A TRAINING MANUAL FOR THE SAFE AND EFFICIENT USE OF PESTICIDES IN PAKISTAN.

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PREFACE

An earlier and shorter version of this manual was produced for inservice training courses in Papua New Guinea. It did not include the chapters on ultra low volume spraying and application technique and the main emphasis was on the application of herbicides. This particular version has been prepared as a course manual for training courses in Pakistan and includes practical worksheets. It is an expanded and revised version of the earlier text. It is aimed primarily at Agricultural Officers and Research Assistants, but it is hoped that parts or all of it will be of use to other agricultural workers no matter what the grade or level of interest.

This Manual has been produced as a part of the Cotton Pest Management Project. A Bilateral Technical Cooperation Project between the Governments of the Islamic Republic of Pakistan and the United Kingdom.

J.A.Sutherland
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CHAPTER 1

INTRODUCTION TO PESTICIDES

1.1 Pesticide Names and Formulations

Pesticide Names

A pesticide is a poisonous chemical which is used to kill pests. The pest may be a weed, an insect, a fungus, a nematode (small worm), a snail or a rat. The type of pesticide depends on the pest it kills.

to kill a weed	- HERBICIDE
to kill an insect	- INSECTICIDE
to kill a fungus	- FUNGICIDE
to kill a nematode	- NEMATICIDE
to kill a mite	- ACARICIDE
to kill a snail	- MOLLUSCICIDE
to kill a rat	- RODENTICIDE

Usually when these chemicals are applied at the correct concentration one type of pesticide does not act as any of the others, so that a herbicide kills only weeds and a rodenticide kills only rats for example. However some insecticides will kill mites (act as acaricides) and some acaricides will kill insects (act as insecticides).

All pesticides have at least three names:

- a CHEMICAL NAME
- a COMMON NAME
- a TRADE NAME

The **CHEMICAL NAME** is the technical name which is long and complicated and is used by pesticide chemists and in specialist books. It describes the structure and type of chemical. It sometimes appears on the pesticide container, e.g. O,O-dimethyl carbamoyl methyl phosphorodithioate.

The **COMMON NAME** is a simple name which is <u>always</u> spelt with a small first letter. It is internationally recognised. ALL pesticides have a single common name. This name is usually found on the label of a pesticide container, e.g. dimethoate.

The **TRADE NAME** of a pesticide is the name that the company producing it gives it. It is <u>always</u> spelt with a capital first letter and may be written in quotation marks, eg "Cygon". The trade name usually contains some indication of the formulation type (see below) and the amount of active ingredient. Some pesticides have several trade names although the common name is always the same. The two names of a pesticide that you will need to be able to recognise are the <u>common name</u> and the <u>trade name</u>.

The trade name refers to the **PRODUCT** which is sold. Examples of the three types of name for some pesticides used in Pakistan are given below:

CHEMICAL NAME = 1,1'-dimethyl-4,4'bipyridinium ion
COMMON NAME = paraquat
TRADE NAME = Gramoxone, Dextrone-X

CHEMICAL NAME = alpha-cyano-3-phenoxybenzyl 3-(2-chloro-3,3,3-trifluoroprop-1-enyl)-2,2-dimethylcyclopropane carboxylate
COMMON NAME = cyhalothrin (lambdacyhalothrin applied for)
TRADE NAME = Karate 2.5 EC

CHEMICAL NAME = N-(1-ethylpropyl)-2,6-dinitro-3,4-xylidine
COMMON NAME = pendimethalin
TRADE NAME = Stomp 330 EC

CHEMICAL NAME = 1-naphthlenyl methylcarbamate
COMMON NAME = carbaryl
TRADE NAME = Sevin 44 XLR, Sevin 85 SP

In a few cases the common name is the same as the trade name. For example malathion, atrazine and DDT are all common names but these pesticides are also sold under these trade names.

The purest form of the pesticide is known as the **TECHNICAL** (eg "technical dimethoate" or "dimethoate technical"). It is the technical which the manufacturers produce and use in preparing pesticides for sale. Only very small amounts of the technical are necessary to kill the pest and so it is prepared for sale in a form which can be easily handled and diluted. This preparation is known as the **FORMULATION.** The formulation is a mixture of the technical and other chemicals. It is sold as the **PRODUCT** with a **TRADE NAME.**

Pesticide Formulations

There are two basic types of formulation, those which are to be **SPRAYED** and those which are applied **DRY.** Formulations to be sprayed are always diluted with water unless very special methods of application are used (ultra low volume and electrostatic spraying). Dry formulations are usually applied without any dilution.

All formulations contain two parts, an **ACTIVE INGREDIENT** and a **NON-ACTIVE INGREDIENT.** The active ingredient is often abbreviated to **AI or ai.** The active ingredient is the technical product or the pesticide. The non-active ingredient is made up of several different chemicals which make the active ingredient more effective and safer to handle.

The concentration of the active ingredient is expressed as a percentage either weight per weight (abbreviated as w/w) or

weight per volume (abbreviated as w/v). For example, 30% w/w means 30 g of active ingredient in 100 g of formulation and 30% w/v means 30 g of active ingredient in 100 ml of formulation.

Formulations to be Applied as Sprays

Most technical products will not dissolve in water and need to be mixed with other chemicals so that they can be diluted for spraying. There are two main kinds of formulation which are mixed with water, **EMULSIFIABLE CONCENTRATES** and **WETTABLE POWDERS.**

EMULSIFIABLE CONCENTRATES (abbreviated as **EC or ec**) - The most important non-active ingredient of an EC is the **EMULSIFIER.** The technical product is dissolved in a special oil or chemical known as a **SOLVENT** and the emulsifier allows this solvent to mix with water when the formulation is diluted. The type of solvent depends on the technical product and some solvents are so expensive that some pesticides are not formulated as emulsifiable concentrates, instead they are made into solid formulations which mix with water. The solvent oils and emulsifiers very often increase the rate at which the pesticide is absorbed through the insect skin or plant surface.

WETTABLE POWDERS (abbreviated to **WP** or **wp**) - These are sometimes known as **WATER DISPERSIBLE POWDERS** (**WDP**) or **SPRAYABLE POWDERS.** They should not be confused with dust or granule formulations (see below). The active ingredient in a wettable powder is mixed with chemicals known as **SURFACTANTS** which allow the technical product to mix with water. **INERT FILLERS** make up the rest of the formulation. These are chemicals which dilute the technical product in the formulation and allow it to be processed efficiently in the factory where it is made. When water is added to a wettable powder the pesticide does not dissolve, it becomes suspended in the water. If the mixed spray is allowed to stand for too long the solids settle to the bottom of the spray tank. Some pesticides are sold as **FLOWABLE PASTES** or **COLLOIDAL SUSPENSIONS,** these are really pre-mixed wettable powders in which the active ingredient is suspended like fine mud particles in water.

In addition to the chemicals which allow the active ingredient to mix with water, formulations for spray application may also contain **SPREADERS** and **STICKERS.** Spreaders (also known as "wetters") are a type of detergent which allow the spray droplets to spread out over a waxy surface such as a banana leaf or insect body. Stickers, as the name suggests, help prevent the spray from being washed off the leaf by heavy rain.

ULTRA LOW VOLUME (abbreviated to **ULV** or **ulv**) - These formulations are NEVER mixed with water. They are applied using specially adapted sprayers or special ulv spraying machines. The formulations are complex mixtures of **SOLVENTS** to dissolve the technical material, **OILS** to prevent evaporation and **INERT FILLERS.** The solvents which are used to dissolve the technical

material often increase the speed and efficiency of uptake by the target pest. These solvents also make absorption by humans more rapid. ULV formulations should be handled VERY CAREFULLY. They are usually sprayed at much higher concentrations than formulations mixed with water. Some ULV formulations may damage plants if used incorrectly. The technique of ULV spraying requires special training and knowledge (see Chapter 10, page 134).

ELECTROSTATIC (abbreviated to **ED**) - These are extremely specialised formulations that can only be used with a special type of electrostatic sprayer (known as the Electrodyn). They are NEVER mixed with water and come in special bottles which also contain the sprayer nozzle. These special **BO**ttle/no**ZZLE** containers are known as **BOZZLES**. They cannot be opened.

Formulations Applied Without Water

There are two types of formulation which fall into this category, **DUSTS** and **GRANULES**. The main difference between dusts and granules is in the size of the particles. Dusts are much finer than granules. These dry formulations are diluted by the manufacturer and are applied without any further dilution by the user. The main disadvantages with dry formulations are:

- Bad handling or poor quality creates very fine particles which can be a danger to health (see page 42).

- Because the chemicals are diluted they are bulky and expensive to transport.

- In humid tropical conditions they are difficult to keep dry in storage (NOT a problem in Pakistan!!).

The main advantages are:

- They are already diluted and are therefore much safer to handle.

- Very toxic chemicals can be formulated as weak concentration granules which are safer to handle than more concentrated emulsifiable concentrates (eg Furadan granules).

The final trade name of a pesticide which is sold to farmers contains information about the formulation type and the concentration. This information is useful when it comes to calculating the quantities to use, and also tells you something about the properties of the pesticide.

E.g. Rogor 30EC is an emulsifiable concentrate which contains 30% active ingredient. By looking at the label we can see that it is 30% w/v and the common name of the pesticide is dimethoate.

ALWAYS READ THE LABEL, it will tell you many things, including

the common name, the formulation type, the concentration of the active ingredient, special handling and storage requirements (see page 26) recommendations for use and any mixes with other chemicals that should not be made.

1.2 Measures of Pesticide Toxicity to Non-Target Organisms

Pesticides are dangerous poisons which are designed to kill pests, but which can also kill humans and animals if mishandled or misused. The **TOXICITY** is a measure of how poisonous a pesticide is. There are two ways in which this toxicity may become apparent.

ACUTE TOXICITY or poisoning, is when a single dose of the pesticide causes poisoning and the effect is quickly seen.

CHRONIC TOXICITY or poisoning is when many small doses of the pesticide build-up over a period of days, weeks or months and cause poisoning. On its own each dose is insufficient to cause signs (symptoms) of poisoning, but the effect of all the small doses is.

Pesticides can enter the body in three ways to cause poisoning. They can be swallowed, this is known as **ORAL POISONING.** They can enter through the skin, this is known as **DERMAL POISONING.** They can enter through the lungs as fine droplets, dust particles or fumes, this is known as **INHALATION POISONING.** Inhalation poisoning also applies to fish when they take up a pesticide from the water in which they are living, through their gills.

Oral poisoning is most common with suicides, murder and when a pesticide is accidentally swallowed from an unmarked container. This type of poisoning is usually acute (see above) since a single dose is taken and the effect is quickly seen.

Dermal poisoning may be a result of acute poisoning, when an accident involves the breakage or spillage of a pesticide container or it may be associated with small leaks over a long period of time, chronic poisoning. It can be caused by a leaking sprayer, failure to wash protective clothing or bad spray methods. Dermal poisoning is a **VERY IMPORTANT** type of pesticide poisoning and is easily avoided.

Inhalation poisoning is usually acute and is caused by either bad spraying and mixing methods or bad storage.

Not all pesticides are equally poisonous to humans and other animals. In order to understand which are more dangerous than others they are all tested on animals in laboratories before being released for sale. Both the oral and dermal toxicities are measured, and sometimes the inhalation toxicity as well. The most common animals used in tests are rats, rabbits, mice, fish and birds. The toxicity is usually quoted as either an **LD50** or **LC50.**

LD50 - This is the Lethal Dose (LD) which will kill 50% (50) of animals in the test population. It may be a **DERMAL LD50**, in which case the dose is applied to the skin or it may be an **ORAL LD50** in which case the dose is swallowed. It is usually quoted as **ACUTE** in which case it is the dose that would kill 50% of the test animals in 24 hours. If the **CHRONIC** toxicity is quoted it usually states the number of doses and the time involved. The **ACUTE ORAL LD50** is the most commonly quoted figure. It is expressed in mg (1000mg = 1 g) of active ingredient/kg of body weight or mg/kg body weight.

LC50 - This is the Lethal Concentration (LC) which will kill 50% (50) of the animals in the test population. It is a measure of the **INHALATION** toxicity. As with the LD50 it may be either **ACUTE** or **CHRONIC**. Lethal concentration is used when measuring the toxicity of pesticides to fish and other aquatic animals.

When the toxicity of a pesticide is quoted it refers to the pure or technical product. The type of toxicity and the test animal used are quoted as part of the toxicity.

It is often assumed that values for these test animals are the same as the toxicity of the chemical to human beings, but this is not necessarily so. Pesticides may be more or less toxic to humans than the test animals used. It is best to assume that they will NEVER be less toxic and remember they may be more so. It can be seen from the following example that values for the same chemical and different animals can vary a great deal.

E.g. Technical acephate (Orthene) has an acute oral LD50 for female rats of 866 mg/kg, for male rats 945 mg/kg, for mice 361 mg/kg, for chickens 852 mg/kg for mallard ducks 350 mg/kg, for ringneck pheasants 140 mg/kg.

This means that the technical product of acephate will kill 50% of female rats if it was fed to them at the rate of 866 mg for every 1 kg of body weight. If a rat weighed 0.25 kg (a quarter of 1 kg) then it would have a 50% chance of surviving if it ate 214 mg of technical acephate (866 divided by four).

Using the example above for acephate, if the toxicity to man is the same as for the female rat (866 mg/kg) then a 65 kg man would have a 50% chance of dying if he ate 56290 mg (866 x 65) of the technical product, 56.29 g (about 2 ounces).

The most commonly quoted measures for the toxicity of pesticides are the **ACUTE ORAL LD50(rats)** and the **ACUTE DERMAL LD50(rabbits)**, measured in **MG of TECHNICAL PRODUCT/KG of BODY WEIGHT**. This is written as mg/kg. Table 1 shows some common chemicals and the LD50 values for them.

TABLE 1 THE TOXICITIES OF SOME COMMON AGRICULTURAL CHEMICALS. DATA TAKEN FROM "PESTICIDE MANUAL, A WORLD COMPENDIUM", PUBLISHED BY THE BRITISH CROP PROTECTION COUNCIL, 6th Edition.

Common Name	Trade Name	Function	Acute Oral LD50 (rat) mg/kg	Acute Dermal LD50(rabbit) mg/kg
acephate	Orthene	Insecticide	866	>2000
aldicarb	Temik	Insecticide	0.93	5
carbaryl	Septene	Insecticide	850	>2000
carbofuran	Furadan	Insecticide	8	2550
cypermethrin	Cymbush	Insecticide	251	2400
DDT	DDT	Insecticide	115	2510
glyphosate	Roundup	Herbicide	4320	>7940
malathion	Malathion	Insecticide	2800	4100
paraquat	Gramoxone	Herbicide	150	236
pendimethalin	Stomp	Herbicide	1050	>5000

Pesticides can be classified into groups according to their toxicity to test animals and Table 2 shows the classification system used by the World Health Organisation (WHO).

TABLE 2 WORLD HEALTH ORGANISATION CLASSIFICATION OF PESTICIDES

Class - Hazard	Oral Toxicity (mg/kg)		Dermal Toxicity (mg/kg)	
	Solids	Liquids	Solids	Liquids
IA EXTREMELY HAZARDOUS	<5	<20	<10	<40
IB HIGHLY HAZARDOUS	5-50	20-200	10-100	40-400
II MODERATELY HAZARDOUS	50-500	200-2000	100-1000	400-4000
III SLIGHTLY HAZARDOUS	>500	>2000	>1000	>4000

The measures of toxicity described here are based on the pure, or technical product, but very few pesticides are sold in this form. The formulations which are available contain varying amounts of active ingredient (technical product). A simple formula can be used to calculate the approximate toxicity of a formulation or a mixed spray if the toxicity of the technical product is known.

$$\frac{\text{(LD50 of active ingredient) x 100}}{\text{\% active ingredient in formulation or mixture}} = \text{LD50 of the mixture or formulation (mg/kg)}$$

E.g. Cygon 400 EC
Acute oral LD50 (rats)=500mg/kg
Formulation is 40% active ingredient

$$\text{LD50 of formulation} = \frac{500 \times 100}{40} \text{ mg/kg}$$

$$= 1250 \text{ mg/kg}$$

For a mixed spray of dimethoate (Cygon 400 EC) the same method of calculation can be made to determine an LD50 for the mixture.

E.g. Cygon 400 EC (Acute Oral LD50 = 500 mg/kg) mixed spray of 0.1% active ingredient

$$\text{LD50 of mixture} = \frac{500 \times 100}{0.1} \text{ mg/kg}$$

$$= 500000 \text{ mg/kg (500 g or 0.50 kg)}$$

For a 65 kg man this would then mean he had to swallow 35.75 kg (0.50 x 65 kg) of the mixture to have a 50% chance of dying!!

This is only an approximate value since factors affect the toxicity of a chemical when it is in a formulation, and direct comparison of rat and human toxicity (for example) may not be realistic. However it is often the only information available.

In Pakistan there is a special sign on every registered pesticide container. It is a skull and cross bones symbol with a coloured circle around it. The colour of the circle indicates the toxicity of the product in the container:

RED = CLASS IA – EXTREMELY HAZARDOUS
BLUE = CLASS IB – HIGHLY HAZARDOUS
YELLOW = CLASS II – MODERATELY HAZARDOUS
BROWN = CLASS III – SLIGHTLY HAZARDOUS

Dry formulations tend to have lower dermal toxicities than wet ones, because they are less readily absorbed through the skin. An EC formulation may be more toxic than calculated because solvents in the formulation increase the absorption through the skin. Table 3 shows some common pesticide formulation concentrations and mixed sprays. REMEMBER the values for toxicity are from animal studies and may not be directly applicable to man.

TABLE 3 TOXICITIES OF SOME FORMULATIONS AND MIXED SPRAYS DERIVED FROM THE TOXICITIES OF THE TECHNICAL PRODUCT (see Table 1).

Trade Name and Concentration	Acute Oral LD50 (rat)	Acute Dermal LD50 (rabbit)	WHO Class oral	WHO Class Dermal
FORMULATIONS	**mg/kg body wt**			
DDT 25 EC	460	10040	II	III
Birlane 24 EC	41	1737	IB	II
Cygon 200 EC	2500	4000	III	III
Decis 0.5 ULV	27000	400000	III	III
Furadan 5 G	220	51000	II	III
Gramoxone 30 EC	500	786	II	III
Mavrik 2 EC	315000	1000000	III	III
Temik 5 G	18.6	100	IB	IB
MIXED SPRAYS	**g/kg body wt**			
DDT @ 0.4%	28.8	627.5	III	III
Folidol-M 50 EC @ 0.1%	14.0	67.0	III	III
Gramoxone @ 0.1%	150.0	236.0	III	III
Hostathion 25 ULV	0.23	4.4	II	III
Karate 2.5 EC	790.0	6320.0	III	III
Monitor 500 EC @ 0.1%	49.0	83.0	III	III
Sevin @ 0.1%	850.0	2000.0	III	III
FOR A 65kg MAN	**kg/65kg man**			
Folidol-M 50 EC	0.0018		0.0087	
Folidol-M @ 0.1%	0.91		4.36	
Gramoxone 30%	0.03		0.05	
Hostathion 25 ULV	0.015		0.286	
Roundup @ 0.3%	93.6		172.0	
Sevin @ 0.1%	55.25		130.0	
Temik 5%	0.0012		0.007	

1.3 Types of Insecticides

Pesticides which kill insects are called **INSECTICIDES.** They can act to kill the insect in different ways. This is known as the MODE OF ACTION. There are basically three modes of action, which will be considered below.

STOMACH POISONS. These affect the insect when they are swallowed. They may be swallowed when a leaf or part of a plant is eaten or chewed, or they may be taken up in the plant juices, or sap. An insecticide which travels in the plant is known as a **SYSTEMIC**

INSECTICIDE (Figure 1). Systemic insecticides are stomach poisons and are used to control insect pests which suck plant juices. Generally speaking they do not have much effect on other insects. Systemic insecticides can be aplied as liquid sprays (such as Cygon) or as granules (such as Furadan or Temik) which are mixed in the soil.

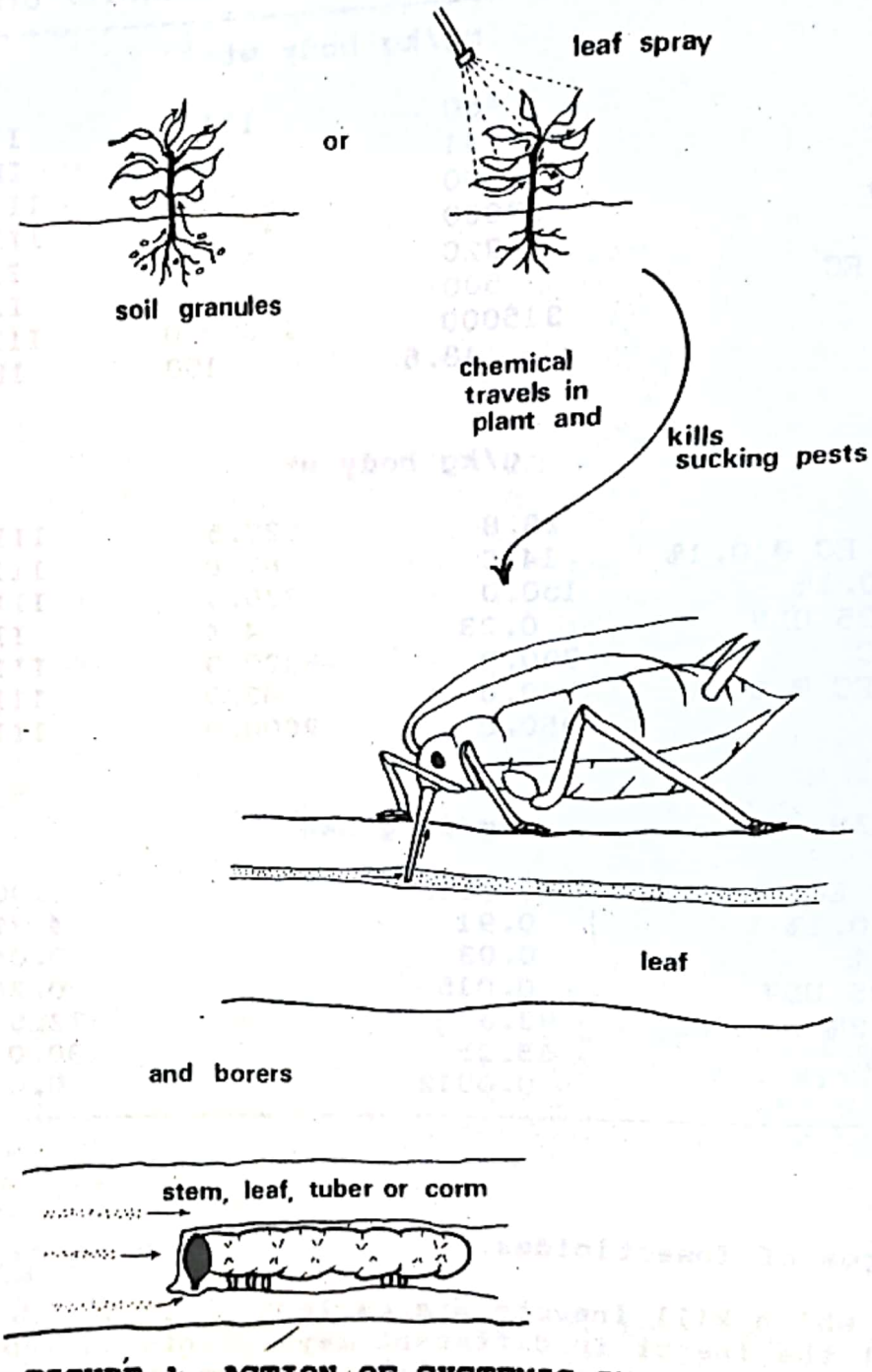

FIGURE 1 ACTION OF SYSTEMIC INSECTICIDES

CONTACT POISONS. These are taken into the body of the insect through the skin or cuticle (Figure 2). Contact poisons cover the plant or sprayed surface and the insect picks up the poisonous

dose when it walks over the surface. This type of action is used in mosquito control, when walls are sprayed with DDT. Very often the action of an insecticide is a combination of stomach and contact effects.

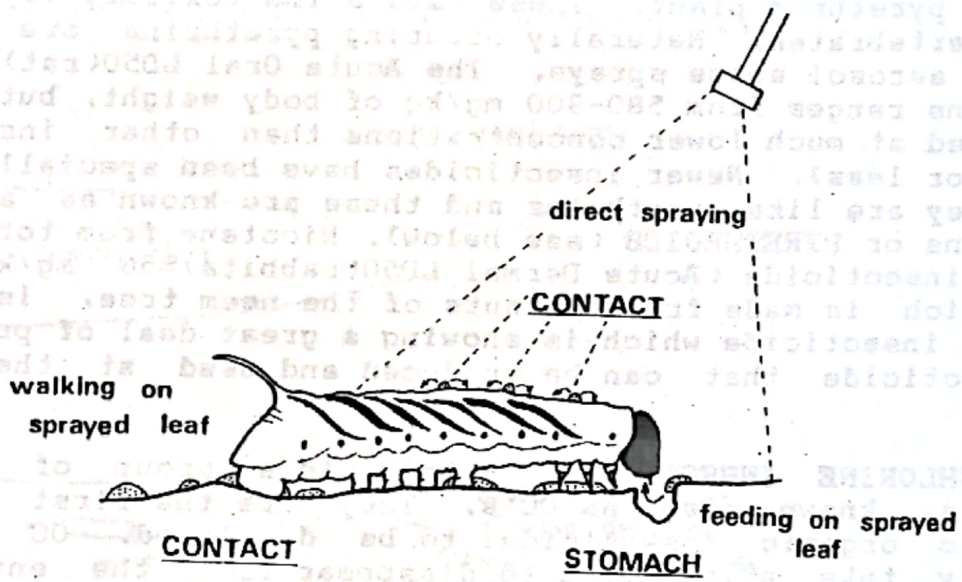

FIGURE 2 ACTION OF CONTACT AND STOMACH INSECTICIDES

INHALED POISONS. These are taken into the insect's body through the breathing holes (spiracles). These insecticides are usually refered to as **FUMIGANTS.** They act as gases. They are used for the control of insects in stored products such as maize and rice. Some insecticides applied to crops also have a fumigant action, for example Actellic (pirimiphos methyl).

The ways in which an insect is killed by insecticides are the same ways in which human beings can be accidentally or deliberately poisoned by these chemicals (see page 9).

Insecticides may be divided into groups according to their chemical structure. Each of the groups contains many chemicals, but those in any one group have certain characteristics in common. The groups are;

- INORGANICS
- NATURALLY OCCURING INSECTICIDES
- ORGANO-CHLORINE *
- ORGANO-PHOSPHATE *
- CARBAMATES *
- PYRETHROIDS *

(* = Synthetic Organic Compounds)

INORGANIC INSECTICIDES - Some of the first insecticides ever used are in this category. Chemicals such as sulphur and lead arsenate

(Acute Oral LD50(rats)=100 mg/kg). These chemicals are not much used these days, since the new synthetic organic products are generally more effective and less damaging to the environment.

NATURALLY OCCURING INSECTICIDES - The most important insecticides in this group are the **PYRETHRINS** which are made from the flower of the pyrethrum plant. These have a low toxicity to man and other vertebrates. Naturally occuring pyrethrins are commonly used in aerosol space sprays. The Acute Oral LD50(rat) for the pyrethrins ranges from 580-900 mg/kg of body weight, but they are also used at much lower concentrations than other insecticides (0.01% or less). Newer insecticides have been specially made so that they are like pyrethrins and these are known as artificial pyrethrins or **PYRETHROIDS** (see below). Nicotene from tobacco is a natural insecticide (Acute Dermal LD50(rabbits)=50 mg/kg). Neem oil, which is made from the nuts of the neem tree, is another natural insecticide which is showing a great deal of promise as an insecticide that can be produced and used at the village level.

ORGANO-CHLORINE INSECTICIDES - This is a group of synthetic chemicals, known also as OC's. They were the first group of synthetic organic insecticides to be developed. OC compounds generally take a long time to disappear from the environment. They do not get quickly broken down into non-toxic compounds. OC compounds can sometimes accumulate in the bodies of animals and cause chronic toxicity to develop. The main advantage of the OC group is that they are cheap. The best known insecticide in this group is DDT, an insecticide which has saved millions of lives through its use in mosquito control programmes. Nowadays organo-chlorine compounds are only used in a limited way because alternatives which are less damaging to the environment are available.

ORGANO-PHOSPHATE INSECTICIDES - This is a fairly new group of chemicals which was developed during the 1940's and released as insecticides during the 1950's. Organo-phosphate is often abbreviated as OP. The OP's vary in toxicity from extremely hazardous (parathion) to slightly hazardous chemicals such as malathion. OP's may be contact, stomach or fumigant in action, they are not nearly as persistant as the OC's and they do not accumulate in the fat tissues of animals.

CARBAMATE INSECTICIDES - This is the new group of synthetic insecticides. The toxicity of these varies from aldicarb (Acute Oral LD50(rat) 0.93 mg/kg) to carbaryl (Acute Oral LD50(rat) 850 mg/kg). They are similar to the OP's in properties and action, but are a much smaller group.

PYRETHROID INSECTICIDES - There are three groups of pyrethroids. These are sometimes referred to as **FIRST, SECOND and THIRD GENERATION PYRETHROIDS.** First generation pyrethroids have little or no persistance and are not used on field crops. Their main use is in aerosol cans of flyspray. Often they are mixed with a **SYNERGIST.** This is a non insecticide which increases the

effectiveness of the pyrethroid. Second generation pyrethroids are persistant enough to be used on field crops, and include compounds such as permethrin and cypermethrin. They are not effective against mites and can cause mite populations to increase if they are used incorrectly. The third generation pyrethroids are the latest group of chemicals. They are extremely potent insecticides used at very low concentrations. They may have some capacity for controlling mite populations.

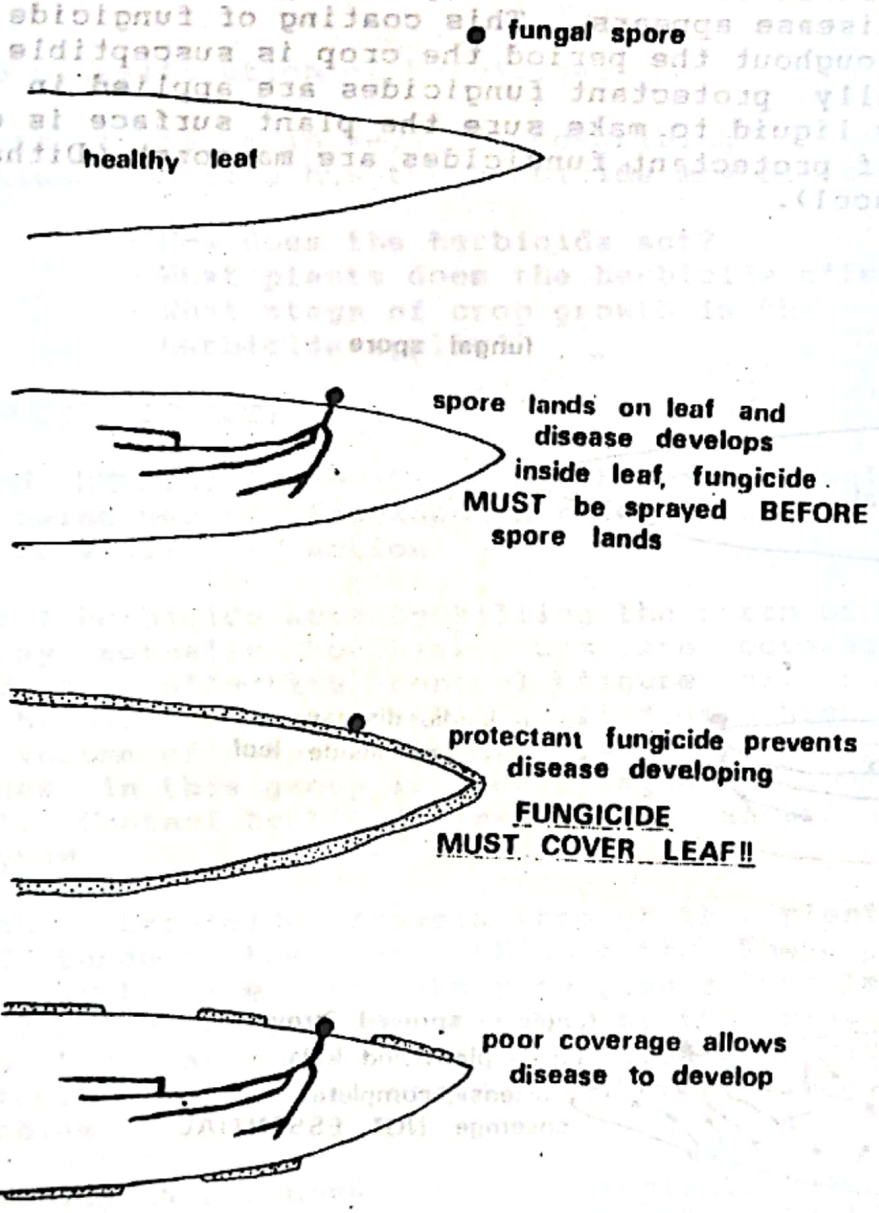

FIGURE 3 ACTION OF PROTECTANT FUNGICIDES

Most of the insecticides used today are OP insecticides. OC's are used only in special circumstances where there is no alternative. Carbamate insecticides are used in the same way as OP's. The use of pyrethroids is becoming increasingly more common.

1.4 Classification of Fungicides

Fungicides are classified into two groups, **PROTECTANT** and **ERADICANT.**

PROTECTANT FUNGICIDES - These fungicides act by preventing the infective stages of the fungi penetrating through the leaves or stem and establishing a disease (Figure 3). To be effective the entire plant must be coated with fungicide BEFORE the infectious stage of the disease appears. This coating of fungicide must be maintained throughout the period the crop is susceptible to the disease. Normally protectant fungicides are applied in a high volume of spray liquid to make sure the plant surface is covered. Two examples of protectant fungicides are mancozeb (Dithane) and propineb (Antracol).

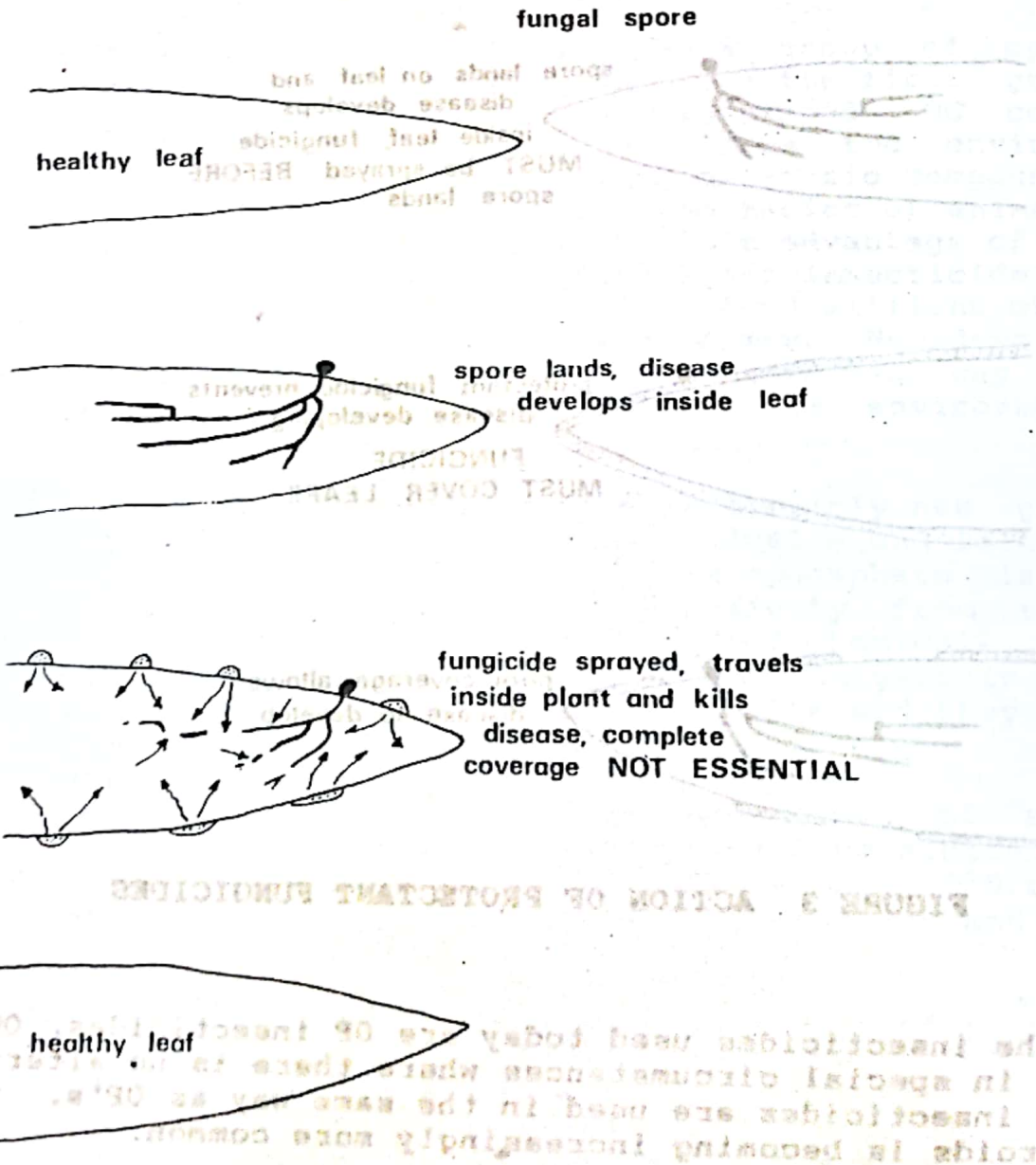

FIGURE 4 ACTION OF ERADICANT OR SYSTEMIC FUNGICIDES

ERADICANT FUNGICIDES - These fungicides move into and through the plant, allowing them to control established infections (Figure 4). Sometimes they are also known as **SYSTEMICS**. Common systemic fungicides include benomyl (Benlate) and metalaxyl (Ridomil). Since the systemic fungicides are taken up into the plant tissues it is not necessary to cover the whole plant and the volume of mixed fungicide which is applied to the crop can be reduced.

1.5 Classification of Herbicides

There are three main ways of describing a herbicide. These descriptions describe how the herbicide may be used:

- How does the herbicide act?
- What plants does the herbicide effect?
- What stage of crop growth is the herbicide applied?

HOW DOES IT ACT?

KNOCKDOWN HERBICIDES - These are herbicides which are used to kill growing weeds. Knockdown herbicides can kill by either a **CONTACT** or a **SYSTEMIC** action.

A Contact herbicide acts by killing the parts of the plant which the spray actually touches, complete coverage is normally required for effective control (figure 5). For this reason contact herbicides are normally applied as a high volume spray in a large volume of water. Death of the weed is rapid. Examples of herbicides in this group include paraquat (Gramoxone) and diquat (Weedol). Contact herbicides are best on annual weeds which will not re-grow.

A systemic herbicide travels through the plant after it is absorbed through the leaves (Figure 6). These herbicides act quite slowly but are more likely to give a "complete" kill of the weeds. Because they are absorbed by the plants and give a complete (or nearly complete) kill, these herbicides are useful for controlling perennial weeds and in situations where regrowth is a problem.

These herbicides can move through the plant, coverage needs to be good, (as with systemic fungicides and insecticides) but not necessarily complete. This is a good thing as it allows less water to be used in the application, which saves time and effort. Examples of systemic herbicides, as knockdown herbicides, are glyphosate (Roundup), 2,4,D, 2,4,5,T, MCPA and 2,2DPA.

RESIDUAL HERBICIDES - These are herbicides which are applied to the soil and are absorbed by the roots of plants. They are effective against germinating seeds in the soil and not usually effective against established weeds or weeds that have regrown from rhizomes (Figure 7). Some herbicides are only Knockdown, or only Residual in their mode of action, whilst some may have both

a residual and a knockdown effect.

Much care needs to be taken when applying residual herbicides. The correct rate MUST be applied. Any mistake could last for a long time or in the case of a perennial crop, cause permanent damage to the crop. The amount of herbicide per hectare is MORE IMPORTANT than the concentration of the spray. Therefore the **VOLUME OF APPLICATION** (see page 91) can be as low as practicable, provided the coverage is uniform. Examples of residual herbicides are diuron (Karmex) and atrazine (Gesaprim).

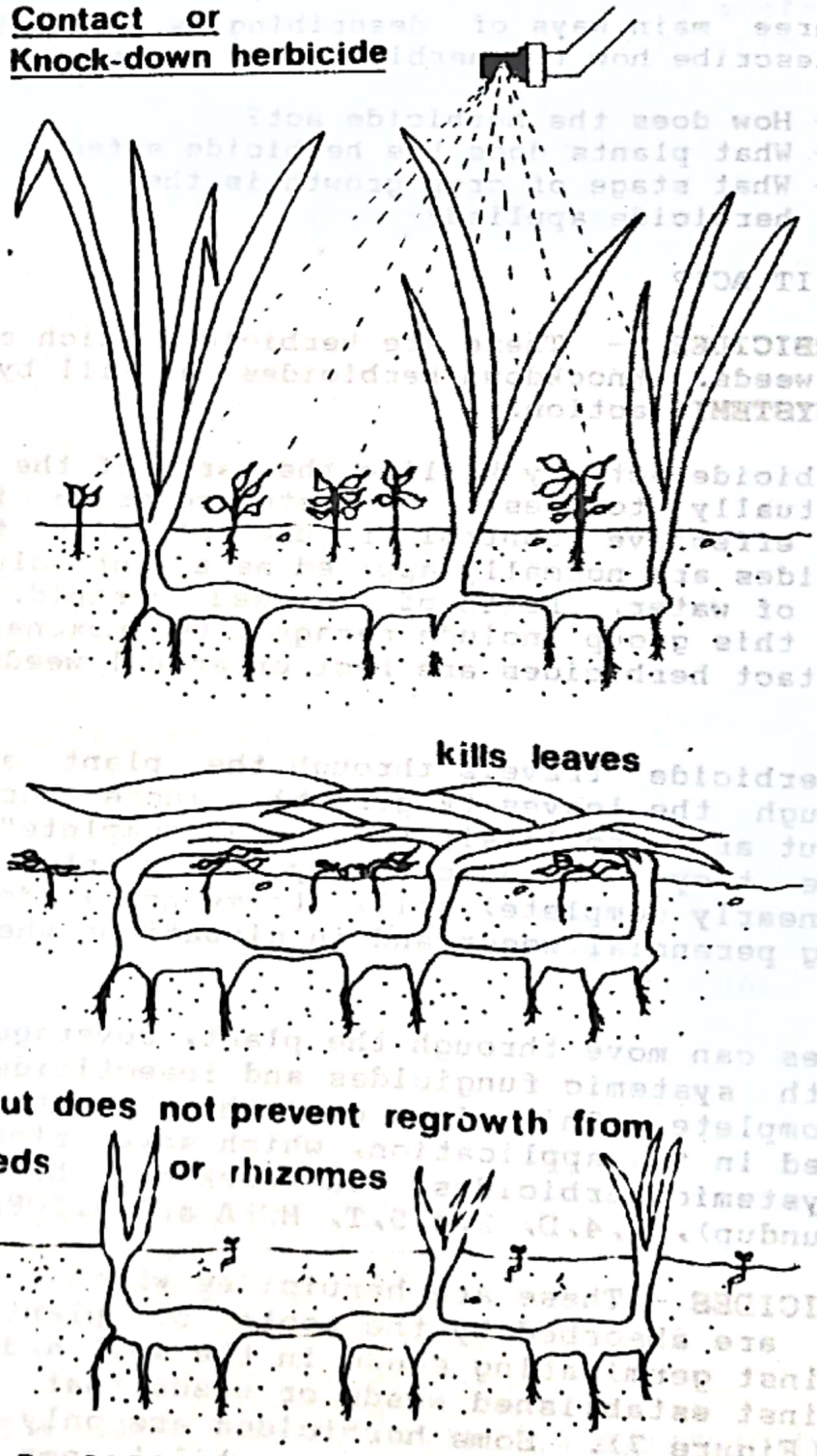

FIGURE 5 ACTION OF CONTACT OR KNOCK-DOWN HERBICIDES

WHAT PLANT DOES IT AFFECT?

Herbicides are either **NON-SELECTIVE** or **SELECTIVE.**

NON-SELECTIVE – These herbicides will kill all plants (crops and weeds) in the sprayed area, and therefore should not be sprayed over crops. With MUCH CARE some of these can be used in perennial crops.

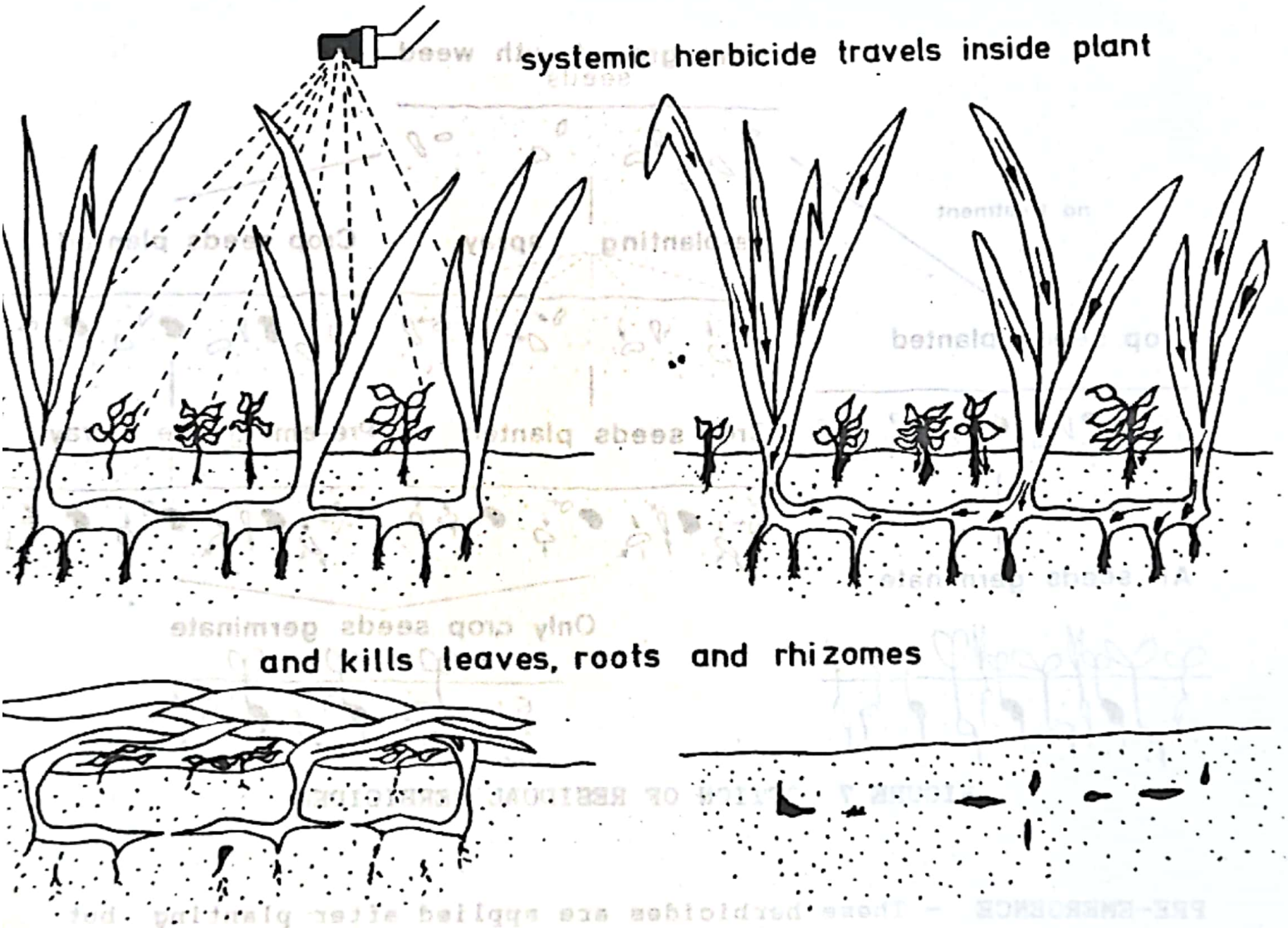

FIGURE 6 ACTION OF SYSTEMIC HERBICIDES

SELECTIVE – These herbicides will kill some plants in the sprayed area without effecting others. Herbicides will only be selective for a particular crop if the instructions on the label are carefully obeyed. Normally these herbicides will not be selective if used at a higher rate than that recommended, or at the wrong stage of the crop growth. Atrazine in corn is used in this way.

WHAT STAGE OF THE CROP GROWTH TO APPLY?

Herbicides can be applied as **PRE-PLANTING, PRE-EMERGENCE** or **POST-EMERGENCE.**

PREPLANTING - These herbicides must be applied before the crop is planted. This group includes herbicides such as glyphosate (Roundup), which is used for chemical "ploughing". Herbicides which have a residual effect must be selective!!!

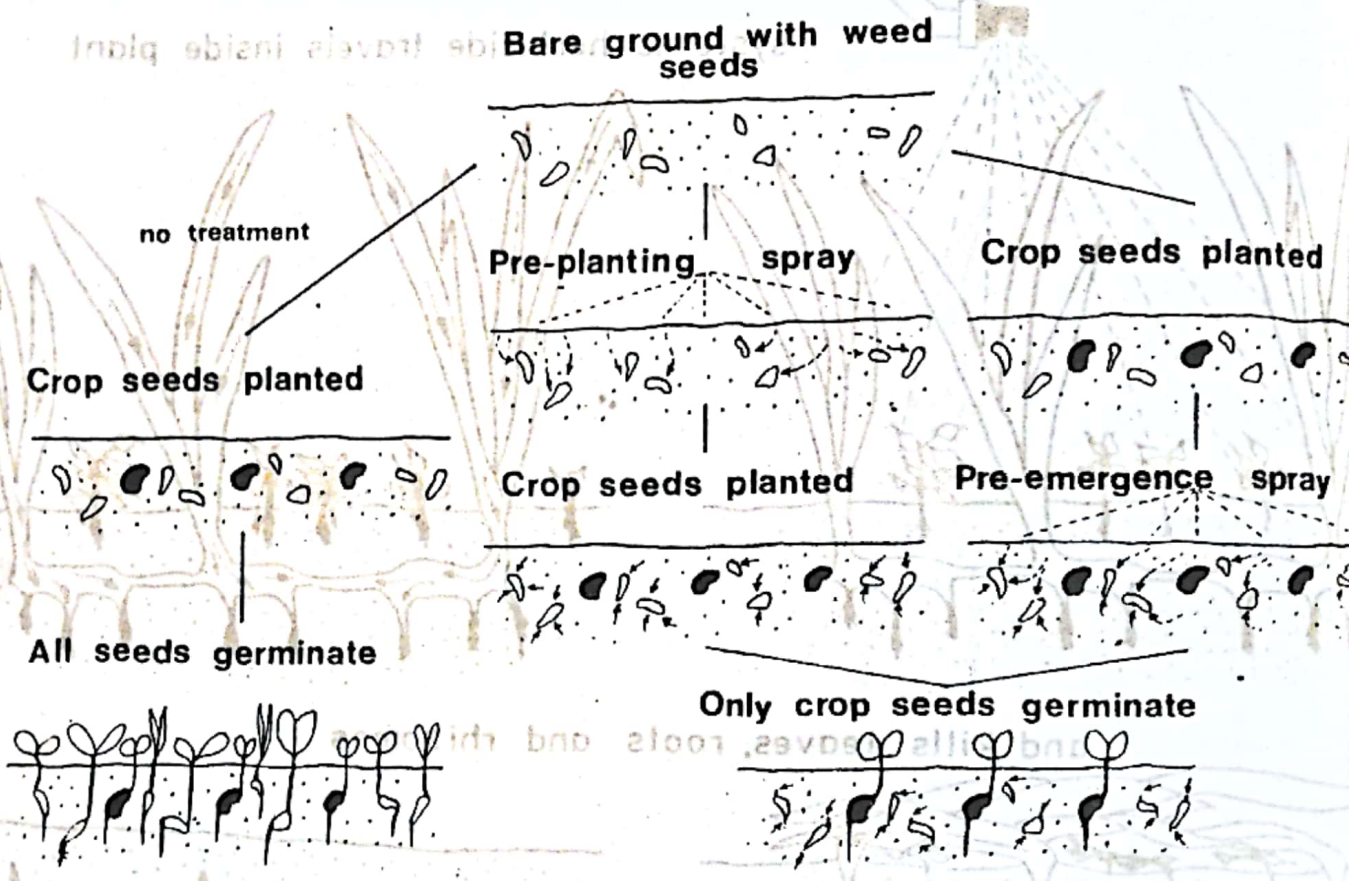

FIGURE 7 ACTION OF RESIDUAL HERBICIDES

PRE-EMERGENCE - These herbicides are applied after planting but before the crop emerges from the soil. Sometimes knockdown herbicides are used to kill young weed seedlings, but this category is usually confined to selective, residual herbicides.

POST-EMERGENCE - These herbicides are applied over a growing crop to kill growing weeds. Normally these herbicides are selective knockdown herbicides. With perennial crops, selective residual herbicides and knockdown herbicides are used.

Herbicides can therefore be described in many ways, and a description for a given herbicides may change with the conditions or situation in which it used.