JULY 1979

PESTICIDE APPLICATOR CERTIFICATION TRAINING

Category 1a Manual

Agricultural Plant Pest Control

EXTENSION DIVISION
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

AGRICULTURAL PLANT PEST CONTROL

A Training Program for the Certification
of Pesticide Applicators

PREPARED BY:

Dr. W. A. Allen, Extension Specialist, Insect Survey
Dr. D. E. Brann, Extension Specialist, Grains
Dr. W. E. Chappell, Extension Specialist, Plant Physiology
Dr. C. R. Drake, Extension Specialist, Plant Pathology
Dr. R. M. McPherson, Extension Specialist, Pest Management, Entomology
Dr. J. R. Martin, Extension Specialist, Pest Management, Weed Science,
Plant Pathology and Physiology
Dr. J. E. Roberts, Sr., Extension Specialist, Entomology
Mr. E. S. Smith, Extension Specialist, Agricultural Engineering

TABLE OF CONTENTS

Page

INTRODUCTION

This training manual is intended to provide additional information that you may need to comply with EPA's Standards for Certification for the Agricultural Plant Pest Control category. It should prepare you to pass the Certification examination prepared and administered by the Virginia Department of Agriculture and Consumer Services.

We wish to credit the Georgia Cooperative Extension Service for developing the original outline which we have modified for specific application in Virginia.

INSECTICIDES
FAMILIES AND PROPERTIES

Insecticides - Mode of Entry

Insecticides enter the insect in a variety of ways and may be classified by their mode of entry. They may be classed as stomach poisons, contact poisons, fumigants, and systemic poisons. Stomach poisons must be ingested by the insect to be effective. An example is lead arsenate. Contact poisons such as carbaryl are readily absorbed through the body wall of the insect and do not have to be ingested. Fumigants such as methyl bromide enter the insect through its respiratory system. Systemics are taken into the plant and kill those insects that feed upon the plant. An example of a systemic insecticide is disulfoton.

Insecticides - Chemical Structure

Insecticides may also be classified into groups or families according to their chemical structure. Using chemical structures for grouping, there are at least ten different groups which could be discussed. For practical purposes, however, a discussion of six or seven of these groups is adequate. The remaining groups contain either older material or little-used compounds, and, therefore, are less important. The first group (the chlorinated hydrocarbon insecticides) may also soon be in this category. Presently, the most widely used groups are the organic phosphate insecticides and the organic carbamate insecticides.

Group I: The Chlorinated Hydrocarbons

In this group are methoxychlor, heptachlor, toxaphene, chlordane, and lindane. They are often referred to collectively as chlorinated hydrocarbon insecticides. This is a fairly large group of materials with many of the compounds having similar structures. The chemical and physical properties of these insecticides are quite similar. Most are very stable compounds and persist in the environment. Most of them have long-lasting residues, are broad-spectrum insecticides, (i.e. they kill many kinds of insects), and their toxicity varies among groups of mammals. Some of them are very toxic. These insecticides are active against the insect's nervous system. They depress the activity of affected insects and subsequently cause an extreme increase in respiratory rate. There are tremors and agitation associated with their action. Finally, paralysis and death result.

Group 2: The Organic Phosphate Insecticides

In Group 2 are the insecticides containing organic phosphorous. This is a very large group of poisons. A conservative estimate is that at least 100 organic phosphates (o.p.'s) have reached the commercial market. The materials in this group of chemicals are different from those previously considered. An important property is that they generally do not have long-lasting residues. They vary greatly in their toxicity to mammals. Malathion, for example, is less hazardous to mammals while others, such as parathion and methyl parathion, are extremely toxic. They are widely used for a variety of purposes including insecticides, acaricides, (miticides) and plant systemics. Initially, there is a period after application in which very little happens to the insect. Following this, there may be a period of increased activity followed by a deep depression. Finally, the insects die. Other compounds in this group include diazinon, trichlorfon, azinphosmethyl, demeton, disulfoton, phorate, mevinphos, and many more too numerous to mention.

Group 3: The Organic Carbamate Insecticides

This is one of the newer groups of insecticides. There are several of these compounds in commercial use, but the market is still developing. Examples of this group include carbaryl and propoxur.

Like the organic phosphate materials, the carbamates generally do not have long-lasting residues. They are considered to be narrow-spectrum insecticides because their toxicity often is restricted to certain selected groups of insects. In general, they are relatively safe to handle, but a few of them are extremely toxic.

The symptoms of carbamate poisoning in insects are disorientation, falling or prostration, and death, with occasional recovery. In the case of carbamate poisoning, the action is sometimes slowly reversible, and this probably explains the recovery which occasionally occurs in carbamate treated insects. Other insecticides in this group include carbofuran, aldicarb, methomyl, and oxamyl.

Group 4: The Dinitro Insecticides

This is a small group of materials which have found limited use as insecticides. One of the better known of these materials is 4-6-dinitro-0-creosol. It is often applied as a dormant oil spray. The symptoms of its action on insects are a large increase in oxygen uptake, restlessness, convulsions, paralysis, and death. Onset of symptoms and death is often quite rapid. It acts as a respiratory poison.

Group 5: The Botanical Insecticides

Here it is necessary to depart from the stated method of classifying insecticides. The basis for classifying this group concerns the origin of the materials rather than their chemical structure. As the title implies, all of the materials in this group are derived from plants. Actually, a very large number of compounds could be listed in this group. For all practical purposes, however, about the only ones that are of any importance today are the pyrethrins, nicotine, and rotenone. Of these, pyrethrins is probably the most important in terms of current usage. Pyrethrins is a mixture of at least four complex organic compounds. Pyrethrins is a good insecticide with an extremely rapid knockdown of affected individuals. Knockdown is almost instantaneous. This compound is often used in combination with other materials in insecticide bombs.

It is put in to shown an immediate action with another material added to insure that the insect will be killed. The principle drawback of pyrethrins is that it is an expensive material,and cannot be used economically on a large scale. Pyrethrins action is often reversible, and the treated insect will often recover.

Nicotine also still finds some use as an insecticide. Nicotine causes insects to become excited when used at low concentrations. At high concentrations, however, it will result in depression, paralysis,and death.

Group 6: The Biological Insecticides

The materials in this group also do not fit the classification set forth at the beginning of this manual. The materials involved are poisons made by bacteria,most commonly from Bacillus thuringiensis. These materials must be eaten by the insect. They often work on only one species or one group of insects. Apparently, they have to be eaten in fairly large quantities in order to be effective. Use of this kind of an insecticide represents a form of biological control of insects. Because the pathogens or their toxins seem to be specific for insects, they probably do not constitute an environmental pollution hazard.

Group 7: Miscellaneous Insecticides

In the past 100 years a large number of chemical compounds has found limited use as insecticides. In addition, new compounds slowly come into prominence as insecticides. Under this heading, therefore, it would be possible to discuss the materials involved at almost any length desired. However, since these compounds have either not reached the commercial market or are of primarily historical significance, this group will not be discussed.

A General Rule

As a commercial applicator, you will often be using insecticides in the organic phosphate and the organic carbamate groups. Therefore, the following general rules may be of importance to you. One of the major differences between the organic phosphate and the organic carbamate insecticides is the range between the oral and dermal LD 50's. The range of the oral and dermal LD 50's of an organic phosphate insecticide is generally smaller than for an organic carbamate insecticide. This generally makes organic carbamate insecticides less hazardous to handle than organic phosphate insecticides with similar figures for the oral LD 50. Like most rules, this one also has exceptions. A few organic carbamate insecticides, such as aldicarb (Temik), have low oral and low dermal LD 50's. Because there are exceptions to most rules, always be sure to carefully check both the oral and dermal LD 50's of any chemical before handling or using it.

Some Highly Toxic Insecticides

Listed below are but a few of the highly toxic insecticides commonly used in Agriculture

	LD 50	
	dermal	oral
demeton (Systox)	14	12
disulfoton (Di Syston)	20	12
carbofuran (Furadan)	885	10
azinphosmethyl (Guthion)	220	13
methyl parathion	67	14
parathion	21	13
mevinphos (Phosdrin)	4.7	6
phorate (Thimet)	6	2.3
adlicarb (Temik)	5	1

Remember - before you use a highly toxic chemical, be sure to check the oral and dermal LD 50's.

Why Are Pesticides Diluted?

Pesticides are diluted to cover more area economically or to reduce hazard.

Dilution is a means of controlling dosage and of providing uniform distribution. The usual carrier for sprays is water. Often, in formulations of dusts, granules and wettable powders, an inert diluent is added as an extender.

Emulsions of liquid in water, on impact with the plant, separate into the two component liquids and leave the active material as a film over the treated surface.

Spray Adjuvants

An adjuvant is a material that is added to a spray to help the active ingredient do a better job. There are many kinds of adjuvants--wetting agents, spreaders, stickers, penetrants, emulsifiers, dispersants--each used for a specific purpose. A thorough discussion of adjuvants is in the core manual.

INSECT PESTS

Insects

Insects are the most abundant form of animal life on earth. There are far more species (kinds) of insects than of all other animals combined. Presently, over 800,000 different species are known to man and others are being described nearly every day.

Relatively few species are considered to be economically damaging to agricultural plants. The number of beneficial insect species outnumber those that cause damage.

However, certain insects do attack crops, and many can destroy a crop. When damaging infestations occur, they must be controlled to prevent unnecessary crop loss. Although control procedures such as crop rotation, cultural practices, destruction of plant residues, planting dates,and resistant varieties are useful in some instances, the most reliable tool for controlling insect populations in crops is still insecticides.

Identify the Pest

The first and most important step in dealing with an insect problem is to identify the pest or pests involved. Once the insect is identified, information on its life cycle and habits, as well as the best methods of control, can be obtained.

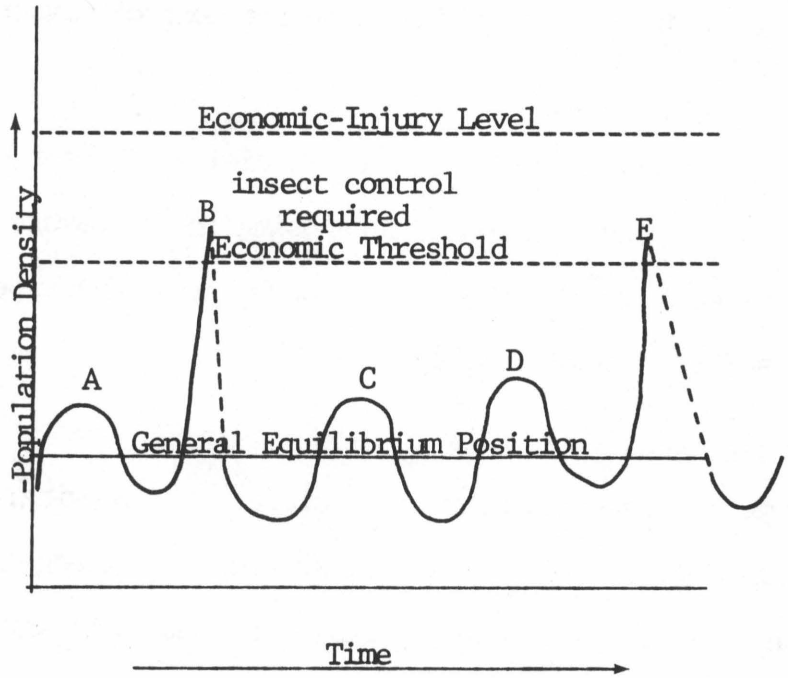
Treat When Necessary

Insect control measures should not be undertaken unless there are enough insects to justify treating. Before making an insect control decision, the concept of the economic threshold should be thoroughly understood. To understand the concept of the economic threshold, it is necessary to define and understand the relationship of an insect's "General Equilibrium Position" and its "Economic-Injury Level."

The General Equilibrium Position is the average insect density over a period of time in the absence of permanent environmental change. Insect populations do not remain at a constant level. Populations rise and fall based upon environmental conditions and the interacting forces of nature. The lower line on the following chart shows the concept of a fluctuating population. The lower line is determined by averaging the insects density over a period of time. Occasionally, an insect population increases rapidly and may threaten a crop. If populations are heavy enough, economic damage may result. Economic damage occurs when the cost of the crop loss is greater than the cost of control. When this occurs, the population of insects has exceeded the economic injury level.

The Economic-Injury Level is the lowest population density that will cause economic damage. It is represented by the uppermost line in the chart.

The Economic Threshold is the density at which control measures should be determined to prevent an increasing pest population from reaching the Economic-Injury Level. It is represented by the middle line in the chart.



From this chart, you need to understand that a certain density of insects (The Economic Threshold) is required before control measures are initiated. Insect control measures which are begun prior to reaching the Economic Threshold will be poorly timed and may be unnecessary. Insect control measures are not justified when populations are less than the economic threshold levels. Points A, C, and D represent populations which should not be controlled. Points B and E represent populations that require control measures. If control is not taken at Points B and E, the population can be expected to rise above the Economic Injury Level. The dotted line represents the change in population due to insect control measures.

Diagnosing Damage

Armed with these concepts, the commercial applicator can better diagnose insect problems. Diagnosing insect damage involves knowledge of: (1) the insect mouth parts; (2) types of damage; and (3) insect life cycles.

Insect Mouthparts

The types of insect mouthparts include: (1) chewing; (2) piercing-sucking; and (3) rasping-sucking. Knowledge of the types of mouthparts is important to commercial agricultural pest control applicators in the plant catagory.

Insects with chewing mouthparts use their mandibles to physically remove and grind plant tissue. Examples include grasshoppers, crickets, caterpillars, grubs, weevils, and beetles. Insects, such as the true armyworm or soybean looper, are in the category which may remove the tissue in an entire area. Insects that remove only part of the leaf include the Mexican bean beetle or the Japanese beetle.

Insects with piercing-sucking mouthparts have mandibles that are modified into a beak. The beak is used to suck juices from the plant. Examples of insects with piercing-sucking mouthparts include the tarnished plant bug, squash bugs, aphids,and stink bugs. Many insects in this catagory also inject a toxic saliva that interferes with growth of the host plant. Examples include "wilt" caused by the squash bug and "cat-facing" of fruit caused by stink bugs and tarnished plant bugs.

Thrips have rasping-sucking mouthparts which are used similar to a file. They scrape the plant's surface; then suck up the oozing sap.

Types of Damage

Insects attack roots, stems, leaves, flowers,and fruits. Root and stem injury affect yield, but are difficult to detect. Root damage includes wireworm injury to seedlings, and corn rootworm injury to peanuts and corn. Very little rootworm damage can be tolerated on some crops such as peanuts because the crop's yield and value are directly effected. A greater density of rootworms in corn can be tolerated because yield is less effected. Stem injury may result from the European corn borer or the common stalk borer. The effects of borer infestation often are subtle at first, but they can greatly affect yield.

Foliage loss reduces yield by reducing the plant's photo-synthetic ability. Most field crops can tolerate some foliage loss without affecting yield. Soybeans can withstand a 35% foliage loss in the prebloom stage and a 20% foliage loss in the pod development stage with no significant affect upon yield. Obviously, foliage loss to a fresh market cabbage crop would not be acceptable.

Flower and fruit loss generally reduce yield, quality, and value. However, a few crops, such as soybeans, can tolerate some pod-loss because the plant compensates by increasing the weight of the remaining beans.

In summary, the Economic Threshold for insects is affected by: (1) the value of the crop, and (2) the plant part attacked. Damage to the saleable product usually cannot be tolerated unless the plant can compensate for the loss. Fruit loss is unacceptable to the fresh fruit producer because of its high value, but some insect injury to the bark and foliage may be acceptable to the fruit grower.

<u>Insect Life Cycles</u>

Knowledge of an insect life cycle is important when making a control decision. A typical life cycle would include the following stages of development:

<u>complete metamorphosis</u>		<u>incomplete metamorphosis</u>
egg		egg
larvae		nymph
pupa	or	
adult		adult

Examples of insects which undergo complete metamorphosis include beetles, wasps, flies, moths, and butterflies. Examples of insects which undergo incomplete metamorphosis include grasshoppers, aphids, and plantbugs.

In the following pages, some of the more important groups of insect pests are discussed briefly. No attempt has been made to cover all damaging insect pests.

Kind of Insect

Caterpillars

Caterpillars are usually called "worms." There are many species (kinds) that attack plants. A caterpillar has four stages in its life cycle. They are egg, larva (caterpillar), pupa,and adult. The adults are moths, butterflies,or skippers.

Only the caterpillar or "worm" stage causes damage. When they hatch from the egg, they are very small and, therefore, eat very little. As they get larger, they eat more of the host plant.

Caterpillars are usually easier to control when they are small. As they get larger, many species are very hard to kill with insecticides. Good coverage of the plant being fed upon is usually essential to good control.

Caterpillars vary widely in color and markings. While a few species may be fairly consistent in their appearance, others vary drastically. Experience and training are essential for proper identification.

Species of plants fed upon are usually variable. Some species of insects may feed on a single kind of plant or a single group of plants, but other insects feed on a variety of different plants. Knowing an insect's host range may be helpful in diagnosing unusual damage.

Foliage and Fruit Feeders

This is the largest group of damaging caterpillars. Some feed only on the foliage, others on the fruit, and still others feed on both. For the purposes of this manual, it is not practical to cover, in detail, even the most important damaging species. The corn earworm has been selected as an example.

Corn Earworm Life Cycle

LIFE STAGES: egg, larva (caterpillar), pupa, adult

PRINCIPAL HOSTS: corn, tomatoes, soybeans, tobacco

GENERATIONS PER YEAR: 3

EXAMPLE ECONOMIC THRESHOLD: soybeans, 2-4 per row foot

The corn earworm is also known as the cotton bollworm, tomato fruitworm,and soybean podworm. It varies in color from light green to almost black and has a yellow stripe down each side. Stiff hairs are scattered over the body.

The caterpillar ("worm") stage lasts from 14 to 21 days, but during hot summer weather it will be much nearer 14 days. The entire life cycle lasts approximately 30 days during hot weather.

This insect is both a foliage and fruit feeder. The more important crops it feeds upon and the plant parts that are damaged are as follows:

Corn - ear and whorl

Small grains and sorghum - head

Soybeans - pod and foliage

Cotton - bud and fruiting forms

Peanuts - foliage

Tomatoes - fruit

Tobacco - bud and other foliage

Pepper - pod

Okra - pod

Other Legumes - foliage and pods

There are many other foliage and fruit feeding caterpillars. Some of the more important kinds are fall armyworm, beet armyworm, "true" armyworm, tobacco budworm, loopers, granulate cutworms, tobacco hornworm, and tomato hornworm.

Boring and Tunneling Insects

Although there are fewer species of caterpillar in this group, some are very important because many crops are attacked.

There is usually a very short period after eggs hatch that these insects are exposed. To control them with insecticides, application must be properly timed. Apply insecticides to coincide with the short period the insects spend outside the plant; i.e. between the time eggs hatch and the caterpillars bore or tunnel into the plants.

The European corn borer is an example of the boring and tunneling group of insects. European corn borers are important pests of corn and closely related grass crops such as sorghum and millet. They have also been found damaging about 200 other kinds of plants. Some of the more important ones are field peas, pimentos, and cotton. Egg masses are laid on the host plant. Eggs hatch and caterpillars feed for a short time on the exterior parts of the plant. They then tunnel into the stalk where they remain until mature (approximately one-inch long). The head is dark brown or black. The upper part of the body is gray to pink with rows of dark spots running lenthwise. The underside of the body is cream colored. Damaged corn tassels often break over.

European Corn Borer Life Cycle

LIFE STAGES: egg, larva (worm), pupa, adult (moth)

PRINCIPLE HOSTS: corn, and 200 other hosts

GENERATIONS PER YEAR: 2-3

EXAMPLE THRESHOLD: none established

Controlling this pest with insecticides is tricky. An effective systemic insecticide must be used or contact insecticides must be applied before the insect tunnels into plant parts.

Some other boring and tunneling caterpillars are the common stalk borer, peachtree borer, lesser cornstalk borer, and several kinds of leaf miners.

Beetles and Beetle Larvae

Beetles and their larvae, (often referred to as grubs), are important pests of agricultural crops. In most instances, both the adult and larval stage damage plants.

Beetles have four stages in their life cycle. They are egg, larva (may be called grub, wireworm, or "worm"), pupa, and adult. The length of life cycles of various species of beetle vary from less than 30 days to one or more years.

The beetle usually feeds on some exterior part of the plant such as the leaves, stalk, or flower, while larvae may feed inside a plant part beneath the soil surface or on the outside of a plant part.

Weevils

Weevils are beetles. Their long snout has biting and chewing mouthparts at the end. Most adult damage is due to feeding injury and egg laying on the fruit of host plants.

After the egg hatches, the grub feeds inside the fruit. Plant parts other than fruit may be fed upon by adults, but this damage generally is not very important.

The cotton boll weevil has been chosen as an example of this group of insects. It is a tan to dark gray or almost black beetle that is 1/8 to 1/3 inch long. Eggs are laid in a hole eaten in a square or boll. The grub completes its development inside the square or boll, changes into a pupa, and finally the adult chews out of the boll. The life cycle requires about 21 days. Boll weevils overwinter as adults in ground trash or other protected areas.

<u>Cotton Boll Weevil Life Cycle</u>

LIFE STAGES: egg, larvae (grub), pupa, adult (weevil)

PRINCIPLE HOSTS: cotton

GENERATION PER YEAR: 3-5

Boll weevil control depends on a series of well-timed insecticide applications intended to kill adults before they have time to mate and continue reproduction.

Some other weevils that are of economic importance in crop production are the cowpea curculio, pecan weevil, plum curculio, and pepper weevil.

<u>Soil Feeding Beetle Larvae</u>

Soil feeding larvae are usually referred to as grubs, wireworms,or "worms". They feed on underground plant parts, often destroying the crop stand or permanently stunting plants.

The length of the beetles' life cycles are variable. Many require one or more years to complete the life cycle while some require no more than one month under favorable conditions.

Control usually consists of a preplant, soil incorporated insecticide application. Some are controlled by insecticides applied to the soil surface after the crop is growing. It is important that the pest be identified, and that a recommended insecticide be applied in the manner that is most effective.

Because this group is so variable, no species has been selected as an example. Some of the insects that fit into this group are white grubs, wireworms, southern corn rootworm, whitefringed beetle grub, and fleabeetle larvae.

Leaf Feeders

Adult leaf feeding beetles may have larvae that feed on plant foliage or they may have larvae that feed beneath the soil surface. In the latter group, adult feeding damage may not be considered to be of economic importance. In these cases, adult leaf feeders may require control occasionally, but larvae may need regular control through soil applications of insecticides. Flea beetles and white-fringed beetles are examples of some of the important insects in this subgroup.

The Mexican bean beetle is an important leaf feeder in both the adult and larvae stages. The insect feeds principally on beans and occasionally on related legumes. All four stages of the life cycle are found on the leaves of its host plant.

Mexican Bean Beetle Life Cycle

LIFE STAGES: egg, larvae (spinyback), pupa, adult (hardshell)

PRINCIPLE HOSTS: snapbeans and soybeans

GENERATIONS PER YEAR: 3-4

EXAMPLE THRESHOLD: soybeans, 150 larvae and adults per 30 row feet

Control of leaf feeding beetles requires a foliar application of a recommended insecticide.

Sucking Insects

The sucking insect group also includes a large number of species. They have mouthparts equipped to pierce the host and to suck plant juices. During feeding, some species inject salivary secretions which cause a deterioration of plant tissue. Feeding may also cause a malformation of plant parts. Many piercing-sucking insects excrete a sticky material called honeydew. A fungus called sooty mold grows on the honeydew. When leaf surfaces are covered with sooty mold, the penetration of sunlight is reduced, and so is photosynthesis.

Insects with piercing-sucking mouthparts have only three stages in their life cycles. They are egg, nymph, and adult. There is no resting stage like the pupa that is present in insects that have four stages in their life cycles. The nymphal stage sheds the skin several times, gradually getting larger until it changes into the adult. The green stink bug is the example chosen for this group.

<u>Green Stink Bug Life Cycle</u>

LIFE STAGES: egg, nymph, adult

PRINCIPAL HOST: fruit, vegetables, soybeans

GENERATION PER YEAR: 3-4

EXAMPLE THESHOLD: soybeans, 20 large nymphs and/or adults per 30 row feet

Many sucking insects can be controlled by the use of preplant, or planting time, in furrow, or soil incorporated applications of systemic insecticides. All can be controlled by recommended foliar applied insecticides. Some of these pests feed primarily from the undersides of leaves, making good coverage essential to effective control.

Some important pests that fit into the sucking insect group are aphids (plant lice), stink bugs, white-flies, plant bugs, leafhoppers, and spider mites. Spider mites are not insects. An example of an aphid life cycle follows:

Aphid Life Cycle

LIFE STAGES: egg, nymph, adult

PRINCIPAL HOSTS: most plants

GENERATION PER YEAR: many

EXAMPLE THRESHOLD: greenbug in small grains

Plant height	#Greenbugs per row foot
3-6	100-300
4-8	200-400
6-16	300-800

SELECTION AND CALIBRATION
OF PESTICIDE APPLICATION EQUIPMENT

Proper selection and operation of pesticide application equipment is important to the success of any pest control program.

Selection of equipment must take into consideration the:

Pesticide material to be applied;

Method of application;

Rate of application;

Size of operation.

Equipment

Types of application equipment:

Sprayers;

Dusters and granular applicators;

Fumigant applicators;

Aerosol generators and foggers.

Sprayers

Sprayers should be:

Designed for the particular job;

Durable;

Convenient to fill, operate, and clean.

Hand Sprayers

Hand sprayers may be used for the application of pesticides in structures, around the home and garden, and in restricted areas where a power unit is not practical. They are economical, mechanically simple, and easy to use, clean, and store.

Low-Pressure Sprayers

Low-pressure sprayers are usually designed to deliver low to moderate volume at 15 to 50 psi. They are often used for applying herbicides and insecticides to field and forage crops, pastures, fence rows, and structures. Their advantages are: medium to large tanks, low cost, light weight, versatility, and minimum drift of pesticides.

High-Pressure Sprayers

High-pressure sprayers are used to spray fruits, vegetables, livestock, ornamentals, and trees where it is important to have pesticide penetration.

Advantages: durability and excellent pesticide penetration.

Limitations: high cost, heavier machines, pesticide drift caused by high pressures, and large power requirements.

Air-Blast Sprayers

Air-blast sprayers use a high-speed air stream to break the nozzle output into fine droplets and carry them to the target. They are widely used in applying pesticides to ornamental plants, trees, fruits, and vegetables and for fly control. They may have either low or high volume output.

Advantages: good coverage and penetration.

Limitations: drift hazards, and difficult to use in small limited target areas.

<u>ULV Sprayers</u>

Ultra-low-volume sprayers are perhaps most frequently found in aerial application of pesticides where little or no water is used in the spray application. Less volume and weight is carried per unit area covered.

Limitations: does not provide thorough wetting, and hazards with high concentrations.

<u>Pumps</u>

The pump is the heart of a sprayer. Its purpose is to provide sufficient flow volume and pressure for the particular job. Pumps should be selected to resist corrosion and abrasion from the materials being pumped.

<u>Centrifugal pumps</u> provide pressures to 75 psi, and provide high volume at low pressure. They have low wear with abrasive materials.

<u>Roller pumps</u> provide pressures to approximately 300 psi, medium-volume output, and are compact. They are economical to purchase, but have short life when used with wettable suspensions.

<u>Piston pumps</u> produce pressures to 1000 psi, are

positive displacement, and resist wear. They require a surge tank to control pulsations, are more expensive and slightly heavier than most other types.

Gear pumps may be used for pressures to 200 psi. They are inexpensive to purchase but produce low volumes and have a short life.

Pump size is dependent on: number and size nozzles; amount of hydraulic agitation needed; and a reserve to allow for wear.

Pumps will be damaged if operated dry or with a restricted inlet. Observe manufacturers' recommendations when installing, operating, and maintaining pumps.

Hoses

Hoses should be selected for strengths greater than the peak operating pressures, resistance to oil and solvents present in pesticides, weather-resistance, and size large enough not to restrict the flow of materials to the nozzles. Suction hoses should resist collapse. Hoses should be replaced at the first sign of deterioration.

Tanks

Tanks should be designed for easy filling and cleaning. They should be made of a corrosion-resistant material. Fiberglass is one of the more popular materials used in tank construction because of its durability, non-corrosiveness, moderate cost, and ease of maintenance. Stainless steel is one of the best materials used in tanks, but is costly.

Strainers

Strainers protect the working parts of a sprayer and avoid time loss and improper application due to clogged nozzle tips. Larger mesh strainers are used on suction lines,with finer mesh (only slightly smaller than nozzle openings) at the nozzle tip. Clean strainers after each use.

Pressure Regulators and Gages

Pressure regulators are used to maintain the desired working pressure.

Pressure gages are necessary to determine operating pressures. They should be protected against corrosive pesticides and pressure surges, and should be checked frequently for accuracy.

Agitators

Agitation is important for proper mixing of spray materials. Bypass agitation may be sufficient for solutions and emulsions. Wettable powders require more positive agitation. Jet or mechanical agitators should be used with wettable powders. Mechanical agitators are more expensive, but give the surest agitation.

Control Valves

Control valves should be large enough not to restrict the flow, and should provide quick and positive on-and-off action. They should be designed for peak operating pressures.

Nozzles

Nozzles help control the rate and pattern of distribution. They are made of many materials.

Nozzle Materials

Brass -

inexpensive

wears rapidly from abrasion

not satisfactory for nitrogen

Stainless Steel -

will not corrode

resists abrasion

has life 6 times that of brass

Aluminum -

resists corrosive materials

not satisfactory for liquid fertilizer

wears rapidly from abrasion

Nylon -

corrosion resistant

subject to wear

Tungsten Carbide and Ceramic -

highly resistant to wear and corrosion

expensive

Basic Types of Nozzles -

solid stream

flat fan - (a) regular flat, narrow oval

(b) even, flat

(c) flooding

hollow cone - (a) core and disk

(b) whirl chamber

full cone

atomizing

broadcast

<u>Selecting Nozzles</u>

Many spray jobs can be done with more than one type of nozzle. General guidelines for nozzle selection are:

Weed Control:

regular flat

flooding

even flat

hollow cone

Disease Control:

hollow cone

full cone

Insect Control Outdoors:

regular flat

hollow cone

solid cone

Insect Control Indoors:

even flat

solid stream

atomizing

To Minimize Drift:

flooding

whirl chamber, hollow cone

Note: use pressures below 30 psi

Clean nozzles only with toothbrush or wooden toothpick.

Check nozzles frequently for uniform pattern and flow rate. Replace those with faulty spray patterns and where flow rate is 5% more or less than average.

Dusters and Granular Applicators

Duster and granular pesticides are used on many field pests.

Hand dusters are used around the home and garden in places similar to a hand sprayer.

Advantages: easy to operate, and good penetration in confined places.

Limitations: high cost for pesticide, difficult to get good foliar coverage, and dust is subject to drifting.

Power dusters use a powdered fan or blower to propel the pesticide.

Advantages: simple, easy to maintain, and low cost.

Limitations: pesticide drift, high cost of pesticide, and less uniform application than with sprayers.

Granular applicators are of two general types. Gravity flow is basically a hopper with a metering hole for discharge by gravity. They often have agitators, but are quite simple and relatively inexpensive. The gravity applicator is usually satisfactory if the granulars are uniform and the rate of speed is maintained constant.

Positive-flow granular applicators are generally either fluted-feed or auger-feed. The feed meters the granules from the hopper and pushes them out the discharge opening. They have a more accurage discharge rate than the gravity-flow type. The delivery rate is usually controlled by a ground drive with different size sprockets and outlet openings for different rates.

Distributors for granular applicators include:

Spinning disk

Banding attachments

Broadcast (width of hopper)

Advantages: low cost, eliminate drift hazards, and less hazard to applicator.

Limitations: high cost of pesticide, limited to certain pests, poor lateral distribution--especially on slopes, speed-sensitive, and bouncing will vary application rates.

Fumigant applicators require many of the components used in a low-pressure sprayer.

Fumigant Applicators:

Low pressure - gravity or pump fed

High pressure - pressure generated by the fumigant or compressed gas forces fumigant into material or space being fumigated.

Aerosol generators and foggers are efficient for distribution of liquid pesticides in enclosed spaces or in dense foliage. They require repeated application to be effective, but may be automated. Aerosols and fogs are extremely sensitive to drift.

Aerosol Generators use atomizing nozzles, spinning disks, or small nozzles at high pressure.

Foggers usually employ thermal generators.

CALIBRATION

Why Calibrate?

Pesticides must be applied properly to be safe, effective, and economical. Improper rates of application are costly. They can result in poor control of pests, waste of pesticide materials, and may cause serious injury to crops, livestock, and humans.

When To Calibrate

Application equipment should be calibrated prior to initial use; following adjustments of equipment, changes in pesticide materials and application rates; and periodically during operation, depending on the corrosiveness and abrasiveness of the pesticide.

Sprayers - Factors Affecting Spray Rates

Factors affecting the application rate of a sprayer include pressure, size of nozzle tip, nozzle spacing, and ground speed. Wind, humidity, and other climatic variables are often disregarded, although it is best to calibrate and apply sprays when air movement is at a minimum. With some spray mixtures the viscosity of the chemical may affect the discharge rate. To apply a pesticide evenly and accurately, a sprayer must move at a constant speed. It also must operate at a constant pressure. Each nozzle must be clean, at the right height and spacing, and directed in the proper direction. In order to deliver the correct amount of pesticide to the target, the proper type and size nozzles must be selected for the job.

Before Calibrating

Before calibrating a sprayer:

1. Read the sprayer Operator's Manual.
2. Make certain that the sprayer is properly mounted.
3. Use clean water and rinse sprayer thoroughly.
4. Remove and clean all nozzles. An old toothbrush, toothpick, or match is handy to clean nozzles and screens without enlarging the nozzle opening. Do not use pocket knives or wire for cleaning.
5. Start sprayer and flush hoses and boom with plenty of clean water.
6. Replace the nozzles and make sure all nozzles are spraying properly.
7. Check all connections for leaks.
8. Adjust the pressure regulator to the desired pressure.
9. Fill sprayer tank with clean water.

Calibration of a sprayer may be done in many ways. You may measure the output for a given time with the sprayer in a stationary position or the output may be determined by spraying a measured area. Start with a full tank. After spraying for a given time or area, measure the amount of water needed to refill the tank. The throttle setting and pressure should be the same while calibrating in a stationary position as that used in spraying. The throttle setting, pressure, and gear (ground travel speed) should be the same while spraying a test area as that used in field spraying.

To determine the rate per acre, you may measure the gallons sprayed over one acre, or you may spray a smaller area and calculate the amount per acre.

Example: Assume you have a boom 20 feet wide and a spray swath 392 feet long using 4.5 gallons of water.

Area covered = 20 feet x 392 feet = 7,840 square feet

$$\text{Acres covered} = \frac{7{,}840 \text{ sq. ft.}}{43{,}560 \text{ sq. ft/acre}} = 0.18 \text{ acres}$$

$$\text{Sprayer Output} = \frac{4.5 \text{ gallons}}{0.18} = 25 \text{ gallons per acre}$$

(One acre = 43,560 square feet)

You may measure the output for a given length of time and then determine the rate per acre at a given speed.

Example: Assume you have a boom 20 feet wide and spray 10 gallons in 2 minutes. What is your rate per acre when traveling at 5 miles per hour? (one mile/hour = 88 feet/min.)

Distance travel = 5 x 88 feet/minute x 2 minutes

= 880 feet

Area Sprayed = 20 feet x 880 feet

= 17,600 square feet

$$\frac{17{,}600 \text{ sq/ft}}{43{,}560 \text{ sq/ft/acre}} = 0.404 \text{ acres}$$

$$\text{Rate} = \frac{10 \text{ gallons}}{0.404 \text{ acres}} = 24.75 \text{ gallons/acre}$$

In addition to these two examples, there are many other ways of measuring the rate per minute or rate per acre. The method you use in determining your rate of spraying is not important, but you must know your spraying rate to do an accurate job.

A short method of calibrating field sprayers is shown in VPI&SU Extension Publication, ME-45, "Sprayer Calibration".

Mixing Pesticides

When mixing a formulation, you should know the recommended rate of active ingredient to be applied per unit area, know the area sprayed per tankful, and then determine the amount of active ingredient needed per tankful.

Example: If you have a liquid pesticide with 4 pounds of active ingredient per gallon of pesticide, and the recommended rate is 1.5 pounds of active ingredient per acre, how much pesticide do you add to a 100 gallon tank of water when your rate of application is 25 gallons per acre?

Area covered per tankful:

$$\frac{\text{100 gallon tankful}}{\text{25 gallons/acre}} = 4 \text{ acres}$$

Amount of active ingredient needed per tankful:

4 acres/tankful x 1.5 pounds/acre = 6 pounds

Amount of pesticide needed per tankful:

$$\frac{\text{6 pounds active ingredient/tankful}}{\text{4 pounds active ingredient/gallon}} = \text{1.5 gallons of pesticide per tankful.}$$

Wettable Powders

Wettable powders should be measured and added to a small amount of water in a clean container and mixed well, forming a slurry. The slurry should then be poured in the sprayer with the sprayer's agitator operating throughout the filling.

Changing Rate of Spraying

There are three ways of changing the rate of application if your sprayer is delivering more or less spray than is recommended.

1. Change the operating pressure.
2. Change the ground travel speed.
3. Change nozzle tips.

Changing the pressure is the least desirable method since doubling the rate would require approximately 4 times the pressure. Halving the travel speed will double the rate. Changing the nozzle tip is the best method for making major changes in the delivery rate.

Dusters and Granular Application

Read the manufacturer's Operating Manual for the operating procedures and the recommended rate setting for dusters and granular applicators. Always set the gate openings from the same direction, such as closed to open. To calibrate:

Fill the hopper to an easily determined level.

Operate over a measured area at normal working speeds and field conditions. The area should be large enough to use at least 1/4 of the hopper contents.

Refill the hopper to the same level, weighing the amount of pesticide needed to replace the amount used.

The rate of application per acre is then determined by dividing the pounds used by the acres covered.

(Area covered in sq. ft. divided by 43,560 sq. ft. per acre)

If the amount is not within 5 percent of the recommended dosage, reset the gate opening and repeat the calibration procedures.

Example: An area 600 feet long and 48 feet wide was covered using 3 pounds of pesticide. What is the rate per acre?

Area covered = 600 x 48 = 28,800 square feet

$$\text{Rate} = \frac{3 \text{ pounds}}{\frac{28{,}800 \text{ square feet}}{43{,}560 \text{ square feet/acre}}} = \frac{3 \text{ pounds}}{0.66 \text{ acres}}$$

= 4.54 pounds per acre

Keep a record of the area treated with each filling. This will help you to know if there is a slight change in the application rate so that periodic corrections may be made.

CARE AND MAINTENANCE OF APPLICATORS

Before operating a new applicator, study the manufacturer's Operator's Manual. Check all designated points for lubrication. Before going in the field, check the operation of all valves, pressure regulators, and the delivery system.

Calibrate under conditions similar to field conditions. Thoroughly clean after each use before placing in storage. Oil or a rust inhibitor should be used in pumps, dusters, and granular applicators to prevent corrosion. Remove all water from the system to prevent damage from freezing.

USING HERBICIDES PROPERLY

Description of Weed Pests

Plant Classification

There are many thousands of plants of various types. In order to recognize them, they are grouped into groups called divisions. Plants within a division are broken down into families and genera. A genera would then be composed of several very closely related but distinctly different plants called species. This enables us to discuss a particular plant and know that we are referring to that plant and no other plant. Each plant is given a scientific name by genus and species. It is not necessary to know scientific names as long as recognized common names exist. Common names vary from locality to locality and many weeds have several common names. As herbicides are often quite selective, it is imperative that one recognize several of the common weeds and be able to match the common name with the list of susceptible weeds on a product label.

The plants that we are primarily interested in are flowering plants (those which produce seeds). Two distinct types of flowering plants are the grasses and broadleaf plants.

Life Cycles

Chemical control varies with the nature of weed involved and its life cycle. Annual weeds germinate to form seed, grow, flower, produce seed, and die within a year. These weeds are often controlled with preemergent herbicides applied prior to seed germination. Annual weeds may germinate in the spring or summer (summer annuals) or germinate in the late fall and grow throughout the winter (winter annuals). Crabgrass and lambsquarters are summer annuals and many of the mustards are winter annuals.

Biennials require two years to complete their life cycle. The musk and curled thistle belong to this group. The seed germinates in the fall and the plant grows vegetatively forming a large rosette during the first growing season. The second growing season the plant sends up a stalk, produces flowers, and then dies. The ideal time to control this plant is during the rosette stage.

Perennials live for indefinite periods, usually several years. They are difficult to control because they have large fleshy underground food reserves. Johnsongrass and bermudagrass (wiregrass) are examples of perennial weeds.

Reproduction of Weeds

Weeds commonly reproduce by forming an abundant seed crop. Many species of weed produce seeds covered with thick coats, and some may remain viable in the soil for periods of 20 years or more. This accounts for the saying that "one year's seeds brings seven years weeds."

Perennial weeds, in addition to producing abundant seed crops, reproduce by vegetative means. This type of reproduction is called vegetative or asexual, as the new plant is identical in every respect to the parent. There are several types of vegetative reproduction. Johnsongrass reproduces by rhizomes (fleshy underground stems); Canada thistle reproduces by spreading roots; nutgrass reproduces by tubers (tiny potato-like roots); wiregrass reproduces by stolons (above-ground runners which root); and, wild garlic reproduces by aerial bulblets and underground bulblets.

Plant Metabolism

Plants, like all living organisms, undergo vital processes that are necessary to sustain life. To interfere with one or more of these processes will cause the plant to die. Many herbicides work by interfering with one or more of the plant's vital processes. Photosynthesis is the process by which green plants convert light energy into food energy. Several herbicides interfere with photosynthesis, and ultimately the plant runs out of food energy. The utilization of food energy is called respiration. Certain herbicides are able to uncouple and waste the energy resulting from digestion of food by the plant. Again, the plant starves. Other herbicides may interfere with protein synthesis or cell division. Paraquat, a contact herbicide, causes rapid destruction of cell membranes. There is no standard method by which an herbicide kills a plant, and the method will vary with the manner in which a given herbicide affects the vital plant processes.

Herbicide Classification

Herbicides can be classified in various manners. Based on chemistry, those which are chemically similar are placed together. The 2,4-D and related compounds are called phenoxy herbicides. Simazine and atrazine belong to the triazine group.

A practical classification is based on the manner in which we use the compounds. Pre-emergent compounds are applied prior to the emergence of the weed and interfere with the metabolism of weed seed after it germinates. They do not affect dormant seed in the soil. They are usually effective for periods ranging from one month to the entire growing season. Certain preemergent herbicides are volatile and will be lost if allowed to remain on the soil surface. To prevent loss of activity, these materials are applied preplant and incorporated.

Materials applied after the weeds and crop emerge are called post-emergent herbicides. Post-emergent herbicides may work through a contact action, such as with paraquat;

or their action may be systemic, as with 2,4-D.

Soil fumigants are materials that have a broad action, killing weed seed in the soil in addition to disease organisms, insects, and nematodes. The most common type utilizes methyl bromide gas which requires a plastic tarp to prevent escape of the gas. The fumigants are quite toxic and extreme caution must accompany their application. Also, they dissipate rapidly from the soil, and new weed seed transported into the area may grow immediately.

The soil sterilants are designed for use when long-term permanent vegetation control is desired. They may persist in the soil for three years or more depending upon the material and rate of application. They must not be used near desirable vegetation.

Chemical Nature of Herbicides

Herbicides have diverse chemical structures. There are more than 150 different basic herbicides on the market. They are formulated in many different formulations and in various combinations with other herbicides and sometimes with fertilizers and insecticides. It is important to recognize the designated common name, as there may be many trade names for the same basic ingredient.

Most herbicides are relatively non-toxic to the applicator. The LD_{50} of most herbicides is in excess of 500, which means they can be safely handled with a minimum of precaution. Certain herbicides, such as paraquat, are toxic enough to bear the skull and crossbones and require special handling requirements. These requirements are printed on the chemical label.

Several plants such as grapes, tobacco, tomatoes, and many ornamentals are extremely susceptible to growth-regulator herbicides. Special precautions must be observed to prevent injury to these plants. Many cases of injury have resulted from spray drift or from contaminated sprayers.

Presently used herbicides are biodegradable. Many of them are broken down within weeds and used as a food source by bacteria in the soil. Others, such as some of the sterilants, are much more resistant to breakdown, and many remain in the soil for years. Some herbicides are quite mobile in the soil and may move down to a considerable depth, while others remain where they are placed at or near the soil surface. A general knowledge of all these factors must govern the use of these materials. Any one of the presently used herbicides can cause problems if used improperly.

Application Procedures

After carefully selecting the best and safest herbicide to control the weed problem in a given crop or area, the user should carefully check the application equipment and be sure it is calibrated correctly. Application of the herbicide in the correct amount is extremely important. Using too much is wasteful and can lead to excessive residue and crop confistication. Too little chemical may cause inadequate weed control and yield loss. Applications at higher rates than those recommended may also result in soil residues that damage succeeding crops.

Careful attention should be given to timing of the application, since the stage of development of the weed at the time of application is critical. For instance, pre-emergence herbicides must be applied before the weeds start to emerge and also before the crop seeds begin to germinate. In other situations, such as selective post-emergence applications in crops, the weeds are easier to kill when small and if not applied early, then there may be little or no control.

Soil texture and organic matter content is a major factor in the effectiveness of pre-emergence herbicides. Heavier soils with high organic matter usually require higher dosages than do light soils with low organic matter. Follow label instructions carefully in deciding on the proper rates for a given situation.

Drift Control Measures

The choice of chemicals for a specific weed control problem is often governed by cost figures, but overall effectiveness and crop safety are of utmost importance.

Spray drift onto adjacent crops or other areas is to be avoided at all times. Spray drift results from fine droplets of spray coupled with air movement. Spray nozzles that deliver large uniform droplets are desirable and should be used at all times wherever possible.

PLANTS, THEIR IMPORTANCE AND LOSSES FROM DISEASES

Plants and Civilization

Daniel Webster once said, "Let us never forget that the cultivation of the earth is the most important labor of man. When tillage begins, other arts follow. Therefore, the farmer is one of the founders of civilization." When reference is made to cultivation one usually thinks of plants or plant life. Thus, plants become the backbone of all civilization.

Plants For Survival

Everything that is made from wood, much of cloth, coal, oil, gasoline, paper, and most human and animal foods come from plants either directly or indirectly. Thus, the entire universe is highly dependent on plants for survival.

Plant Efficiency

Two-thirds of all crop land in North America is used to produce feed for domesticated livestock. This acreage will have to be sharply decreased as the human population increases because plant food is many times more efficient than animal food. One bushel of corn will provide energy and protein for 23 people for one day. One bushel of corn in the form of eggs will supply protein for two people and energy for eight for one day. Further, it requires approximately 10 pounds of grain to produce one pound of meat.

Plant Kingdom

All living things (organisms) are generally divided into two major groups - the animal kingdom and the plant kingdom. Plants differ from animals in that: (1) they usually manufacture their own food (photosynthesis); (2) the embryonic tissues remain relatively or extremely active in plants, this results in unlimited growth (the Giant Sequoia); (3) almost all plants have cells whose walls contain cellulose and are somewhat rigid. Animal cells generally lack cellulose, and their walls are more elastic; and (4) higher plants are anchored to the soil or other solid surface from which they cannot move by their own power. In contrast, most animals are capable of considerable movement.

Plants As Factories

Plants are unique in that they locate themselves in the midst of raw materials that they need (water, carbon dioxide, and solar energy), build and repair themselves, and make their own fuel. The raw materials they take in and the fuel they make are distributed to all parts in a two-way system of supply lines (phloem and xylem). Plants can never suffer from a power shortage because they operate on solar energy which puts them one step ahead of the scientists who have harnessed atomic energy.

Plant Parts

Generally speaking, the plant is divided into or made up of many types of cells. Each group of cells has its own functional part to carry out in the life of the plant within its environment. For example, the xylem (water conducting system) serves to carry water from the roots to the leaves and other parts of the plant. Water passing through the xylem also helps to keep the plant cool. Also, nutrients may be dissolved in the xylem water, and, by this means, they are transported to the part of the plant where they are needed.

Plant Body

On the whole, the Angiosperms (flowering plants) are divided into roots, stems, leaves, and flowers. Each one of these structures has its own specific function. In general terms, the flower generally develops into fruit, seed, grain, nuts, etc. In crop plants, many of the flowers develop into edible products. For example, the flowers of the number one and number two food crops, wheat and rice, respectively, develop into grains or cereal.

Records of Plant Pest

Although plants are extremely important for mankind's survival, approximately 1/3 of their total production is lost annually to pests. Diseases, insects, and weeds are some of the worst pests that cause severe reduction in crop yields. The former two pests of plants (diseases and insects) are mentioned in the Bible and discussed freely by Greek philosophers long before the birth of Christ.

Plant Losses

It has been estimated that diseases alone cause a $45 million annual loss to plant production in Virginia. Similarly, they cause, or result in, a $4 billion annual loss to crop production. in the United States. It has been estimated in the U. S. Department of Agriculture Handbook 291 that approximately $15 billion is lost annually to crop production in the United States as a result of attack by diseases and insects and from competition from weeds.

Plant Disease

In common or simple terms, a plant may be said to be diseased with any condition or change that results or occurs within or on it that interferes with its structure, function, or economic value. The major causal organisms of plant diseases are fungi, bacteria, and nematodes. Viruses which have properties of both living and non-living things are important sources of plant disease incitants.

Diseases Caused by Fungi

Southern corn leaf blight (*Helminthosporium maydis*), apple scab (*Venturia inaequalis*), black stem rust of wheat (*Puccinia graminis tritici*), Dutch elm disease (*Ceratocystis ulmi*), late blight of potato and tomato (*Phytophthora infestans*), early blight of tomato and potato (*Alternaria solani*), Cercospora leaf spot of peanut (Cercospora arachidicola), and brown rot of stone fruits (Monilinia fructicola) are examples of some important fungus diseases and their causal organisms.

Fungi that cause plant diseases are small microscopic plants that, as a rule, are void of chlorophyll and thus must obtain their food from higher plants. Many fungi that cause plant diseases become macroscopic during some stage of their life cycle, such as their fruiting bodies and aggregates of their growth structures (mycelium). Most fungal diseases are controlled with fungicides and resistant varieties.

Diseases Caused By Bacteria

Fire blight of apple and pear (Erwinia amylovora), crown gall of many plants (Agrobacterium tumefaciens), common bacterial blight of beans (Xanthomonas phaseoli), and bacterial soft rot (Erwinia carotovora) are examples of classical bacterial diseases of plants and their causal organisms.

Bacteria are the smallest living plants that cause plant diseases. All known plant pathogenic bacteria are rod shaped. Bacterial diseases are extremely difficult to control. The use of anti-biotics and resistant varieties are only partially successful in their control.

Diseases Caused By Nematodes

The root-knot nematode (Meloidogyne spp.) is the classic of the nematode diseases. It has a wide host range and causes severe losses in production of agricultural crop plants. The most successful method of controlling root-knot nematodes is through eradication with fumigants such as DD (1,2-dichloropropene-1, 2-dichloropropane), Vapam (sodium methyldithiocarbamate hydrate), and methyl bromide (CH_3br) for some crops.

Diseases Caused by Viruses

Virus diseases of plants are caused by nucleo-proteins that are produced only in the living cells of host plants. Peach yellows and tobacco mosaic are classic virus diseases. Peach yellows was so serious in the late 1800's that it caused disastrous financial upheaval in large peach producing areas of the Middle Atlantic states before control measures were developed. Eradication of infected trees and the judicious use of insecticides to control the plum leaf hopper, which is the vector of yellows, along with the use of healthy bud wood is the only complete control of peach yellows. The only control for tobacco mosaic virus is sanitation and resistant varieties. It is a must for tobacco field workers to not use tobacco (smoking or chewing) while working with growing plants.

Diseases Influenced by Weather

One can have a susceptible crop and a virulent pathogen present, but if the weather is not favorable for infection, there will be no disease. Generally speaking, it requires a virulent pathogen, susceptible host, and favorable weather conditions for infection and for an epiphytotic (epidemic) to develop. Some authors (scientists) have referred to this as the triangular situation for disease development.

Diseases Influenced by Moisture

Moisture is extremely important for most disease development. High humidities are necessary for most plant pathogens to grow and produce abundant inoculum. Examples for high moisture requirement diseases are cotton anthracnose (Glomerella gossypii) that requires over 10 inches of rain during the summer for an epidemic to develop. Apple scab, caused by a fungus (Venturia inaequalis) is extremely dependent on moisture (rainfall) for spread of both primary and secondary spores. Late blight of potatoes and tomatoes caused by the Phytophthora infestans is almost nonexistant during dry years.

Temperature Effects on Diseases

Many disease-causing organisms prefer or require cool weather and high humidities for rapid development. For example, the downy mildews, late blight of potatoes, cereal rust, apple scab, peach leaf curl, and Pythium incited diseases all develop more profusely in cool, humid weather. In contrast, most powdery mildews become epidemic during dry, hot weather (cereal powdery mildew is the exception). The Southern blight complex (Sclerotium rolfsii) requires hot, humid conditions for rapid development. Bitter rot of apple caused by the fungus

Glomerella cingulata requires hot weather with frequent showers for an epidemic to develop. Thus, it becomes obvious that commercial pesticide applicators must be somewhat familiar with the nature of the pathogen they are trying to control if they are to be successful.

Effects of Location on Diseases

The site where plants are located is extremely relevant in disease development. Wheat located in a valley is far more rust prone than wheat grown in an upland area with good air drainage. Apple trees grown in sites with well-drained fertile soil have no problems from the Phytophthora collar rot disease. In contrast, however, apple trees established in orchards with shallow, poorly drained clay soils have severe disease problems.

USING FUNGICIDES PROPERLY

Fungi and Plant Losses

Fungi compete with mankind throughout the world for food, fiber, and shelter more than all the other pests put together. Thus, the major discussion on control will be related to some form of fungicide.

Fungicides

In the broadest terms, a fungicide may be defined as an organic or inorganic chemical used to combat fungi or to protect plants from disease-inciting fungi. Most fungicides are solids and are mixed with inert ingredients and applied as a dust, or they are suspended in water and applied as a spray. A few fungicides are liquids and will form a solution when mixed with water, and they also are applied as sprays.

Principles of Fungicide Protection

The principle of fungicide protection falls into three (3) categories as follows: (1) Surface protection refers to applying the fungicide to the fruit, flowers, and leaves. By far, the greatest amount of chemicals are used as surface protectants. (2) Soil treatment is where the fungicide is applied to the soil to control soil-borne pathogens (root rots), in cold frames, greenhouses, hot beds, and plant beds. (3) Eradication usually means treatment of seed or chemotherapy of certain smut diseases and vascular diseases, respectively.

Functional Actions of Fungicides

Most fungicides function through the process of contact of the target organism. On contact, the fungicide acts as either a fungitoxin or as a fungistatic agent to the causal organism. If the fungus structure is killed on contact of the target organism, then the fungicide is said to be fungitoxic. On the other hand, if the target organism is prevented from sporulation or spore germination is inhibited, then the contact surface fungicide is said to be fungistatic, and after the fungicide is eroded away, the pathogen will start to grow again. Some fungicides act as systemics. In simple terms, they are absorbed by plant tissue on contact, or they are injected into the soil, absorbed through the roots, and distributed throughout the plant. These types of fungicide are rare, and most so-called systemics are absorbed locally and thus are only partially systemic (locally systemic). Eradicant fungicides are, as a rule, extremely toxic, and they kill the target organism quickly. The stronger ones, such as liquid lime-sulfur and many coppers, are also phytotoxic to the host; hence, their use is limited. Fumigants, whether in liquid or solid form, form vapors that destroy or inhibit fungi on contact.

Fungicide LD_{50}'s

The LD_{50} of most fungicides is relatively high when compared to the organic phosphates, ranging from 5,200 mg/kg oral on male rats for Zineb to 10,000 mg/kg oral on male rats for Benlate. In contrast, the LD_{50} for Parathion is 13 mg/kg oral for male rats. Therefore, fungicides are relatively safe when used as prescribed.

Fungicide Names

Fungicides are similar to people; they are identified by names. Each fungicide has a common or coined or generic name, a chemical name and a trade name. For example, the following compound is identified as dodine (common name), n-dodecylguanidine acetate (chemical name), and Cyprex (trade name), respectively.

Fungicide Applicator Equipment

Fungicides are applied by various methods and equipment. The type of equipment used generally depends on the type of plants to be protected and the nature of the target organism or organisms. The majority of all fungicides, however, are applied by various types of sprayers. Ground sprayers range from small hydraulic, high pressure, piston type pumps that are relatively inexpensive, to large, air-blast ones that cost 10 to 20 thousand dollars. The former type sprayer uses water as the diluent (the carrying agent) while the latter type uses air as the carrier. The only difference in using air and liquids as diluents is in the density (weight/cu. ft.) and visosity (fluid properties). Air weighs 0.073 lb/cu. ft. while water is 850 times heavier at 62.4 lb/cu. ft. A large air-blowing machine with a capacity of 95,000 CEM (95,000 x 0.073) moves 6,935 lb. of air per minute. If the machine is delivering 50 gal. of spray per minute, then the machine is moving 415 lb. of liquid/minute (50 x 8.3 lbs/gal). Or approximately 15% of the total weight is liquid; thus resulting in a major savings in liquid transport.

<u>Calibration Responsibility</u>

Commercial pesticide applicators must be familiar with the sprayer to be used to apply the toxic agent. No equipment, regardless of the cost or complexity, is any better than the operator. The sprayer must be properly calibrated to deliver the specified amount of the pesticide in question. The procedures to follow vary considerably, depending on the machine. Calibration instructions are furnished with every pesticide application device, or should be requested from the supplier or manufacturer of the equipment if not available. The instructions should be studied and followed carefully.

<u>Aircraft Application</u>

Fixed wing aircraft as well as helicopters are used for the application of fungicide sprays or dusts. Fixed-wing aircraft are more economical; hence, large areas are treated with them. Helicopters, however, are more maneuverable and can be used in areas that are inaccessible to fixed-wing aircraft. Flagmen are a necessity in applying fungicides or pesticides from the air. They direct the plane to the correct swath and they warn people to stay out of the toxin drift. The flagmen must avoid exposure; therefore, they should remain up-wind from the application swath.

Fungicide Dust

Several fungicides are applied as dusts. This type of application is rapid, and large areas can be covered quickly. Dust, however, must be applied during high humidities and preferably during times when the wind is less than 5 mph. The disadvantage of dust is drift, and it is washed off the target during heavy rains.

Drift Problems

Drift is one of the major problems associated with the use of sprays or dusts. Small droplets or dust particles are difficult to control; hence, a distressingly high percentage of the particles that leave the duster or spray nozzle never reach the target. If the spray particle is below 50 (micrones), it is difficult to stick the particle to the target. Thus, it may drift out of the target area. The rate of movement of a pesticide particle is reduced sharply from the time it leaves the nozzle in the droplet phase phase until it reaches the target. For example, the particle may leave the nozzle at 95 mph, but lose speed down to 16-18 mph by the time it has traveled 25 feet.

This reduction in speed of the particle adds time to the target and permits evaporation on a warm day which reduces the size of the particles and multiplies the drift hazard. If a fungicide or pesticide drifts from the target area to another crop for which the pesticide is not approved, the latter crop may be condemned. Therefore, correct measures should be used to avoid drift as follows: (1) Short distance between nozzle and target; (2) large spray droplets; (3) wind velocity below 10 mph; (4) low temperature; (5) high humidity; and (6) large volume of water.

Soil Fumigants

Soil fumigants can be applied by a variety of equipment ranging from sprinkling cans to tractor-mounted or tractor-pulled applicators or attachments. The less volatile fumigants may be applied to the soil as liquids, crystalline solids, or granules. Methyl bromide is a gas; once released from its container, it must be confined under a gas-proof sheet if used for soil fumigation. Fumigants should be applied only by professional operators who are trained in their proper use and have the necessary safety equipment. ALL fumigants are toxic to man. Some of them are also highly flammable.

Special Precautions

Commercial pesticide applicators should be familiar with the type of surface they are trying to cover. They should know if a wetting agent or sticker is required. The applicator should have knowledge of where to apply the fungicide. He should also know if both sides of the leaves are required to be covered to control the pathogen. The man in charge of operations should know how often a specific fungicide should be applied to be effective and when the protection program should be started.

Liability

Who is liable for chemical pesticides? 1) The chemical company? Probably not - since it is so closely regulated by government agencies, the chemical company does not have as much opportunity to be at fault. Furthermore, it is partially protected by its warranty clause. Read the label.

2) The Chemical Applicator? Not unless he has been negligent. Government regulations keep a tight rein on the commercial applicator, too, thereby reducing his chance to be at fault. When the commercial applicator makes a mistake, he has probably also broken a law and risked loss of his license to operate.

3) So who's left? THE GROWER! That's right. The ultimate responsibility for any damage, injury, or death resulting from improper use of pesticides rests on the grower who authorized the use of the materials.

The grower must understand the hazards involved in using pesticides and must be alert to avoiding such dangers as (1) nflicting death or injury upon himself, his family, his employees, or others; (2) illegal residue which can wipe out a crop or a profit; (3) killing livestock, bees, fish, poultry, or pets; (4) drift that damages neighboring crops; (5) public nuisance or threat to public health; and (6) lawsuits, court injunctions, and government regulation resulting from any of the above.

Do's and Don'ts of Storing and Mixing Chemicals

BE SURE TO: (1) obtain required permits; (2) read the label twice (every time you use it); (3) use proper protective clothing; (4) pour dusts and powders slowly; (5) remove screen on spray tank before putting in concentrate; (6) clean out your measuring instrument after use; (7) store chemicals under lock and key in a dry room; (8) keep chemicals out of the reach of children; and (9) handle empty containers as carefully as those that are full, and dispose of empty containers as described on the label by the manufacturer.

DO NOT mix chemicals that are incompatible. DO NOT mix chemicals in an enclosed room. DO NOT allow anyone to sleep in rooms where chemicals are stored. DO NOT think of emptied containers as being empty or harmless. DO NOT permit delivery of pesticides unless a responsible representative or employee is on hand to receive and properly store them.

Applying Chemicals Safety

(1) Have your equipment in good operating condition and properly calibrated; (2) make sure there is no leakage; (3)

use a coarser droplet from spray nozzle when possible; (4) spray so drift will flow away from you; (5) wear protective clothing and wash it after each use; (6) have exactly the correct amount of material made up, and apply the entire batch evenly to the field; (7) empty and flush the spray rig thoroughly when finished (neutralizing agents may be used); (8) flush the formulating area; (9) post the area according to law.

DO NOT allow unnecessary or unauthorized persons into the area. DO NOT apply under bad drift conditions. DO NOT re-enter the area until the chemical has become harmless. DO NOT inhale sprays or dusts.

Do's and Don'ts of General Pesticide Safety

DO: (1) Use protective clothing; (2) keep the label legible; (3) read the label twice; (4) keep chemicals out of the reach of children; (5) lock up chemicals for storage and post a warning sign; (6) store in original containers only; (7) wash with soap and water after application; (8) make sure your local physician is informed on what chemicals you are using and how to treat the accidental poisonings which may occur; (9) if you feel ill, see your doctor promptly; (10) follow first aid procedures if you spill concentrates on your skin or clothing; (11) provide adequate supervision of every step of pesticide handling by a qualified person; (12) keep employees informed on what chemicals are to be used and how to avoid personal injury; (13) use the least hazardous material that will adequately do the job; and (16) use the right material on the right crop at the right time.

DO NOT inhale sprays or dusts. DO NOT store chemicals in drinking containers. DO NOT smoke or eat when spraying or dusting. DO NOT spill pesticides on skin or clothing. DO NOT re-enter treated areas until dusts, sprays, and fumes have dissipated. DO NOT allow children to play in or around areas where chemicals are stored or where they have been recently applied. DO NOT work alone when using dangerous agricultural chemicals.

Conclusion

Generally speaking, pesticides have been of major benefit to man. They have saved millions of lives through control of disease-carrying insects. They have minimized catastrophic crop damage from pests. Although pesticides have been a great asset to our way of life and have increased the life expectancy for some people in underdeveloped countries from about 32 to 47 years, we have advanced to the gray zone where strict regulations must be adhered to in order to ensure a safe and productive environment for those who come or follow.

There are presently over 32,000 pesticide products that are made from one or more of 900 chemical compounds. Thus, it is obvious that pesticides must be under strict management regulations.

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, and September 30, 1977, in cooperation with the U.S. Department of Agriculture. W. R. Van Dresser, Dean, Extension Division, Cooperative Extension Service, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061; M. C. Harding, Sr., Administrator, 1890 Extension Program, Virginia State College, Petersburg, Virginia 23803.