide and can sometimes be confused with those of other illnesses.

Indications of pesticide poisoning

General: extreme weakness and fatigue.
Skin: irritation, burning sensation, excessive sweating, staining.
Eyes: itching, burning sensation, watering, difficult or blurred vision, narrowed or widened pupils.
Digestive system: burning sensation in mouth and throat, excessive salivation, nausea, vomiting, abdominal pain, diarrhoea.
Nervous system: headaches, dizziness, confusion, restlessness, muscle twitching, staggering gait, slurred speech, fits, unconsciousness.
Respiratory system: cough, chest pain and tightness, difficulty with breathing, wheezing.

It is important to obtain additional information:

- Has the patient been working with a pesticide?
- Did contamination occur?
- Precisely which product was used?
- How much was ingested?
- How long ago?

An effort should be made to obtain evidence from pesticide containers or spray equipment; the labels on containers should be read and retained.

If pesticide poisoning is suspected, first aid must be given immediately and medical advice and help must be sought at the earliest opportunity. If possible, the patient should be taken to the nearest medical facility.

First-aid treatment

If breathing has stopped: Give artificial respiration. If no insecticide has been swallowed, mouth-to-mouth resuscitation may be given. Pull the patient's chin up and tilt the head back with one hand to keep the airway clear. Place the other hand on the patient's forehead, with the thumb and index finger toward the nose. Pinch together the patient's nostrils with the thumb and index finger to prevent air from escaping. Take a deep breath, then form a tight seal with your mouth over and around the patient's mouth (Fig. 10.14). Blow four quick, full breaths in first without allowing the lungs to deflate fully. Watch the patient's chest while inflating the lungs. If adequate respiration is taking place, the chest should rise and fall. Remove your mouth and allow the patient to breathe out (Fig. 10.15). Take another deep breath, form a tight seal around the patient's mouth, and blow into the mouth again. Repeat this procedure 10–12 times a minute (once every five seconds).

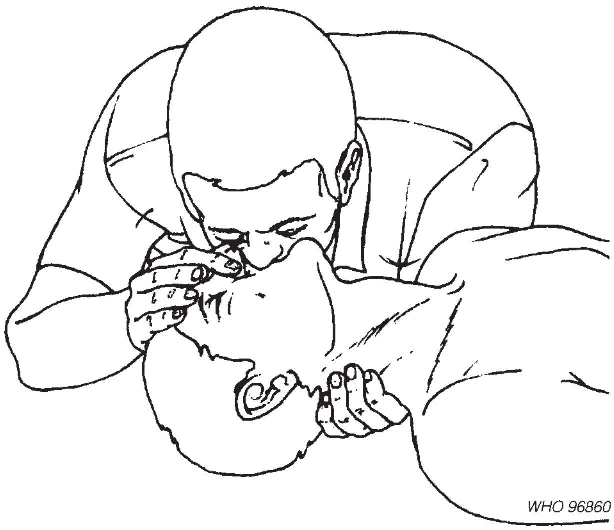


Fig. 10.14
Mouth-to-mouth resuscitation. Take a deep breath, then form a tight seal with your mouth over and around the patient's mouth (© WHO).

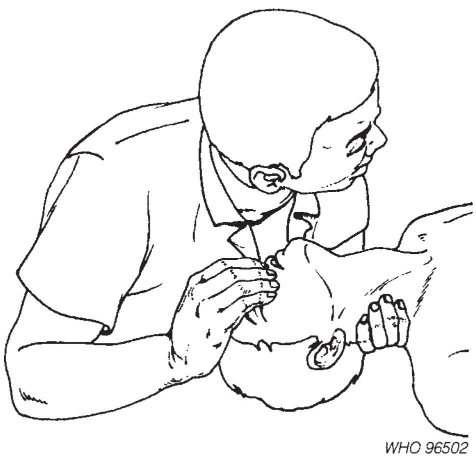


Fig. 10.15
Mouth-to-mouth resuscitation. Remove your mouth and allow the patient to breathe out (© WHO).

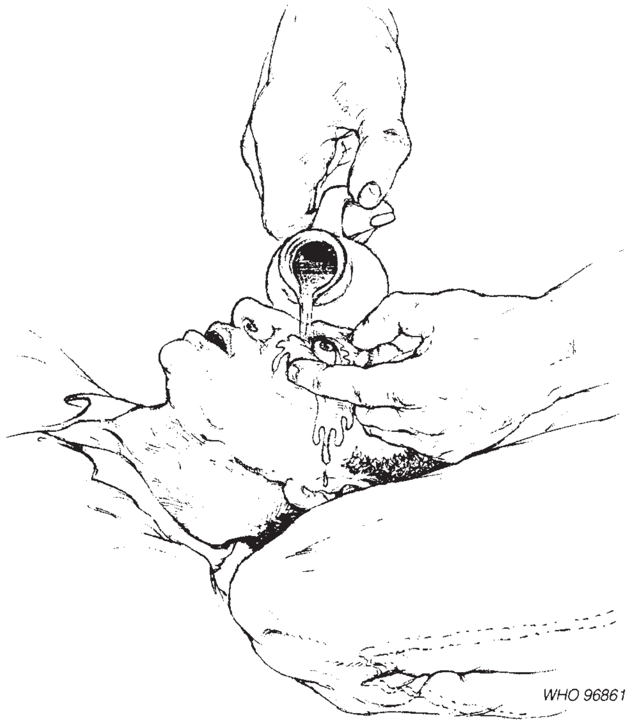


Fig. 10.16
Wash pesticide splashes from the eyes with clean water for at least five minutes (adapted from *3*).

Artificial respiration should be continued for as long as possible if there is still a pulse. If insecticide has been swallowed, another form of artificial ventilation should be used.

If there is insecticide on the skin or in the eyes: Rinse the eyes with large quantities of clean water for at least five minutes (Fig. 10.16). Remove contaminated clothing from the patient and remove the patient from the contaminated area (Fig. 10.17).

Wash the body completely for at least 10 minutes, using soap if possible. If no water is available, wipe the skin gently with cloths or paper to soak up the pesticide. Avoid harsh rubbing or scrubbing.

Vomiting

Do not induce vomiting unless the patient has swallowed pesticide that is known to be highly toxic, and medical help is not expected soon. Never induce vomiting if the patient has swallowed oil spray or products diluted in diesel or kerosene, because of the possibility of inhalation of the vomited material, which would be more dangerous than the intestinal poisoning. The product label should indicate whether the pesticide is highly toxic (skull-and-crossbones signs). Vomiting should be induced only if the patient is conscious. If necessary, sit or stand the person up and tickle the back of the throat with a finger. Whether vomiting occurs or not, give the patient a drink comprising three tablespoonfuls of activated charcoal in half a glass of water. Repeat until medical help arrives.

Caring for the patient

Make the patient lie down and rest because poisoning with organophosphorus and carbamate compounds is made worse by movement. Place the patient on her or his side with the head lower than the body. If the patient is unconscious, pull the chin forward and the head back to ensure a clear airway (Fig. 10.18). Cover the patient with a blanket if he or she feels cold, and cool the patient by sponging with cold water if excessive sweating occurs. If the patient vomits spontaneously, ensure that he or she does not inhale the vomit. In the event of convulsions, put padded material between the teeth to avoid injury.

Fig. 10.17
Remove contaminated clothing immediately and wash the skin (adapted from *3*).

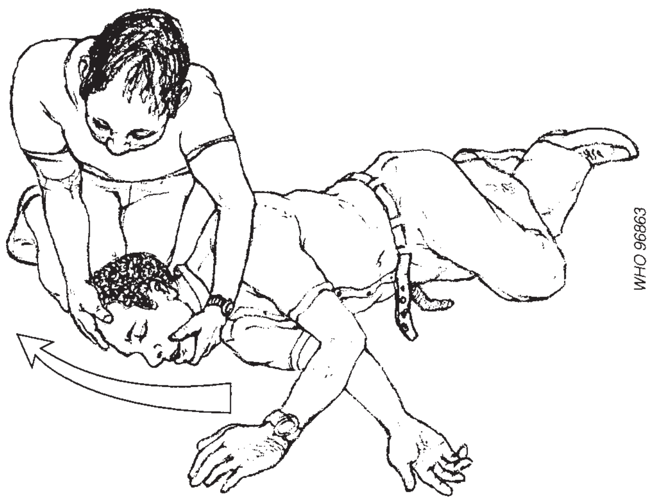


Fig. 10.18
Place an unconscious patient on her or his side and tilt the head back (adapted from *5*).

Do not allow patients to smoke or drink alcohol. Do not give milk. Water can be given.

Further treatment

Patients requiring further medical treatment should be referred to the nearest medical facility. Detailed guidelines for the management of poisoning are being prepared by WHO (*6*). A list of poisons information centres is also available on request (*7*).

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Selected further reading

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