Course Outline

Debre Markos University

Department of Plant Science

Course title: Agricultural Pesticides

Semester II

Instructor: Belete Negash *(PhD)*

Course Description: Pesticides are agricultural chemicals used to control harmful pests and also can play role in preventing, destroying, repelling or mitigating any pest. This course will provide students with knowledge of agricultural pesticides and their proper usage and concepts and scientific application of integrated pest management which include historical development of agricultural pesticides; nomenclature and chemistry of agricultural pesticides; classification and formulation of agricultural pesticides; chemical composition; mode of action; toxicological effects and general description of fungicides, insecticides, herbicides, acaroids, etc.

Course objective:- The course enables students to understand the type and chemistry of pesticides, know the classification of pesticides, understand the role of pesticides in agriculture, understand how to apply pesticides, understand the potential hazards of pesticides, understand safe use of herbicides and advice users to use them properly, advice pesticide users to use other options and consider pesticides as the last resort for the management of pest problem and also the course enables students to recognize common disease/pest problems of major crops; to carry out diagnosis of known and unknown diseases; to identify insect pest problems and injury symptoms in different crops; monitor crop pests / diseases, carry out crop loss assessment, identify priorities for research; plan appropriate management strategies for particular crop pest/disease problems, learn and appreciate use of integrated tactics for pest control.

1. Agricultural pesticides

1.1. Why pest problems became rising?

1.2. History of development and future trends in agricultural pesticides

1.3. Toxicological terms and estimation of toxicity

1.4. Formulation of agricultural pesticides and spray adjuvants

1.5. Pesticide names

2. Classification of insecticide

2.1. Common insecticides- their chemistry

2.1.1. Inorganic insecticides

2.1.2. Organic insecticides- synthetic origin

2.1.3. Organic insecticides- plant origin/ Botanicals

2.1.4. Biorational insecticides

2.2. Mode of actions of insecticide

3. Herbicides

3.1. Herbicides and other pesticides

3.2. Herbicides classification

3.3. Common herbicides

3.4. Mode of actions of herbicides

3.5. Herbicide mixture/combination

3.6. Periods and ways of application of herbicides

3.7. Rates of use of the active ingredient and the solvent

4. Fungicides

4.1. Classification of fungicide

4.2. Common fungicides

4.3. Mode of actions of fungicides

5. Pesticide resistance pests and their management

6. Advantage and disadvantages of pesticide use in pest management

7. Precautionary measures while using pesticides

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1. AGRICULTURAL PESTICIDES DEFINITION

Pest: is any organism that interferes with the objectives of humans.

Cidos: the act of killing or murdering

Pesticide: is any substance that prevents, kills, repeal or attract pests during production, storage, transportation or processing of agricultural commodities

Pesticide: is any thing that is intended to prevent, destroy, repeal, attract or manage a pest.

1.1. WHY PEST PROBLEMS BECOME INCREASING?

In the last 50-60 years there are tremendous increase in agricultural production due to the increase in human population. The intensification of agriculture has created new or greater pest problems in a number of ways:

i- The concentration of a single plant species/variety in ever large and more extensive monocultures increases its apparency to pests and the number of pest species which colonize it

ii- Generally, high yielding crop cultivars can provide improved conditions for pest colonization, spread and rapid growth.

iii- Reduction of natural enemies around crop means that natural enemies of pests must come to the crop from increasingly small and more distant non-crop reservoirs, entering crops too late or in too little numbers to prevent pest outbreaks.

iv- Intensification results in a reduction of intervals between plantings of the same crop, or overlap of crops, which provides a continuous resource to pests.

v- The search for better cultivars and accelerated movement of plant material around the world and with it the movement of pests.

These and other factors contributed to the increase and outbreak of insect pests, diseases and weeds. And to reduce the losses incurred by these pests the use of pesticides will be unquestionable.

1.2. HISTORY OF DEVELOPMENT AND FUTURE TRENDS IN AGRICULTURAL PESTICIDES

Since before 2500B.C., humans have used pesticides to prevent damage to their crops. The first known pesticide used at that time was elemental sulphur dust. By the 15^{th} century, toxic chemicals such as arsenic, mercury and lead were being applied to crops to kill pests. In the 17^{th} century, nicotine was extracted from tobacco leaves for use as an insecticide.

In 1939, Swiss scientist Paul Muller discovered that DDT was a very effective insecticide. It quickly becomes the most widely used pesticides in the world. DDT was the first synthetic insecticide. In its early days, it was hailed as a miracle for a number of reasons:

- It was toxic to wide range of insect pests **("broad spectrum")** yet appeared to have low toxicity to mammals.
- It was **persistent** (didn't break down rapidly in the environment) so that it didn't have to be reapplied often.
- It was not water soluble (**insoluble**), so didn't get washed off by rains.
- It was **inexpensive** and easy to apply.

It was so effective at killing pests and thus boosting crop yields and was so inexpensive to make that its use quickly spread over the globe. It was extensively used during World War II for body lice and malaria. Paul Muller won Nobel Prize in 1948 for its discovery of life saving drug (medicine- DDT). It was after World War II the modern era of chemical control was started with the introduction of a new concept of insect control- *synthetic organic insecticides*, the first of which was DDT.

However, in 1960s, things began to temper the enthusiasm for pesticides. Notable among these was the publication of Rachel Carson's best selling book " **Silent Spring**''which was published in 1962. She (a scientist) issued grave warnings about pesticides, and predicted massive destruction of the planet' fragile ecosystems unless more was done to halt what she called the "rain of chemicals". In retrospect, this book really launched the environment movement.

She was focusing on the chlorinated hydrocarbons, such as DDT, and pointed to evidence linking them to death of **nontarget** creatures (organisms other than those that the pesticide is intended to kill), such as birds and fishes. She reported that insect and worm eating birds were dying in areas where pesticide had been aerially applied (hence her title, "**Silent Spring**") which was a huge threat to biodiversity. DDT is now banned in at least 86 countries, but it is still in use in some developing nations including Ethiopia to prevent malaria by killing mosquitoes. Pesticide use has increased 50 fold since 1950, and 2.5 million tons of industrial pesticides are now used in each year

The current trend of pesticides is to produce:

- biodegradable pesticides
- high mammalian safety
- low residual life (non-persistent)
- compatible with non-target organisms (species specific)

1.3. TOXICOLOGICAL TERMS AND ESTIMATION OF TOXICITY

Toxicity: is the inherent capacity of a pesticide to cause injury by altering the biological system of an organism. When we say toxicity it is not only to the pest but also to any organism.

Hazard: the probability of a chemical to produce toxicity in a particular species. One chemical may be hazard to one organism not to the other. The degree of hazard depends on the toxicity of the active ingredient and the chance of exposure to toxic amounts of the product. According to the risks of pesticides use, two types of human poisoning can be distinguished, acute and chronic.

Acute Toxicity: acute toxicity causes illness or death from a single dose or exposure. This type of poisoning is of particular concern to persons involved directly in the manufacture and application of pesticides, because they are at greatest risk. Acute poisoning also occur among nonprofessionals, however, usually as a result of accidents, ignorance, suicide, or crime.

Chronic Toxicity: occurs from long-time exposure to low levels of a toxicant. This type of poisoning often is reveled only after several weeks of exposure and is of special concern to the general public. The main worry is that food will contain residues capable of causing sickness or death after repeated consumption over time.

The estimation of an active ingredient’s inherent toxicity to humans is required before pesticides can be registered and sold. The estimate is made by the manufacturer using prescribed laboratory tests with rats or rabbits. Toxicity in this instance is defined as the dose that will kill 50 percent of the test animals. This lethal dose is expressed as milligrams of toxicant per kilogram (mg/kg) body weight of test animals and is referred to as the **LD_{50}.** The LD_{50} of an insecticide is used to asses its potential danger. LD stands for Lethal Dose.

Toxicity is established by feeding (oral), skin application (dermal), and inhalation (respiratory) tests. These tests are used to rank pesticides for toxicological ranking. Another value, the **LC_{50}**, is the concentration given as milligrams or cubic centimeters per animal. It is used most frequently in environmental studies where it also is expressed as parts per million (ppm) or parts per billion (ppb) in the medium (usually water) that kills 50 percent of the test organisms. Note that the lower the LD_{50}, the greater the toxicity. Factors determining toxicity to humans include dose, length of exposure, and route of absorption. But size of the dose is probably of greatest single importance.

Pesticide containers have got labels on them. An important part of this label are **signal words** that give the user some idea of the toxicity of the material. Knowledge of these words is very useful. There are four categories of pesticides based on their potential hazard, each with its own signal word. All categories also must bear the words, “Keep Out of Reach of Children”.

- Category I. *Highly toxic*-signal words **Danger-Poison**, accompanied by a skull and crossbones symbol. Pesticides in this group have oral LD_{50}s of 50 mg/kg or fewer- a few drops to one teaspoon. Dermal LD_{50}s in this group are fewer than 200 mg/kg.
- Category II. *Moderately toxic*- Signal word **Warning**. Pesticides in this group have oral LD_{50}s within the range of 50 to 500mg/kg- one teaspoon to two tablespoons. Dermal LD_{50}s in this group are between 200 and 2,000mg/kg.
- Category III. *Slightly toxic*- signal word **Caution.** Pesticides in this group have oral LD_{50}s within the range of 500 to 5,000mg/kg. Dermal LD_{50}s in this group are between 2,000 and 20,000mg/kg.

- Category IV. *Low Toxicity*- signal word **Caution** applied here also. Pesticides in this group have oral LD_{50}s of more than 5,000mg/kg and dermal LD_{50}s of more 20,000mg/kg.

1.4. FORMULATION OF AGRICULTURAL PESTICIDES AND SPRAY ADJUVANTS

1.4.1. Spray adjuvants

Spray adjuvants are chemicals that are usually part of the formulated pesticides although in some circumstances they are added to the insecticide tank mix prior to application. These additives may improve mixing with the diluent, or improve the pesticide activity in the field. Adjuvant is a broad term and includes surfactants, stickers, spreaders, etc.

i. **Surfactants:** the term surfactant is a euphemism for several agents that aid or enhance the surface-modifying properties of a pesticide formulation. It is derived from the words surface active agent. Surfactants improve emulsifying, wetting, and spreading properties of the mixture.

Usually, liquid pesticides, oils, and pesticides in water-insoluble solvents are formulated and applied as water emulsions. Emulsions are suspensions of microscopic droplets of one liquid in another. These can be formed by vigorous agitation but not very effectively. For effective suspensions, detergent like materials are added to the insecticide formulation to enhance mixing. In most instances, when the pesticide and emulsifier are added to water, the oil carrier disperses immediately and uniformly, giving a milky appearance. A thoroughly emulsified liquid has efficient wetting and spreading properties, as opposed to a crude suspension.

Generally, surfactants are chemicals that modify the surface properties of materials they contact. There are three reasons for the addition of surfactants in formulation

- Lowering of the surface tension- resulting in a better covering of leaves and also has an influence on the retention or run-off the pesticide and on the size of the spray drops.
- Promote the penetration and transport of the pesticide in the target organisms thereby increasing the biological activity.
- Stabilization of the formulated product

ii. ***Stickers-*** are adjuvants that cause the pesticide to adhere to the organism and also to resist wash-off. Spreader-stickers are combined products that provide better spray coverage and adhesion. Such materials as casein, gelatin, and vegetable oils have been used to as pesticide stickers or adhesives.

iii. ***Diluents:*** are substances combined with concentrated pesticides as carriers and are necessary to obtain proper coverage of treated surfaces. Diluents can be either liquid or solid. Liquid diluents of pesticides are usually water or refined oils. Solid diluents include organic flours (for example, wheat flour) and minerals (clay, ash or sand).

iv. ***Deodorants:*** are materials added to pesticides to mask unpleasant odors. Many pesticides have strong odors that can be offensive. This is particularly unacceptable when formulated for home use. Therefore, various substances are to pesticides concentrates to disguise their odor.

v. ***Dyes-*** These are used for safety reasons. Ex. in a formulation of seed dressing and in granules.

1.4.2. Formulation

The technical product of a chemical insecticide is rarely suitable for application in its pure form. It is usually necessary to add other non-pesticide substances so that the chemical can be used at the required concentration and in an appropriate form, permitting ease of application, handling transportation, storage, and maximum killing power. Thus, chemical insecticides may be formulated as emulsion and suspension concentrates, water dispersible powders, baits, dusts, fumigants, granules and pellets.

The pesticide in the pesticide formulation that actually kills the pest(s) is termed the **active ingredient.** The chemical(s), those which make the product easy and safe to formulate or apply, are termed the **inert ingredients**. The mixture of active and inert ingredients for killing pests is called **pesticide formulation**. There are many kinds of formulations available on the market, including liquids and solids, and a few are prepared for release of the active ingredient over a period of time. Only the most widely used formulations are discussed here.

1.4.2. 1. Liquid Formulations

Liquid formulations usually are sold in small canes and bottles, medium-sized pails, or large drums. If mixing is required, these formulations are the most convenient to use.

a) Emulsifible Concentrate (EC/E)

These are liquid formulations in an oil solvent. Consists of active ingredient a solvent (not mixable with water) and emulsifier. They contain emulsifiers which aid in the mixing of the oil solvents with water for making the final spray. Emulsifible Concentrates are applied after mixing with water and they contain high percentage of the a.i. When they are mixed with water they form white milky suspensions (emulsions) (15-50%). Require mild agitation to keep properly mixed in spray tank.

b) Solutions (S)

Solutions are also liquid concentrates that may be used directly or require diluting. Those used directly from the container are suitable for spraying products as small quantities of liquid (2.5-5lit/ha). The smaller volume used with **ULV (ultra low volume spray)** spraying is sufficient to give a good covering because more small droplets are produced. ULV formulations requires special characteristic of the solvent, since the small droplets must not evaporate too quickly. ULV formulations do not require dilution before use. A disadvantage of the small droplet size is the tendency to drift.

c) Aerosols

Aerosols are the most frequently used formulation of pesticides around households. Pesticdes used in aerosols are dissolved in volatile petroleum solvents. The solution then is pressurized in a can by a propellant gas like carbon dioxide or fluorocarbons. When sprayed, the solution is atomized and quickly evaporates, leaving microsized droplets suspended in air. Aerosols are sold in push-button or total-release containers.

1.4.2. 2. Dry Formulations

Dry formulations are usually sold in paper bags or cans, which may be lined with plastic. Some are used directly from the container, but others require a diluent.

a) Wettable Powder (WP or **W)**

These are powder formulations look like dusts while in the container but are formulated to be mixed with water and sprayed on surfaces. They contain surface-active wetting and dispersing agents which aids in uniform dispersion of the particle in the spray liquid. Wettable powders are applied after mixing with water and they form water suspension. The concentration a.i. is relatively higher than both dust and granule formulations (15-95 percent active ingredient).

Form an unstable suspension when mixed with water, and require continuous vigorous agitation, with agitation, a solid precipitate forms at the bottom of the tank.

b) Soluble powders (SP)

Unlike wettable powders, soluble powders dissolve in water, forming a true solution. Some agitation is needed to get SPs in to solution, but after they are dissolved, additional agitation is not needed. Usually, SPs are formulated with 50 percent or more active ingredients and always require dilution.

c) Dust Powder (D)

Composition: active ingredient and inert carrier. The formulated product is a finely grounded mixture of both components. The proportion of active compound is generally low. Dusts are often easy to use in small areas because they can be shaken directly on a surface from the container or puffed into cracks and crevices with an applicator. However, dusts are the least effective, least economical pesticide formulations for use. This is because of wind-caused drift and poor rates of deposit on foliage and other surfaces. Sometimes only 10 to 40 percent of the pesticide reaches a crop when dust is applied by airplane, as opposed to 60 to 90 percent with an EC spray. This characteristic makes dusts rather poor pest management formulations for outdoor use.

d) Granules (G)

Composition: active ingredient, carrier, and additives. Granules are ready to use formulation and consist of granules up to 3mm. The proportion of active compound is generally quite small (2-25 percent). Granules can be sprayed directly and only become active after the pesticide is released by diffusion and disintegration. Because of the size of the granular particle, this formulation is much safer- because it can not be inhaled- to apply than dusts or even ECs. In general, they are more difficult to apply uniformly than a sprayed material.

e) Baits:

A formulation in which the pesticide is mixed with food or another compound that is attractive to the target organism (pest).

f) Fumigants

Fumigants are chemical formulations that have a relatively high vapor pressure and hence can exist as a gas in sufficient concentrations to kill pests in soil or enclosed spaces. Also known as slow-release formulations.

1.5. PESTICIDE NAMES

Pesticide nomenclature is the formal process by which pesticides are named. Pesticides are named three ways: by active ingredient, by trade name, and by chemical name.

The active ingredient- is the chemical that controls the pest. The name of the active ingredient is also known as the **common name** and is written beside the guarantee on a pesticide label. The first letter of an active ingredient (common name) is normally lower case.

The trade name- is the brand name that the manufacturer gives to the pesticide. The trade name is the prominent name on the front of a pesticide label. The first letter of a trade name is normally upper case. Pesticides with different trade names can contain the same active ingredient.

The chemical name- provides a description of the pesticides structure and is formed by following the "Definitive Rules for the Nomenclature of Organic Chemistry," which are developed by the International Union of Pure and Applied Chemistry. It is commonly used by scientists.

Ex. 1.
- glyphosate = a.i. (common name) in Roundup
- Roundup = trade name of herbicide
- N- (Phosphonomethyl) glycine = chemical name of the a.i. in Roundup

Ex. 2.
- 2,4 –D= a.i.
- Dacamine, Esteron, Trinoxal, etc= trade name
- 2, 4- Dichlorophenoxyl acetic acid

2. CLASSIFICATION OF INSECTICIDES

Insecticide- Insect- insect and Cidos- means the act of killing or murdering

Insecticides are agents of chemical or biological origin that control insects. Control may result from killing the insect or other wise preventing it from engaging in behaviors deemed destructive. Since 10,000 species of the more than 1,000,000 species of insects are crop–eating, and of these, approximately 700 species worldwide cause most of the insect damage to mans' crops in the field and storage.

Insecticides can be classified based on the basis of their entry in to the insect body as:

- **Stomach poisons:** enter the insect body through the gut and are fatal only after they are eaten.
- **Contact poisons:** they usually enter the body when the insect walks or crawls over a treated surface. The insecticide is absorbed through the body wall. If the treated surface is a food source like a leaf or blossom, these poisons may also enter the digestive tract and be absorbed through it. Grouping of insecticide by manner of entry begins to break down when multiple entry sites are encountered. Still, the primary entry sites of contact poison is from the environment and through the body wall.
- **Fumigants**: are insecticides that become gases at temperatures above 5oc. These insecticides are applied to enclosures and to soil. Being volatile, they enter the tracheal system, circulate, and subsequently are absorbed by body tissues.

Or on the basis of their origin as:

- **Inorganic compounds**: lacking carbon atom
- **Organic compounds of plant origin (Botanicals):** possessing carbon atoms and made from plants
- **Organic compounds (Synthetic origin):** possessing carbon atoms and obtained from mineral oils- by refining petroleum.
- **Biorational insecticides:** derived from microbial pathogens.

3. COMMON INSECTICIDES, THEIR CHEMISTRY

I. Inorganic Insecticides

Inorganic insecticides are those that do not contain carbon. These compounds were mainly used before the introduction of DDT and other synthetic organic compounds. Presently they are no longer used because another more effective, safe, and degradable chemicals are available today.

The commonly used inorganic insecticides are; Arsenic compounds, fluorine compounds, sulphur and its compounds, phosphorous compounds, Mercury compounds, etc.

II. Synthetic organic compounds

i. Organochlorines

The organochlorines are insecticides that contain carbon (thus- organo), hydrogen, and chlorine. They are also known by other names- chlorinated hydrocarbons, chlorinated organics, chlorinated insecticides, and chlorinated synthetics.

The best known orgonochlorine insecticide is DDT, noted for its

- broad spectrum of activity
- persistence and
- accumulation in the body fat of mammals

DDT shares these properties with the other organochlorines like aldrin, dieldrin, endosulfan. etc. The orgnochlorines can be divided into sub-groups according to structural differences but they have common chemical activities like;

- high melting point
- low vapour pressure
- insoluble in water, moderate solubility in organic solvents
- high stability

The stability and insolubility of the organochlorine means that they are highly persistence and this may lead to long term contamination of the environment and gradual accumulation in animal fat. If organochlorine present in the body fat reach a high level, when the fat is broken down during periods of food shortage sufficient chemical can be released in to the blood to cause poisoning and even death. For this reasons organochlorine insecticides have been banned by most developed countries, although they are still produced, sold and used in many developing countries where they are usually one of the cheapest insecticide available.

The broad spectrum activity of organochlorine, their persistence and hazard to the environment mean that their use in insect pest management is largely considered inappropriate. Although, as a chemical group there still remain situations where they are an important control options- mosquito control.

2.1.3. Organic insecticides- Plant origin/botanicals

Botanical are naturally occurring insecticides derived from plant sources. The ideal insecticide should control target pests adequately and should be target-specific (able to kill the pest insect but not other insects or animals), rapidly degradable, and low in toxicity to humans and other mammals. Botanical insecticides, sometimes referred to as “botanicals”, are naturally occurring insecticides derived from plants. Botanical insecticides are promising alternatives for use in insect management. However, like conventional synthetic insecticides, botanicals have advantages and disadvantages and should be judged accordingly. It should be evaluated in terms of its toxicity, effectiveness, environmental impacts, and costs.

Advantages of botanical insecticides

Many compounds with diverse chemical structures and different modes of action are classified as botanical insecticides. it is therefore difficult to present a detailed list of advantages that apply to all of the compounds included in this category. Some general advantages shared by most of these compounds are:

- ***Rapid degradation.*** Botanicals degrade rapidly in sunlight, air, and moisture and are readily broken down by detoxification enzymes. This is very important because rapid breakdown means less persistence in the environment and reduced risks to non-target organisms. Botanicals may be applied to food crops shortly before harvest without leaving excessive residues.
- ***Rapid action.*** Botanicals act very quickly to stop feeding by pest insects. Although they may not cause death for hours or days, they often cause immediate paralysis or cessation of feeding.
- ***Law mammalian toxicity.*** Most botanicals have low to moderate mammalian toxicity. but there are exceptions.

- ***Selectivity.*** Although most botanicals have broad-spectrum activity in standard laboratory tests, in the filed their rapid degradation and the action of some as stomach poisons make them more selective in some instances for plant-feeding pest insects and less harmful to beneficial insects.
- ***Low toxicity to plants.*** Most botanicals are not phyto-toxic (toxic to plants).

Disadvantages of botanical insecticides

The following disadvantages do not preclude the effective use of botanicals, but do call attention to certain factors that must be considered when using this insecticide.

- ***Rapid degradation.*** Rapid breakdown of botanicals although desirable from an environmental and human health standpoint, creates a need for more precise timing, more frequent insecticides application or both.
- ***Toxicity.*** Although botanicals are the lesser of many "evils" in terms of general pesticide toxicities, they are toxins nonetheless. All toxins used in pest control pose some hazard to the user and to the environment. In addition, toxins are useful only when incorporated into a conscientious program of pest management that includes sanitation, cultural control, crop rotation, and use of resistant plant varieties. No insecticides, natural or synthetic, should be used as the sole means defense against pest insects.
- ***Cost and availability.*** Botanicals tend to be more expensive than synthetics, and some are not as widely available. In addition to problems of supply, the potency of some botanicals may differ from one source or batch to the next.
- ***Lack of test data.*** Data on effectiveness and long term (chronic) toxicity are unavailable for some botanicals. Tolerance for residues of some botanicals on food crops have not been established.

I. Pyrethrum and Pyretheins

Pyrethrum is the powdered, dried flower head of the pyrethrum daisy, *Chrysanthemum cinerariaefolium*. Most of the world's pyrethrum crop is grown in Kenya. The term "pyrethrum" is the name for the crude flower dust itself, and the term "pyrethrins" refers to the six related insecticidal compounds that occur naturally in the crude material. The pyrethrins constitute 0.9 to 1.3 percent of dried pyrethrum flowers. They are extracted from crude pyrethrum dust as a resin that is used in the manufacture of various insecticidal products.

Pyrethrins exert their toxic effects by disrupting the sodium and potassium ion exchange process in insect nerve fibers and interrupting the normal transmission of nerve impulses. Pyrethrin insecticides are extremely fast acting and cause an immediate 'knockdown' paralysis in insects. Pyrethrins are low in mammalian toxicity and few cases of human poisoning have been ever reported. When ingested, pyrethrins are not readily absorbed from the digestive tract, and they are rapidly hydrolyzed under the acid conditions of the gut and the alkaline condition of the liver.

Pyrethrins are contact poisons that have almost no residual activity in most applications. They breakdown very rapidly in sunlight, air, and moisture. Degradation is accelerated under acid or alkaline conditions, and for this reason pyrethrins should not be mixed with lime or soap solutions for application.

II. Nicotine

Nicotine is a simple alkaloid derived from tobacco, *Nicotiana tabacum*, and other *Nicotiana* species. Nicotine contains 2 to 8 percent of dried tobacco leaves.

2.1.4. Biorational Insecticide

Bacteria

Bacterial; pathogens used for insect control are rod-shaped bacteria in the genus *Bacillus*. They occur commonly I soils, and most insecticidal strains have been isolated from soil samples. Bacterial insecticides must be eaten by target insects to be effective; they are not contact poison. Insecticidal products composed of a single *Bacillus* species may be active against an entire order of insects, or they may be effective against only one or a few species.

When *Bt* is ingested by a susceptible insect, the protein toxin is activated by alkaline conditions and enzyme activity in the insects' gut. The toxicity of the activated toxin is dependent on the presence of specific receptor sites on the insects' gut wall. The necessary match between toxin and receptor sites determines the range of insect species killed by each *Bt* subspecies and isolates. If the activated toxin attaches to the receptor sites, it paralyzes and destroys the cells of the insect's gut wall, allowing the gut contents to enter the insects' body cavity and blood stream. Poisoned insects may die quickly from the activity of the toxin or may die with in 2 or 3 days from the effects of septicemia (blood-poisoning). Although few days may elapse before the insect dies, it stops feeding (and therefore stops damaging crops) soon after ingesting *Bt*.

Bt does not colonize or cycle (reproduce and persist to infect subsequent generations of the pest) in the environment in the magnitude necessary to provide continuing control of target pests. The bacteria may multiply in the infected host, but bacterial multiplication in the insect does not result in production of abundant spores or crystalline toxins. The usual result is that few infective units are released in to the environment when a poisoned insect dies. Consequently, *Bt* products are applied much like synthetic insecticides. *Bt* treatments are inactivated fairly rapidly 9with in one to a few days) in many outdoor situations, and repeated applications may be necessary for some crops and pests. *Bt* formulations are commercially successful and widely available as liquid concentrates, wettable powders, and ready-to-use dusts and granules. Separate stages of insects differ in their susceptibility to *Bt;* isolates that are effective against larval stages of butterflies, moths, or mosquitoes will not kill adults. Because susceptible insects must consume *Bt* to be poisoned, treatments must be directed to the plant parts or other material that the target pests will eat. Where this is not possible (for example, where pests bore into plant tissue without feeding much on the surface of foliage or fruits), *Bt* is usually not effective. *Bt* does not kill susceptible insects immediately. Poisoned insects normally remain on plants for a day or two after treatment, but they do not continue feeding and will die soon.

Where *Bt* is applied to plant surfaces or other sites exposed to sunlight, it is deactivated rapidly by direct ultraviolet radiation. To maximize the effectiveness of *Bt* treatments, sprays should thoroughly cover all plant surfaces, including the undersides of leaves. Treating in the underside of leaves. Treating in the late afternoon or evening can be helpful because the insecticide remains effective on foliage overnight before being inactivated by exposure to intense sunlight the following day. Treating on cloudy (but not rainy) days provides a similar result.

Viruses

The larvae of many insect species vulnerable to devastating epidemics of viral diseases. The viruses that causes these outbreaks are very specific, usually acting against only a single insect genus or even a single species. Most of the viruses that have been studie3d for use as potential insecticides are nuclear polyhedrosis viruses (NPVs), in which numerous virus particles are “packaged” together in a crystalline envelope within insect cell nuclei, or granulosis viruses (GVs), in which one or two virus particles are surrounded by granular or capsule like protein crystal found in the host cell nucleus. These groups of viruses infect caterpillars and the larval stages of some dipteras.

Viruses, like bacteria, must be ingested to infect insect hosts. In diptera larvae, virus infections are limited to the gut, and disease symptoms are not as obvious as they are in caterpillars. In caterpillars, virus particles pass through the insect’s gut wall and infect other body tissues. As an infection progresses, the caterpillar’s internal organs are liquefied, and its cuticle (body covering) discolors and eventually ruptures. Caterpillars killed by virus infection appear limp and soggy. They often remain attached to foliage or twigs for several days, releasing virus particles that may be consumed by other larvae. The pathogen can be spread throughout an insect population in this way (especially when rain drops help to splash the virus particles to adjacent foliage) and by infected adult females depositing virus-contaminated eggs. Dissemination of viral pathogens is deterred by exposure to direct sunlight, because direct ultraviolet radiation destroys virus particles. Although, naturally occurring epidemics do control certain pests, these epidemics rarely occur before pest populations have reached outbreak levels.

The development and use of virus-based insecticides have been limited. Unlike *Bt,* insect viruses must be produced in live host insects. Although such production practices can be cost-effective, they require different facilities than those now in use by insecticide Manufacturers. Because many viruses are genus or species specific, each viral insecticide has a limited market. The economic factors, coupled with the fact that virus insecticides are slow-acting and often less effective than available synthetic chemical insecticides, have limited their development.

Most viruses are host specific and effective only against immature stages of the target species; users must be sure to match that pathogen and the target pest correctly. Virus particles are killed by ultraviolet radiation; treating in the evening or on cloudy days should increase their effectiveness.

Fungi

Fungi, like viruses, often act as important natural control agents that limit insect populations. Most of the species that cause insect diseases spread by means of asexual spores called conidia. Although conidia of different fungi vary greatly in ability to survive adverse environmental conditions, desiccation and ultraviolet radiation arte important causes of mortality in many species. Where viable conidia reach a susceptible host, free water or very high humidity is usually required for germination. Unlike bacterial spores or virus particles, fungal conidia can germinate on the insect cuticle and produce specialized structures that allow the fungus to penetrate the cuticle and enter the insect’s body. Fungi do not have to be ingested to cause infections. In most instances insects are killed by fungal toxins, not by the chronic effects of parasitism.

Fungal pathogens differ in the range of life stages and species they are able to infect. Many important fungal pathogens attack eggs, immatures and adults of a variety of insect species. Others are more specific to immature stages or to a narrow range of insect species. Once applied, pathogenic fungi often are effective only if environmental conditions are favorable; high humidity or rainfall usually is important. Where fungal pathogens are incorporated into soil to control below ground pests, the adverse effects of ultraviolet radiation and desiccation are minimized.

Nematodes

To be accurate, nematodes are not microbial agents. Instead, they are multicellular roundworms. Nematodes used in insecticidal products are, however, nearly microscopic in size, and they are used much like the truly microbial products discussed previously. Nematodes used for insect control infect only insects or related arthropods; they are called entomogenous nematodes.

Summary

Microbial insecticides offer effective alternatives for the control of many insect pests. Their greatest strength is there specificity as most are essentially nontoxic and nonpathogenic to animals and humans. Although not every pest problem can be controlled by the use of a microbial insecticide, these products can be controlled by the use of a microbial insecticide, these products can be used successfully in place of more toxic insecticides to control many lawn and garden pests and several important filed crop and forest insects. Because most microbial insecticides are effective against only a narrow range of pests and because these insecticides are vulnerable to rapid inactivation in the environment, users must properly identify target pests and plan the most effective application. These same qualities mean microbial insecticides can be used without undue risks of human injury or environmental damage. Consequently, microbial insecticides are likely to become increasingly important tools in insect management.