COURSE CODE:	CPT 510
COURSE TITLE:	Pesticides in Agriculture
NUMBER OF UNITS:	2 Units
COURSE DURATION:	1 hr. theory + 2 hrs. practical

COURSE DETAILS:

Course Coordinator: **Dr. Akinola Rasheed POPOOLA** *B.Sc., M.Sc., PhD*
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Office Location: **Room 217, COLPLANT Building**
Other Lecturers: **Dr. A.A. Fajinmi**

COURSE CONTENT:

Theory
Definition of pesticides. Types of pesticides. Biopesticides. Pesticides Ingredients. Chemistry and actions of Insecticides. Pesticides Regulations. Pesticides Applications and associated problems. Alternatives to Pesticides Application. Pesticides residue problems in developing countries. Health and safety precautions. Uses and abuses. Pesticides : Hazards and Alternatives.
Practical
Pesticide application, crop protection equipment, usage and maintenance; Practical health and safety precautions in pesticide application, protective clothing; Application of artificial respiration on pesticides victims.

COURSE REQUIREMENTS:

This is an elective course. Students are expected to participate in all the course activities and have minimum of 75% attendance to be able to write the final examination.

READING LIST:

1. Pesticides in Agriculture and the Environment. 2002. Editor : Willis B. Wheeler. Publisher : Marcel Dekker Inc.
2. FAO (1990) International code of conduct on the distribution and use of pesticides, amended to include Prior Informed Consent, Rome/Italy

LECTURE NOTES

LECTURE OUTLINE

- Key Concepts
    - What is a pest
    - Pesticides : Types and Uses

- Pros and Cons of using pesticides
- Pesticides regulations
- Alternatives to chemical pests

- Pest and Pesticide
  - Unwanted organism, interferes with food production, human health, and peace and quietness of environment and causes economic harm
  - The word pesticide itself means “pest killer.” Pests include bacteria, fungi, insects, weeds, rodents, and other living things that affect humans, animals, or plants adversely. Depending on the kind of pest against which they are effective, pesticides are known as bactericides, fungicides, nematicides, insecticides, herbicides, and so on.

  - A pesticide is any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest. Pests can be insects and insect-like organisms, mice and other vertebrate animals, unwanted plants (weeds), or fungi, bacteria and viruses that cause plant diseases. Though often misunderstood to refer only to insecticides, the term pesticide also applies to herbicides, fungicides, and various other substances used to control pests.

  - Any material, whether naturally derived or not, that is sold or distributed with the intent to control or eliminate any pest (weeds, insects, microorganisms, etc.) is classified as a pesticide. By their very nature, pesticides create some risk of harm to humans, animals, or the environment because they are designed to kill or otherwise adversely affect living organisms. Many household products are pesticides

- An ideal pesticide:-
  - Kills target pest
  - Non-persistent, short lived
  - No adverse effects on other organisms.
  - No genetic resistance
  - Less costly than economic losses

- Types of Pesticides:-
  Chemical, organism, facility or activity that kills pest organisms.
  - Insecticides
  - Herbicides
  - Fungicides
  - Bactericides
  - Rodenticides
- Biopesticides

  Biopesticides (also known as biological pesticides) are pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals. For example, canola oil and baking soda have pesticidal applications and are considered biopesticides.

- Types of Biopesticides
    - Microbial pesticides
    - Plant pesticides
    - Biochemical pesticides

Microbial pesticides consist of a microorganism (e.g., a bacterium, fungus, virus, or protozoan) as the active ingredient. Microbial pesticides can control many different kinds of pests, although each separate active ingredient is relatively specific for its target pest[s]. For example, there are fungi that control certain weeds, and other fungi that kill specific insects.

The most widely used microbial pesticides are subspecies and strains of Bacillus thuringiensis, or Bt. Each strain of this bacterium produces a different mix of proteins, and specifically kills one or a few related species of insect larvae. While some Bt's control moth larvae found on plants, other Bt's are specific for larvae of flies and mosquitoes. The target insect species are determined by whether the particular Bt produces a protein that can bind to a larval gut receptor, thereby causing the insect larvae to starve.

Plant pesticides are pesticidal substances that plants produce from genetic material that has been added to the plant. For example, scientists can take the gene for the Bt pesticidal protein and introduce the gene into the plant's own genetic material. Then the plant, instead of the Bt bacterium, manufactures the substance that destroys the pest. Both the protein and its genetic material are regulated by EPA; the plant itself is not regulated.

Biochemical pesticides are naturally occurring substances that control pests by non-toxic mechanisms. Conventional pesticides, by contrast, are generally synthetic materials that directly kill or inactivate the pest. Biochemical pesticides include substances, such as insect sex pheromones, that interfere with mating, as well as various scented plant extracts that attract insect pests to traps. Because it is sometimes difficult to determine whether a substance meets the criteria for classification as a biochemical pesticide, EPA has established a special committee to make such decisions.

Advantages of Biopesticides
- Biopesticides usually are inherently less harmful than conventional pesticides.
- Biopesticides generally affect only the target pest and closely related organisms, in contrast to broad-spectrum conventional pesticides that may affect organisms as different as birds, insects, and mammals.
- Biopesticides often are effective in very small quantities and often decompose quickly, thereby resulting in lower exposures and largely avoiding the pollution problems caused by conventional pesticides.
- When used as a component of Integrated Pest Management (IPM) programs, biopesticides can greatly decrease the use of conventional pesticides, while crop yields remain high.

- First Generation Pesticides (i.e. pre 1940s)
    - Natural substances
    - Sulphur, lead, arsenic, mercury
    - Plant extracts: nicotine, pyrethrum

        - Degradable

- Second Generation Pesticides
    - Synthetic organic compounds
        - 630 biologically-active compounds, 35,000 pesticide products
    - DDT – Dr. Mueller, Nobel Prize in 1948
    - Attributes : cheap, easy to produce, persistent, insoluble in water.

- Third Generation Pesticides (1985+)
    - Genetically engineered predators
    - Genetically engineered plants
        - Round-up ready corn, wheat, rice.

Pesticide Ingredients

- Pesticide products contain both "active" and "inert" ingredients. The terms "active ingredient" and "inert ingredient" have been defined by Federal law, the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), since 1947.

- Active Ingredients
  An active ingredient is one that prevents, destroys, repels or mitigates a pest, or is a plant regulator, defoliant, desiccant, or nitrogen stabilizer. By law, the active ingredient must be identified by name on the label together with its percentage by weight.

- Inert Ingredients
  An inert ingredient is simply any ingredient in the product that is not intended to affect a target pest. For example, isopropyl alcohol may be an active ingredient and antimicrobial pesticide in some products; however, in other products, it is used as a solvent and may be considered an inert ingredient. The law does not require inert ingredients to be identified by name and percentage on the label, but the total percentage of such ingredients must be declared.

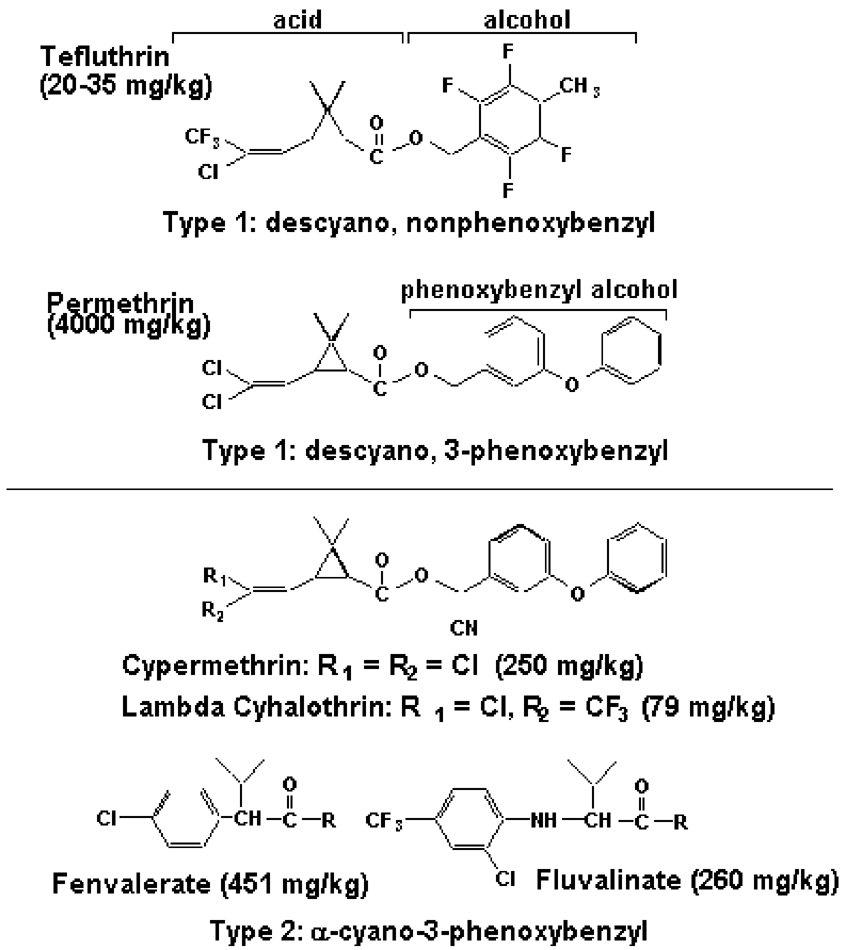
Chemistry and Mode of Action of Insecticides

(Source :- http://pesticide.umd.edu)

Compounds Affecting Voltage-Dependent Sodium Channels

Pyrethroids, Figure 1.

Pyrethroids, Figure 1



The pyrethroid insecticides are typically esters of chrysanthemic acid having a high degree of lipophilicity (fat solubility). The original compounds in this series were the natural pyrethrins, which are isolated from the flowers of chrysanthemum. Pyrethroid chemistry and action are classified as Type 1 or Type 2, depending on the alcohol substituent. The Type 1 group is rather broadly defined and includes pyrethroids containing descyano-3-phenoxybenzyl or other alcohols. Many of the older nonphenoxybenzyl Type 1 compounds (*e.g*., pyrethrins, allethrin, tetramethrin) are unstable in the environment and this characteristic prevented their use in row crops. Introduction of the phenoxybenzyl (*e.g*., permethrin) or certain halogenated alcohols (*e.g*., tefluthrin) improved chemical stability and allowed the use of pyrethroids in the field. The Type 2 pyrethroids are more narrowly defined in terms of their chemical structure. They specifically contain an a-cyano-3-phenoxybenzyl alcohol, which increases insecticidal activity about 10-fold. Moreover, some commercially important Type 2 pyrethroids have altered the acid portion of the molecule to include a phenyl ring (*e.g*., fenvalerate and fluvalinate). The stereoisomerism of pyrethroids is important for their toxic action, but a detailed discussion of this topic is beyond the scope of this course on IPM.

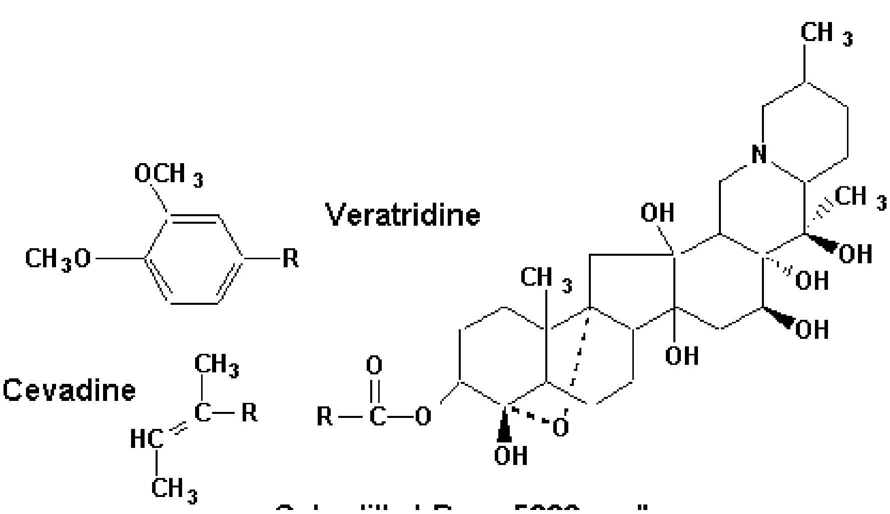
The signs of intoxication by pyrethroids develop rapidly and there exist different poisoning syndromes for the two types of compounds. Typical signs of intoxication by Type 1 pyrethroids include hyperexcitability and convulsions in insects and a whole body tremor in mammals. In insects, the Type 2 pyrethroids cause predominantly ataxia and incoordination, while in mammals they produce choreoathetosis (sinuous writhing) and salivation. In insects, the effects of pyrethroids (especially Type 1) can develop within 1-2 minutes after treatment and can result in knockdown, which is a loss of normal posture and locomotion. Human dermal exposure to either type of pyrethroid can cause paresthesia, a tingling or burning sensation of the skin, but this effect is more intense for Type 2 compounds.

Pyrethroid intoxication results from their potent effects on nerve impulse generation within both the central and peripheral nervous systems. Under normal conditions, neurons possess a transmembrane voltage of about -60 mV on the inside. The nerve impulse or action potential consists of a transient depolarization (positive wave) whose upstroke is driven by an influx of Na+ ions, followed by a downstroke from the efflux of K+ ions.

Compounds Affecting the Neuro-muscular Functions

These ion fluxes occur due to the opening and closing of specific ion channel proteins embedded within the nerve membrane. The action potential is propagated down the axon until it reaches the nerve terminal, where it stimulates the release of chemical transmitters. Type 1 compounds induce multiple spike discharges in peripheral sensory and motor nerves, as well as interneurons within the central nervous system (CNS). In contrast, Type 2 pyrethroids depolarize the axon membrane potential, which reduces the amplitude of the action potential and eventually leads to a loss of electrical excitability. All these effects occur because pyrethroids prolong the current flowing through sodium channels by slowing or preventing the shutting of the channels. The somewhat different actions observed for Type 1 and Type 2 compounds are due to differences in the degree of physiological effect: the duration of modified sodium currents by Type 1 compounds lasts tens or hundreds of milliseconds, while those of Type 2 compounds last for minutes or longer. These effects on the sodium current also cause a profound increase in the release of neurotransmitters from nerve terminals. The insect neuromuscular synapse is an especially important target for the pyrethroids, as well as other insecticides

Veratrum Alkaloids, Figure 3

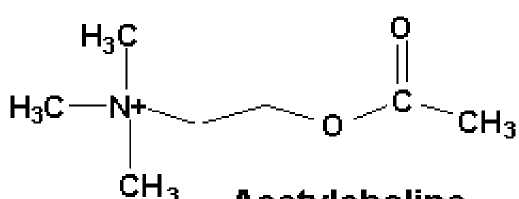


When used in organic farming or gardening, the veratrum alkaloids are usually applied as an extract (sabadilla) from the seeds of plants belonging to the genus *Schoenocaulon*. The insecticidal activity of sabadilla comes from the alkaloid fraction, which constitutes 3-6% of the extract. The two most important compounds are the lipophilic alkaloids veratridine and cevadine, with veratridine having greater insecticidal potency. Sabadilla breaks down rapidly in sunlight.

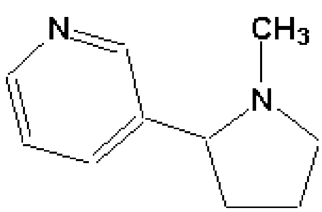
The major effects of sabadilla poisoning include muscle rigor in mammals and paralysis in insects. In addition, sabadilla strongly irritates mucous membranes in mammals and can cause violent sneezing. Sabadilla extract is much less toxic to mammals than most other insecticides and therefore is safe to use.

The mode of action of the veratrum alkaloids is similar to that of the pyrethroids. When applied to nerve, veratridine causes an increase in the duration of the action potential, repetitive firing, and a depolarization of the nerve membrane potential, due to effects on the sodium channel (The Nerve Impulse, Neuromuscular Transmission and the Action of Insecticides, Figure 2). Veratridine prolongs the open state of the sodium channel by delaying channel shutting and by increasing the probability of channel opening.

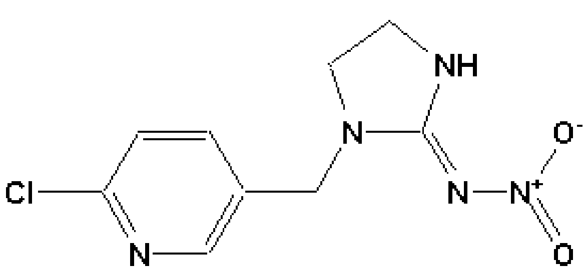
Acetylcholine Mimics, Figure 5



Acetylcholine



Nicotine (55 mg/kg)



The tobacco alkaloid nicotine has been used as an insecticide since the middle of the 18th century. This compound is miscible with water and is often formulated as the sulfate salt. Nicotine has excellent contact activity, due to its ability to penetrate the integument of insects. This property increases the hazards of handling nicotine, as its contact toxicity to mammals is also significant. A newer compound in this class is the nitroguanidine, imidacloprid. This compound generally works best as a stomach poison, and has plant systemic activity as well. It is much less toxic to mammals than nicotine.

Nicotine and imidacloprid mimic the action of acetylcholine, which is a major excitatory neurotransmitter in the insect CNS. After acetylcholine is released by the presynaptic cell, it binds to the postsynaptic nicotinic acetylcholine receptor and activates an intrinsic cation channel.

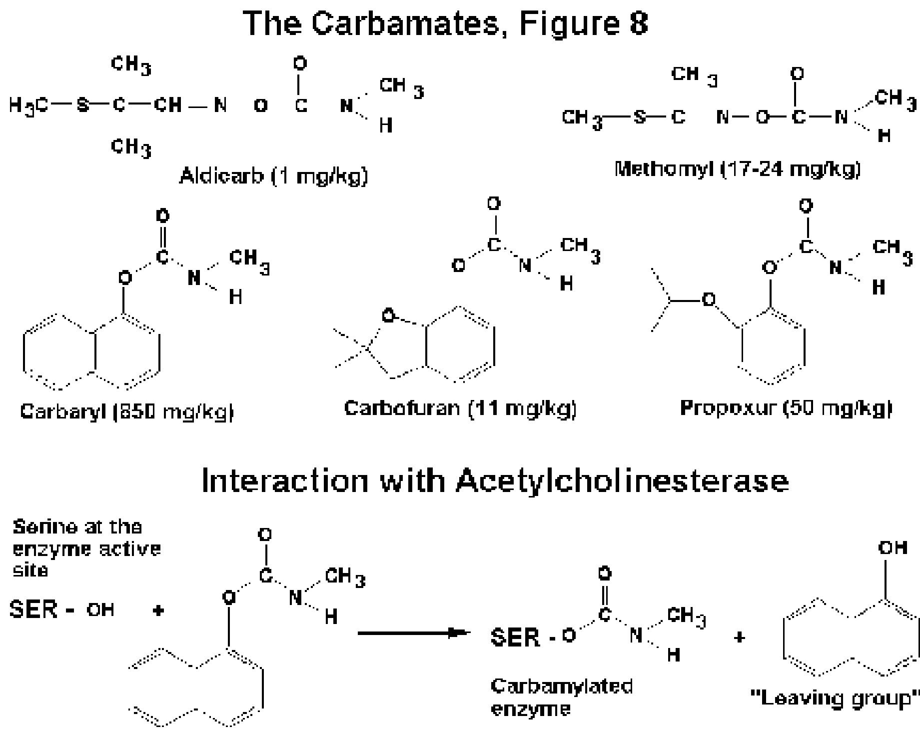
This results in a depolarization of the postsynaptic cell due an influx of sodium and calcium ions. The synaptic action of acetylcholine is terminated by the enzyme acetylcholinesterase, which rapidly hydrolyzes the ester linkage in acetylcholine. Nicotine and imidacloprid also activate the nicotinic acetylcholine receptor, but do so persistently, since they are insensitive to the action of acetylcholinesterase. This persistent activation leads to an overstimulation of cholinergic synapses, and results in hyperexcitation, convulsions, paralysis, and death of the insect.

Acetylcholinesterase Inhibitors

The organophosphorus insecticides (OPs) are a very important group of compounds that vary tremendously in chemical structure and chemical properties. These compounds can be miscible with water, but more typically are miscible in organic solvents. OPs can be classified into several groups depending on the atoms that are directly attached to the central phosphorus. Thus, the majority of OPs exist as phosphates, phosphonates, phosphorothionates, phosphorodithioates, phosphoramidothioates, etc (Organophosphorous Insecticides, Figure 7). An important bioactivation step occurs for OPs containing a sulfur atom attached to the phosphorus by a double bond (*e.g.,* phosphorothionates). For these compounds, oxidative desulfuration occurs via cytochrome P450 monooxygenases, which are enzymes that oxidase a wide variety of xenobiotics (Organophosphorous Insecticides, Figure 7). However, in this casethe oxidized metabolite possesses greater toxicity. The acute toxicity of the OPs varies substantially, but many of them have a high mammalian toxicity.

The primary target site for the OPs is the enzyme acetylcholinesterase. The OPs react with a serine hydroxyl group within the enzyme active site, phosphorylating this hydroxyl group and yielding a hydroxylated "leaving group" (Organophosphorous Insecticides, Figure 7). This process inactivates the enzyme and blocks the degradation of the neurotransmitter acetylcholine. The synaptic concentrations of acetylcholine then build up and hyperexcitation of the CNS occurs. The signs of intoxication include restlessness, hyperexcitability, tremors, convulsions, and paralysis. In insects, the effects of OPs are confined to the CNS, where virtually all of the cholinergic synapses are located. Because they often require bioactivation and must penetrate into the CNS, the OPs do not have a rapid action like that of the pyrethroids. The phosphorylation of acetylcholinesterase by OPs is persistent; reactivation of the enzyme can take many hours or even days.

Carbamates, Figure 8



The carbamate insecticides exist as esters of carbamic acid, typically having some kind of aryl (ring) substituent as the leaving group. These compounds are most soluble in organic solvents. Other carbamates are more aliphatic in nature and may possess sufficient miscibility with water to act as effective plant systemic insecticides (e.g., aldicarb). The carbamates are often highly toxic to mammals, and must be handled carefully. Among insects, they are particularly toxic to beneficial hymenoptera such as honeybees.

The mode of action of the carbamates is similar to that of the OPs. In this case, the reaction yields a carbamylation of the serine hydroxyl group (Carbamates, Figure 8). An hydoxylated leaving group is also generated. The CNS is the site of action of carbamates and the signs of intoxication are also similar to those of the OPs. Compared to phosphorylation, the carbamylated enzyme complex is relatively less stable; it will typically hydrolyze over a time course of minutes.

- Pesticides Regulation
  - Standard Organisation of Nigeria.
  - Agricultural Plant Quarantine Service of Nigeria

  - NAFDAC
  - NDLEA
  - Options: register for use, testing, label requirement, regulation on use.

- Alternatives to Chemical Pesticides
  - Use of economic threshold principle
  - Adjusting cultivation practices
  - Use genetically-resistant plants
  - Biological pest control
  - Insect birth control
  - Hormones and pheromones
  - Ionizing radiation.

- Integrated Pest Management
  - Ecological system approach
  - Reduce pest population to economic threshold
  - Field monitoring of pest populations
  - Use of biological agents.
  - Chemical pesticides should be the last resort.

Pesticide Application and its associated problems

- Labeling Requirements

  Labeling requirements control when and under what conditions pesticides can be applied, mixed, stored, loaded, or used, fields can be reentered after application, and crops can be harvested. Requirements also are imposed on container specifications and disposal.

- Personal Protective Equipment

  Personal protective equipment (PPE) is the clothing and devices that are worn to protect the human body from contact with pesticides or pesticide residues. Personal protective equipment includes such items as coveralls or protective suits, footwear, gloves, aprons, respirators, eyewear, and headgear. Ordinary shirts, pants, shoes, and other regular work clothing usually are not considered personal protective equipment, although pesticide labeling may require pesticide handlers to wear specific items of work clothing during some activities. Users of pesticides must make sure that all personal protective equipment instructions that appear on the pesticide label or labeling are followed.

- Spray Drift of Pesticides

· The drift of spray from pesticide applications can expose people, wildlife, and the environment to pesticide residues that can cause health and environmental effects and property damage. For these reasons, and because EPA's Office of Pesticide Programs (OPP) is responsible for regulating the use of pesticides in the United States, OPP has been actively engaged in a number of initiatives to help prevent such problems. These initiatives include broadening EPA's understanding of the science and predictability of spray drift based on many new studies, helping pesticide applicators to reduce spray drift by improving product label use directions, and promoting education and training programs on spray drift for applicators.

- Surface and Groundwater Contamination

· When pesticide contamination of surface or groundwater occurs, it is the result of either point-source or non-point-source pollution. Point-source pollution comes from a specific, identifiable place (point), such as the movement of pesticides into water from a spill at a mixing and loading site. Non-point-source pollution comes from a wide area, such as the movement of pesticides into streams after broadcast applications to crop areas. Most pesticide movement into water is across the treated surface (runoff) or downward from the surface (leaching). Runoff water may travel into drainage ditches, streams, ponds, or other surface water where the pesticides can be carried great distances offsite. Pesticides that leach downward through the soil sometimes reach the groundwater.

- Tolerances

· Any pesticide that remains in or on food or feed is called a residue. Residues that remain in food or feed at harvest or slaughter are monitored to avoid hazards to the humans and domestic animals that will eat them. EPA establishes maximum residue levels (tolerances) when registering a pesticide. A tolerance is the maximum amount of pesticide residue that may legally remain on or in treated crops and animals (and animal products such as milk or eggs) that are to be sold for food or feed. Food or feed with residues that lack tolerances or with residues exceeding tolerances are subject to seizure and the applicators or producers are subject to prosecution, if misuse is found.

- Pest Resistance

Pesticides are important pest management tools. Many pesticides have gradually lost their effectiveness due to the development of resistance by pests they once controlled. Pest resistance is an heritable and significant decrease in the sensitivity of a pest population to a pesticide that is shown to reduce the field performance of pesticides. Pests may include insects, mites, weeds, and fungi and bacteria which cause plant disease. The management of pesticide resistance development is an important part of sustainable pest management and this, in conjunction with alternative pest management strategies and Integrated Pest Management (IPM) programs, can make significant contributions to reducing risks to humans and the environment.

· An important pesticide resistance management strategy is to avoid the repeated use of a particular pesticide, or pesticides that have a similar target site of action as the pest control mechanism in the same field. One pest control strategy is rotating pesticides and/or using tank mixtures or premixes with different mode/target sites of action. This will delay the onset of resistance, as well as slow the development and subsequent buildup of resistance, without resorting to increased rates and frequency of application, and ultimately, will prolong the useful life of many pesticides.

· A resistance management strategy should also consider cross-resistance between pesticides with different modes/target sites of action. Pests may develop cross-resistance to pesticides based on mode/target site of action.

Health and Safety Issues

- Case for Pesticides
  - Save human lives
  - Increase supplies and lower cost of food

- Work better and faster than alternatives
- Health risks may be insignificant compared to benefits.
- Newer pesticides are becoming safer
- New pesticides are used at lower rates.

- Case Against Pesticides
  - Genetic resistance
  - Can kill non-target and natural control species
  - Can cause an increase in other pest species
  - Pesticides do not stay put
  - Can harm wildlife
  - Potential human health threats.

APPLICATION OF AGRICULTURAL PESTICIDES

Pesticide application technology has developed following the demand of the new approach to pest control and the pressure for the use of pesticides in a manner that is also safer for environment and humans.

Design Features

The characteristics of modern application equipment allow a fairly safe and efficient application of pesticides of all kinds. This is valid for knapsack sprayers, tractor equipment and airplanes. The highest standards for application equipment are found in countries where legal requirements for human and environmental safety, as well as farmer's demands for efficient and exact application, have forced manufacturers to offer equipment that reflects the actual state of the art. This is the case in some European countries.

Some features of this category are, for example, filler openings, low level intake bowls, clean water tanks, the use of materials for tank and fittings chemical resistant and easy to clean, pressure control systems, boom suspensions, ergonomic features and others.

The design of equipment has impact mostly on the operator and environmental safety preventing unnecessary contamination, accidents, losses and spills and allowing an even distribution of the product.

Monitoring and Controls

The use of modern electronics can improve the accuracy of dosing and distribution. In general modern equipment uses electronic flow meters, pressure gauges, speed sensors and computers allowing the working parameters to remain within a pre-set value thus providing a much higher application accuracy than manual controls.

The use of global positioning systems (GPS) allows exact tracking of the swarms and other migratory pests.

Sensor controlled systems would only open the nozzle in case a target is appearing in front of it.

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The use of electronics in modern application equipment allows exact dosing and can avoid off target spraying, thus contributing to product savings and therefore reducing environmental contamination.

Atomizer Technology

Spray nozzles are one of the most important parts of a sprayer ensuring an environmentally safe and efficient application. Design features of hydraulic nozzles, still the most commonly used atomizers on pesticide application equipment, highly influence the output characteristics, spray pattern and droplet size distribution and thus the creation of the appropriate type of spray with a minimum of drift or off-target contamination. Among the latest developments are spray nozzles with variable orifice allowing a fairly constant droplet spectrum and spray angle over a range of pressure and flow rate (DLG, 1995).

Double flow nozzles improve the penetration of the spray into the crop and allow the adjustment of the droplet size without changing the flow rate (Thornhill & Matthews, 1995). Other nozzles draw the air into the nozzle body where it is mixed with the spray, creating air-bubbles inside the droplets (Göbel, 1995). Rotary nozzles allow the application of a very narrow droplet spectrum. The purpose of these developments is to improve coverage and penetration with low volumes and reduced drift problems.

The spray nozzle, although it would appear to be insignificant, is one of the most important parts of pesticide application equipment; modern spray nozzles represent a product of sophisticated engineering. The use of good quality nozzles has a very high potential for saving pesticides and reducing environmental pollution.

Technology for Improved Penetration and Coverage

Insecticides and fungicides acting by direct contact have to be applied with the best possible coverage. This is achieved with small droplets allowing at the same time cost savings by reducing the application volume (Pompe et al., 1992). However, under field conditions, the application of small droplets is prone to increase drift.

Air support systems, now available with boom sprayers, can reduce drift problems with small droplets increasing at the same time target coverage and penetration if set correctly (Jeffrey, 1994). Electrostatic charging of sprays to achieve the same effect is obviously also becoming popular again (McGill, 1995). Combining the air support systems with electrostatic charge of droplets could contribute to improving operator safety and reducing environmental pollution and application cost (Cooper, 1993).

Application equipment that improves penetration and coverage with air-streams or electrostatic charges can contribute to a more efficient operation, thus reducing product losses. In addition, the use of lower application volumes which reduces the cost for the farmer is possible. In countries with a strong public and legal pressure on the use of pesticides and well trained farmers, the demand for those technologies is actually increasing.

Field reality

Unfortunately in many countries the pesticide application practised on field level is far from reflecting the actual state of the art. While modern pesticides have reached the most remote parts of the world, the technology used for their application often reflects technical standards of 40 years ago, resulting in a waste of pesticides and unnecessary environmental contamination. Cases have been reported where by only changing the nozzles of lever operated knapsack sprayers, 70% of pesticides could be saved compared to the farmer's previous practice (Stallen & Lumkes, 1990).

The Agricultural Engineering Branch of FAO has carried out studies in Central and Eastern Europe (Lavers, 1994) as well as in South America (Wiles, 1994) which showed various levels of deficiencies in the field of pesticide application technology.

Operator Knowledge

Farmers' and application equipment operators' knowledge of the action principles of pesticides and the correct method of application is usually deficient or non existing. In many cases they do not receive any training on this issue (Heong et al., 1992). Already at University level the topic is often neglected. Therefore, extension services normally do not have technicians with a specialized knowledge of application technology. In many countries the only specialists offering practical advice to farmers on application technology, handling and calibration of their equipment are representatives of pesticide companies. However, they normally don't have a natural interest in showing the farmer how to save major quantities of the product.

There are several consequences of this lack of knowledge. Starting with the selection of equipment, a farmer without technical criteria will usually choose the cheapest equipment, possibly the most durable. Aspects of operator safety, comfort or efficiency are of lesser importance, especially if the equipment is not operated by the farmer himself but by hired farm labour.

Another common problem is the use of excessive spray volumes and pressures. Application volumes of 6,000 l/ha in flowers and 10,000 l/ha in orchards have been reported (Wiles, 1994) causing run off of product and thus contaminating soil and probably groundwater resources.

It is common that farmers and spray equipment operators still believe in high volumes, high pressure and high doses being perceived as the most appropriate ways for pesticide application.

Equipment Design

In a free market situation and if the market does not demand quality, manufacturers are not encouraged to offer equipment with any extras to improve safety, comfort or efficiency, not considered essential for smooth functioning of the equipment. Some examples are:

- For knapsack sprayers: pressure regulators, wide straps and waist belts, long lances, quality nozzles

For tractor equipment:boom suspension, anti-drip devices, easy draining tanks, appropriate controls

In addition, inferior materials often are used. Examples include tanks with rough surfaces, hoses or washers not being pesticide proof, and crimped hose clips. In some countries small workshops assemble spraying equipment from components without an idea of the basic principles of spraying. This sort of equipment competes on the market as it is sold at a very low price difficult to be matched by quality equipment.

In countries where the farmer as client does not have the technical knowledge to select good equipment and is mainly choosing by price, cheap equipment can force good equipment off the market.

The lack of technical knowledge and awareness of farmers as clients as well as of manufacturers offering the equipment, are the main reasons for the low quality of equipment found in some countries.

Service Conditions of Equipment

Usually the major part of the spraying equipment in use is in extremely poor condition, due to lack of maintenance. A report from the Philippines shows that a high percentage of farmers never change sealing washers in their equipment

(Withaker, 1993). As a result, most spray equipment leaks. A study carried out in Indonesia reported that 58% of manual spray equipment leaked (Hirschhorn, 1993). Data from Nicaragua confirm this observation, mentioning pesticide spill over the operator's back from leaking knapsack sprayers, as being a common source of intoxications (Matus & Beck, 1991).

Nozzles are normally not replaced and are even enlarged on purpose to achieve higher flow rates. The distribution patterns under these conditions are uneven, leaving sections with no pesticide coverage and others receiving overdoses. At the beginning of a calibration programme for spray aeroplanes in Nicaragua, the majority of the equipment was found in bad condition as far as all components of the equipment were concerned (PAAT, 1992). Airplanes with defective anti drip devices releasing pesticides over populated areas where a common feature at that time.

Again it is mainly the lack of technical knowledge and awareness of farmers and equipment operators that cause negligence regarding proper maintenance of the equipment thus resulting in poor service conditions.

Concepts for Improvements

Education and Training

The lack of knowledge on all levels has been identified as the main reason for deficiencies in pesticide application practice. As a long term strategy this has to be addressed, beginning at the university level. The subject of pesticide application technology should be mandatory for agricultural engineers as well as for plant protection specialists.

On the other hand, practical training of farmers and equipment operators has to be introduced. The use of government extension services for this purpose has usually not proved to be efficient and sustainable. A better approach would be the creation of small groups of trainers dedicated specifically to this subject who are paid for their courses. Ideally these trainers should have a practical background, having operated spraying equipment themselves. They should be trained and kept up to date with refresher courses by master trainers. The established training capacity should cover the expected long-term needs. Training could begin strategically with contractors, offering service to other farmers and then be extended to private farmers and operators. The cost of the training could be paid by trainees, agro-chemical companies (preferable indirectly through taxes), by equipment manufacturers and, of course, by the government as a representative of the public interest in a safe environment.

The introduction of a mandatory license for pesticide equipment operators can help to increase farmers' interest in this training. Although it is always better to count on the awareness and voluntary participation, examples from Europe have shown that at a certain stage it is necessary to introduce legal pressure in order to assure interest in the training (Devereux-Cooke, 1995).

The objective of the training programme should be to provide, in a sustainable manner, farmers and application equipment operators with the technical knowledge necessary for a safe and efficient application. The introduction of a mandatory license should never be an end in itself and only be considered if it contributes to more efficient training.

Equipment Quality

While in some countries there might be a need for training of equipment manufacturers, in the majority of the cases, the manufacturers are able to offer good quality equipment if the market demands it. In these cases, incentives for improved quality have to be introduced. In many developing countries the demand is due to lack of knowledge not leading in that direction. There the only solution is to limit the market access to quality equipment only, introducing a certification system based on technical standards for application equipment.

For a government to introduce such a certification system, it is not necessary to have its own test centres or to test each piece of equipment themselves. On the other hand, a certification system can also be introduced on a voluntary basis by manufacturers and their organizations using the certificate as a quality trade mark and for sales promotion.

A certification system can only be implemented if there are approved national standards for that kind of equipment.

Technical standards have two aspects. One is to describe minimum requirements of the equipment in order for it to be approved or certified. This type of standards will usually be used for an official certification system. Standards could also describe the desired level of technology in order to induce improvements in equipment quality. These standards can be introduced by manufacturers' or users' organizations who provide a quality seal for equipment fulfilling the requirements.
Standards will have to be dynamic and reflect the actual technological development and scientific knowledge.

The introduction of standards or a certification system is no end in itself. They should be used to guarantee a minimum quality of equipment available on the market and induce technological progress.

Equipment Testing

Apart from the standards of new equipment, the working conditions of application equipment in actual use give reason for concern. Therefore, structures have to be implemented to ensure the proper operation of application equipment. The necessary checks and repairs can be carried out by the commercial sector. Especially in an introductory phase this approach should be the first choice to convince the involved parties of the benefits this activity provides for each of them. The farmer saves money through reduced pest control costs by using a properly adjusted and calibrated equipment and the commercial sector earns by providing the service or even selling the required wear parts.

The test service can therefore be provided through agricultural equipment dealers and workshops, extension services, or government entities. In any case, it should pay for itself through fees.

Eventually it might become necessary to introduce mandatory check systems. In Germany, this system was introduced in 1993 after past experience with voluntary checks which had only been used by 20% of the farmers. As in these checks only 50% of the equipment was found in perfect condition, the government decided to introduce mandatory checks (Wehmann, 1993). In Nicaragua mandatory checks on spray aeroplanes were introduced in 1991, following a one-year voluntary check with a heavy publicity campaign. By that time the checks were widely accepted and the introduction of mandatory checks did not cause any problem (Friedrich, 1995). However, mandatory checks can only be introduced after the infrastructure to carry out the checks is installed.

Regular checks of pesticide application equipment should be promoted in a way that all participants see a clear advantage for themselves.

Infrastructure Aspects

Pesticide application is becoming more and more complicated. As a result in some countries this work is increasingly being taken over by contractors who specialize in the subject and make use of the latest developments in application equipment.

On the other hand equipment dealers and sales outlets are an important issue. In many countries, the salesperson is the only contact the farmer has for technical advice. Therefore, dealers selling pesticide application equipment should in the same way as pesticide dealers receive special training and probably require a license to sell those products. Situations should be eliminated where spraying equipment is sold in general country stores without any technical advice, spare part supply or repair service. Application equipment should be sold through specially qualified sales outlets. These can be either pesticide dealers or agricultural equipment dealers (Dandy, 1994).

The training of those distributors together with their mechanical repair workshop operators could be financed by equipment manufacturers or other private enterprises. The government's role would be to monitor the sector and, if necessary, introduce a licensing system.

FAO Activities in Pesticide Application

For many years now FAO has been dedicated to promoting a rational use of pesticides. The most visible work in this respect was probably the introduction of the International Code of Conduct on the Distribution and Use of Pesticides in 1985 with the Prior Informed Consent in 1989 (FAO, 1990).

Already in 1985, a FAO Panel of Experts Working Group on Pesticide Application Standards highlighted the importance of equipment standards and appropriate training programmes (FAO, 1986).

The issue was taken up again by FAO in 1994 with the introduction of a Programme for Safe and Efficient Application of Agro-chemicals and Bio-products. The objective of the programme is to create awareness and establish the basic structures in FAO member countries for the introduction of sustainable long-term improvements in pesticide application practice at the field level.

The programme is oriented toward experiences of countries advanced in pesticide application technology. These experiences show that, in general, apart from awareness and knowledge, legal pressure is required to introduce good practice. The relation between awareness and pressure, however, depends on the current condition of each country and therefore has to be decided individually. The programme consists of a series of alternatives which can be selected and adapted according to the need of a specific country.

The programme was first started with two workshops in 1995, one for Central and Eastern Europe and one for the South Cone of Latin America.

An important activity within the programme is the formulation of FAO standards for the most common types of agricultural application equipment. These standards are limited to aspects of safety and efficiency and should be applicable world-wide.

The set of standards consist of two groups:

1. Guidelines for the Basic Requirements for Pesticide Application Equipment: These guidelines reflect the absolute minimum requirements for application equipment actually met by the majority of equipment commercially available world-wide. Their immediate use is standard for FAO's purchase of equipment.

However, they will be sent to other donor agencies and FAO member countries for their adoption.

2. FAO Standards for Pesticide Application Equipment: These are more comprehensive standards, including test procedures that would lead to the status of "FAO-Approved equipment". After official adoption by FAO, these standards will be forwarded to FAO member countries as guidelines for the code of conduct and proposals for the introduction of harmonized national standards.

The programme starts usually with a regional workshop to create awareness among government representatives, farmers and the commercial sector. The situation is presented, problems and possible solutions discussed. Implementation remains the responsibility of each country. FAO offers technical assistance if needed and provides a follow-up of the implementation.