$2.50
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Applying Pesticides Correctly

A Guide for Private and Commercial Applicators

OREGON STATE UNIVERSITY EXTENSION SERVICE

SAFETY CODE FOR HANDLING PESTICIDES

1. Always read the label before using sprays or dusts. Note warnings and cautions each time before opening the container.
2. Keep sprays and dusts out of reach of children, pets, and irresponsible people. They should be stored outside of the home and away from food and feed.
3. Always store sprays and dusts in original containers and keep them tightly closed. Never keep them in anything but the original container.
4. Never smoke while spraying or dusting.
5. Avoid inhaling sprays or dusts. When directed on label, wear protective clothing and masks.
6. Do not spill sprays or dusts on the skin or clothing. If they are spilled, remove contaminated clothing immediately and wash thoroughly.
7. Wash hands and face and change to clean clothing after spraying and dusting. Also wash clothing each day before reuse.
8. Cover food and water containers when treating around livestock or pet areas. Do not contaminate fishponds.
9. Use separate equipment for applying hormone-type herbicides in order to avoid accidental injury to susceptible plants.
10. Always dispose of empty containers so that they cannot harm humans, animals, or valuable plants.
11. Observe label directions and cautions to keep residues on edible portions of plants within the limits permitted by law.
12. If symptoms of illness occur during or shortly after spraying or dusting, call a physician or get the patient to a hospital immediately.

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In memory of Dr. Gerald T. Weekman for his many years of dedicated service and concern for the safe handling and use of pesticides.

Preface

This manual was prepared to supercede two earlier publications: "Apply Pesticides Correctly, A Guide for Private Applicators" and "Apply Pesticides Correctly, A Guide for Commercial Applicators," both published in 1974 by the U. S. Department of Agriculture and the Environmental Protection Agency. In contrast to these two predecessors, this manual attempts to do more than establish a working threshold for those applicators seeking initial certification as provided by the Federal Insecticide, Fungicide and Rodenticide Act of 1972.

This manual contains information that will allow you, the applicator, to satisfy the general requirements in all states. As an applicator, however, you should keep in mind that each state has adopted rules establishing minimum requirements for certification and recertification of applicators operating within its borders. Because certification does require knowledge of specific situations among the various categories of pesticide application, be advised to check carefully with your local agricultural extension agent to learn of your state's general and specific certification requirements.

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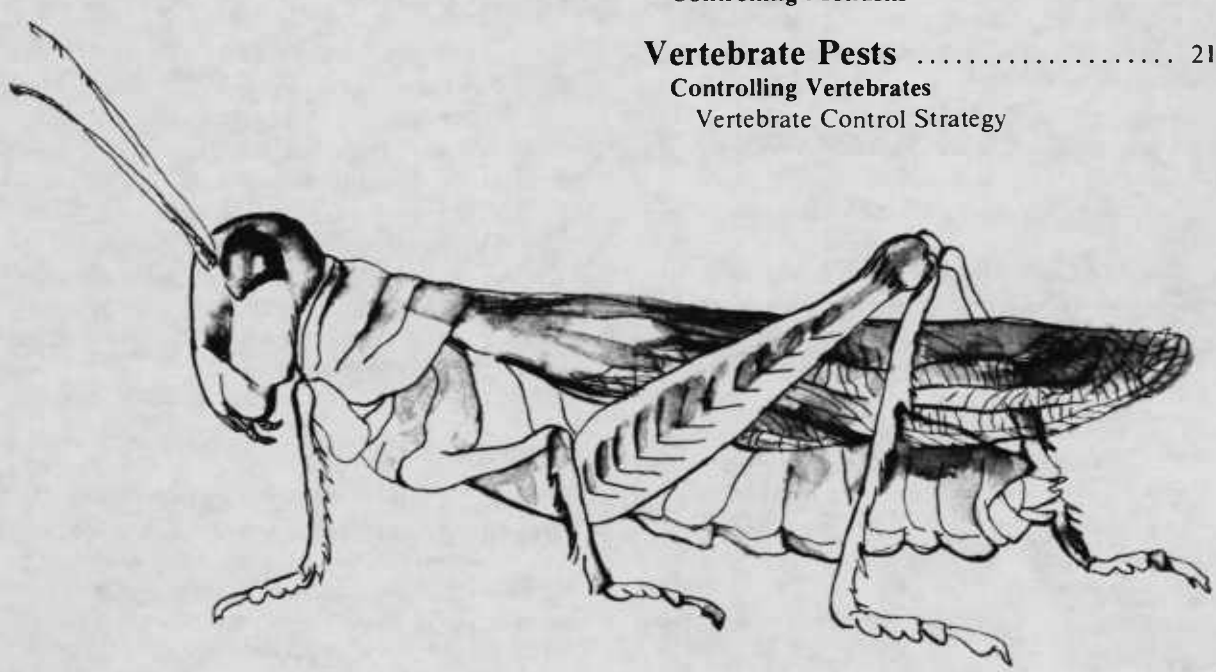


Pests and Pest Control

A pest is anything that:

- competes with humans, domestic animals, or crops for food, feed, or water,
- injures humans, animals, crops, structures, or possessions,
- spreads disease to humans, domestic animals, or crops,
- annoys humans or domestic animals.

Pests can be placed in five main categories:

- insects (and related animals),
- plant disease agents,
- weeds,
- mollusks, and
- vertebrates.

As a certified applicator, you must be familiar with the pests likely to be encountered in the area covered by your certification category. To be able to identify and control the pests, you need to know about some aspects of:

- the common features of pest organisms,
- characteristics of the damage they cause, and
- pest development and biology.

You can get identification aids, publications, and pictures from your Cooperative Extension Service agent or ask other experts for advice.

To solve pest problems, the applicator must:

- identify the pest,
- know what control methods are available,
- evaluate the benefits and risks of each method or combination of methods,
- choose the methods that are most effective and will cause the least harm to people and the environment,
- use each method correctly,
- observe local, state, and federal regulations that apply to the situation.

The most important principle of pest control is this:

Use a pest control method only when that method will prevent the pest from causing more damage than is reasonable to accept.

Even though a pest is present, it may not do very much harm. It could cost more to control the pest than would be lost because of the pest's damage.

The three main objectives of pest control are:

- prevention—keeping a pest from becoming a problem,
- suppression—reducing pest numbers or damage to an acceptable level,
- eradication—destroying an entire pest population.

Pest Control Methods

The use of a combination of methods to control pests is basic to all pest control. Successful pest control is based on the ability to:

- keep pest damage to a minimum by choosing an appropriate combination of control methods,
- recognize when direct action, such as a pesticide application, is necessary, and
- endanger the environment as little as possible.

The combination of methods you choose will depend on the kind and amount of control you need.

Natural Forces

Some natural forces act on pests, causing the populations to rise and fall. These natural forces act independently of humans and may either help or hinder pest control. You usually cannot alter the action of natural forces on a pest population, but you should be aware of their influence and take advantage of them whenever possible. Some forces which affect the pest population include climate, natural enemies, topography, and food and water supply.

Climate

Weather conditions, especially temperature, day length, and humidity, affect pests' activity and their rate of reproduction. Pests may be killed or suppressed by rain, frost, freezing temperatures, drought, or other adverse weather.

Climate also affects pests indirectly by influencing the growth and development of their hosts. The population of plant-eating pests is related to growth of the host plants. Unusual weather conditions can change normal patterns so that increased or decreased damage results.

Natural Enemies

Birds, reptiles, amphibians, fish, mammals, and predatory and parasitic insects feed on some pests and help control their numbers. More than half of all insect and insect-like species feed on other insects, some of which are pests. Disease organisms often suppress pest populations.

Topography

Features such as mountains and large bodies of water restrict the spread of many pests. Other features of the landscape can have similar effects. Soil type is a prime factor affecting wireworms, grubs, nematodes, and other soil organisms. Some pests live in heavy, poorly drained soil, others in light, sandy soils. Soil type also affects the distribution of plants (including weeds), which in turn affects the population of insects and other plant pests.

Food and Water Supply

Pest populations can thrive only as long as their food and water supply lasts. Once the food source—plant or animal—is exhausted, the pests die or become inactive. The life cycle of many pests depends on the availability of water.

Other Methods

Unfortunately, natural controls often do not control pests quickly enough to prevent unacceptable injury or damage. Then other pest control methods must be initiated. Those available include:

- host resistance,
- biological control,
- cultural control,
- mechanical control,
- sanitation, and
- chemical control.

Host Resistance

Some crops, animals, and structures resist pests better than others. Some varieties of crops, wood, and animals are immune to certain pests. Use of resistant types helps keep pest populations below harmful levels by making the environment less favorable for the pests. Host resistance works in two main ways:

- chemicals in the host prevent the pest from completing its life cycle,
- the host is more vigorous or tolerant than other varieties and thus less likely to be seriously damaged by pest attacks.

Biological Control

Biological control involves the use of naturally occurring enemies—parasites, predators, and disease agents (pathogens). It also includes methods by which the pest is biologically altered, as in the production of sterile males and the use of pheromones or juvenile hormones. Most kinds of biological control agents occur naturally. Releasing more of a pest's enemies into the target area can supplement this natural control.

Biological control is never complete. The degree of control fluctuates. There is always a time lag between pest population increase and the corresponding increase in natural controls. But, under proper conditions, sufficient control can be achieved to eliminate the threat to the crop or animal to be protected. Biological control can be a low-cost control method particularly suited to low-value crops (pastureland, clover, and hay crops) or in areas where some injury can be tolerated (golf course fairways, forest areas).

Cultural Control

Cultural practices are agricultural practices used to alter the environment, the condition of the host, or the behavior of the pest to prevent or suppress an infestation. Planting, growing, harvesting, and tillage practices sometimes can be manipulated to reduce pest populations. Other practices such as crop rotation, pasture rotation, varying the time of planting, and use of trap crops also affect pests.

Mechanical Control

Devices and machines used to control pests or alter their environment are called mechanical controls. Traps, screens, barriers, radiation, and electricity can sometimes be used to prevent the spread of pests or reduce an infestation. Lights, heat, and refrigeration can alter the environment sufficiently to suppress or eradicate some pest populations.

Sanitation

Sanitation practices help to suppress some pests by removing sources of food and shelter. Other forms of sanitation which help prevent pest spread include using pest-free seeds or plants and decontaminating equipment, livestock, and other possible carriers before allowing them to enter a pest-free area.

Chemical Control

Pesticides are chemicals used to destroy pests, control their activity, or prevent them from causing damage. Some pesticides either attract or repel pests. Chemicals which regulate plant growth or remove foliage may also be classified as pesticides.

Pesticides are generally the fastest way to control pests. In many instances, they are the only weapon available. Choosing the best chemical for the job is important.

Pest Resistance to Pesticides

The ability of pests to resist poisoning is called pesticide resistance. Consider this when planning pest control programs that rely on the use of pesticides.

Rarely does any pesticide kill all the target pests. Each time a pesticide is used, it selectively kills the most susceptible pests. Some pests avoid the pesticide. Others are able to withstand its effects. Pests that are not destroyed may pass along to their offspring the trait that allowed them to survive.

When we use one pesticide repeatedly in the same place, against the same pest, the surviving pest population may show greater resistance to the pesticide than did the original population. Some pests have become partially immune to poisoning by certain pesticides.

Not every pesticide failure is caused by pest resistance, however. Make sure that you have used the correct pesticide and the correct dosage, and that you have applied the pesticide correctly. Also remember that the pests that are present may be part of a new infestation that occurred after the chemical was applied.

Factors Affecting Pesticide Use Outdoors

Soil Factors—Organic matter in soils may "tie up" pesticides, limiting their activity. Soils with high organic matter content may need higher rates of some pesticides for best control.

Soil texture also affects the way pesticides work. Soils with fine particles (silts and clays) have the most surface area. They may need higher rates for total coverage. Coarser soils (sands) have less surface area. Use lower rates on them.

Surface Moisture—Pesticides work best with moderate surface moisture. Wetness may keep the pesticide from adequately contacting the protected surface. Dryness may prevent the pesticide from spreading evenly over the surface and contacting the target pest.

Rain may interfere with pest control by causing pesticides to run off or to leach down through the soil. Rain during or soon after over-the-top or foliar applications may wash pesticides off the plant. However, some protectant fungicides are sometimes purposely applied just before periods of expected high humidity and light rain. When preemergence pesticides are applied to the surface, moderate rainfall aids in carrying them down through the soil to the pests. Rain may also release pesticide action after some granular applications.

Humidity and Temperature—Humidity also affects the way pesticides work. Herbicides often work best when weeds are growing fast—usually in high humidity and optimum temperature. However, these same conditions may make the protected plant more susceptible to pesticide injuries.

High temperature and sunlight will cause some pesticides to break down when they are left exposed on top of the soil or on other surfaces. Low temperatures may slow down or stop the activity of some pesticides.

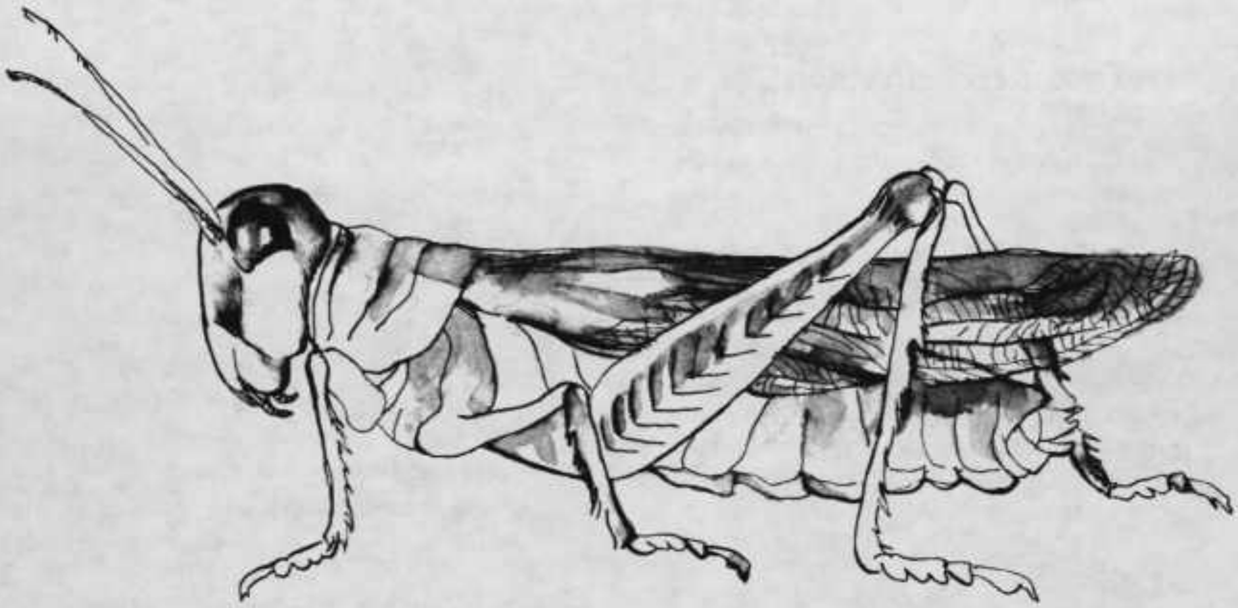
Wind—Wind speed and direction can greatly alter the effectiveness of a pesticide application. Excessive wind can blow the pesticide off target and result in inadequate control. Even moderate winds can greatly alter the coverage of ULV and mist blower applications. Sometimes the applicator can compensate for minor winds by applying the pesticides at an angle where the winds blow the chemical towards the area to be protected.

Insects

There are more kinds of insects on earth than all other living animals combined. They are found in soil, hot springs, water, snow, air, and inside plants and animals. They eat the choicest foods from our table. They can even eat the table.

The large number of insects can be divided into three categories according to their importance to man:

- species of minor importance—About 99 percent of all species are in this category. They are food for birds, fish, mammals, reptiles, amphibians, and other insects. Some have aesthetic value.
- beneficial insects—In this small but important group are the predators and parasites that feed on destructive insects, mites, and weeds. Examples are ladybird beetles, some bugs, ground beetles, tachinid flies, praying mantids,



many tiny parasitic wasps, and predaceous mites. Also in this category are the pollinating insects, such as bumblebees and honeybees, some moths, butterflies, and beetles. Without pollinators, many kinds of plants could not grow. Honey from honeybees is food for humans. Secretions from some insects are made into dyes and paints. Silk comes from the cocoons of silkworms.

- destructive insects—Although this is the category which usually comes to mind when insects are mentioned, it includes the fewest number of species. These are the insects that feed on, cause injury to, or transmit disease to humans, animals, plants, food, fiber, and structures. In this category are, for example, aphids, beetles, fleas, mosquitoes, caterpillars, and termites.

Physical Characteristics

All insects in the adult stage have two physical characteristics in common. They have three pairs of jointed legs, and they have three body regions —the head, thorax, and abdomen.

Head

The head contains antennae, eyes, and mouthparts. The antennae vary in size and shape and can be a help in identifying some pest insects. Insects have compound eyes, made up of many individual eyes. These compound eyes enable insects to discern motion, but probably not clear images.

The four general types of mouthparts are:

- chewing,
- piercing-sucking,
- sponging, and
- siphoning.

Chewing mouthparts contain toothed jaws that bite and tear the food. Cockroaches, ants, beetles, caterpillars, and grasshoppers are in this group. **Piercing-sucking mouthparts** consist of a long slender tube which is forced into plant or animal tissue to suck out fluids or blood. Insects with these mouthparts are stable flies, sucking lice, bed bugs, mosquitoes, true bugs, and aphids. **Sponging mouthparts** have a tubular tonguelike structure with a spongy tip to suck up liquids or soluble food. This type of mouthpart is found in the flesh flies, blow flies, and house flies. **Siphoning mouthparts** are formed into a long tube for sucking nectar. Butterflies and moths have this type.

Thorax

The thorax contains the three pairs of legs and (if present) the wings. The various sizes, shapes, and textures of wings and the pattern of the veins can be used to identify insect species.

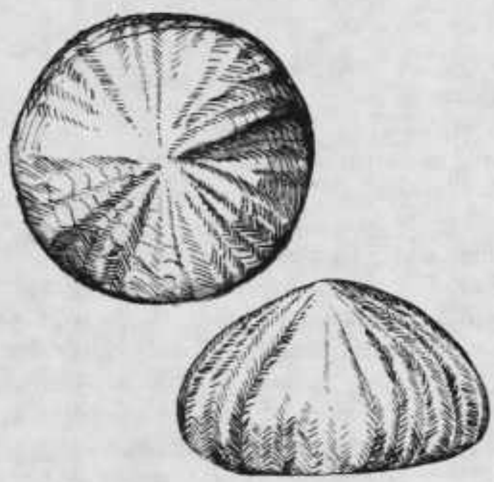
The forewings take many forms. In the beetles, they are hard and shell-like; in the grasshoppers, they are leathery. The forewings of flies are membranous; those of true bugs are part membranous and part hardened. Most insects have membranous hindwings. The wings of moths and butterflies are membranous but are covered with scales.

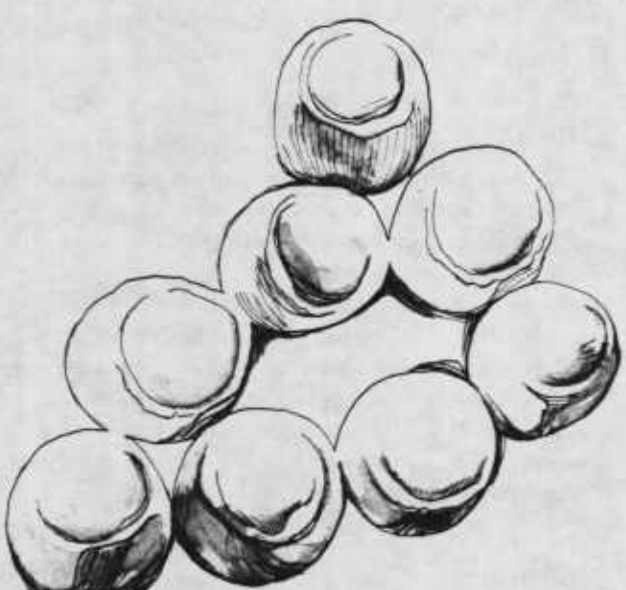
Abdomen

The abdomen is usually composed of 11 segments. Along each side of most of the segments are openings (called spiracles) through which the insect breathes. In some insects, the tip end of the abdomen carries tail-like appendages.

Insect Development

Most insect reproduction results from the males fertilizing the females. The females of some aphids and parasitic wasps produce eggs without mating. In some of these insect species, males are unknown. A few insects give birth to living young; however, life for most insects begins as an egg. Temperature, humidity, and light are some of the major factors influencing the time of hatching. Eggs come in various sizes and shapes—elongate, round, oval, and flat. Eggs of cockroaches, grasshoppers, and praying mantids are laid in capsules. Eggs may be deposited singly or in masses on or near the host—in soil or on plants, animals, or structures.





Metamorphosis

The series of changes through which an insect passes in its growth from egg to adult is called metamorphosis.

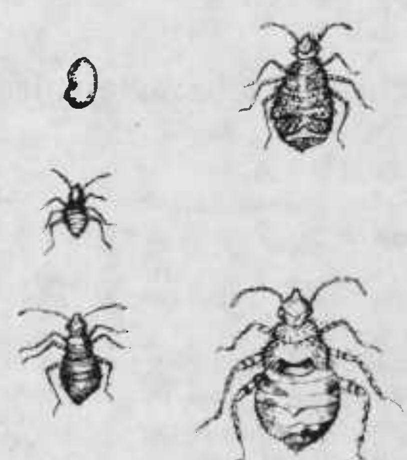
When the young first hatches from an egg, it is either a larva, nymph, or naiad. After feeding for a time, the young grows to a point where the skin cannot stretch further; the young molts and new skin is formed. The number of these stages (called instars) varies with different insect species and, in some cases, may vary with the temperature, humidity, and availability and kinds of food. The heaviest feeding generally occurs during the final two instars.

No Metamorphosis

Some insects do not change except in size between hatching and reaching the adult stage. The insect grows larger with each successive instar until it reaches maturity. Examples are silverfish, firebrats, and springtails. The food and habitats of the young (called nymphs) are similar to those of the adult.

Gradual Metamorphosis

Insects in this group pass through three quite different stages of development before reaching maturity: egg, nymph, and adult. The nymphs resemble the adult in form, eat the same food, and live in the same environment. The change of the body is gradual, and the wings become fully developed only in the adult stage. Examples are cockroaches, lice, termites, aphids, and scales.



Incomplete Metamorphosis

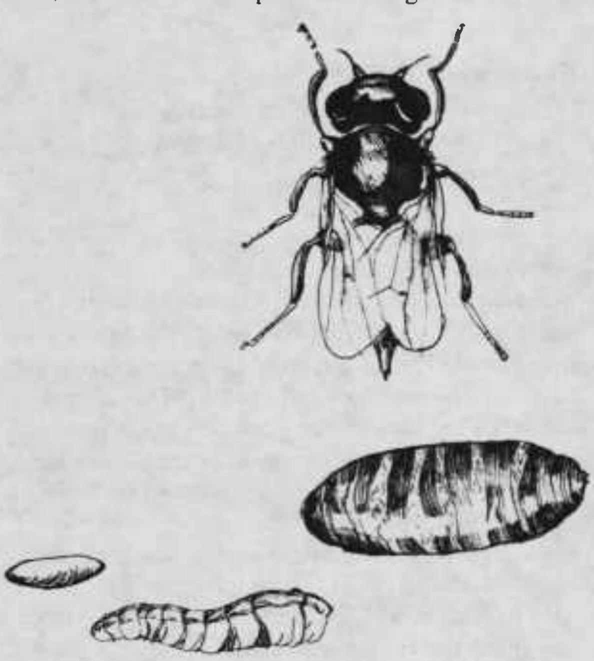
The insects with incomplete metamorphosis also pass through three stages of development: egg, naiad, and adult. The adult is similar to the young, but the naiads are aquatic. Examples: dragonflies, mayflies, and stoneflies.

Complete Metamorphosis

The insects with complete metamorphosis pass through four stages of development: egg, larva, pupa, and adult. The young, which may be called larvae, caterpillars, maggots, or grubs, are entirely different from the adults. They usually live in different situations and in many cases feed on different foods than adults. Examples are the beetles, butterflies, flies, mosquitoes, fleas, bees, and ants.

Larvae hatch from the egg. They grow larger by molting and passing through one to several instar stages. Moth and butterfly larvae are called caterpillars; some beetle larvae are called grubs; most fly larvae are called maggots. Caterpillars often have legs; maggots are legless. Weevil grubs are legless; other kinds of beetle larvae usually have three pairs of legs.

The pupa is a resting stage during which the larva changes into an adult with legs, wings, antennae, and functional reproductive organs.



Insect-Like Pests

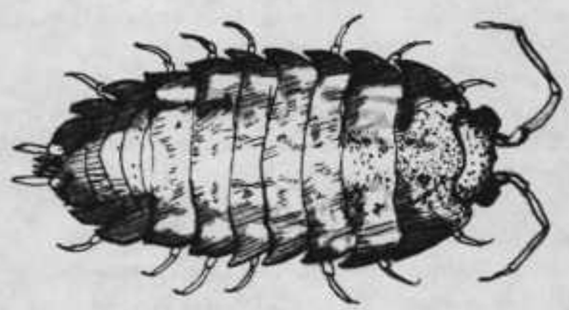
Mites, ticks, spiders, sowbugs, pillbugs, centipedes, and millipedes resemble insects in size, shape, life cycle, and habits. Pest species usually can be controlled with the same techniques and materials used to control insects.

Arachnids

Ticks, scorpions, spiders, and mites have eight legs and only two body regions. They are wingless and lack antennae. The metamorphosis is gradual and includes both larval and nymphal stages. Eggs hatch into larvae (six legs) which become nymphs (eight legs) and then adults. Ticks and mites have modified piercing-sucking mouthparts; spiders and scorpions have chewing mouthparts.

Crustaceans

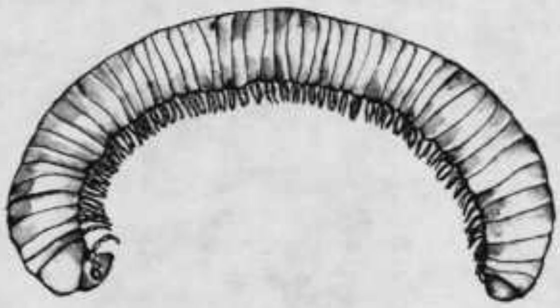
Sowbugs and pillbugs, water fleas, and wood lice have 14 legs. They are wingless and contain only one segmented body region. They have two pairs of antennae and chewing mouthparts. Sowbugs and pillbugs have a hard, protective shell-like covering and are related to the aquatic lobsters, crabs, and crayfish. The metamorphosis is gradual, and there may be up to 20 instars before adulthood is reached.



Centipedes and Millipedes

Centipedes are made up of 30 segments, each containing one pair of legs. They have chewing mouthparts. Some species can inflict painful bites on humans.

Millipedes contain 30 segments and are cylindrical like an earthworm. The body is wingless and each segment bears two pairs of legs. The antennae are short and mouthparts are comblike. Millipedes feed on decaying organic matter, seeds, bulbs, and roots.



There is no metamorphosis; centipedes and millipedes do not change except in size between hatching and reaching the adult stage.

Controlling Insects

Control of insects and their relatives may involve any of the three basic pest control objectives. Control is usually aimed at **suppression** of pests to a point where the presence or damage level is acceptable. **Prevention** and **eradication** are useful only in relatively small, confined areas such as indoors or in programs designed to keep foreign pests out of a new area.

The key to successful control of insect and insect-like pests is knowledge of the stage(s) of their life cycle in which they are most vulnerable. It is generally difficult to control insects in either the egg or pupal stage, because these stages are inactive: not feeding, immobile, and often in inaccessible areas such as underground, in cocoons or cases, and in cracks or crevices.

Controlling insects in the late instar and adult stages is moderately successful. The insects, because of their size, are most visible in these stages and usually are causing the most destruction. Therefore, control attempts are often begun at these times. However, the larger insects are often more resistant to pesticides, and adults already may have laid eggs for another generation.

The best control usually is achieved during the early larval or nymphal stages when the insects are small and vulnerable. Control during these stages requires careful monitoring of pest populations and thorough knowledge of the pest's life cycle, habitats, and feeding patterns.

Environmental conditions, such as humidity, temperature, and availability of food, can alter the rate of growth of insects and thus affect the length of the life cycle. Optimum environments (usually warm and humid) can decrease the time of development from egg to adult.

Insect Control Strategy

Control methods used for insects include:
- host resistance,
- biological control,
- cultural control,
- mechanical control,
- sanitation, and
- chemical control.

Host Resistance

Some crops, animals, and structures resist insects and their relatives better than others. Some varieties of crops and wood are immune to certain insects. Use of resistant types helps keep pest populations below harmful levels by making the environment less favorable for the pests.

Biological Control

Biological control of insects includes:
- predators and parasites,
- pathogens,
- sterile males,
- pheromones, and
- juvenile hormones.

Predators and Parasites—Organisms known to attack insect (and insect-like) pests in their native environment can be imported or reared in laboratories and released in infested areas. This is done only after the parasites or predators are determined to be harmless to man, animals, plants, and other beneficial organisms. For example, several kinds of parasites and predators of the alfalfa weevil have been imported from Europe and Asia and released in the infested areas in this country. Several species have become established and are helping to reduce pest numbers. However, they do not always prevent serious outbreaks and the resultant damage.

Pathogens—Parasitic bacteria, viruses, and fungi may be introduced into an infested area to control insects by subjecting them to disease. These disease agents, like predators, are often found in the pest's native environment. They can be imported or they can be reared in laboratories.

For example, the use of pathogens is an important part of the pest control program for Japanese beetles. Japanese beetles are subject to attack by two naturally occurring species of bacteria which cause the fatal milky disease. Preparations containing spores of the contagious bacteria are produced commercially and released in infested areas.

Sterile Males—Males of some pest insect species may be reared and sterilized in laboratories and released in large numbers into infested areas to mate with native females. These matings produce infertile eggs or sterile offspring and help reduce the pest population. This technique has been used successfully in only a few species and is still being developed. The screw worm, which attacks cattle, is one insect on which this technique has been effective.

Pheromones—Some insects (and insect-like organisms) produce natural chemicals, called pheromones, which cause responses in other insects of the same or very closely related species. Once a particular insect pheromone is identified and the chemical is synthetically produced, it can be used to disrupt the behavior of that insect species. Synthetic pheromones may be used to disrupt normal reproduction, or they may be used to attract the pests into a trap.

Because each pheromone affects only one specific group of insects, their use poses no risk of harm to other organisms, including man. Unfortunately, only a few have been discovered and produced synthetically, and the use of pheromones is still in the experimental stages. It is very costly to discover, produce, and market a chemical which will be useful in controlling only one pest species.

Juvenile Hormones—Another type of species-specific chemical is also being developed. Juvenile hormones interrupt the metamorphosis of insects (and insect-like organisms). These chemicals prevent reproduction by keeping immature insects from maturing into adults. Each chemical acts against a single pest species and has the same advantages and disadvantages as pheromones. The few juvenile hormones available are usually applied as a broadcast spray to reach as many target pests as possible.

Cultural Control

Cultural control methods for insects include:

- crop rotation,
- trap crops,
- delay of planting, and
- harvest timing.

Crop Rotation—Taking infested fields out of production and leaving them fallow or planting an alternate crop may deprive pests of host plants on which to feed and reproduce. Rotations are most effective against insects which have long life cycles and infest the crop during all stages of growth. Many of the traditional rotational schemes were developed to reduce pest problems.

Trap Crops—Other crops attractive to the pests may be planted early or nearby to draw pests away from the main crop. Destruction of such crops at the proper time breaks the reproductive cycle of the pest before the desired crops are infested. To control the pickle worm in cucumbers, for example, the grower might also plant yellow squash, to which the pest is more attracted. The squash crop can be sprayed or destroyed before the pest can complete its development.

Delay of Planting—Delaying the date of planting may reduce the population of certain pests by eliminating the host plant needed for food and reproduction when the pest population is at its peak. For example, prevention of Hessian fly damage in wheat can be avoided by delaying planting until fly reproduction has ended for the year.

Harvest Timing—Crops should not be left in the field after maturity if they are susceptible to pest attack. For example, wireworm damage to mature potatoes causes a serious quality reduction. Damage increases if the crop is left in the ground even for a very short time after maturity.

Mechanical Control

Mechanical controls used on insects are:

- screens and other barriers,
- traps,
- light,
- heat and cold, and
- radiation and electrocution.

Screens and Other Barriers—A major aspect of insect control indoors is the use of screens and other barriers to keep insects out. Flying insects, such as mosquitoes, wasps, and flies, are kept outside by blocking any openings with screening. The effective mesh size depends on the size of the smallest flying insect pests in that environment. Crawling insects are also kept outside by screens or by other barriers such as tightly sealed doors and windows. Barriers made of sticky substances sometimes can be used to stop crawling insects from entering an area.

Traps—Traps are sometimes used to control the target pest. More often, however, they are used to survey for the presence of insect pests and to determine when the pest population has increased to the point where control is needed.

Light—Many insect pests may be attracted to artificial light at night. However, since not all the pests are killed, the light attractant may actually help create infestations.

Heat and Cold—It is sometimes possible to expose insect pests to the killing effects of the heat of summer or cold of winter. Insects that feed on stored grain and flour, for example, can sometimes be controlled by ventilating grain elevators in winter.

Radiation and Electrocution—Radiation and electrocution are sometimes used to kill pests in a limited area. The electric screens in such places as outdoor restaurants and amusement parks are used to attract and electrocute a variety of nocturnal insect pests. Ionizing radiation is used to sterilize pests by destroying reproductive tissues, and ultrasonic radiation is used to kill pests in some products.

Sanitation

Cultivation, moldboard plowing, and burning of crop residues soon after harvest greatly aid in the control of some insect pests on agricultural crops. Pink bollworm infestations in cotton, for example, can be greatly reduced by plowing the field immediately after harvest.

Removing litter from around buildings helps control pests which use it for breeding or shelter. Ants, termites, and some other indoor pests may be suppressed by using this technique.

Sanitation is important in the control of animal parasites and filth flies. Fly control in and around barns and livestock pens, for example, is greatly aided by proper manure management. A major aspect of fly control in residential areas and cities is weekly or biweekly garbage removal. This scheduling prevents fly eggs and maggots in the garbage from reaching adult fly stage, since the fly's life cycle is 10 to 14 days, even in very warm weather.

Indoors, sanitation is a major method of preventing insect pest problems. Keeping surfaces in restrooms and food preparation areas immaculately clean and dry is an important factor in suppressing or eliminating ant, fly, and cockroach infestations.

Chemical Control

Chemicals used to control insects and insect-like pests include insecticides, miticides, and acaricides. Most chemicals used to control insects act in one of two ways:

- repellents—These products keep pests away from an area or from a specific host. Products designed to keep mosquitoes, chiggers, and ticks off humans are an example.
- direct poisons—Common insecticides include chemicals that poison one or more life systems in the pest. Some will poison an insect if they are eaten (stomach poisons); others require only contact with the insect's body (contact poisons).

A few insecticides interfere mechanically with the insect's functions. For example, mineral oils suffocate insects; silica dusts destroy their body water balance by damaging their protective wax covering.

Outdoors—With few exceptions, insecticides labeled for outdoor use are designed to be used for full coverage of an area. The objective is to cover the entire surface to be protected with a residue of active insecticide. Insects which then eat or otherwise contact the treated surface are killed.

Thorough knowledge of the target insects helps determine the frequency of application and the choice of chemicals. One well-timed application of an effective pesticide may provide the desired control. Sometimes repeated insecticide applications will be necessary as the insect infestation continues and pesticide residues break down.

The pesticide label, Cooperative Extension Service recommendations, and other sources usually indicate a range of treatment intervals and dosages. By carefully observing the pest problem and applying chemicals when the pests are most vulnerable, you often will be able to use lower doses of pesticides and apply them less often. Over a long growing period, this can mean considerable savings in time, money, and total pesticide chemicals applied.

Most control strategies take advantage of the natural controls provided by the pest's natural enemies. When you choose a pesticide, consider what effect it will have on these beneficial organisms. Ask your pesticide dealer, your agricultural extension agent, or other experts for advice.

Indoors—Most indoor insect control is aimed at prevention or eradication of the pest problem while minimizing the exposure of humans and animals to chemicals. The most common application techniques are crack and crevice treatments, spot treatments, and fumigation of entire structures, commodities, or individual pieces of equipment.

Plant Disease Agents

A plant disease is any harmful condition that makes a plant different from a normal plant in its appearance or function. Plant diseases caused by biological agents (pathogens) are of primary interest to pesticide applicators because they often can be controlled with pesticides. Pathogens include:

- fungi,
- bacteria,
- viruses and mycoplasmas, and
- nematodes.

Parasitic seed plants, discussed in the section on weeds, are sometimes considered plant disease agents because of the type of injury they cause to the host plant.

Pathogenic Plant Diseases

Pathogens which cause plant disease are parasites which live and feed on or in host plants. They can be passed from one plant to another. Three factors are required before a pathogenic disease can develop—a susceptible host plant, a pathogenic agent, and an environment favorable for development of the pathogen.

A pathogenic disease depends on the life cycle of the parasite. The environment affects this cycle greatly. Temperature and moisture are especially important. They affect the activity of the parasite, the ease with which a plant becomes diseased, and the way the disease develops.

The disease process starts when the parasite arrives at a part of a plant where infection can occur. If environmental conditions are favorable, the parasite will begin to develop. If the parasite can get into the plant, the infection starts. The plant is diseased when it responds to the parasite.

The three main ways a plant responds are:

- overdevelopment of tissue, such as galls, swellings, and leaf curls,
- underdevelopment of tissue, such as stunting, lack of chlorophyll, and incomplete development of organs, and
- death of tissue, such as blights, leaf spots, wilting, and cankers.

The parasites which cause plant diseases may be spread by wind; rain; insects, birds, snails, slugs, and earthworms; transplant soil; nursery grafts; vegetative propagation (especially in strawberries, potatoes, and many flowers and ornamentals); contaminated equipment and tools; infected seed stock; pollen; dust storms; irrigation water; and people.

Fungi

Fungi are plants that lack chlorophyll and cannot make their own food. They get food by living on other organisms. Some fungi live on dead or decaying organic matter. Most fungi are beneficial because they help release nutrients from dead plants and animals and thus contribute to soil fertility. These fungi are a pest problem when they rot or discolor wood. They can do considerable damage to buildings and lumber which are improperly ventilated or in contact with water or high humidity.

Most fungi which cause plant diseases are parasites on living plants. They may attack plants and plant products both above and below the soil surface. Some fungus pathogens attack many plant species, but others are restricted to only one host species.

Most fungi reproduce by spores, which function about the same way seeds do. Fungus spores are often microscopic in size and are produced in tremendous numbers. Most of them die because they do not find a host plant to attack. Some can survive for weeks or months without a host plant. Water or high humidity (above 90 percent) are nearly always essential for spore germination and active fungal growth. Spores can spread from plant to plant and crop to crop. Mildew and smut are examples of fungus diseases.

Bacteria

Bacteria are microscopic, one-celled organisms. They usually reproduce by single cell division. Each new cell possesses all the characteristics of the parent cell. Bacteria can build up fast under warm, humid weather conditions. Some can divide every 30 minutes. Bacteria may attack any part of a plant, either above or below the soil surface. Many leaf spots and rots are caused by bacteria.

Viruses and Mycoplasmas

Viruses and mycoplasmas are so small that they cannot be seen with an ordinary microscope. They are generally recognized by their effects on plants. Often it is difficult to distinguish between diseases caused by viruses or mycoplasmas and those caused by other plant disease agents such as fungi and bacteria.

Viruses depend on other living organisms for food and to reproduce. They cannot exist separately from the host for very long and technically are not considered to be living organisms. They can induce a wide variety of responses in the host plants. A few can kill the plant. More commonly, the response is lowered product quality and reduced yields. Mosaic diseases, for example, are usually caused by viruses.

Mycoplasmas are the smallest known independently living organisms. They can reproduce and exist apart from other living organisms. They obtain their food from plants. Yellows diseases and some stunts are caused by mycoplasmas.

Nematodes

Nematodes are small, usually microscopic, eel-like roundworms. Many nematodes are harmless. Others attack and feed on plants grown for food, feed, ornamentals, turf, or forests. Some species attack above-ground plant parts, such as leaves, stems, and seeds. But most pest nematode species feed on or in the roots. They may feed in one location, or they may constantly move throughout the roots. The root-feeding nematodes directly interfere with water and nutrient uptake. Typical host plant symptoms include stunting, yellowing, loss of vigor, and general decline. Nematode damage may go unrecognized or be blamed on something else, such as nutrient deficiencies.

All nematodes that are parasites on plants have a hollow stylet which they use to puncture plant cells and feed on the cell contents. Nematodes may develop and feed either inside or outside of a plant. They move with an eel-like motion in water, even water as thin as the film of moisture around plant cells or soil particles. Their life cycle includes an egg, several larval stages, and an adult. Most larvae look like adults, but are smaller.

In adverse conditions, the females of some species, such as root knot and cyst nematodes, form an inactive, resistant form called a cyst. The cyst is the hard, leathery, egg-filled body of the dead female. It is difficult to penetrate with pesticides. Cysts may provide protection for several hundred eggs for as long as 10 years.

Diagnosis of Plant Disease

Attempting to control plant diseases without sufficient information usually results in failure. For maximum effectiveness, the first step is to diagnose the disease correctly.

Diseased plants may be recognized by comparing them with healthy plants. Knowledge of normal growth habits is necessary for recognition of a diseased condition. To identify the cause of plant disease, you must observe:

- symptoms—reaction of the host plant to the disease agent, and
- signs—actual evidence of the presence of the disease agent.

Many plant diseases cause similar **symptoms** in the host plants. Such things as leaf spots, wilts, galls on roots, or stunted growth may be caused by many different agents, including many that are not pathogens. For example, the symptoms may be a result of mechanical injury, improperly applied fertilizers and pesticides, or frost. Often the only way to pinpoint the cause is by finding the **signs** of the particular disease agent—such as fungal spores and mycelium or bacterial ooze. Many pathogenic disease agents, including some fungi, bacteria, and nematodes, may have to be positively identified by an expert with access to sophisticated laboratory procedures. However, other pathogenic diseases occur regularly on specific agricultural, ornamental, and forestry plantings and the appearance of specific symptoms is enough to correctly identify the cause.

Controlling Plant Disease

At present, plant disease control measures are mainly preventive. Once a plant or plant product is infected and symptoms appear, few control methods—including pesticides—are effective.

In Greenhouses

In greenhouse production, the keys to prevention of plant disease buildup are:

- host resistance—use of disease-resistant varieties,
- mechanical control—use of temperature and humidity control, and soil sterilization by heat,
- chemical control—use of chemicals for specific pest outbreaks, and chemical soil sterilization.

The major elements of the environment can be manipulated in a greenhouse to prevent pathogens from building up rapidly enough to damage crops.

On Stored Food and Feed

As in greenhouses, the environment in storage facilities can be manipulated. To achieve disease control in storage, you must have good sanitation in the storage facility before storage; be sure that the crop is relatively pathogen-free at time of storage; and provide adequate ventilation to control the buildup of temperature and humidity.

Ideal storage conditions vary from crop to crop. Favorable environmental conditions must be maintained to ensure the quality of the product being stored. However, if these same conditions favor a rapid development of plant diseases, the two factors must be weighed carefully.

Outdoors

The main methods for control of plant diseases outdoors include:

- host resistance,
- cultural control,
- mechanical control,
- sanitation, and
- chemical control.

Host Resistance

The use of disease-resistant varieties is usually one of the most effective, long-lasting, and economical ways to control plant disease, if the resistant varieties are otherwise acceptable. Resistant varieties have long been one of the major factors in maintaining high levels of crop productivity in the United States. For certain crops, 95 to 98 percent of the acreage grown is planted with varieties that are resistant to specific diseases.

In some cases, resistant varieties are the only way to ensure continued production. For many diseases in low-value forage and field crops, for example, chemical controls are too costly. For other diseases, such as many soil-borne pathogens, no economical or effective chemical control method is available.

Cultural Control

A pathogen and its host must be brought together under specific environmental conditions for a plant disease to develop. Cultural practices are used to alter the environment, the condition of the host, or the behavior of the pathogen to prevent an infection.

Crop Rotation—Pathogenic organisms nearly always can be carried over from one growing season to the next in the soil or in plant debris. Continual production of the same or closely related crops on the same piece of land leads to a disease buildup. Crop rotation reduces the buildup of pathogens, but seldom provides complete disease control. Obviously, crop rotation is not always possible, practical, or desirable. Perennial crops such as trees, woody ornamentals, and turfgrass must remain in one location for many years. Some crops, such as corn, cotton, or wheat, often are more practical to grow on the same land year after year despite the potential for a buildup of plant disease pathogens.

Planting Time—Cool-weather crops, such as spinach, peas, and some turfgrass, are subject to attack by certain diseases if planted when the temperatures are warmer. They often emerge and establish poorly under such conditions. Conversely, beans, melons, and many flowers should be planted under warm conditions to avoid disease.

Seed Aging—Some seed pathogens can be deactivated by holding the seed in storage. Proper storage conditions are essential to ensure that seed viability is not lowered.

Mechanical Control

Hot water treatments are effective in producing clean seed and planting materials. Seed and vegetative propagation materials (such as roots, bulbs, corms, and tubers) may be treated before planting to eliminate some fungal, bacterial, and viral diseases.

Sanitation

Pathogen-Free Seed Stock—Production of clean seed stock is important in reducing plant disease spread. Often, seeds are grown in arid areas where the amount of moisture is controlled by an irrigation system. This eliminates infection by diseases which require high moisture and humidity levels.

Pathogen-Free Propagation—Plant disease pathogens are frequently carried in or on vegetative propagation materials (such as roots, bulbs, tubers, corms, and cuttings). Production of clean planting stock is especially important in the culture of certain high-value agricultural and ornamental crops. These plants must be grown in pathogen-free greenhouses or in sites isolated from growing areas for these crops. When planning for isolation, consider how far the pathogen may spread, how the pathogen is spread, and the distance between potential growing sites.

Clean Planting Sites—In some crops, certain plant disease pathogens can be controlled or reduced by eliminating other nearby plants which are hosts for the same disease organisms. These may be:

- plants which harbor the pathogens, such as weeds around field borders, ditch banks, and hedgerows, or
- plants which the organism requires for one stage of its life cycle. An apple grower, for example, can control cedar apple rust by eliminating nearby cedar (juniper) trees.

Removing Infected Plants—Diseases often can be controlled by systematically removing infected plants or plant parts before the disease pathogen spreads to other "clean" plants. This method can be especially important for the control of some viral and mycoplasma pathogens for which no other controls are available.

Crop Residue Management—Infected crop residues often provide an ideal environment for carry-over of many pathogens. In some cases the pathogens increase greatly in the residues. Three basic techniques are used in crop residue management:

- deep plowing buries pathogen-infested residucs and surface soil and replaces them with soil relatively free from pathogens,
- fallowing reduces pathogen carry-over because their food source decays and is no longer available,
- burning kills some pathogens and removes the residue they live on. This practice may not be legal in some areas.

Disinfecting Equipment and Tools—Some plant diseases can be spread from plant to plant, field to field, and crop to crop by workers and their equipment. Disinfecting equipment, tools, and clothing before moving from an infected area to a disease-free area can prevent or delay disease spread. This method of disease spread is especially important in high humidity and wet field conditions, because the pathogens are transported in the droplets of water which form on the equipment, tools, and skin.

Chemical Control

Chemicals used to control plant disease pathogens include fungicides, bactericides (disinfectants), and nematicides. The general term "fungicide" is often used to describe chemicals which combat fungi and bacteria. Fungicides may be classified as protectants, eradicants, and systemics.

Protectants must be applied before or during infection by the pathogen. In order to be effective, they must either persist or be applied repeatedly. Most chemicals now available to combat plant diseases are protectants.

Eradicants are less common and are applied after infection has occurred. They act on contact by killing the organism or by preventing its further growth and reproduction.

Systemics are used to kill disease organisms on living plants. Systemic chemicals are transported in the sap stream from the application site to other plant parts. This type of chemical may act as both a protectant and an eradicant.

Successful chemical control of plant diseases requires proper timing. Plant disease control on some crops must begin **before** infection occurs. The protectant chemical must be applied when environmental conditions are expected to be ideal for the development of plant pathogens. If the protectant is not applied in time, major crop damage may result or the application of the more expensive eradicant sprays may be needed. Label directions often call for routine protectant applications every 7 to 10 days during periods of prime infection risk. Almost all plant disease control chemicals are applied as cover sprays. The purpose is to reach and protect all potential sites of infection.

Weeds

Any plant can be considered a weed when it is growing where it is not wanted. Weeds are a problem because they reduce crop yields, they increase costs of production, and they reduce the quality of crop and livestock products. In addition, some cause skin irritation and hay fever, and some are poisonous to man and livestock. Weeds also can spoil the beauty of turf and landscape plants.

Weeds harm desirable plants by:

- competing for water, nutrients, light, and space,
- contaminating the product at harvest,
- harboring pest insects, mites, vertebrates, or plant disease agents, and
- releasing toxins in the soil which inhibit growth of desirable plants.

Weeds may become pests in water by:
- hindering fish growth and reproduction,
- promoting mosquito production,
- hindering boating, fishing, and swimming, and
- clogging irrigation ditches, drainage ditches, and channels.

Weeds can harm grazing animals by:
- poisoning, and
- causing an "off-flavor" in milk and meat.

Weeds are undesirable in rights-of-way because they:
- obscure vision, signs, guideposts, crossroads, etc.,
- increase mowing costs,
- hinder travel,
- provide cover for rodents and other pest animals, and
- clog drainage areas.

In cultivated crops, the weeds that are favored by the crop production practices do best. The size and kind of weed problem often depends more on the crop production method, especially the use or nonuse of cultivation, than on the crop species involved. In noncrop areas, the weed problem may be affected by factors such as:
- weed control programs used in the past,
- frequency of mowing or other traffic in the area, and
- susceptibility to herbicides.

Development Stages

All plants have four stages of development:
- seedling—small, vulnerable plantlets.
- vegetative—rapid growth; production of stems, roots, and foliage. Uptake and movement of water and nutrients is rapid and thorough.
- seed production—energy directed toward production of seed. Uptake of water and nutrients is slow and is directed mainly to flower, fruit, and seed structures.
- maturity—little or no energy production or movement of water and nutrients.

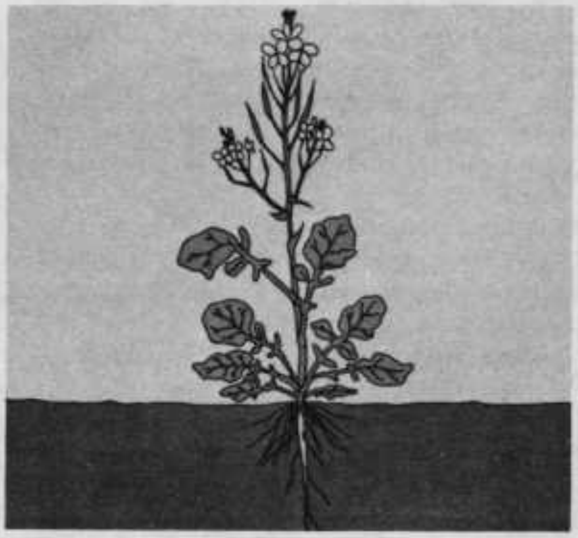
Life Cycles of Plants

Annuals

Plants with a one-year life cycle are annuals. They grow from seed, mature, and produce seed for the next generation in one year or less. They are grasslike (crabgrass and foxtail) or broadleaved (pigweed and cocklebur). There are two types:

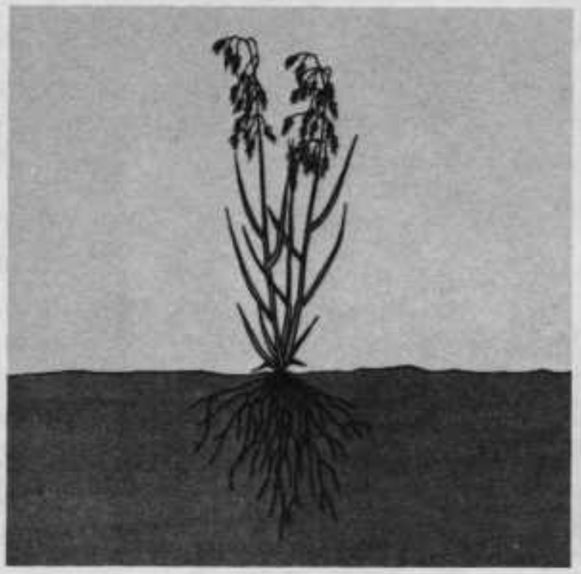
Summer annuals are plants that grow from seeds which sprout in the spring. They grow, mature, produce seed, and die before winter. Examples: crabgrass, foxtail, cocklebur, pigweed, and lambsquarters.

Winter annuals are plants that grow from seeds which sprout in the fall. They grow, mature, produce seed, and die before summer. Examples: cheat, henbit, and annual bluegrass.



Biennials

Plants with a two-year life cycle are biennials. They grow from seed and develop a heavy root and compact cluster of leaves (called a rosette) the first year. In the second year, they mature, produce seed, and die. Examples: mullein, burdock, and bull thistle.



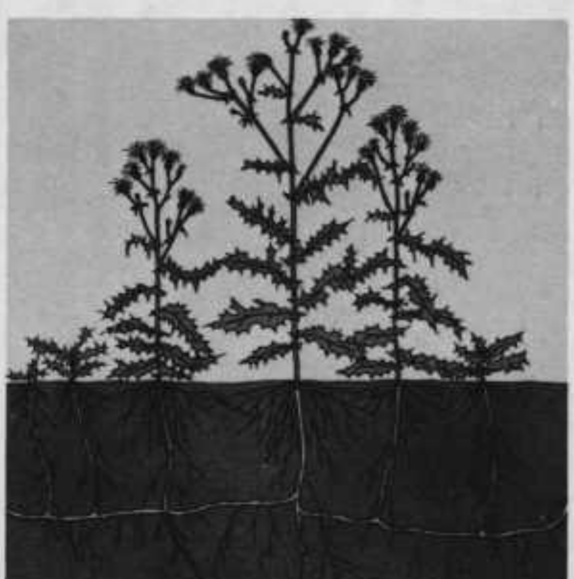
Perennials

Plants which live more than two years and may live indefinitely are perennials. Perennial plants may mature and reproduce in the first year and then repeat the vegetative, seed production, and maturity stages for several following years. In other perennials, the seed maturity and production stages may be delayed for several years. Some perennial plants die back each winter; others, such as trees, may lose their leaves, but do not die back to the ground. Most perennials grow from seed; many also produce tubers, bulbs, rhizomes (below-ground rootlike stems), or stolons (above-ground stems that produce roots). Examples of perennials are johnsongrass, field bindweed, dandelion, and plantain.

Simple perennials normally reproduce by seeds. However, root pieces which may be left by cultivation can produce new plants. Examples: dandelions, plantain, trees, and shrubs.

Bulbous perennials may reproduce by seed, bulblets, or bulbs. Wild garlic, for example, produces seed and bulblets above ground and bulbs below ground.

Creeping perennials produce seeds but also produce rhizomes (below-ground stems), or stolons (above-ground stems that produce roots). Examples: johnsongrass, field bindweed, and Bermudagrass.



Weed Classification

Land Plants

Most pest plants on land are grasses, sedges, or broadleaves.

Grasses

Grass seedlings have only one leaf as they emerge from the seed. Their leaves are generally narrow and upright with parallel veins. Most grasses have fibrous root systems. The growing point on seedling grasses is sheathed and located below the soil surface. Some grass species are annuals; others are perennials.

Sedges

Sedges are similar to grasses except that they have triangular stems and three rows of leaves. They are often listed under grasses on the pesticide label. Most sedges are found in wet places, but principal pest species are found in fertile, well-drained soils. Yellow and purple nutsedge are perennial weed species which produce rhizomes and tubers.

Broadleaves

Broadleaf seedlings have two leaves as they emerge from the seed. Their leaves are generally broad with netlike veins. Broadleaves usually have a taproot and a relatively coarse root system. All actively growing broadleaf plants have exposed growing points at the end of each stem and in each leaf axil. Perennial broadleaf plants may also have growing points on roots and stems above and below the surface of the soil. Broadleaves contain species with annual, biennial, and perennial life cycles.

Aquatic Plants

Vascular Plants

Many aquatic plants are similar to land plants and have stems, leaves, flowers, and roots. Most act as perennial plants—dying back and becoming dormant in the fall and beginning new growth in the spring. They are classified as:

- emergent (emersed)—most of the plant extends above the water surface. Examples are cattails, bulrushes, arrowheads, and reeds.
- floating—all or part of the plant floats on the surface. Examples are waterlilies, duckweeds, waterlettuce, and waterhyacinth.
- submergent (submersed)—all of the plant grows beneath the water surface. Examples are watermilfoil, elodea, naiads, pondweeds (Potamogeton), and coontails.

Emergent and floating plants, like some land plants, have a thick outer layer on their leaves and stems which hinders herbicide absorption. Submergent plants have a very thin outer layer on their leaves and stems and are very susceptible to herbicide injury.

Algae

Algae are aquatic plants without true stems, leaves, or vascular systems. For control purposes, they may be classified as:

- plankton algae—microscopic plants floating in the water. They sometimes multiply very rapidly and cause "blooms" in which the surface water appears soupy green, brown, or reddish brown, depending on the algal type.
- filamentous algae—long, thin strands of plant growth which form floating mats or long strings extending from rocks, bottom sediment, or other underwater surfaces. Examples are cladophora and spirogyra.
- macroscopic freshwater algae—these larger algae look like vascular aquatic plants. The two should not be confused, because their control is different. Many are attached to the bottom and grow up to 2 feet tall; however, they have no true roots, stems, or leaves. Examples are chara and nitella.

Parasitic Seed Plants

Dodders, broomrape, witchweed, and some mosses are important weeds on some agricultural, ornamental, and forest plants. They live on and get their food from the host plants. They can severely stunt and even kill the host plants by using the host plant's water, food, and minerals. These plants reproduce by seeds. Some can also spread from plant to plant in close stands by vining and twining.

Controlling Weeds

Weed control is nearly always designed to suppress a weed infestation. Prevention and eradication are usually only attempted in regulatory weed programs.

To control weeds which are growing among or close to desirable plants, you must take advantage of the differences between the weeds and the desired species. Be sure that the plants you are trying to protect are not susceptible to the weed control method that you choose. Generally, the more similar the desirable plant and the weed species are to one another, the more difficult weed control becomes. For example, broadleaf weeds are most difficult to control in broadleaved crops, and grass weeds are often difficult to control in grass crops.

Weed Control Strategy

A plan to control weeds may include:

- biological control,
- cultural control,
- sanitation, and
- chemical control.

Biological Control

Biological weed control usually involves the use of insects and disease-causing agents which attack certain weed species. An example is the control of St. Johnswort by the Chrysolina beetle in the western United States. To be effective, biological control requires two things:

- the insect or disease must be specific to the weed to be controlled; otherwise, it may spread to other species— such as crops and ornamentals—and become a pest itself.
- the insects must have no natural enemies that interfere with their activity.

Grazing is another form of biological control sometimes used to control plant growth along ditches, fence rows, and roadsides. Sheep and goats are used most often, but geese are used for weeding some crops.

Cultural Control

Tillage—This is an effective and often-used method to kill or control weeds in row crops, nurseries, and forest plantings. However, tillage may bring buried seeds to the surface where they can either germinate and compete with the newly planted crop or be spread to nearby fields. Tillage also may increase soil erosion and may help to spread established plant diseases to uninfected areas of the field.

Time of Planting—Crops and turfgrass planted in the spring compete well against winter annual weeds. Sometimes the planting date can be delayed until after weeds have sprouted and have been removed by cultivation or by herbicides.

Nurse Crops—Plant species (usually annuals) which germinate quickly and grow rapidly are sometimes planted with a perennial crop to provide competition with weeds and allow the crop to become established. The nurse crop is then harvested or removed to allow the perennial crop to take over. For example, oats are sometimes used as a nurse crop to help establish alfalfa or clover. Annual ryegrass is sometimes used in mixtures to provide a nurse crop for perennial rye, fescue, or bluegrass.

Burning—Fire may be used to control limited infestations of annual or biennial weeds. Fire destroys only the above-ground parts of plants and is usually not effective against many herbaceous perennial weeds.

Mulching—Mulching is used to prevent light from reaching weed seeds, thus preventing weed growth between rows, around trees and shrubs, or in other areas where no plants are desired.

Mowing—Mowing may be used to reduce competition between weeds and crops and to prevent flowering and seeding of annual or biennial weeds. Mowing is often used in orchards to control weeds and prevent soil erosion. To be most effective, mowing height must be adequate to ensure control of weed plants and encourage desired vegetation. Mowing is an important aspect of turfgrass weed control.

Mowing and harvesting is good for both short-term and long-term control of aquatic weeds. It depletes the nutrients, removes seeds, and reduces vegetative spread.

Flooding—Flooding has long been used for weed control in rice. The water covers the entire weed, killing it by suffocation.

Reduced Tillage—This method has been used successfully to reduce weed growth and to reduce soil erosion. With limited tillage, weed seeds are not turned up and those that do germinate do not have as much light or space to get started. However, the remaining debris may harbor insects and plant disease agents.

Shading—Aquatic weeds are sometimes controlled by shading them with floats of black plastic, adding dye to the water, or using similar methods for shading out the sunlight. Land weeds can be shaded by planting crops so closely together that they block the light from emerging weeds.

Sanitation

The use of seeds with few weed-seed contaminants is important in reducing weed problems.

Chemical Control

Chemicals used to control weeds are called herbicides. They kill plants by contact or systemic action. **Contact herbicides** kill only the plant parts which the chemical touches. **Systemic herbicides** are absorbed by roots or foliage and carried throughout the plant. Systemic herbicides are particularly effective against perennial weeds because the chemical reaches all parts of the plant—even deep roots and woody stems, which are relatively inaccessible. Contact herbicides are usually used to control annuals and biennials and are characterized by the quick die-back they cause. Systemics may take a longer time to provide the desired results —up to 2 or 3 weeks, or even longer for woody perennials.

Herbicide activity is either selective or nonselective. **Selective herbicides** are used to kill weeds without significant damage to nearby plants. They are used to reduce weed competition in crops, lawns, and ornamental plantings. **Nonselective herbicides** are chemicals that kill all plants present if applied at an adequate rate. They are used where no plant growth is wanted, such as fence rows, ditch banks, driveways, roadsides, parking lots, and recreation areas.

Herbicide selectivity may vary according to the application rate. High rates of selective herbicides usually will injure all plants at the application site. Some nonselective herbicides can be used selectively by applying them at a lower rate. Other factors that affect selectivity include the time and method of application, environmental conditions, and the stage of plant growth.

Several factors affect a plant's susceptibility to herbicides:

Growing Points—Those that are sheathed or located below the soil surface are not reached by contact herbicide sprays.

Leaf Shape—Herbicides tend to bounce or run off narrow, upright leaves. Broad, flat leaves tend to hold the herbicide longer.

Wax and Cuticle—Foliar sprays may be prevented from entering the leaf by a thick wax and cuticle layer. The waxy-surface also tends to cause a spray solution to form droplets and run off the leaves.

Leaf Hairs—A dense layer of leaf hairs holds the herbicide droplets away from the leaf surface, allowing less chemical to be absorbed into the plant. A thin layer of leaf hairs causes the chemical to stay on the leaf surface longer than normal, allowing more chemical to be absorbed into the plant.

Size and Age—Young, rapidly growing plants are more susceptible to herbicides than are larger, more mature plants.

Deactivation—Certain plants can deactivate herbicides and are less susceptible to injury from these chemicals. Such plants may become dominant over a period of time if similar herbicides are used repeatedly.

Stage in Life Cycle—Seedlings are very susceptible to herbicides and to most other weed control practices. Plants in the vegetative and early bud stages are very susceptible to translocated herbicides. Plants with seeds or in the maturity stage are the least susceptible to weed control practices.

Timing of Stages in the Life Cycle—Plants that germinate and develop at different times than the crop species may be susceptible to carefully timed herbicide applications.

Chemicals Which Change Plant Processes

Plant growth regulators, defoliants, and desiccants are classified as pesticides in federal laws. These chemicals are used on plants to alter normal plant processes in some way. They must be measured carefully, because they usually are effective in very small amounts. Overdosing will kill or seriously damage the plants.

A plant growth regulator will speed up, stop, retard, prolong, promote, start, or in some other way influence vegetative or reproductive growth of a plant. These chemicals are sometimes called growth regulators or plant regulators. They are used, for example, to thin apples, control suckers on tobacco, control the height of some floral potted plants, promote dense growth of ornamentals, and stimulate rooting.

A defoliant causes the leaves to drop from plants without killing the plants. A desiccant speeds up the drying of plant leaves, stems, or vines. Desiccants and defoliants are often called "harvest-aid" chemicals. They usually are used to make harvesting of a crop easier or to advance the time of harvest. They are often used on cotton, soybeans, tomatoes, and potatoes.

Mollusks

Mollusks are a large group of land and water animals including slugs, oysters, clams, barnacles, and snails. They have soft, unsegmented bodies and often are protected by a hard shell.

Snails and Slugs

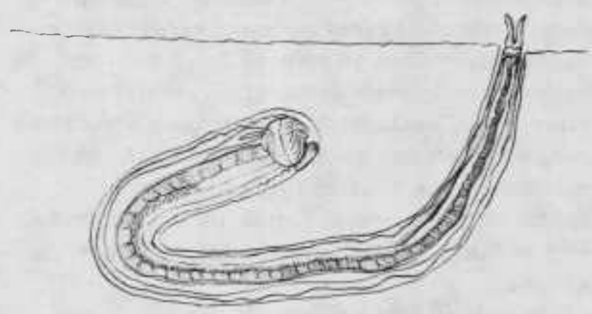
Land snails and slugs are soft-bodied and have two pairs of antennae-like structures. Their bodies are smooth and elongated. Snails have a spiral-shaped shell into which they can completely withdraw for protection when disturbed or when weather conditions are unfavorable. Slugs do not have a shell and must seek protection in damp places.

Snails and slugs feed on plants at night. They tear holes in foliage, fruits, and soft stems, using a rasp-like tongue. They may eat entire seedlings. As they move, snails and slugs leave a slime-like mucous trail which dries into silvery streaks. These streaks are undesirable on floral and ornamental crops and on those portions of crops to be sold for human food.

Snails and slugs deposit eggs in moist, dark places. The young mature in a year or more, depending on the species. Adults may live for several years. They overwinter in sheltered areas. They are active all year in warm regions and in greenhouses.

Shipworms

Shipworms are marine mollusks which cause extensive damage by boring into wood which is in contact with salt or brackish water. Of all the marine borers, shipworms are the most rapid destroyers of untreated wood. Adults lay eggs which hatch into free-swimming larvae. The larvae bore into submerged wood (marine pilings, wharf timbers, wooden boats) using a pair of boring shells located on their heads. The tail remains at the entrance, but the body grows in length and diameter as the animal extends its tunnel up to several feet in length. Shipworms use the wood for food and shelter. The internal structure of the wood may be honeycombed with tunnels but only a tiny ($\frac{1}{16}$- to $\frac{1}{8}$-inch) entrance hole will be visible on the surface.



Pholads

Pholads are another species of marine mollusks which attack and destroy submerged wood. Pholads look like small clams and remain enclosed in a shell even as adults. Like shipworms, they burrow within the wood. After boring a small ($\frac{1}{8}$-inch) entrance hole, they enlarge their burrow to accommodate the growth of their bodies. Pholads are of economic importance mainly along the Gulf Coast and in Hawaiian waters.

Controlling Mollusks

Mollusk pests on land (usually snails and slugs) can be controlled by many of the same techniques that are used to control insects outdoors. Effective techniques include:

- cultural practices—especially cultivation and trap crops,
- mechanical controls—especially traps and barriers,
- sanitation—especially eliminating crop debris and other sources of moisture, and
- chemicals—many insecticide formulations also control mollusks. In addition, specific molluscicides are available, usually as baits.

Marine mollusk control usually depends on impregnating wood with preservatives or applying repellent coatings to prevent infestations.

Vertebrate Pests

All vertebrate animals have a jointed backbone. They include mammals, birds, reptiles, amphibians, and fish. Most vertebrate animals are not pests. They are a necessary and enjoyable part of our environment.

A few vertebrate animals can be pests in some situations. Some, such as birds, rodents, raccoons, or deer, may eat or injure agricultural and ornamental crops. Birds and mammals may eat newly planted seed. Birds and rodents consume stored food and often contaminate and ruin even more than they eat. Birds and mammals which prey on livestock and poultry cause costly losses to ranchers each year. Large numbers of roosting birds can soil populated areas.

Burrowing and gnawing mammals may damage dams, drainage and irrigation tunnels, turf, and outdoor wood products such as furniture and building foundations. Beavers may cause flooding in low-lying land by building dams.

Undesirable fish species may crowd out desirable food and sport species. The few poisonous species of snakes and lizards become a problem when humans, livestock, or pets are threatened. Water snakes and turtles may cause disruption or harm in fish hatcheries or waterfowl nesting reserves.

Rodents, other mammals, and some birds are potential reservoirs of serious diseases of humans and domestic animals such as rabies, plague, and tularemia. Rodents are an annoyance and a health hazard when they inhabit homes, restaurants, offices, and warehouses.

Controlling Vertebrates

As in insect pest control, techniques for control of vertebrate pests depend on whether the pest problem is indoors or outdoors.

Indoor vertebrate pest control usually is aimed at preventing pest entrance and eradicating pest infestations. Nearly all indoor vertebrate pests are rodents, but others, such as bats, birds, and raccoons, also may require control.

Outdoors, the strategy usually is to suppress the pest population to a level where the damage or injury is economically acceptable.

Local and state laws may prohibit the killing or trapping of some animals such as birds, coyotes, muskrats, and beavers without special permits. Always check with local authorities before beginning a control program.

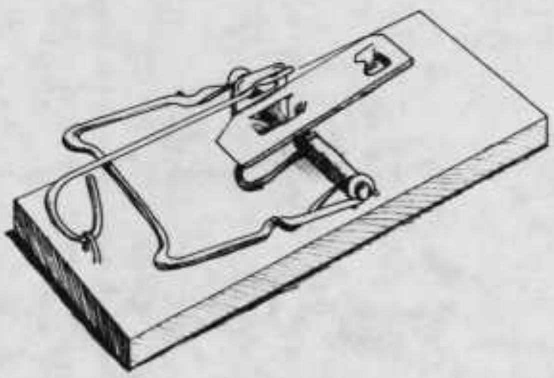
Vertebrate Control Strategy

Methods of vertebrate pest control include:
- mechanical control,
- sanitation, and
- chemical control.

Mechanical Control

Mechanical control methods for vertebrate pests include traps, barriers, gunning, attractants, and repellents.

Traps—Traps are sometimes desirable in vertebrate pest control. Leg-hold traps have been used traditionally, but such traps are nonselective and may injure nontarget animals. Traps which quickly kill only target pests are more desirable. Traps should be checked daily to maintain their effectiveness.



Barriers—Barriers are designed to prevent pests from passing through. These include fences, screens, and other barriers which cover openings, stop tunneling, and prevent gnawing. Materials used include sheet metal, hardware cloth, concrete, asbestos board, and similar materials. This kind of approach is especially effective in control of rodents, bats, and birds in structures.

Gunning—Gunning, though highly selective, is expensive and time-consuming. It works best in combination with other methods. It will often take larger predators not controlled by traps or toxic devices.

Attractants—Many techniques, such as light and sound, are used to attract pests to a trap. Predator calling can increase the efficiency of gunning efforts on larger predators.

Repellents—Repellents include a variety of devices aimed at keeping pests from doing damage. Automatic exploders, noisemakers, recordings of scare calls, moving objects, and lights are some of the repellents used. The efficacy of some of these devices is variable and may be highly dependent on placement.

Sanitation

Removing sources of food and shelter helps to suppress some vertebrate pests. Sanitation techniques are used widely to control rodents in and around homes, institutions, restaurants, food-processing facilities, and other related areas.

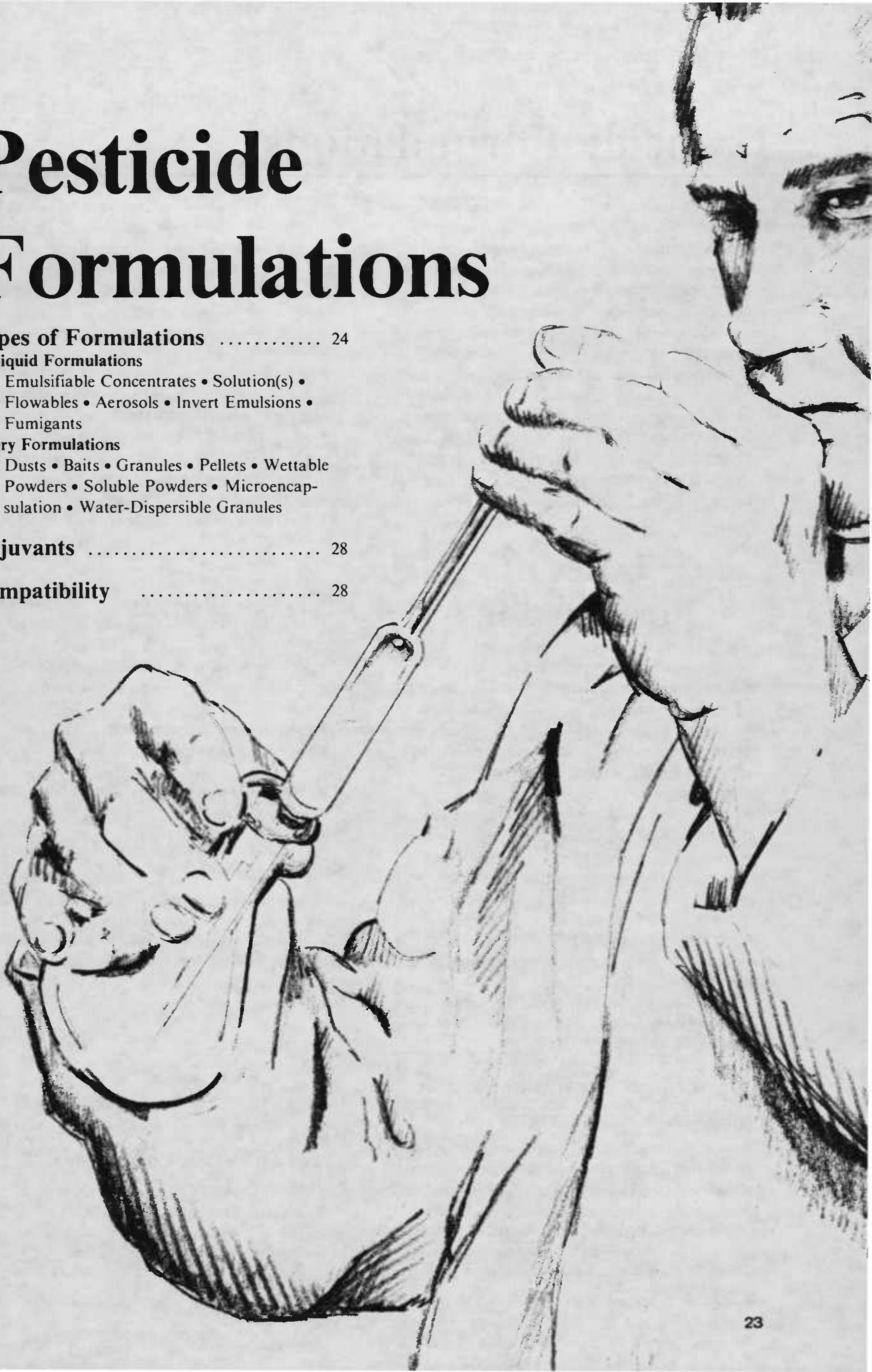
Chemical Control

Pesticides for rodent pest control usually are formulated in baits. The chemicals may be highly toxic to humans, livestock, and other animals. Therefore, correct bait placement is important in order to control the pest while protecting non-pest species. Thorough knowledge of the pest's habits is necessary.

Few pesticides are available for non-rodent vertebrate pest control, and most require special local permits for use. The chemicals which are registered are usually bait applications. A few chemicals designed for aquatic pests or massive populations of pest birds are used as broadcast applications.

The chemicals used to control vertebrate pests include rodenticides, piscicides (fish), avicides (birds), and predacides (predators).

Pesticide Formulations



Pesticide Formulations

The active ingredients in a pesticide are the chemicals that control the target pest. The pesticide product you purchase is rarely made up only of active ingredients. Usually the pesticide is diluted in water or a petroleum solvent, and other chemicals are added before the product is offered for sale. These other chemicals may include wetting agents, spreaders, stickers, extenders, or diluents. They usually make the product safer, easier to apply, more convenient to handle, and more accurate to measure. This mixture of active and inert (inactive) ingredients is called a pesticide formulation. Some formulations are ready for use. Others must be further diluted with water, a petroleum solvent, or air by the user before they are applied.

Types of Formulations

A single active ingredient often is sold in several different kinds of formulations. You must choose the formulation that will be best for each use. In making your choice, consider:

- the plant, animal, or surface to be protected (phytotoxicity, animal absorption, pitting or marring surface),
- application machinery available and best suited for the job,
- hazard of drift and runoff (nearness to sensitive areas, likelihood of wind or rain),
- safety to applicator, helpers, and other humans and pets likely to be exposed,
- habits or growth patterns of the pest (bait vs. broadcast spray, granular vs. foliar spray),
- cost,
- type of environment in which the application must be made (agricultural, aquatic, forest, urban, etc.)

Liquid Formulations

Emulsifiable Concentrates (EC or E)

An emulsifiable concentrate formulation usually contains the active ingredient, one or more petroleum solvents, and an emulsifier which allows the formulation to be mixed with water. Each gallon of EC usually contains 2 to 8 pounds of active ingredient. EC's are among the most versatile formulations. They are used against agricultural, ornamental and turf, forestry, structural, food processing, livestock, and public health pests. They are adaptable to many types of application equipment, from small, portable sprayers to hydraulic sprayers, low-volume ground sprayers, mist blowers, and low-volume aircraft sprayers.

Advantages:

- High concentration means price per pound of active ingredient is relatively low and product is easy to handle, transport, and store,
- Little agitation required; not abrasive; will not settle out or separate when equipment is running,
- Little visible residue on fresh fruits and vegetables and on finished surfaces.

Disadvantages:

- High concentration makes it easy to overdose or underdose through mixing or calibration errors,
- Phytotoxicity hazard usually greater,
- Easily absorbed through skin of humans or animals,
- Solvents may cause rubber or plastic hoses, gaskets, and pump parts and surfaces to deteriorate,
- May cause pitting or discoloration of painted finishes,
- May be corrosive.

Solutions (S)

A few pesticide active ingredients dissolve readily in water. Formulations of these pesticides contain the active ingredient and one or more additives. When mixed with water, they form a solution which will not settle out or separate. Solutions may be used in any type of sprayer indoors or outdoors.

Advantages:

- No agitation necessary.

Disadvantages:

- Very few formulations of this type available.

Ultra Low Volume Concentrate Solutions (ULV)

ULV concentrate solutions contain 8 or more pounds of active ingredient per gallon. They may approach 100 percent active ingredient. ULV concentrates are designed to be used as is or to be diluted with only small quantities of specified solvents. These special-purpose formulations must be applied with highly specialized spray equipment. They are mostly used in outdoor applications such as in agricultural, forestry, ornamental, and mosquito control programs. The advantages and disadvantages are similar to those for emulsifiable concentrates.

Low Concentrate Solutions (S)

These formulations, usually solutions in petroleum solvents, contain small amounts (usually one percent or less) of active ingredient per gallon. They are designed to be used without further dilution. Low concentrate solutions are used for:

- structural and institutional pests,
- clothes moths,
- livestock and poultry pests,
- space sprays in barns and warehouses,
- mosquito control.

Advantages:

- No mixing necessary,
- Household formulations have no unpleasant odor; do not stain fabric.

Disadvantages:

- Expensive,
- Limited number of uses.

Flowables (F or L)

Some active ingredients are insoluble solids. These may be formulated as flowables in which the finely ground active ingredients are mixed with a liquid, along with inert ingredients, to form a suspension. Flowables are mixed with water for application and are similar to EC formulations in ease of handling and use. They are used in the same types of pest control operations for which EC's are used.

Advantages:

- Seldom clog nozzles,
- Easy to handle and apply.

Disadvantages:

- Require moderate agitation,
- May leave a visible residue.

Aerosols

These formulations contain one or more active ingredients and a solvent. Most aerosols contain a low percentage of active ingredient. There are two types of aerosol formulations—the ready-to-use type, and those made for use in smoke or fog generators.

Ready-to-use aerosols are usually small, self-contained units which release the pesticide when the nozzle valve is triggered. The pesticide is driven through a fine opening by an inert gas under pressure, creating fine droplets. These products are used in greenhouses, in small areas inside buildings, or in localized outdoor areas. Commercial models hold 5 to 10 pounds of pesticide, and these are usually refillable.

Advantages:

- Ready to use,
- Easily stored,
- Convenient way of buying small amount of a pesticide,
- Retain their potency over fairly long time.

Disadvantages:

- Expensive,
- Practical for very limited uses,
- Risk of inhalation injury,
- Hazardous if punctured, overheated, or used near an open flame,
- Difficult to confine to target site or pest.

Formulations for smoke or fog generators are not under pressure. They are used in machines which break the liquid formulation into a fine mist or fog (aerosol) using a rapidly whirling disk or heated surface. These formulations are used mainly for insect control in structures such as greenhouses and warehouses and for mosquito and biting fly control outdoors.

Advantages:

- Easy method of filling entire space with pesticide.

Disadvantages:

- Highly specialized use,
- Fairly expensive for pounds of active ingredient per gallon,
- Difficult to confine to target site or pest,
- Risk of inhalation injury.

Invert Emulsions

This unusual mixture contains a water-soluble pesticide dispersed in an oil carrier. Invert emulsions require a special kind of emulsifier that allows the pesticide to be mixed with a large volume of petroleum carrier, usually fuel oil. When applied, invert emulsions form large droplets which do not drift easily. Invert emulsions are most commonly used in vegetation control along rights-of-way where drift to susceptible nontarget plants is a problem.

Fumigants

Fumigants are pesticides which form poisonous gases when applied. Sometimes the active ingredients are gases which become liquids when packaged under high pressure. These formulations become gases when released during application. Other active ingredients are volatile liquids when enclosed in an ordinary container and so are not formulated under pressure. They become gases during application. Others are solids that release gases when applied under conditions of high humidity or in the presence of water vapor.

Fumigants are used for structural pest control, in food and grain storage facilities, and in regulatory pest control at ports of entry and at state and national borders. In agricultural pest control, fumigants are used in soil and in greenhouses, granaries, and grain bins.

Advantages:

- Toxic to a wide range of pests,
- Can penetrate cracks, crevices, wood, and tightly packed areas such as soil or grains,
- Single treatment will usually kill most pests in treated area.

Disadvantages:

- The target area must be enclosed or covered to prevent the gas from escaping,
- Highly toxic to humans—specialized protective equipment, including respirators, must be used with fumigants.

Dry Formulations

Dusts (D)

Most dust formulations are ready to use and contain a low percentage of active ingredient (usually 1 to 10 percent), plus a very fine dry inert carrier made from talc, chalk, clay, nut hulls, or volcanic ash. The size of individual dust particles is variable.

Dust concentrates contain a greater percentage of active ingredient. These must be mixed with dry inert carriers before they can be applied.

Dusts are always used dry and easily drift into nontarget areas. They sometimes are used for agricultural applications. In structures, dust formulations are used in cracks and crevices and for spot treatments. They are widely used in seed treatment. Dusts are also used to control lice, fleas, and other parasites on pets and domestic animals and poultry.

Advantages:

- Usually ready to use, with no mixing,
- Effective where moisture from a spray might cause damage,
- Require simple equipment,
- Effective in hard-to-reach indoor areas.

Disadvantages:

- Drift hazard high,
- Expensive because of low percentage of active ingredient.

Baits (B)

A bait formulation is an active ingredient mixed with food or another attractive substance. The bait attracts the pests, which are then killed by eating the pesticide it contains. The amount of active ingredient in most bait formulations is quite low, usually less than 5 percent. Baits are used inside buildings to control ants, roaches, flies, and other insects and for rodent control. Outdoors they are sometimes used to control slugs and some insects, but their main use is for control of vertebrate pests such as birds, rodents, and other mammals.

Advantages:

- Ready to use,
- Entire area need not be covered, since pest goes to bait,
- Controls pests which move in and out of an area.

Disadvantages:

- Often attractive to children and pets,
- May kill domestic animals and nontarget wildlife outdoors,
- Pest may prefer the crop or other food to the bait,
- Dead pests may cause odor problem,
- Other animals feeding on the poisoned pests may also be poisoned,
- Application costs are high.

Granules (G)

Granular formulations are similar to dust formulations except that granular particles are larger and heavier. The coarse particles are made from an absorptive material such as clay, corn cobs, or walnut shells. The active ingredient either coats the outside of the granules or is absorbed into them. The amount of active ingredient is relatively low, usually ranging from 1 to 15 percent.

Granular pesticides are most often used to apply chemicals to the soil to control weeds, nematodes, and insects living in the soil. They also may be used as systemics—formulations that are applied to the soil, then absorbed into the plant through the roots and carried throughout the plant. They are sometimes used in airplane or helicopter applications because drift is minimal. Granular formulations are also used to control larval mosquitoes and other aquatic pests. Granules are used in agricultural, ornamental, turf, aquatic, right-of-way, and public health (biting insect) pest control operations.

Advantages:
- Ready to use; no mixing,
- Drift hazard is low—particles settle quickly,
- Low hazard to applicator—no spray, little dust,
- Weight carries the formulation through foliage to soil target,
- Simple application equipment—often seeders or fertilizer spreaders,
- May be more persistent than WP's or EC's.

Disadvantages:
- Does not stick to foliage,
- More expensive than WP's or EC's,
- May need to be incorporated into soil,
- May need moisture to activate pesticidal action.

Pellets (P or PS)

Pellet formulations are very similar to granular formulations; the terms often are used interchangeably. A pellet, however, is a formulation manufactured to create a pellet of specific weight and shape. The uniformity of the particles allows them to be applied by precision applicators such as those being used for precision planting of pelleted seed.

Wettable Powders (WP or W)

Wettable powders are dry, finely ground formulations which look like dusts. They usually must be mixed with water for application as a spray. A few products, however, may be applied either as a dust or as a wettable powder—the choice is left to the applicator. Wettable powders contain 5 to 95 percent active ingredient, usually 50 percent or more. Wettable powder particles do not dissolve in water. They settle out quickly unless constant agitation is used to keep them suspended.

Wettable powders are one of the most widely used pesticide formulations. They can be used for most pest problems and in most types of spray machinery where agitation is possible.

Advantages:
- Low cost,
- Easy to store, transport, and handle,
- Lower phytotoxicity hazard than EC's and other liquid formulations,
- Easily measured and mixed,
- Less skin and eye absorption than EC's and other liquid formulations.

Disadvantages:
- Inhalation hazard to applicator while pouring and mixing the concentrated powder,
- Require good and constant agitation (usually mechanical) in the spray tank,
- Abrasive to many pumps and nozzles, causing them to wear out quickly,
- Residues may be visible.

Soluble Powders (SP)

Soluble powder formulations look like wettable powders. However, when mixed with water, soluble powders dissolve readily and form a true solution. After they are thoroughly mixed, no additional agitation is necessary. The active ingredient in soluble powders ranges from 15 to 95 percent—usually over 50 percent.

Soluble powders have all the advantages of the wettable powders and none of the disadvantages except the inhalation hazard during mixing. Few pesticides are available in this formulation, because few active ingredients are soluble in water.

Microencapsulation

Microencapsulated formulations are particles of pesticides (either liquid or dry) surrounded by a plastic coating. The formulated product is mixed with water and applied as a spray. Once applied, the capsule slowly releases the pesticide. The encapsulation process can prolong the active life of the pesticide by providing a timed release of the active ingredient.

Advantages:
- Increased safety to applicator,
- Easy to mix, handle, and apply.

Disadvantages:
- Constant agitation necessary in tank,
- Some bees may pick up the capsules and carry them back to the hives where the released pesticide may poison the entire hives.

Water-Dispersible Granules (Dry Flowables)

Water-dispersible granular formulations are like wettable powder formulations, except the active ingredient is prepared as granule-sized particles. Water-dispersible granules must be mixed with water to be applied. The formulation requires constant agitation to keep it suspended in water. Water-dispersible granules share the advantages and disadvantages of wettable powders except:
- They are more easily measured and mixed,
- They cause less inhalation hazard to the applicator during pouring and mixing.

Adjuvants

An adjuvant is an inert material added to a pesticide formulation or tank mix to increase the effectiveness of the active ingredient. Most pesticide formulations contain at least a small percentage of additives. Some applicators add additional adjuvants while mixing for special applications. Some product labels may caution the user against adding adjuvants. Common adjuvants are:

Wetting agents—allow wettable powders to mix with water and stick on plant or animal surfaces.

Emulsifiers—allow petroleum-based pesticides (EC's) to mix with water.

Invert emulsifiers—allow water-based pesticides to mix with petroleum carrier.

Spreaders—allow pesticide to form a uniform coating layer over the treated surface.

Stickers—allow pesticide to stay on the treated surface.

Penetrants—allow the pesticide to get through the outer surface to the inside of the treated area.

Foaming agents—reduce drift.

Thickeners—reduce drift by increasing droplet size.

Safeners—reduce phytotoxicity of pesticide to protected crop.

Compatibility agents—aid in combining pesticides effectively.

Buffers—allow mixing of pesticides of different acidity or alkalinity.

Anti-foaming agents—reduce foaming of spray mixtures that require vigorous agitation.

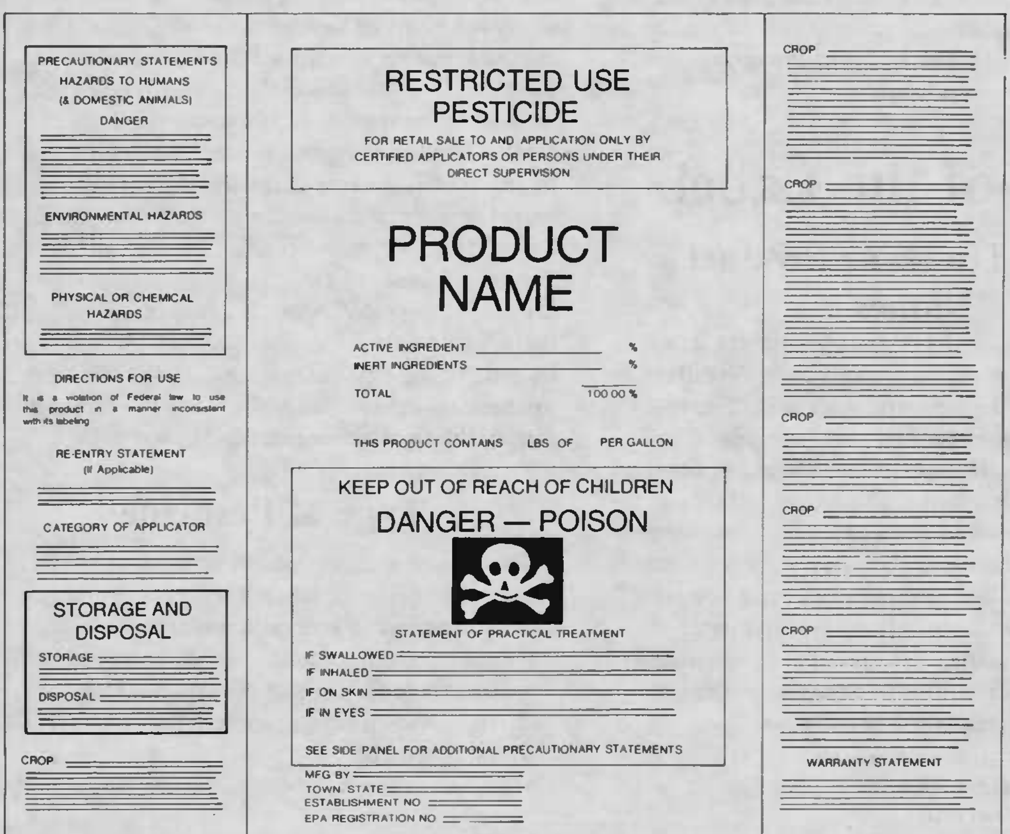
Compatibility

Two or more pesticides which can be mixed together to control a wider range of pests with a single application are said to be compatible with each other. Sometimes the pesticides are formulated together by the manufacturer, but the applicator often must mix separate formulations in the tank. It is important to remember that not all pesticides work well in combination. Pesticides which are not compatible can cause:

- loss of effectiveness against the target pests,
- injury to the treated surface (phytotoxicity in plants, toxicity in treated animals, stains or corrosion on treated surfaces),
- separation of ingredients into layers or settling out of solids.

Some pesticide labels list other pesticides with which the product is compatible. Pesticide publications, land grant universities, and independent experts can supply information based on local experience. Be careful with do-it-yourself mixes; they could cost you time and money.

Labels and Labeling



Labels and Labeling

Each pesticide you buy has a label which gives you instructions on how to use the product. The manufacturer may also provide additional forms of labeling.

Labeling is all information that you receive from the manufacturer about the product. Labeling includes not only the label on the product container, but also any supplemental information accompanying the product. This may include such things as brochures, leaflets, and information handed out by your dealer.

The **label** is the information printed on or attached to the container of pesticides.

- To the manufacturer, the label is a "license to sell."
- To the state or federal government, the label is a way to control the distribution, storage, sale, use, and disposal of the product.
- To the buyer or user, the label is a source of facts on how to use the product correctly and legally.
- To physicians, the label is a source of information on proper treatment for poisoning cases.

Some labels are easy to understand. Others are complicated. All labels will tell you how to use the product correctly. This section will explain the items that must be on a label.

Parts of the Label

Brand, Trade, or Product Names

Each manufacturer has a brand name for its products. Different manufacturers may use different brand names for the same pesticide active ingredient. Most companies register each brand name as a trademark and will not allow any other company to use that name. The brand or trade name is the one used in ads and by company salespersons. The brand name shows up plainly on the front panel of the label. Applicators must beware of choosing a pesticide product by brand name alone. Many companies use the same basic name with only minor variations to designate entirely different pesticide chemicals. For example:

Tersan^R LSR = zinc and maneb
Tersan^R SP = chloroneb
Tersan^R 1991 = benomyl
Tersan^R = thiram.

Ingredient Statement

Each pesticide label must list what is in the product. The list is written so you can see quickly what the active ingredients are and the amount (in percentage) of each ingredient listed. The ingredient statement must list the official chemical names and/or common names for the active ingredients. Inert ingredients need not be named, but the label must show what percent of the total contents they comprise.

Chemical Name

The chemical name is a complex name which identifies the chemical components and structure of the pesticide. This name is almost always listed in the ingredient statement on the label. For example, the chemical name of AAtrex^R is 2-chloro-4-ethylamino-6-isopropylamino-l, 3, 5-triazine.

Common Name

Because pesticides have complex chemical names, many are given a shorter "common" name. Only common names which are officially accepted by the U. S. Environmental Protection Agency may be used in the ingredient statement on the pesticide label. The official common name may be followed by the chemical name in the list of active ingredients. For example, a label with the brand name Sevin^R 50% WP would read:

Active ingredient:
carbaryl (l-naphthyl N methyl carbamate) .. 50%
Inert ingredients 50%

By purchasing pesticides according to the common or chemical names, you will always be certain of getting the right active ingredient.

Type of Pesticide

The type of pesticide usually is listed on the front panel of the pesticide label. This short statement usually indicates in general terms what the product will control. Examples:

- insecticide for control of certain insects on fruits, nuts, and ornamentals,
- soil fungicide,
- herbicide for the control of trees, brush, and weeds,
- algicide.

Net Contents

The front panel of the pesticide label tells you how much is in the container. This can be expressed as pounds or ounces for dry formulations and as gallons, quarts, or pints for liquids. Liquid formulations may also list the pounds of active ingredient per gallon of product.

Name and Address of Manufacturer

The law requires the maker or distributor of a product to put the name and address of the company on the label. This is so you will know who made or sold the product.

Registration and Establishment Numbers

These numbers are needed by the pesticide applicator in case of accidental poisoning, claims of misuse, or liability claims.

Registration Numbers

An EPA registration number (for example, EPA Reg. No. 3120-280-AA) appears on most pesticide labels. This indicates that the pesticide label has been approved by the federal government. In cases of special local needs, pesticide products may be approved by a state. These registrations are designated, for example, as EPA SLN No. KS-770009. In this case, **SLN** indicates "special local need" and **KS** means that the product is registered for use in Kansas.

Establishment Numbers

The establishment number (for example, EPA Est: No. 5840-AZ-1) appears on either the pesticide label or container. It identifies the facility that produced the product. In case something goes wrong, the facility that made the product can be traced.

Signal Words and Symbols

Almost every label contains a signal word giving you a clue to how dangerous the product is to humans. Knowing the product's hazard helps you choose the proper precautionary measures for yourself, your workers, and other persons (or animals) which may be exposed.

The signal word must appear in large letters on the front panel of the pesticide label. It immediately follows the statement, "Keep Out of Reach of Children," which must appear on every pesticide label.

DANGER—This word signals you that the pesticide is highly toxic. A taste to a teaspoonful taken by mouth could kill an average sized adult. Any product which is highly toxic orally, dermally, or through inhalation or causes severe eye and skin burning will be labeled "DANGER".

All pesticides which are highly toxic orally, dermally, or through inhalation will also carry the word POISON printed in red and the skull and crossbones symbol.

WARNING—This word signals you that the product is moderately toxic. As little as a teaspoonful to a tablespoonful by mouth could kill the average sized adult. Any product which is moderately toxic orally, dermally, or through inhalation or causes moderate eye and skin irritation will be labeled WARNING.

CAUTION—This word signals you that the product is slightly toxic. An ounce to more than a pint taken by mouth could kill the average adult. Any product which is slightly toxic orally, dermally, or through inhalation or causes slight eye and skin irritation will be labeled CAUTION.

Precautionary Statements

All pesticide labels contain additional statements to help you decide the proper precautions to take to protect yourself, your helpers, and other persons (or domestic animals) which may be exposed. Sometimes these statements are listed under the heading, "Hazards to Humans and Domestic Animals." They are composed of several sections.

Route of Entry Statements

The statements which immediately follow the signal word, either on the front or side of the pesticide label, indicate which route or routes of entry (mouth, skin, lungs) you must particularly protect. Many pesticide products are hazardous by more than one route, so study these statements carefully. A "Danger" signal word followed by "May be fatal if swallowed or inhaled" gives you a far different warning than, "Danger: Corrosive—Causes eye damage and severe skin burns."

Typical DANGER label statements include:

- Fatal if swallowed,
- Poisonous if inhaled,
- Extremely hazardous by skin contact—rapidly absorbed through skin,

- Corrosive—causes eye damage and severe skin burns.

These statements are not uniform on all labels, so many variations may be found. More than one or even all four precautions may be stated on the same label.

Typical WARNING label statements include:

- Harmful or fatal if swallowed,
- Harmful or fatal if absorbed through the skin,
- Harmful or fatal if inhaled,
- Causes skin and eye irritation.

Statements on a WARNING label may be exactly like those found on a DANGER label or a CAUTION label. Or they may be a combination of the two; for example, "harmful or fatal." Many WARNING label precautionary statements simply drop the words "may" or "may be" from the caution statements. This leaves a stronger signal, which is in keeping with the moderate toxicity of products possessing a WARNING label.

Typical CAUTION label statements include:

- Harmful if swallowed,
- May be harmful if absorbed through the skin,
- May be harmful if inhaled,
- May irritate eyes, nose, throat, and skin.

These statements may vary considerably. They usually are more moderate than the statements found on a DANGER label, using "harmful" instead of "fatal" or "poisonous;" "irritant" instead of "corrosive;" and qualifying the warnings with "may" or "may be." This is in keeping with the much lower toxicity of products possessing a **CAUTION** label.

Specific Action Statements

These statements usually follow immediately after the route of entry statements. They recommend the specific action you should take to prevent poisoning accidents. These statements are directly related to the toxicity of the pesticide product (signal word) and the route or routes of entry which must particularly be protected.

DANGER labels typically contain statements such as:

- Do not breathe vapors or spray mist,
- Do not get on skin or clothing,
- Do not get in eyes.

(You would not deliberately swallow the pesticide, so the "Do not swallow" statement is omitted.)

These statements correspond to the strongest statements in the "route of entry" section. For example, if the only reason a product has a DANGER label is because it can cause corrosive eye damage, the specific action statement might read: "Do not get in eyes. Avoid contact with skin and breathing vapors, dusts, or spray mists." Most DANGER label products, however, are highly toxic through most or all of the entry routes, so several "Do not" statements will appear.

Typical WARNING labels combine specific action statements from DANGER and CAUTION labels. Depending on which route or routes are most likely to cause poisoning, the label might list "do not get in skin or eyes," but "avoid breathing vapors and spray mist." This indicates that poisoning by inhalation of the pesticide is less likely than receiving skin or eye injury.

CAUTION labels generally contain specific action statements which are much milder than those on the DANGER label:

- Avoid contact with skin or clothing,
- Avoid breathing dust, vapors, or spray mists,
- Avoid getting in eyes.

These statements indicate that the toxicity hazard is not as great.

The specific action statements help you prevent pesticide poisoning by taking the necessary precautions and wearing the correct protective clothing and equipment.

Protective Clothing and Equipment Statements

Pesticide labels vary in the type of protective clothing and equipment statements they contain. Many labels carry no statement at all. The best way to determine the correct type of protective clothing and equipment is to use the signal word, the route of entry statements, and the specific action statements, along with the basic guidelines listed in the chapter on safety.

You should follow all advice on protective clothing or equipment which appears on the label. However, the lack of any statement or the mention of only one piece of equipment does not rule out the need for additional protection.

A WARNING label, for example, might carry the statements: "Causes skin and eye irritation. Do not get in eyes, on skin, or on clothing. Wear goggles while handling." Even though the label does not specifically require them, you should wear a long-sleeved shirt, long-legged trousers, and gloves. You should consider wearing rubberized or waterproof clothing if you will be in prolonged contact or wet by an overhead spray application.

Some pesticide labels fully describe appropriate protective clothing and equipment. A few list the kinds of respirators which should be worn when handling and applying the product. Others require the use of a respirator but do not specify type or model to be used.

Other Precautionary Statements

Labels often list other precautions to take while handling the product. These are self-explanatory:

- Do not contaminate food or feed,
- Remove and wash contaminated clothing before reuse,
- Wash thoroughly after handling and before eating or smoking,
- Wear clean clothes daily,
- Not for use or storage in and around a house,
- Do not allow children or domestic animals into the treated area.

These statements represent actions which a competent applicator will always follow. The absence of any or all of them from the label DOES NOT indicate that they need not be performed.

Statement of Practical Treatment

These statements tell you the first aid treatments recommended in case of poisoning. Typical statements include:

- In case of contact with skin, wash immediately with plenty of soap and water,
- In case of contact with eyes, flush with water for 15 minutes and get medical attention,
- In case of inhalation exposure, move from contaminated area and give artificial respiration, if necessary,
- If swallowed, drink large quantities of milk, egg white, or water—do not induce vomiting,
- If swallowed, induce vomiting.

All DANGER labels and some WARNING and CAUTION labels contain a note to physicians describing the appropriate medical procedures for poisoning emergencies and may identify an antidote.

Environmental Hazards

Pesticides may be harmful to the environment. Some products are classified RESTRICTED USE because of environmental hazards alone. Watch for special warning statements on the label concerning hazards to the environment.

Special Toxicity Statements

If a particular pesticide is especially hazardous to wildlife, that will be stated on the label. For example:

- This product is highly toxic to bees,
- This product is toxic to fish,
- This product is toxic to birds and other wildlife.

These statements alert you to the special hazards that the use of the product may pose. They should help you choose the safest product for a particular job and remind you to take extra precautions.

General Environmental Statements

Some of these statements appear on nearly every pesticide label. They are reminders of common sense actions to follow to avoid contaminating the environment. The absence of any or all of these statements DOES NOT indicate that you do not have to take adequate precautions.

Sometimes these statements follow a "specific toxicity statement" and provide practical steps to avoid harm to wildlife. Examples of general environmental statements include:

- Do not apply when runoff is likely to occur,
- Do not apply when weather conditions favor drift from treated areas,
- Do not contaminate water by cleaning of equipment or disposal of wastes,
- Keep out of any body of water,
- Do not allow drift on desirable plants or trees,
- Do not apply when bees are likely to be in the area.

Physical or Chemical Hazards

This section of the label will tell you of any special fire, explosion, or chemical hazards the product may pose. For example:

- Flammable—Do not use, pour, spill, or store near heat or open flame. Do not cut or weld container.
- Corrosive—Store only in a corrosion-resistant tank.

NOTE: Hazard statements (hazards to humans and domestic animals, environmental hazards, and physical-chemical hazards) are not located in the same place on all pesticide labels. Some newer labels group them in a box under the headings listed above. Other labels may list them on the front panel beneath the signal word. Still other labels list the hazards in paragraph form somewhere else on the label under headings such as "Note" or "Important". You should search the label for statements which will help you apply the pesticide more safely and knowledgeably.

Classification Statement

Every use of every pesticide will be classified by the U. S. Environmental Protection Agency as either "general" or "restricted." When a pesticide is classified for general use, the words "General Classification" will appear immediately below the heading "Directions for Use."

Every pesticide product which has been restricted must carry this statement in a prominent place at the top of the front panel of the pesticide label:

RESTRICTED USE PESTICIDE
For retail sale to and use only by certified applicators or persons under their direct supervision and only for those uses covered by the certified applicator's certification.

NOTE: At this printing, EPA has not completed the classification of the many pesticide products on the market. Therefore, the absence of a RESTRICTED USE statement does not necessarily indicate that the product has a low hazard level. Use the signal word and the precautionary statements to judge the toxicity hazard of all pesticide products.

Reentry Statement

Some pesticide labels with the signal word DANGER or WARNING (especially cholinesterase-inhibiting pesticides) contain a reentry precaution. This statement tells you how much time must pass before people can reenter a treated area without appropriate protective clothing. These reentry intervals are set by both EPA and some states. Reentry intervals set by states are not always listed on the label; it is your responsibility to determine if one has been set. It is illegal to ignore reentry intervals.

The minimum legal protective clothing for early reentry following agricultural and other outdoor treatments is:

- long-sleeved shirt,
- long-legged trousers or coveralls,
- hat,
- sturdy shoes with socks.

Gloves are suggested. For early reentry in enclosed areas, a respirator may be necessary.

The reentry statement may be printed in a box under the heading "Reentry" or it may be in a section with a title such as "Important," "Note," or "General Information."

If no reentry statement appears on the label or is set by your state, then you must wait at least until sprays are dried or dusts have settled before reentering or allowing others to reenter a treated area without protective clothing. That is the minimum legal reentry interval.

Storage and Disposal

All pesticide labels contain general instructions for the appropriate storage and disposal of the pesticide and its container. State and local laws vary considerably, so specific instructions usually are not included. Typical statements include:

- Not for use or storage in or around the home,
- Store away from fertilizers, insecticides, fungicides, and seeds,
- Store at temperatures above 32° F (0° C),
- Do not reuse container,
- Do not contaminate water, food, or feed by storage and disposal,
- Open dumping is prohibited,
- Triple rinse and offer this container for recycling or reconditioning, or dispose in an approved landfill or bury in a safe place.
- Use excess or dispose in an approved landfill or bury in a safe place,
- Do not reuse bag. Burn or bury in a safe place.

One or more of these statements may appear on a pesticide label. You should try to determine the best storage and disposal procedures for your operation and location. These statements may appear in a special section of the label titled "Storage and Disposal" or under headings such as "Important," "Note," or "General Instructions."

Directions for Use

The instructions on how to use the pesticide are an important part of the label for you. This is the best way you can find out the right way to apply the product.

The use instructions will tell you:

- the pests which the manufacturer claims the product will control. (You may legally apply a pesticide against a pest not specified on the labeling if the application is to a crop, animal, or site which the labeling approves.)
- the crop, animal, or site the product is intended to protect,
- in what form the product should be applied,
- the proper equipment to be used,
- how much to use,
- mixing directions,
- compatibiity with other often-used products,
- phytotoxicity and other possible injury or staining problems,
- where the material should be applied,
- when it should be applied.

Labels for agricultural pesticides often list the least number of days which must pass between the last pesticide application and harvest of crops, or slaughter, or grazing of livestock. These are intervals set by EPA to allow time for the pesticide to break down in the environment. This prevents illegal residues on food, feed, or animal products and possible poisoning of grazing animals. This information may appear as a chart or it may be listed just after application directions for the target crop or animal.

Label Terminology

Many terms are used on the label to describe when and how to use pesticides. They also are found in leaflets and bulletins that you may get from your local Cooperative Extension agent, land-grant university, or other agencies. Your understanding of these terms will help you get the best results from pesticides.

Terms that tell you **when to use** the pesticide product include:

Preplant—used before the crop is planted.

Preemergence—used before crop or pests emerge. May also refer to use after crops emerge or are established, but before pests emerge.

Postemergence—used after the crop or pests have emerged.

Terms that tell you **how to use** the pesticide product include:

Band—application to a strip over or along a crop row or on or around a structure.

Basal—application to stems or trunks at or just above the ground line.

Broadcast—uniform application to an entire, specific area.

Crack and crevice—application in structures to cracks and crevices where pests may live.

Dip—complete or partial immersion of a plant, animal, or object in a pesticide.

Directed—aiming the pesticide at a portion of a plant, animal, or structure.

Drench—saturating the soil with a pesticide; also, the oral treatment of an animal with a liquid.

Foliar—application to the leaves of plants.

In-furrow—application to the furrow in which a plant is planted.

Over-the-top—application over the top of the growing crop.

Pour-on—pouring the pesticide along the midline of the back of livestock.

Sidedress—application along the side of a crop row.

Soil application—application to the soil rather than to vegetation.

Soil incorporation—use of tillage implements to mix the pesticide with the soil.

Soil injection—application beneath the soil surface.

Spot treatment—application to a small area.

Reading the Label

Before you buy a pesticide, read the label to determine:

- whether it is the pesticide you need for the job,
- whether the pesticide can be used safely under the application conditions.

Before you mix the pesticide, read the label to determine:

- what protective equipment you should use,
- what the pesticide can be mixed with (compatibility),
- how much pesticide to use,
- the mixing procedure.

Before you apply the pesticide, read the label to determine:

- what safety measures you should follow,
- where the pesticide can be used (livestock, crops, structures, etc.),
- when to apply the pesticide (including the waiting period for crops and animals),
- how to apply the pesticide,
- whether there are any restrictions for use of the pesticide.

Before you store or dispose of the pesticide or pesticide container, read the label to determine:

- where and how to store the pesticide,
- how to decontaminate and dispose of the pesticide container,
- where to dispose of surplus pesticides.

Protecting the Environment

Protecting the Environment

The environment is our surroundings and its many forms of life. Water, air, soil, plants, and wildlife are important parts of our environment. Because pesticides can be pollutants, you must use them correctly to prevent harm to the environment. You should be aware of how pesticide contamination can affect our natural resources. By knowing and following good application practices, you can protect the environment and yourself and be a responsible pesticide applicator.

Potential Hazards

When pesticides are used in a way other than as directed on the label, they can:

- injure nontarget plants and animals,
- leave harmful residues, and
- move from the application site into the surrounding environment.

Direct Kill of Nontarget Plants and Animals

Pesticides which are improperly applied can kill nontarget organisms. Drift from the target area may injure fish, birds, other wildlife, and sensitive plants. Drift of herbicides can damage nearby crops, forests, or landscape plantings. Poorly timed applications can kill bees and other pollinators which are working in the area. Or you may kill beneficial parasites and predators that help control pests.

Runoff from treated areas can kill fish and other aquatic animals and plants in nearby ponds, streams, and lakes. Aquatic life also can be killed by careless tank filling or draining and by rinsing or discarding used containers along or in waterways.

Pesticides can harm other wildlife, too. Even tiny amounts of pesticide may kill them or destroy their source of food. Pesticides applied over large areas, such as in mosquito, biting fly, and forestry pest control, must be chosen with great care to avoid poisoning nontarget plants and animals in the area.

Ask for help in choosing the safest pesticide for the job. Injury or death to nontarget plants and animals can lead to lawsuits, fines, and loss of your applicator certification.

Long-Term Effects

Pesticides can be harmful in the environment even if they do not cause direct kills of nontarget plants and animals. Some pesticides can build up in the bodies of animals (including humans). These are called **accumulative** pesticides. The chemicals may be stored in an animal's body until they are harmful to it or to the meat-eater which feeds on it. Long-term effects include eggs that will not hatch and young that will not develop normally. The behavior of an animal may be altered so that predators can more easily catch and kill it. Many accumulative pesticides are in the chlorinated hydrocarbon family (DDT, heptachlor, and aldrin) and have limited uses in the United States.

Some pesticides stay in the environment without change for long periods of time. These are **persistent** pesticides. Persistent pesticides which are not stored by animal tissues are often harmless to the environment. They may stay on or in the soil and give long-term pest control without repeated applications. Sometimes these pesticides injure sensitive plants planted in the treated soil.

Pesticides which break down quickly in the environment to form harmless materials are called **nonpersistent**. These pesticides are often broken down easily by microorganisms or sunlight or are highly soluble in water. Most organophosphate and carbamate pesticides are nonpersistent.

Pesticide Movement

Pesticides which move away from the target area are problems in the environment. Highly volatile pesticides such as 2-4-D esters can move great distances as invisible vapor in the air and injure nontarget plants. Dusts, aerosols, and fogs can easily drift away from the target area with air currents. Any application that produces fine dust or spray particles may result in drift.

Pesticides move off target in other ways also. They may be carried off target by rain and runoff water. They may leach through the soil to areas nearby or to ground water below.

Whenever you are applying a pesticide, select the pesticide, the formulation, and the application equipment which will most likely result in an application which stays on target.

Contamination of Soils

Pesticides which move off target onto soil or which persist in soil may limit the use of that soil. Agricultural, ornamental, turf, and forestry crops may be killed or contaminated if planted on the site. Residential, grazing, and recreational uses of the soil may be impossible if the soil contains pesticide residues. The pesticide label will list crop rotation limits and other growing restrictions.

Contamination of Air

The movement of pesticides in the air cannot be controlled. The polluted air creates a hazard for people, animals, or plants that come into contact with it. Pesticides in the air may settle onto water, crops, livestock, trees, parks, or houses. Provide adequate spacing or a buffer zone when applying pesticides near sensitive areas. Keep in mind that the wind can carry pesticide particles or droplets many miles off target.

Contamination of Water

Water is necessary for all life. Humans and animals need clean water for drinking and bathing. Most fish and other aquatic animals and plants can survive only slight contamination of their water environment.

Farmers, ranchers, horticulturists, foresters, and turf growers need uncontaminated water for their livestock and for irrigation. Polluted water can injure the plants or animals directly or cause illegal residues in the food, feed, poultry, or livestock products.

Pesticides get into water in many ways. Sometimes they are applied directly to the water to control aquatic pests. Pesticide contamination of water occurs most often when pesticides reach the water through carelessness or misuse of pesticides.

Potential Benefits

Pesticides can help the environment when they are used carefully and wisely. For years they have been used to control pests which are harmful to humans. With the help of pesticides, we produce food, feed, and fiber. Forests, ornamentals, buildings, and turfgrass plantings can be protected. Diseases, insects, and other plant pests can be greatly reduced. There can be higher yields and better crop quality using less land to produce more food products.

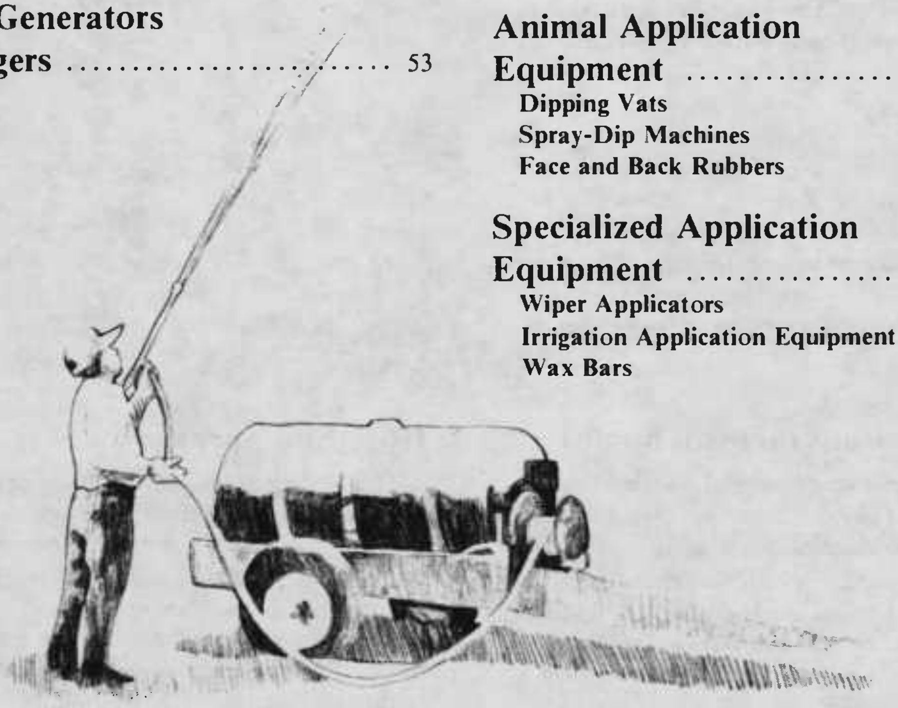
Pesticides can be used to enhance outdoor activities in parks and camping areas. Fly and mosquito control programs give relief from the annoying pests. Aquatic pest control programs help keep lakes and waterways usable for swimming, boating, and fishing.

Pesticides protect livestock and domestic animals from harmful and annoying pests. The quantity and quality of livestock products—milk, eggs, meat, wool, and leather—are improved when pests are controlled.

Herbicides help keep rights-of-way clear of weeds. Highways, runways, train tracks, and utility rights-of-way must be weed-free to allow safe, unobstructed traffic flow. Barnyards, warehouses, utility lines, and other similar areas are safer when herbicides are used to keep weeds out.

By selecting pesticides wisely and applying them correctly, the responsible pesticide applicator can use these chemicals for the benefit of the environment.

Application Equipment



Application Equipment

The pesticide application equipment you use is important to the success of your pest control job. You must first select the right kind of application equipment; then you must use it correctly and take good care of it. Here are some things you should know about choosing, using, and caring for equipment.

Sprayers

Sprayers are the most common pesticide application equipment. They are standard equipment for nearly every professional pesticide applicator and are used in every type of pest control operation. Sprayers range in size and complexity from simple, hand-held models to intricate machines weighing several tons.

Hand Sprayers

Hand sprayers are often used to apply small quantities of pesticides. They can be used in structures and they can be used outside for spot treatments or in hard-to-reach areas. Most operate on compressed air which is supplied by a manually-operated hand pump. These sprayers are usually used in the structural pest control industry and are common in home gardens.

Advantages:
- economical,
- simple to operate,
- easy to clean and store.

Limitations:
- pressure and output rate fluctuate,
- often provide too little agitation to keep wettable powders in suspension; must be shaken frequently.

Pressurized Cans (aerosol bomb)

This type of sprayer consists of a sealed container of compressed gas and pesticides. The pesticide is driven through an aerosol-producing nozzle when the valve is activated. Pressurized cans usually have a capacity of less than 1 quart (1 liter) and are not reusable. Larger reusable cylinders are available for structural pest control and for some greenhouse uses.

Trigger Pump Sprayer

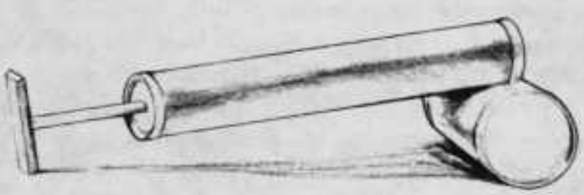
With trigger pump sprayers, the pesticide is not packaged under pressure. Instead, the pesticide and diluent are forced through the nozzle by pressure created when the pump is squeezed. Their capacity ranges from 1 pint to 1 gallon.

Hose End Sprayer

This device causes a fixed rate of pesticide to mix with the water flowing through the hose to which it is attached. The mixture is expelled through a high-volume nozzle. These sprayers usually hold no more than 1 quart (1 liter) of concentrated pesticide, but because the concentrate mixes with the water, they may deliver 20 gallons or more of finished spray solution before refilling.

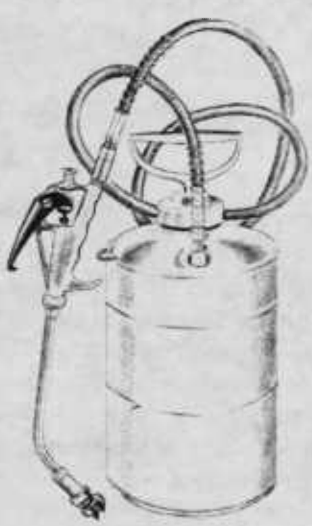
Push-Pull Hand Pump Sprayer

This type of sprayer depends on a hand-operated plunger which forces air out of a cylinder, creating a vacuum at the top of a siphon tube. The suction draws pesticide from the small tank and forces it out with the air flow. Capacity is usually 1 quart (1 liter) or less.



Compressed Air Sprayer

A hand-carried sprayer which operates under pressure, created by a self-contained manual pump. Capacity usually 1-3 gallons. Commonly used by homeowners and pest control operators.



Backpack Sprayer

A backpack sprayer is similar to a push-pull sprayer, except that it is a self-contained unit (tank and pump) and is carried on the operator's back. A mechanical agitator plate may be attached to the pump plunger. Capacity of these sprayers is usually less than 5 gallons.

Bucket or Trombone Sprayer

These sprayers involve a double-action hydraulic pump which is operated with a push-pull motion. The pesticide is sucked into the cylinder and pushed out through the hose and nozzle with the stroke. Pressures up to 150 psi can be achieved. The separate tank often consists of a bucket with a capacity of 5 gallons or less.

Wheelbarrow Sprayer

The wheelbarrow sprayer is similar to the backpack sprayer, but has a larger tank and longer hose line. The tank is mounted on a wheel for easy transport. The capacity of these sprayers is usually less than 25 gallons.

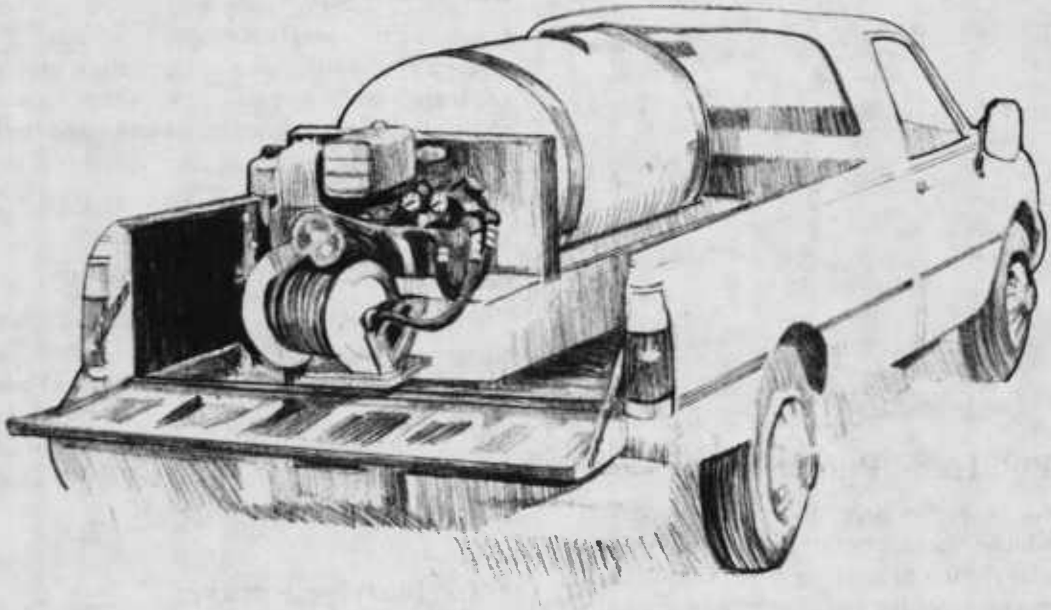
Small Motorized Sprayers

Some small sprayers have all the components of larger field sprayers but are usually not self-propelled. They may be mounted on wheels so they can be pulled manually; mounted on a small trailer for pulling behind a small tractor; or skid-mounted for carrying on a small truck. They may be low-pressure or high-pressure, according to the pump and other components with which they are equipped.

Standard equipment includes a hose and an adjustable nozzle on a handgun. Some models have multi-nozzle booms. These sprayers are suitable for relatively small outdoor areas, especially small orchards, ornamental and nursery plantings, and golf course greens.

Advantages:
- larger capacity than hand sprayers,
- low- and high-pressure capability,
- built-in hydraulic agitation,
- small enough for limited spaces.

Limitations:
- not suitable for general field use,
- cost relatively high.



Estate Sprayers

These sprayers are mounted on a two-wheel cart with handles for pushing. Trailer hitches are available for towing the units. Spray material is hydraulically agitated. Some models have 15- to 30-gallon tanks. Pumps deliver $1\frac{1}{2}$ to 3 gallons per minute at pressures up to 250 psi.

Larger models have 50-gallon tanks and pumps that deliver 3 to 4 gallons per minute at pressures up to 400 psi. Power is supplied by an air-cooled engine of up to 5 horsepower.

Power Wheelbarrow Sprayer

This sprayer is simply a powered version of the manually-operated wheelbarrow sprayer described above. It may deliver up to 3 gallons per minute and can develop pressures up to 250 psi. The $1\frac{1}{2}$- to 3- horsepower engine is usually air-cooled. The tank size ranges from 12 to 18 gallons. The spray mixture may be either mechanically or hydraulically agitated.

Larger Power-Driven Sprayers

Low-Pressure Sprayers

These sprayers are designed to distribute dilute liquid pesticides over large areas. They are most often used in agricultural, ornamental, turf, forestry, aquatic, regulatory, and right-of-way pest control operations. They deliver a low to moderate volume of spray—usually 10 to 60 gallons per acre—at working pressures ranging from 10 to 80 psi.

These sprayers are usually mounted on tractors, trucks, or boats, but some are self-propelled. Roller and centrifugal pumps are most often used and provide outputs from 5 to more than 20 gallons per acre. Tank sizes range from 50 gallons or less to 1,000 gallons. The spray material is usually hydraulically agitated, but mechanical agitation may be used.

Advantages:

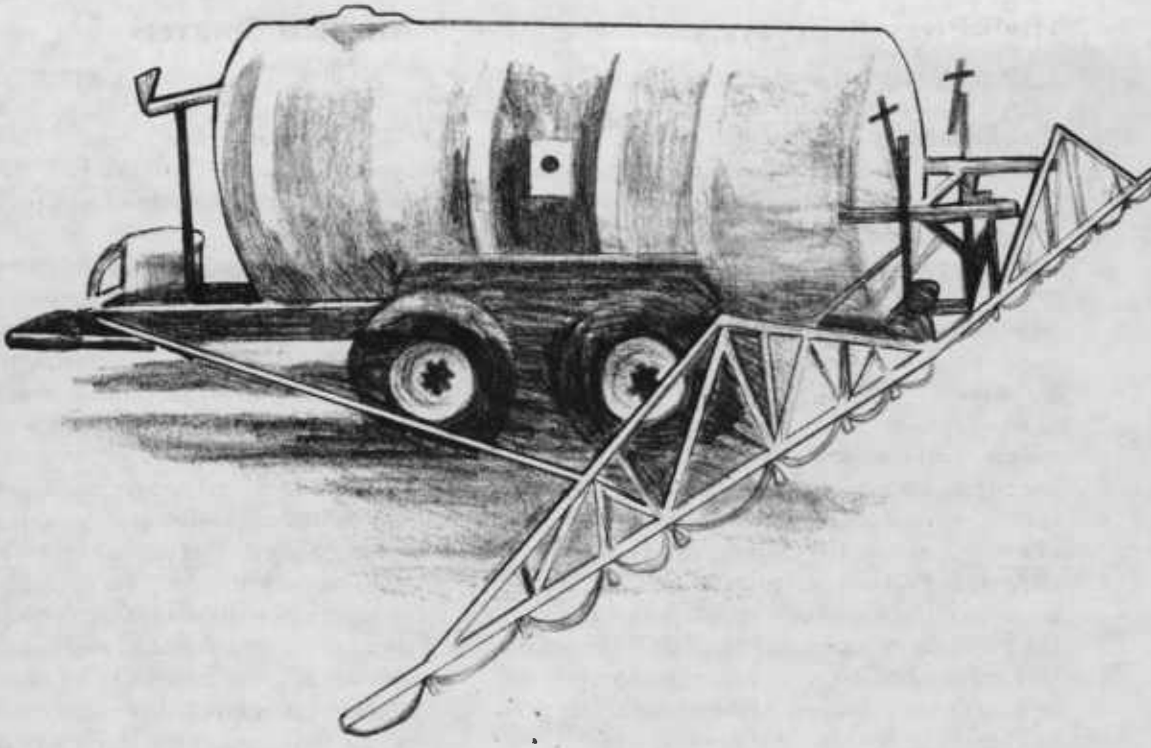
- medium to large tanks,
- lower cost than high-pressure sprayers,
- versatility.

Limitations:

- low pressure limits pesticide penetration and reach.

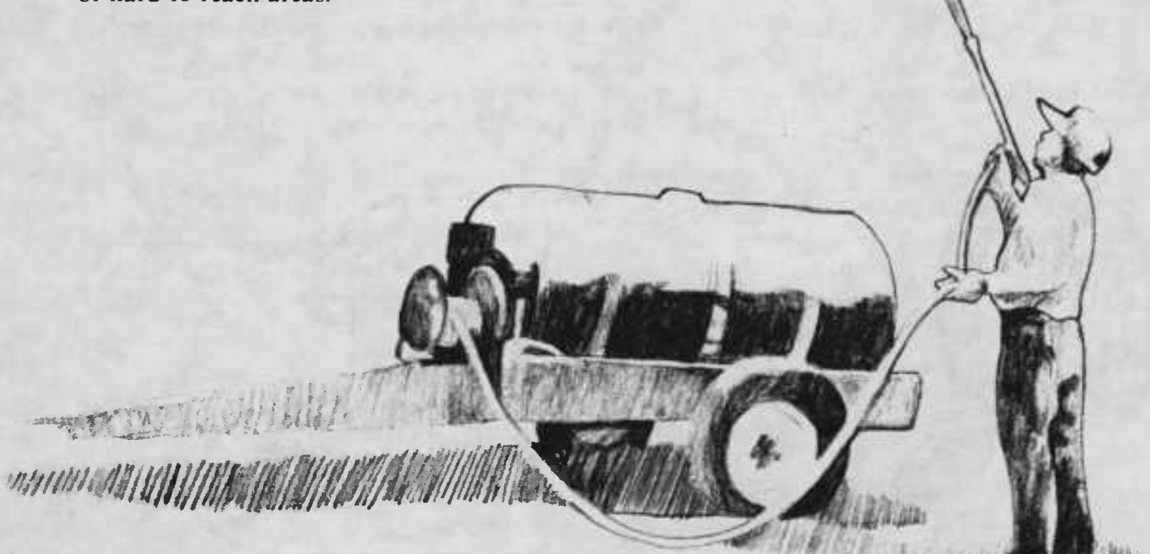
Boom Sprayers

Low-pressure sprayers are often equipped with sprayer booms ranging from 10 to 60 feet in length. The most common booms are between 20 and 35 feet long and contain many nozzles. The height of the sprayer boom must be easily adjusted to meet the needs of the job. Boom supports should allow the boom to be set at any height from 12 to 72 inches above the surface being sprayed. Many nozzle arrangements are possible, and special-purpose booms are available.



Boomless Sprayers

Low-pressure sprayers which are not equipped with booms generally have a central nozzle cluster that produces a horizontal spray pattern. The resulting swath is similar to the pattern made by a boom sprayer. These sprayers are useful in irregularly-shaped areas, because they can move through narrow places and avoid trees and other obstacles. Some low-pressure sprayers are equipped with a hose and handgun nozzle for applications in small or hard-to-reach areas.



High-Pressure Sprayers

These sprayers are used to spray through dense foliage, thick animal hair, to the tops of tall trees, and into other areas where high-pressure sprays are necessary for adequate penetration. Commercially, they are used in agricultural, livestock, ornamental, turf, forestry, regulatory, right-of-way, and some structural pest control operations. Often called "hydraulic" sprayers, they are equipped to deliver large volumes of spray—usually 20 to 500 gallons per acre—under pressures ranging from 150 to 400 psi or more.

These sprayers are usually mounted on tractors, trailers, trucks, or boats, or are self-propelled. Piston pumps are used and provide outputs up to 60 gallons or more per minute. Because the application rate is usually 100 gallons per acre or more, large tanks (500 to 1,000 gallons) are used. Mechanical agitators are usually standard equipment, but hydraulic agitators may be used. When fitted with correct pressure unloaders, these sprayers can be used at low pressures. All hoses, valves, nozzles, and other components must be designed for high-pressure applications.

High-pressure sprayers may be equipped with a hose and single handgun nozzle for use in spraying trees and animals. These sprayers are also fitted with a boom for agricultural, ornamental, nursery, and aquatic applications.

Advantages:

- provide good penetration and coverage of plant surfaces,
- usually well-built and long-lasting if properly cared for.

Limitations:

- high cost,
- large amounts of water, power, and fuel needed,
- high pressure may produce fine droplets which drift easily.

Air Blast Sprayers

Air blast sprayers use a combination of air and liquid rather than liquid alone to deliver the pesticide to the surface being treated. They are used in agricultural, ornamental and turf, biting fly, forestry, livestock, and right-of-way pest control operations.

These sprayers usually include the same components as low-pressure or high-pressure sprayers, plus a high-speed fan. Nozzles operating under low pressure deliver spray droplets directly into the high-velocity airstream. The air blast shatters the drops of pesticide into fine droplets and transports them to the target. The air blast is directed to one or both sides as the sprayer moves forward, or it may be delivered through a movable nozzle.

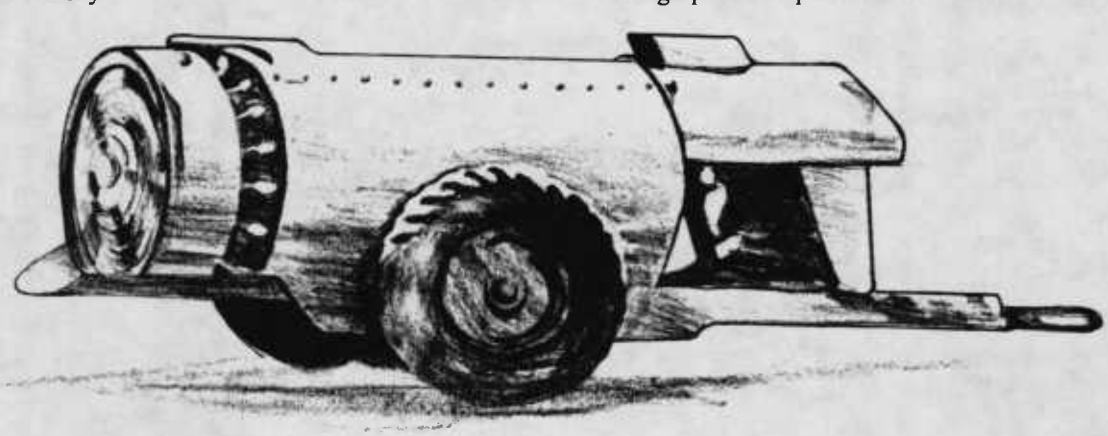
Most air blast sprayers are trailer-mounted, but tractor-mounted models are available. Tank capacity ranges from 100 to 1,000 gallons. Most of these sprayers can be adapted to apply either high or low volumes of spray material as well as concentrates. Mechanical agitation of the spray mixture is usual. An air blast sprayer may cover a swath up to 90 feet wide and reach trees up to 70 feet tall.

Advantages:

- good coverage and penetration,
- mechanical agitation,
- high capacity,
- can spray high or low volumes,
- low pump pressures.

Limitations:

- high cost of equipment,
- drift hazards,
- use of concentrated pesticides may increase chance of dosage errors,
- not suitable for windy conditions,
- hard to confine discharge to limited target area,
- difficult to use in small areas,
- high power requirement and fuel use.



Other Sprayers

Ultra Low Volume (ULV) Sprayers

These are sprayers that use special pesticide concentrates. They may be used in agricultural, ornamental, turf, forestry, right-of-way, biting fly, and some structural pest control operations. ULV sprayers may be hand-held or mounted on either ground equipment or aircraft.

Advantages:
- no water is needed, so less time and labor are involved,
- equal control with less pesticide.

Limitations:
- does not provide for thorough coverage,
- hazards of using high concentrates,
- chance of overdosage,
- small number of pesticides registered for ULV use.

Spinning Disc Sprayers

These sprayers use a special type of nozzle which spins at a high speed and breaks the liquid into uniformly sized droplets by centrifugal force. The droplets may be carried to the target by gravity or by an airstream created by a fan. Power to spin the nozzles is provided by small electric or hydraulic motors. Sizes range from a small hand-held type to large tractor-mounted and trailer-mounted units.

Advantages:
- low volume of water required,
- produces narrower range of droplet sizes than conventional nozzles, thus reducing drift,
- droplet size can be adjusted by speed of rotation,
- low-pressure pump and components.

Limitations:
- relatively high cost,
- foliar penetration may be limited on gravity type,
- not suitable for use in windy conditions.

Recirculating Sprayers

These devices usually are used to apply contact herbicides to weeds which are taller than the crop in which they are growing. Solid streams of highly concentrated herbicides are directed across rows above the crop. Spray material which is not intercepted by the weeds is caught in a box or sump on the opposite side of the row and is recirculated.

Advantages:
- uses small quantities of pesticide,
- less pesticide moves off target and into environment,
- permits treatment of weeds which have escaped other control measures,
- protects susceptible nontarget plants from injury.

Limitations:
- use limited to special situations,
- relatively high cost.

Electrostatic Sprayers

Electrostatic sprayer systems are designed to reduce drift and apply less pesticide per acre. The pesticide is charged with a positive electric charge as it leaves the nozzles. Plants have a natural negative charge, so the pesticides are attracted to the plants. The spray is directed horizontally through or above the crop (depending on the pesticide being applied).

Sprayer Parts

Tanks

Tanks should have large openings for easy filling and cleaning. They should allow straining during filling and have provision for mechanical or hydraulic agitation. The tank should be made of corrosion-resistant material such as stainless steel or fiberglass. If made of mild steel, it should have a protective lining or coating.

The tank should have a large drain, and other outlets should be sized to the pump capacity. If you use dual tanks, make sure the plumbing allows for agitation and adequate withdrawal rates in both tanks. All tanks should have a gauge to show the liquid level. External gauges should be protected to prevent breakage. All tanks should have a shut-off valve for storing liquid pesticide temporarily while other sprayer parts are being serviced.

Pumps

The pump must have sufficient pumping capacity to supply the needed volume to the nozzles and to the hydraulic agitator (if necessary) and to maintain the desired pressure. The pump parts should be resistant to corrosion and abrasion if abrasive materials such as wettable powders are to be used. Select gaskets, plunger caps, and impellers that are resistant to the swelling and chemical breakdown caused by many liquid pesticides. Consult your dealer for available options.

Never operate a sprayer pump at speeds or pressures above those recommended by the manufacturer. Pumps will be damaged if run dry or with restricted inlet or outlet. Pumps depend on the spray liquid for lubrication and removal of the heat of friction.

Roller Pumps

Roller pumps are among the least expensive and most widely used of all sprayer pumps. They provide moderate volumes (8 to 30 gpm) at low to moderate pressure (10 to 300 psi). Often used on low-pressure sprayers, roller pumps are positive-displacement self-priming pumps. The rollers, made of nylon, teflon, or rubber, wear rapidly in wettable powders but are replaceable. A pump that will be subjected to such wear should have a capacity about 50 percent greater than that needed to supply the nozzles and agitator. This reserve capacity will extend the life of the pump. The pump case is usually cast iron or a nickel alloy. Roller pumps are best for emulsifiable concentrates, soluble powders, and other nonabrasive pesticide formulations.

Gear Pumps

Gear pumps are used on sprayers with low operating pressures. They provide low to moderate volume (5 to 65 gpm) at low to moderate pressures (20 to 100 psi). Often used on special-purpose sprayers, gear pumps are positive-displacement, self-priming pumps. The self-priming ability is rapidly lost as the pump wears. These pumps are designed for oil solution formulations and wear rapidly when suspensions of wettable powders are used. The parts are generally not replaceable. The pump is not affected by solvents, since all parts are metal. The case may be bronze with stainless steel impellers, or it may be made entirely of bronze.

Centrifugal Pumps

Centrifugal pumps are relatively inexpensive pumps adaptable to a wide variety of spray applications. Generally, they deliver high volume (up to 200 gpm) at low pressures (5 to 70 psi); however, two-stage pumps develop high pressures (up to 200 psi). Used on agricultural sprayers, commercial spray-dip machines, and other equipment, these are not positive-displacement pumps, so pressure regulators and relief valves are not necessary. They are not self-priming and must be mounted below the tank outlet or with a built-in priming system. Centrifugal pumps are well adapted for spraying abrasive materials because the impeller does not contact the pump housing. Many models are easily repairable. The pump case is usually iron; the impeller is iron or bronze.

Diaphragm Pumps

Diaphragm pumps deliver low volume (3 to 10 gpm) at low to moderate pressure (10 to 100 psi). They withstand abrasion from wettable powder mixtures much better than the gear or roller pumps because the spray mixture does not contact any moving metal parts except the valves. Diaphragm pumps are positive-displacement, self-priming pumps. The rubber or neoprene diaphragm may be damaged by some solvents. The pump case is usually iron.

Piston Pumps

Piston pumps are the most expensive of the commonly used sprayer pumps. They deliver low to medium volumes (2 to 60 gpm) at low to high pressures (20 to 800 psi). Used for high-pressure sprayers or when both low and high pressures are needed, piston pumps are positive-displacement, self-priming pumps. They have replaceable piston cups made of leather, neoprene, or nylon fabric which make the pump abrasion-resistant and capable of handling wettable powders for many years. The cylinders are iron, stainless steel, or porcelain-lined. The pump casing is usually iron.

Strainers (Filters)

Pesticide mixtures should be filtered to remove dirt, rust flakes, and other foreign materials from the tank mixture. Proper filtering protects the working parts of the sprayer from undue wear and avoids time loss and uneven application caused by clogged nozzle tips.

Filtering should be progressive, with the largest mesh screens in the filler opening and in the suction line between the tank and the pump. They should be keyed to the size of the nozzle opening. Total screen area should be large enough to prevent pump starvation. This requires at least 2 square inches of screen area for each gpm of flow in the suction line. Put a smaller mesh strainer in the pressure line between the pump and the pressure regulator, with at least 1 square inch of screen area for each gpm of flow. Put the finest mesh strainer nearest the nozzles. Do not use a strainer in the suction line of a centrifugal pump, but be sure the tank has a strainer to take out large trash particles.

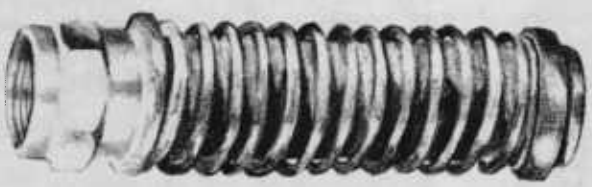
Strainers should be placed:

- on the filler opening (12 to 25 mesh),

- on the suction or supply line to the pump (15 to 40 mesh).
- between the pressure relief valve and the boom (25 to 100 mesh).
- on the nozzle body (50 to 100 mesh).

Clean strainers after each use, or during use if they become clogged. A shut-off valve between the tank and suction strainer is necessary to allow cleaning the strainer without draining the contents of the tank. Replace damaged or deteriorated strainers.

Strainers are your best defense against nozzle plugging and pump wear. Nozzle screens should be as large as nozzle size permits; however, the screen opening should be less than the nozzle opening. Nozzle catalogs specify the proper screen size for each nozzle.



Hoses

Select neoprene, rubber, or plastic hoses that:

- have burst strength greater than the peak operating pressures.
- have a working pressure at least equal to the maximum operating pressure.
- resist oil and solvents present in pesticides.
- are weather resistant.

Suction hoses should be reinforced to resist collapse. They should be larger than pressure hoses, with an inside diameter equal to or larger than the inlet part of the pump. All fittings on suction lines should be as large as or larger than the inlet part of the pump.

Keep hoses from kinking or being rubbed. Rinse them often, inside and outside, to prolong life. During the off season, store the unit out of the sun. Replace hoses at the first sign of surface deterioration (cracking or checking).

Pressure Gauges

Pressure gauges monitor the function of your spraying system. They must be accurate and have the range needed for your work. For example, a 0 to 100 psi gauge with 2-pound gradations would be adequate for most low-pressure sprayers.

Check frequently for accuracy against an accurate gauge. Excess pressure will destroy a gauge. If yours does not zero, replace it. Use gauge protectors to guard against corrosive pesticides and pressure surges.

Pressure Regulators

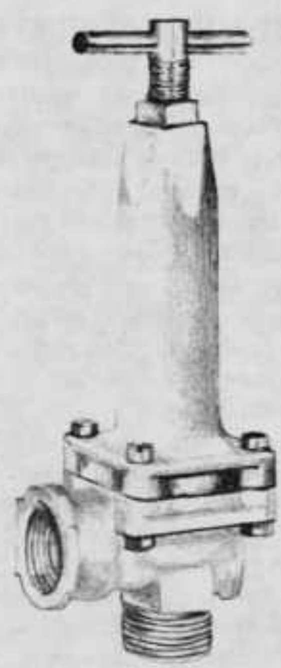
The pressure regulator controls the pressure and, indirectly, the quantity of spray material delivered by the nozzles. It protects pump seals, hoses, and other sprayer parts from damage due to excessive pressure.

The bypass line from the pressure regulator to the tank should be kept fully open and unrestricted and should be large enough to carry the total pump output without excess pressure buildup. The pressure range and flow capacity of the regulator must match the pressure range you plan to use and the capacity of the pump. Agitation devices should never be attached to the bypass line discharge.

Pressure regulators are usually one of three types:

Throttling valves simply restrict pump output, depending on how much the valve is open. These valves are used with centrifugal pumps, whose output is very sensitive to the amount of restriction in the output line.

Spring-loaded bypass valves (with or without a diaphragm) open or close in response to changes in pressure, diverting more or less liquid back to the tank to keep pressure constant. These valves are used with roller, diaphragm, gear, and small piston pumps.



Unloader valves work like a spring-loaded bypass valve when the sprayer is operating. However, when the nozzles are shut down, they reduce strain on the pump by moving the overflow back into the tank at low pressure. These valves should be used on larger positive-displacement pumps (piston and diaphragm) to avoid damage to the pump or other system components when the nozzles are cut off.

Agitators

Every sprayer must have agitation to keep the spray material uniformly mixed. If there is too little agitation, the pesticide will be applied unevenly. If there is too much agitation, some pesticides may foam and interfere with pump and nozzle operation. The type of agitation necessary depends on the pesticide formulation to be used.

Bypass Agitators

Soluble powders and liquid formulations such as solutions and emulsifiable concentrates require little agitation. Bypass agitation is sufficient for these formulations. Bypass agitation uses the returning liquid from the pressure relief valve to agitate the tank: The return must extend to the bottom of the tank to prevent excessive foaming.

Bypass agitation is not sufficient for wettable powders or in tanks larger than 55 gallons unless a centrifugal pump is used. Centrifugal pumps usually have large enough outputs to make bypass agitation adequate even for wettable powders in tanks less than 100 gallons.

Hydraulic (Jet Action) Agitators

Hydraulic agitation is required for wettable powder and flowable formulations in small tanks and for liquid formulations in 100-gallon or larger tanks with gear, roller, piston, or diaphragm pumps. Hydraulic agitation is provided by the high-pressure flow of surplus spray material from the pump. The jet or jets are located at the bottom of the tank. The agitator is connected to the pressure side of the pump. Jet agitator nozzles should never be placed in the bypass line. The pump and tank capacity and operating pressure determine the minimum jet number and size:

- 55 gallon = 1 or more jets,
- 100 to 150 gallon = 3 or more jets,
- 200 gallon and larger = 5 or more jets.

Mechanical Agitation

Wettable powder formulations are best mixed and kept in suspension with mechanical agitation. The mechanical agitator usually consists of flat blades or propellers mounted on a shaft which is placed lengthwise along the bottom of the tank. The paddles or propellers are rotated by the engine to keep the material well mixed. Mechanical agitators are usually found only on large high-pressure hydraulic sprayers.

Control Valves

Quick-acting cutoff valves should be located between the pressure regulator and the nozzles to provide positive on-off action. These control valves should be rated for the pressures you intend to use and should be large enough not to restrict flow when open. Cutoff valves to stop all flow or flow to any section of the spraying system should be within easy reach of the sprayer operator.

There are many kinds of control valves. Mechanical valves must be accessible to the operator's hand; electrically operated valves permit remote control of flow. For tractors or self-propelled sprayers with enclosed cabs, the remote-controlled valves permit all hoses carrying pesticides to be kept safely outside the cab.

Nozzles

Nozzles are made up of four major parts: the nozzle body, the cap, the strainer (screen), and the tip or orifice plate. They may also include a separate spinner plate. Successful spraying depends on the correct selection, assembly, and maintenance of the nozzles.

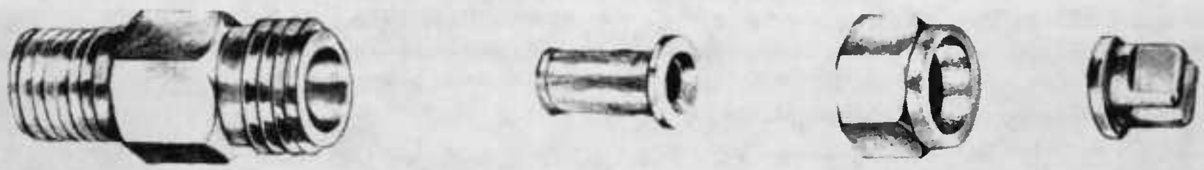
The nozzle **body** holds the strainer and tip in proper position. Several types of tips that produce a variety of spray patterns may be interchanged on a single nozzle body made by the same manufacturer.

The **cap** is used to secure the strainer and the tip to the body. The cap should not be overtightened.

The **nozzle strainer** is placed in the nozzle body to screen out debris which may clog the nozzle opening. The type of nozzle strainer needed depends on the size of the nozzle opening and the type of chemical being sprayed.

Special nozzle screens fitted with a check valve help prevent nozzle dripping. Check valves should be used in situations where a sprayer must be stopped and started frequently, such as in small target areas, near sensitive crops or areas, indoors, or for right-of-way treatments. The operator must check these spring-loaded ball valves frequently to assure proper operation.

Nozzle tips break the liquid pesticide into droplets. They also distribute the spray in a predetermined pattern and are the principal element that



controls the rate of application. Nozzle performance depends on:

- nozzle design or type,
- operating pressure,
- size of the opening,
- discharge angle,
- distance of nozzle from the target.

Nozzle Patterns

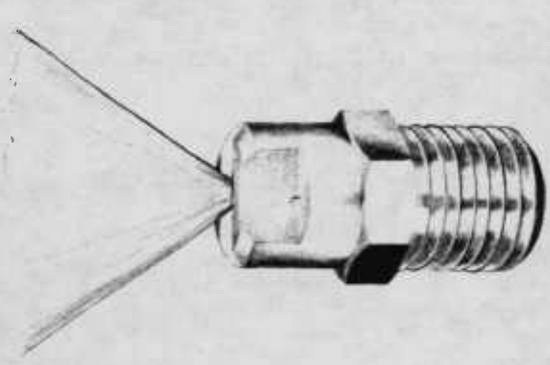
Nozzle patterns are of three basic types: solid stream, fan, and cone. Some special-purpose nozzle tips or devices produce special patterns. These include "raindrops," "flooding" and others that produce wide angle fan or cone-shaped patterns.

Solid stream nozzles—These nozzles are used in handgun sprayers to spray a distant or specific target such as livestock, nursery, or tree pests, and for crack and crevice treatment in and around buildings. They also may be attached to booms to apply pesticides in a narrow band or inject them into the soil.

Fan pattern nozzles—At least three types of nozzle tips have fan patterns. They are used mostly for uniform spray coverage of surfaces; for example, applying herbicides or fertilizers to soil.

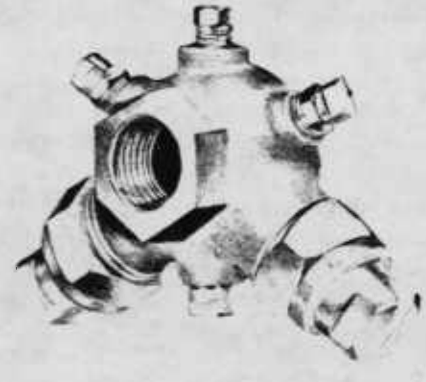
The **regular flat fan** nozzle tip makes a narrow oval pattern with tapered ends. It is used for broadcast herbicide and insecticide spraying at 15 to 60 psi. The pattern is designed to be used on a boom and to be overlapped 30 to 50 percent for even distribution. Spacing on the boom, spray angle, and boom height determine proper overlap and should be carefully controlled. Tips are available in brass, plastic, stainless steel, and hardened stainless steel.

The **even flat fan** nozzle makes a narrow oval pattern. Spray delivery is uniform across its width. It is used for band spraying and for treating walls and other surfaces. It is not useful for broadcast applications. Boom height and nozzle spray angle determine the width of the band sprayed. These tips are available in brass, plastic, stainless steel, and hardened stainless steel.



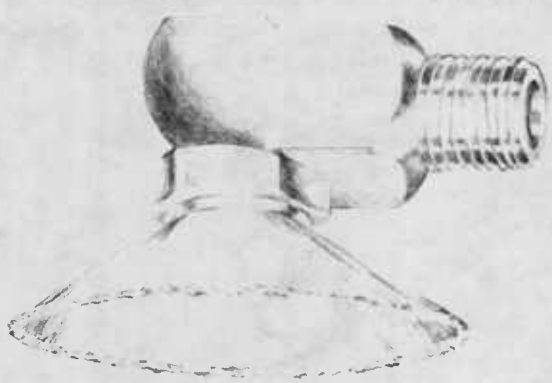
The **flooding** (flat fan) nozzle delivers a wide-angle flat spray pattern. It operates at very low pressure and produces large spray droplets. Its pattern is fairly uniform across its width but not as even as the regular flat fan nozzle pattern. If used for broadcast spraying, it should be overlapped to provide double coverage. It is frequently used for applying liquid fertilizers or fertilizer- pesticide mixtures or for directing herbicide sprays up under plant canopies. These tips are available in plastic, brass, or stainless steel.

Cluster nozzles are used either without a boom or at the end of booms to extend the effective swath width. One type is simply a large flooding deflector nozzle which will spread spray droplets over a swath up to 70 feet wide from a single nozzle tip. Cluster nozzles are a combination of a center-discharge and two or more off-center-discharge fan nozzles. The spray droplets vary in size from very small to very large, so drifting is a problem.



Coverage may be variable because the spray pattern is not uniform. Since no boom is required, these nozzles are particularly well suited for spraying roadside hedgerows, fence rows, rights-of-way and other inaccessible locations where uniform coverage is not critical.

Cone pattern nozzles—Hollow and solid cone patterns are produced by several types of nozzles. These patterns are used where penetration and coverage of plant foliage or other irregular targets are desired. They are most often used to apply fungicides and insecticides to foliage, although some types are used for broadcast soil applications of herbicides or fertilizers or combinations of the two. When cone pattern nozzles are used for air blast sprayer broadcast application, they should be angled to spray between 15° and 30° from the horizontal and should be spaced to overlap up to 100 percent at the top of the manifold. These tips are available in stainless steel, hardened stainless steel, and tungsten carbide.



The side-entry hollow cone or "whirl-chamber" nozzle produces a very wide angle hollow cone spray pattern at very low pressures. It has a large opening and resists clogging. Because of the wide spray angle, the boom can be operated low, reducing drift. Spacing for double coverage and angling 15° to 45° to the rear is recommended for uniform application. These nozzles may be used in place of flat fan nozzle tips in broadcast applications.

Core-insert cone nozzles produce either a solid or hollow cone spray pattern. They operate at moderate pressures and give a finely atomized spray. They should not be used for wettable powders because of small passages which tend to clog and wear rapidly due to abrasion.

Disc-core nozzles produce a cone-shaped spray pattern which may be hollow or solid. The spray angle depends on the combination of disc and core used and also, to some extent, on the pressure. Discs made of very hard materials resist abrasion well, so these nozzles are recommended for spraying wettable powders at high pressures.

Adjustable cone nozzles change their spray angle from a wide cone pattern to a solid stream when the nozzle collar is turned. Many manual sprayers are equipped with this type of nozzle. Handguns for power sprayers have adjustable nozzles which usually use an internal core to vary the spray angle.

Nozzle Materials

Most nozzle parts are available in several materials. Here are the main features of each kind:

Brass:
- moderately expensive,
- resists corrosion from most pesticides,
- wears quickly from abrasion,
- probably the best material for general use,
- liquid fertilizers will corrode.

Plastic:
- moderately expensive,
- will not corrode,
- resists abrasion better than brass,
- may swell when exposed to organic solvents.

Stainless Steel:
- moderately expensive,
- resists abrasion, especially if hardened,
- good corrosion resistance,
- suited for high pressures, especially with wettable powders.

Aluminum:
- inexpensive,
- resists some corrosive materials,
- is easily corroded by some fertilizers.

Tungsten Carbide and Ceramic:
- very expensive,
- highly resistant to abrasion and corrosion,
- best material for high pressures and wettable powders.

Sprayer Selection, Use, and Care

Choosing the correct sprayer for each job is important. Your sprayer should be:

- designed to do the job you want to do,
- durable,
- convenient to fill, operate, and clean.

Always read and follow the operator's manuals for all your spray equipment. They will tell you exactly how to use and care for it. After each use, rinse out the entire system. Check for leaks in lines, valves, seals, and tank. Remove and clean nozzles, nozzle screens, and strainers.

Be alert for nozzle clogging and changes in nozzle patterns. If nozzles clog or other trouble occurs in the field, be careful not to contaminate yourself while correcting the problem. Shut off the sprayer and move it to the edge of the field before dismounting. Wear protective clothing while making repairs. Clean plugged nozzles only with a toothbrush or wooden toothpick or similar instrument. Never use your mouth.

To prepare spray equipment for storage, rinse and clean the system. Then fill the tank almost full with clean water. Add a small amount of new light oil to the tank. Coat the system by pumping this mixture out through the nozzles or handgun. Drain the pump and plug its openings or fill the pump with light oil or antifreeze. Remove nozzles and nozzle screens and store in light oil or diesel fuel.

Aerosol Generators and Foggers

Aerosol generators and foggers convert special formulations into very small, fine droplets (aerosols). Single droplets cannot be seen, but large numbers of droplets are visible as a fog or mist. Aerosol generators and foggers are usually used to completely fill a space with a pesticidal fog. Some insects in the treated area are killed when they come in contact with the poison. Other insects are simply repelled by the mist and return quickly after it has settled.

Thermal foggers, also called thermal generators, use heat to vaporize a special oil formulation of a pesticide. As the pesticide vapor is released into the cooler air, it condenses into very fine droplets, producing a fog.

Other aerosol generators (cold foggers) break the pesticide into aerosols by using mechanical methods such as:

- rapidly spinning discs,
- extremely fine nozzles and high pressure (atomizing nozzles),
- strong blasts of air.

This specialized equipment is most often used in greenhouses, barns, warehouses, and other structures and for biting fly and mosquito control in outdoor recreation areas.

Advantages:

- no unsightly residue,
- safe reentry immediately after ventilating the area,
- penetration in dense foliage,
- penetration of cracks and crevices and furniture,
- some indoor devices are automatic and do not require presence of applicator.

Limitations:

- aerosols and fogs drift easily from target area —use outdoors is limited,
- no residual control—pests may return to the area as soon as fog dissipates,
- risk of explosion in enclosed areas.

Selection, Use, and Care

Choose an aerosol generator according to where you will use it—indoors or outdoors. Aerosol and fog generators are manufactured for many special uses. There are truck- and trailer-mounted machines for use outdoors. Most hand-operated or permanently mounted automatic machines are for use indoors.

In general, use and care for an aerosol generator as you would a sprayer. They do require special precautions. Be sure that the pesticides used in them are registered for such use. Keep them on the target. Because of the effects of weather conditions during application, follow special use instructions. The operator, other humans, and animals must be kept out of the fog or smoke cloud.

Soil Fumigation Equipment

The equipment needed for applying soil fumigants depends on the kind of fumigant being used. There are two types of fumigants:

- low-pressure (low volatility) liquid fumigants, and
- highly volatile fumigants which remain as liquids only when placed under pressure.

Low-Pressure Liquid Fumigators

Equipment for applying low-pressure fumigants is widely varied but uses two basic designs for delivering the amount of fumigant to be metered out. These delivery systems are either pressure (pump)-fed or gravity-fed.

Pressure-fed applicators have a pump and metering device and deliver fumigant at pressure to the nozzle openings (orifices) as with a low-pressure sprayer.

Gravity-flow applicators use the size of the nozzle orifice and the pressure created by gravity to regulate the output of fumigant. Constant speed is necessary to maintain a uniform delivery rate. In most applicators, a constant head gravity flow device keeps the pressure at the orifice(s) constant as the tank or container of fumigant empties. Needle valves, orifice plates or discs, and capillary tubes are used to adjust the flow rate.

Low-pressure fumigators usually use the soil itself or water to keep the fumigant from vaporizing and moving off target too quickly. Some of the methods used are:

- soil injection,
- soil incorporation,
- drenching or flooding.

Soil Injection

Soil injectors use a variety of mechanisms to insert the fumigant into the soil (usually 6 inches or more) and then cover the area with soil again to seal in the fumigant. The principal mechanisms include:

- chisel cultivators, blades, or shovels,
- sweep cultivator shovels,
- planter shoes,
- plows.

Soil Incorporation

Soil incorporators are used when applying low-volatility fumigants. The fumigant usually is sprayed onto the soil surface. The area is immediately cultivated, usually to a depth of 5 inches or less, and then compacted with a drag, float, or cultipacker. Power-driven rotary cultivators are also used.

Drenching or Flooding

This method uses water as a sealant. The fumigant may be applied in the water as a drench. Equipment used depends on the size and timing of the application. It may be applied with a sprinkling can, sprinkler system, or irrigation equipment. Or the fumigant may be applied by spraying the soil surface and immediately flooding the area. The depth of the water seal (usually 1/2 to 4 inches of wetted soil) depends on the volatility of the fumigant.

High-Pressure Fumigators

Effective application of highly volatile fumigants depends on tightly sealing the soil with tarps, plastic film, or similar covers.

There are two major methods of using vapor-proof tarps:

- tarp supported off the ground and sealed around the edges; fumigant introduced under the tarp,
- tarp applied to the soil by the injection chisel applicator immediately after the fumigant is injected.

Highly volatile fumigants must be handled in closed pressurized containers or tanks. The equipment is similar to gravity-flow low-pressure fumigators. The pressure in the tank maintains the pressure at the nozzle orifices. The tank is either precharged with sufficient pressure to empty its contents, or an inert pressurized gas is fed into the tank during application to displace the fumigant. A gas pressure regulator maintains uniform pressure in the system. To insure accurate application, the fumigant must be under enough pressure to maintain a liquid state in the tank, pressure lines, manifold, and metering devices.

Selection

Pumps, tanks, fittings, nozzles or metering orifices, and lines must be corrosion-resistant. Soil injection knives should be designed to shed trash and allow the soil to seal over the fumigant.

Select high-pressure fumigators designed to handle the pressure created by the fumigant and the corrosive action of the product you plan to use.

Dusters and Granular Applicators

Dusters

Dusters are used mostly by home gardeners and by pest control operators in structures.

Hand Dusters

Hand dusters may consist of a squeeze bulb, bellows, tube, shaker, sliding tube, or a fan powered by a hand crank.

Advantages:

- lightweight—do not require water,
- the pesticide is ready to apply without mixing,
- good penetration in confined spaces.

Limitations:

- high cost for pesticide,
- hard to get good foliar adherence,
- dust is difficult to direct and is subject to drifting.

Power Dusters

Power dusters use a powered fan or blower to propel the dust to the target. They include knapsack or backpack types, units mounted on or pulled by tractors, and specialized equipment for treating seeds. Their capacity in area treated per hour compares favorably with some sprayers.

Advantages:

- lightweight—no water required,
- simply built,
- easy to maintain,
- low in cost.

Limitations:

- drift hazards,
- high cost of pesticide,
- application may be less uniform than with sprays,
- difficult to get foliar adherence.

Granular Applicators

Granular applicators are used mainly in agricultural, ornamental and turf, forestry, and aquatic pest control. They distribute granular pesticides by several different methods, including:

- forced air,
- spinning or whirling discs (fertilizer spreaders),
- multiple gravity-feed outlets (lawn spreaders, grain drills),
- soil injectors (furrow treatments),
- ram-air (agricultural aircraft).

Granular applicators may be designed to apply the pesticides:

- broadcast—even distribution over the entire area,
- to specific areas—banding, in-furrow, sidedress,
- by drilling—soil incorporation or soil injection.

Advantages:

- inexpensive,
- simple in design,
- eliminates mixing—no water needed,
- minimal drift hazard,
- less exposure hazard to applicator.

Limitations:

- high cost for pesticides,
- limited use against some pests because granules will not adhere to most foliage,
- need to calibrate for each different granular formulation,
- spinning disc types may give poor lateral distribution, especially on side slopes.

Selection, Use, and Care

Look for a power duster that is easy to clean. It should give a uniform application rate as the hopper is emptied. Look for both hand and power dusters that direct the dust cloud away from the user.

Choose a granular applicator that is easy to clean and fill. It should have mechanical agitation over the outlet holes. This prevents clogging and helps keep the flow rate constant. Application should stop when drive stops even if outlets are still open.

Both dusters and granular applicators are speed-sensitive, so maintain uniform speed. Do not travel too fast for ground conditions. Bouncing equipment will cause the application rate to vary. Stay out of any dust created by action of the equipment.

Watch band applicators to see that band width stays the same. Small height changes due to changing soil conditions may cause rapid changes in band width.

Clean equipment as directed by the operator's manual.

Seed Treaters

Seed treaters are used to coat seeds with a pesticide. The amount of pesticide the seeds receive is important. Too much can injure the seed; too little will not control the pests. The three basic types of commercial seed treaters are:

- dust treaters,
- slurry treaters,
- liquid treaters.

Dust Treaters

These treaters mix seeds with a pesticide dust in a mechanical mixing chamber until every seed is thoroughly covered. The amount of pesticide to be added depends on the weight of seeds in the mixing chamber. Seed flow is controlled by adjusting the gate opening on the feed hopper. The gate opening is correct when the required weight of seeds is dumped into the mixing chamber with each batch. The amount of pesticide added is controlled by a vibrating feeder which is adjusted to achieve the desired dosage.

Slurry Treaters

These treaters coat seeds with wettable powder pesticide formulations in the form of a slurry. Only a small amount of water is used with the pesticide so that seed germination or deterioration will not be triggered. As with dust treaters, a specific amount of pesticide is added to a specific weight of seeds in a mechanical mixing chamber. Slurry tanks have 15- to 35-gallon capacities, depending on the size of the treater. Agitators keep the material mixed during the treating operation. Wettable powders will rapidly separate from the water if not continuously agitated. Be sure to mix the pesticide and water thoroughly before starting the treater and before resuming treatment after any stoppage. Sediment on the bottom of the individual slurry cups must be stirred into the liquid after any stoppages.

Liquid or Direct Treaters

These treaters are designed to apply a small amount of pesticide solution to a large quantity of seeds. The pesticides suitable for this treatment are moderately volatile liquids which need not cover each seed entirely to achieve good pest control. Some of these treaters have dual tanks which allow treatment with more than one pesticide at a time.

Panogen Liquid Seed Treater

The Panogen treater meters one treatment cup of pesticide per dump of seed into a revolving mixing drum. The pesticide flows into the drum from a tube and is distributed over the seed as the seeds rub against the walls of the drum. The correct dosage is achieved by selecting the appropriate size of treatment cup for the chosen seed dump weight.

Mist-O-Matic Seed Treater

The Mist-O-Matic treater applies the pesticide as a mist directly onto the seed. The treater delivers one treatment cup of pesticide per dump of seed. The pesticide flows onto a rapidly whirling disc which breaks the liquid pesticide into a fine mist. The seeds fall onto a large cone which spreads the seeds out so they are evenly coated with the pesticide spray mist. The desired dosage is obtained by selecting the appropriate treatment cup size and adjusting the seed dump weight.

Animal Application Equipment

Dipping Vats

Dipping vats are large tanks (vats) of liquid pesticide mixture used to treat livestock for external parasites. They are used in farm, ranch, and regulatory pest control operations. Portable dipping vats are usually trailer-mounted tanks with a set of folding ramps and railings. The animals are driven up the ramp onto a platform and forced into the tank so they are completely immersed. The animal's head may have to be pushed under the surface.

Maintaining the proper concentration of pesticide in the vat is very important. The bath volume should never be allowed to fall below the 7/8 level. Replenishment ratios are usually based on a knowledge of the amount of liquid used from the vat.

Spray-Dip Machines

Spray-dip machines are used to treat livestock for external parasites. They are used in farm, ranch, regulatory, and other livestock pest control operations. A spray-dip machine usually consists of a trailer-mounted chute with solid walls and gates at either end. The chute is located above a shallow tank and is equipped with several rows of large nozzles mounted in a manner that directs the spray mixture to thoroughly cover each animal. A large centrifugal pump supplies the pesticide to the nozzles. Surplus and runoff spray falls back into the tank where it is filtered and recycled to the nozzles.

Face and Back Rubbers

Face and back rubbers are bags or other containers of dry or liquid pesticide formulation used to control external parasites of livestock. They are used in farm, ranch, and other livestock confinement operations. The face and back rubbers are hung or mounted in areas adjacent to high livestock traffic, such as feeding troughs, waterers, and narrow gate entrances. When the animal rubs against the device, the pesticide is transferred to the animal's face, back, sides, or legs.

Specialized Application Equipment

Some other types of application equipment do not fit into the common categories. They include wiper applicators, irrigation application equipment, and wax bars.

Wiper Applicators

These devices are used to apply contact or translocated herbicides selectively to weeds in crop areas. Wicks made of rope, rollers made of carpet or other material, or absorbent pads made of sponges or fabric are kept wet with a concentrated mixture of contact herbicide and water and brought into direct contact with weeds. The herbicide is "wiped" onto the weeds, but does not come in contact with the crop. Application may be to tall weeds growing above the crop or to lower weeds between rows, depending on the way the wiper elements are designed. Pumps, control devices, and nozzles are minimal or are eliminated altogether, and tanks are quite small because of the small amount of liquid applied.

Advantages:
- low cost,
- simple to operate,
- no drift,
- reduces amount of pesticide used.

Limitations:
- applicable only in special situations,
- difficult to calibrate.

Irrigation Application Equipment

This equipment adds herbicides to irrigation water. This has become a common method for applying preemergence herbicides in most irrigated areas of the United States and it is also used to apply insecticides, fungicides, and other pesticides. The pesticide is injected into the main irrigation stream with a positive-displacement pump. Accuracy of calibration and distribution is achieved by metering a large volume of dilute pesticide into the irrigation system. Antisiphon and switch valves prevent contamination of the irrigation water source or overflow into the slurry feed tank.

Advantages:
- inexpensive,
- convenient,
- field access unnecessary.

Disadvantages:
- constant agitation needed in slurry tank,
- application of more water per acre than recommended on label will result in leaching the chemical from the effective soil zone,
- sprinkler distribution must have appropriate overlap pattern to avoid underdosing or overdosing,
- injection of pesticides into flood and furrow irrigation systems may result in uneven concentrations of pesticides throughout the field, depending on soil permeability and field contours.

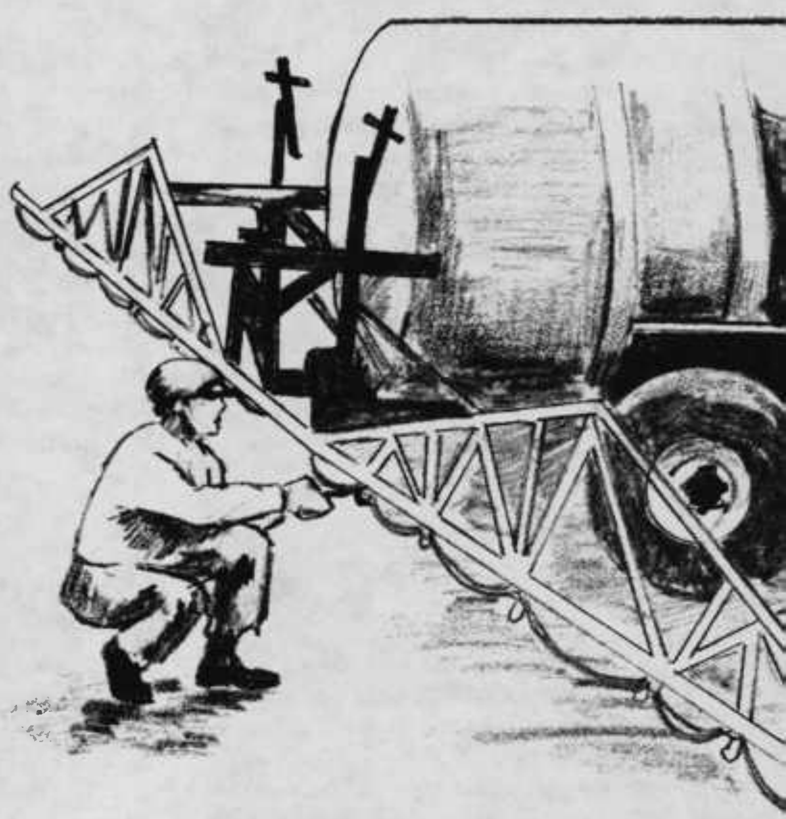
Wax Bars

Herbicides are sometimes applied to turfgrass and vineyards with wax bars. The wax bars are impregnated with herbicides, then dragged slowly over the area to be protected.

Advantages:
- no drift,
- no calibration.

Disadvantages:
- highly specialized, not readily available.

Calibration



Calibration

Calibration is the process of measuring and adjusting the amount of pesticide your equipment will apply to the target area. Proper calibration is an essential but often neglected task. You need to be sure you are using the correct amount of pesticide. Too little pesticide can result in inadequate control. Too much pesticide can result in injury to the target plant, animal, or surface; illegal residues; excess runoff or other movement from the target; injury to persons, pets, or wildlife reentering the area; and lawsuits and fines.

Overdosing with pesticides is illegal and carries severe penalties. Another important consideration is the high cost of using the wrong dosage. You may have to repeat the entire application if insufficient pest control results from underdosing. With the high cost of pesticide chemicals, overdosing is very expensive. The key is to take time to calibrate your equipment carefully and correctly. Then check it regularly to detect change due to wear, corrosion, and aging.

Calibration does not have to be difficult. You must be familiar with the operation of the machinery you are using and follow the manufacturer's directions carefully. Pesticide labels and university and professional association recommendations give you much of the information you need in order to calibrate correctly.

Before you begin to calibrate any equipment, check it carefully to be sure that all components are clean and in good working order. The many types of application equipment differ in the details of their operation, but if you understand the basic principles of calibration, you can apply them in any situation. Study the manufacturer's instructions carefully—they explain exactly how to adjust the equipment. They often contain suggestions on such things as the appropriate rate of travel, the range of most efficient pump pressures, approximate settings for achieving various delivery rates; and types of nozzles which can be used.

Calibration requires some simple mathematics; this chapter provides some standard formulas to help you. The easiest and most accurate way to do the calculations is with a calculator.

Precalibration Decisions

Before beginning to calibrate, you need to develop an application strategy. Using your knowledge of the pests to be controlled, the condition and location of the application site, the other pest control methods being used, and the risks and benefits involved, you must choose:

- the pesticide to be applied, and
- the equipment to be used to apply it.

These two factors are closely related. If you have a choice, select the formulation and equipment which is least hazardous to you, other people, and the environment. In any situation, choose equipment which you feel competent to use, and which:

- is designed for the type of chemical being applied, and
- is appropriate for the size and type of application job.

If the equipment you have chosen is not motorized, the calibration may be fairly simple. In fact, some equipment (such as aerosol cans and hand dusters) does not need any calibration. The pesticide is applied to the point of runoff or is directed at a specific target. You are applying the correct dosage if you have covered the target completely. Other equipment of this type (such as granular spreaders for use on turf) needs to be calibrated only to adjust the delivery rate. This equipment delivers pesticide only when the wheels are in motion, and the speed does not affect the amount of pesticide being deposited per unit area.

If your equipment is motorized, you will need to determine the rate of speed best suited for the type of equipment and for the particular requirements of your application job. The equipment manufacturer's directions may offer a range of appropriate speeds. Your knowledge of factors such as field conditions and drift hazard, plus your experience with the equipment, will help you determine an appropriate speed.

NOTE: To calibrate accurately, you must know your **exact** speed. Due to wheel slippage under field conditions, the actual over-the-ground speed will differ from speedometer readings. Mark off measured distances of 100, 200, or 300 feet in the field where the application is to be done. Then run the equipment over these distances at the operating speed, carefully marking the throttle setting or speedometer reading and recording run times. Be sure the tractor has reached full operating speed before you reach the starting point. The following chart converts the time measured to speed in miles per hour.

Table 1: Time-Distance-Speed

Ground speed in miles per hour	Time required in **seconds** to travel a distance of: 100 feet	200 feet	300 feet
0.5	136	272	408
1.0	68	136	204
1.5	45	91	136
2.0	34	68	192
2.5	27	54	82
3.0	23	45	68
3.5	20	39	58
4.0	17	34	51
4.5	15	30	45
5.0	14	27	41
6.0	11	23	34
7.0	9.7	19	29
8.0	8.5	17	26
9.0	7.6	15	23
10.0	6.8	14	20
12.0	5.7	11	17
15.0	4.5	9	13.6
20.0	3.4	6.8	10.2

or

Ground speed in miles per hour	Feet traveled per minute
0.5	44
1.0	88
1.5	132
2.0	176
2.5	220
3.0	264
3.5	308
4.0	352

Calibrating Sprayers

Before You Calibrate

If the equipment you have chosen is spray equipment, you must determine three other factors in addition to the precalibration decisions in the preceding section:

- the appropriate pump pressure,
- the spray volume needed,
- the type of carrier (diluent) to be used.

Pump Pressure

The pump pressure is largely controlled by the type of equipment—particularly the type of pump—you have chosen. Each pump has a range of optimum pressures which it should provide. To protect the pump and to insure steady pressure output, do not attempt to exceed or go under the working capacity.

Within the optimum pressure range, you can determine which specific pressure to use by considering such factors as:

- drift hazard (lower pressure produces less drift),
- penetration required (penetration of foliage, animal hairs, soil surfaces, and other barriers requires higher pressure),
- recommendations on the label or from other sources.

Spray Volume

The label (or other spray recommendations) often lists the amount of spray volume needed for effective application. The spray volume is the amount of diluted pesticide mixture (pesticide plus carrier) to be applied per unit of area. The recommendation may be for a specific volume, such as 20 gallons per acre or $2^1/_2$ gallons per 1,000 square feet. In other cases, a wide range of acceptable volumes may be listed; for example, "up to 400 gallons per acre," or "15 to 40 gallons per acre." You must choose the spray volume most appropriate for your spray job on the basis of your experience with the equipment and such factors as:

- the size of the spray tank,
- the availability and cost of water or other carrier, such as kerosene or oil,
- the surface to be treated (dense foliage, animal hairs, and porous surfaces require more volume).

Spray volume recommendations are usually given in terms of broadcast spraying. The band rate may also be included. If not, you will have to do some figuring to determine the appropriate rate for band spraying. Divide the band width by the row spacing to determine what proportion of the field area is actually being sprayed. Then multiply by the broadcast rate per acre to determine the gpa needed for band spraying.

$$\frac{\text{Band width} \times \text{Broadcast rate}}{\text{Row Spacing}} = \text{gpa needed for band spraying}$$

Example:

$$\frac{\text{Band width (10in.)} \times \text{Broadcast rate (20gpa)}}{\text{Row spacing (40in.)}} = \text{Band gpa (5)}$$

$$10 \times 20 \div 40 = 5$$

Type of Carrier

Most spray applications use water as the carrier or diluent. However, your situation may require the use of another carrier, such as an oil. The pesticide label usually recommends the carrier that works best with that product. You must know what carrier you will use before you can select the appropriate nozzles for the job. Because most selection charts provided by nozzle manufacturers are based on spraying with water, the gallons per acre (gpa) or gallons per minute (gpm) figures will not be correct if you are using another carrier. A table such as the one below is often provided to help you adjust the figures to fit your situation.

Table 2. Conversion Factors

Weight of Solution	Conversion Factors
6.6 lbs. per gallon - KEROSENE	1.26
7.0 lbs. per gallon	1.09
8.0 lbs. per gallon	1.02
8.34 lbs. per gallon - WATER	1.00
9.0 lbs. per gallon	.96
10.0 lbs. per gallon	.91
11.0 lbs. per gallon	.87
12.0 lbs. per gallon	.83
14.0 lbs. per gallon	.77
16.0 lbs. per gallon	.72
18.0 lbs. per gallon	.68
20.0 lbs. per gallon	.65

Multiply the gpm or gpa values on the charts by this correction factor for the correct gpm or gpa for the solution being sprayed.

Example: The nozzle selection chart shows that you would be applying 6 gallons per acre, and your solution weighs 16 pounds per gallon:

6 gpa × .72 (conversion factor from Table 2) = 4.32 gpa.

6 × .72 = 4.32

Selecting Nozzle Tips

Nozzle manufacturers help applicators choose the right tip for each job by providing detailed charts of tip performance. The applicator matches the specific needs of the job to the "givens" on the chart to determine the tips and strainers to use.

The charts include the factors you must consider in order to choose appropriate nozzles—pressure, equipment speed, and spray volume. Charts which show spray volume in terms of both gallons per acre (gpa) and gallons per minute (gpm) allow you to choose your nozzles without further figuring. Some manufacturers, however, list only gallons per minute. Then you must convert your desired gallons per acre to gallons per minute.

$$\frac{\text{Gallons per acre} \times \text{mph} \times \text{W}}{5{,}940} = \text{Gallons per minute (per nozzle)}$$

W = nozzle spacing in boom spraying; or sprayed width in boomless spraying (in *inches*).

Example:

$$\frac{10 \text{ gpa} \times 4 \text{ mph} \times 20'' \text{ nozzle spacing}}{5{,}940} = 0.13 \text{ gpm}$$

10 × 4 × 20 ÷ 5,940 = 0.13

Boom Sprayers

Boom sprayers meter the pesticide solution out of several nozzles along a long pipe or other structure called a boom. Each nozzle (or cluster of nozzles) delivers the same amount of pesticide to the application site as every other nozzle (or cluster) on the boom. The spacing of the nozzles along the boom is determined by:

- the type or make of boom,
- the row spacing (in band or directed applications),
- individual preferences.

Nozzles usually are spaced 20, 30, or 40 inches apart along the boom. Nozzle manufacturers have often incorporated a factor for spacing into their charts. If the nozzle spacing on your boom is different from those used on the charts, a conversion factor must be used. Multiply the gallons per acre figure on the nozzle chart by the appropriate factor from Table 3.

Table 3. Nozzle Spacing Conversion Factors

Where Tables Are Based on 20″ Nozzle Spacing

Other Spacing	8″	10″	12″	14″	16″	18″	22″	24″	30″
Conversion Factor	2.5	2.0	1.67	1.43	1.25	1.11	.91	.83	.66

Where Tables Are Based on 40″ Nozzle Spacing

Other Spacing	28″	30″	32″	34″	36″	38″	42″	44″	48″
Conversion Factor	1.43	1.33	1.25	1.18	1.11	1.05	.95	.91	.83

Example: A nozzle selection chart based on 20-inch nozzle spacing shows that the tips you are using would be applying 6 gallons per acre. Your nozzles are spaced at 16 inches:

6 gpa × 1.25 (conversion factor from Table 3) = 7.5 gpa

$6 \times 1.25 = 7.5$

The height of the boom above the soil surface (or above the plants in over-the-top applications) influences the type of nozzle tips you choose for broadcast or band applications. In directed spraying, the boom height is not a factor in nozzle selection because the nozzles can be positioned to direct the spray at specific parts of the plant.

Boom height is determined by the equipment you have chosen and by such factors as:

- crop height,
- obstacles which may have to be cleared.

Broadcast Spraying

Broadcast boom spraying is the uniform application of a pesticide over an entire area. In order to select nozzles for a broadcast boom sprayer, the applicator must know:

- approximate boom height,
- nozzle spacing on the boom,
- pump pressure,
- sprayer speed,
- volume of spray (in gallons) to be applied per acre.

Example:

- boom height is 22 inches,
- nozzles are spaced 20 inches apart on the boom,
- pump pressure is 30 psi,
- sprayer speed is 4 mph,
- spray volume is 10 gpa.

Table 4 quickly shows that:

- the 65° series will accommodate a 22-inch boom height,
- the 20-inch nozzle spacing is factored into the chart,
- any of the nozzle tips listed will operate at 30 psi,
- the 4 mph tractor speed narrows the choice to nozzle tip number 502, which delivers 9.7 gpa. The chart requires a 100-mesh strainer for that nozzle.

Note that other nozzle tips could be used if you changed the speed and the pump pressure. However, it is more economical to purchase the tips which allow you to operate your equipment at its optimum pressure and speed.

Band Spraying

Band spraying is application of a pesticide to a strip over or along a crop row. Choosing nozzles for a band sprayer is very similar to choosing them for a broadcast sprayer. However, if the label lists the spray volume in terms of broadcast spraying, you must first convert that figure to the band rate. (See section on spray volume.)

Before you select the nozzles for your band sprayer, you must know:

- the boom height (the height of the boom above the surface will dictate the angle of nozzles you choose to achieve the desired band width),
- row spacing (same as nozzle spacing on boom),
- pump pressure,
- sprayer speed,
- spray volume per acre (band rate),
- the width of band you wish to use.

Example:

- boom height is 6 inches,
- row spacing is 40 inches,
- pump pressure is 30 psi,
- sprayer speed is 5 mph,

Table 4. Flat Fan Nozzle Tips

65° Series
(Accommodates Boom Heights 21-23 inches)

FLAT SPRAY TIP NO. and strainer screen size	Pressure in p.s.i.	Capacity 1 Nozzle in G.P.M.	GALLONS PER ACRE (20″ Nozzle Spacing) 4 M.P.H.	5 M.P.H.	7.5 M.P.H.	10 M.P.H.
501 (100 Mesh)	20	.07	5.3	4.3	2.8	2.2
	25	.08	5.9	4.7	3.1	2.4
	30	.09	6.4	5.1	3.4	2.6
	40	.10	7.4	6.0	4.0	3.0
	50	.11	8.3	6.7	4.5	3.4
	60	.12	9.1	7.4	4.9	3.7
502 (100 Mesh)	20	.11	7.8	6.3	4.3	3.2
	25	.12	8.8	7.1	4.7	3.6
	30	.13	9.7	7.7	5.2	3.9
	40	.14	11.1	8.9	6.0	4.5
	50	.15	12.4	10.0	6.7	5.0
	60	.16	13.6	10.9	7.4	5.5
503 (50 Mesh)	20	.14	10.5	8.4	5.6	4.2
	25	.16	11.8	9.4	6.3	4.7
	30	.17	12.9	10.3	6.9	5.2
	40	.20	14.8	11.8	7.9	5.9
	50	.23	16.5	13.2	8.8	6.6
	60	.25	18.1	14.4	9.7	7.2
504 (50 Mesh)	20	.21	15.7	12.6	8.4	6.3
	25	.24	17.6	14.1	9.4	7.1
	30	.26	19	15.4	10.3	7.7
	40	.30	22	17.8	11.8	8.9
	50	.34	25	20	13.2	10.0
	60	.37	27	22	14.4	10.9
505 (50 Mesh)	20	.28	21	16.8	11.2	8.4
	25	.32	24	18.7	12.5	9.4
	30	.35	26	21	13.7	10.3
	40	.40	30	24	15.8	11.9
	50	.45	33	27	17.7	13.3
	60	.49	36	29	19.4	14.6
506 (50 Mesh)	20	.35	26	21	14	10.5
	25	.40	29	23	15.7	11.7
	30	.43	32	26	17.2	12.9
	40	.50	37	30	19.8	14.9
	50	.56	42	33	22	16.6
	60	.61	45	36	24	18.2
507 (50 Mesh)	20	.42	31	25	16.9	12.6
	25	.47	35	28	18.7	14.1
	30	.52	39	31	21	15.5
	40	.60	45	36	24	17.8
	50	.67	50	40	27	20
	60	.73	55	44	29	22

- spray volume for band application is 5 gpa,
- band width is 10 inches.

Table 5 shows that you need 103 tips with 50-mesh strainers. Table 6 indicates that the 80° fan tip is needed with a 6-inch boom height in order to achieve a 10-inch band width.

Table 5. Even Flat Fan Tips

TIP NO.	LIQUID PRESSURE (PSI)	NOZZLE CAPACITY (GPM)	GALLONS PER ACRE (40" NOZZLE SPACING) 3 M.P.H.	4 M.P.H.	5 M.P.H.	7.5 M.P.H.	10 M.P.H.
101 (100 mesh)	20	.07	3.5	2.6	2.1	1.4	1.1
	30	.09	4.3	3.2	2.6	1.7	1.3
	40	.10	5.0	3.7	3.0	2.0	1.5
102 (100 mesh)	20	.11	5.3	3.9	3.2	2.1	1.6
	30	.13	6.4	4.8	3.9	2.6	1.9
	40	.15	7.4	5.6	4.5	3.0	2.2
103 (50 mesh)	20	.14	7.0	5.3	4.2	2.8	2.1
	30	.17	8.6	6.4	5.1	3.4	2.6
	40	.20	9.9	7.4	5.9	4.0	3.0
104 (50 mesh)	20	.21	10.5	7.9	6.3	4.2	3.2
	30	.26	12.9	9.6	7.7	5.1	3.9
	40	.30	14.9	11.1	8.9	5.9	4.5
105 (50 mesh)	20	.28	14.0	10.5	8.4	5.6	4.2
	30	.35	17.1	12.9	10.3	6.9	5.1
	40	.40	19.8	14.9	11.9	7.9	5.9
106 (50 mesh)	20	.35	17.5	13.1	10.5	7.0	5.3
	30	.43	21	16.1	12.9	8.6	6.4
	40	.50	25	18.6	14.9	9.9	7.4
107 (50 mesh)	20	.42	21	15.8	12.6	8.4	6.3
	30	.52	26	19.3	15.4	10.3	7.7
	40	.60	30	22	17.8	11.9	8.9
108 (50 mesh)	20	.57	28	21	16.8	11.2	8.4
	30	.69	34	26	32	13.7	10.3
	40	.80	40	30	24	15.8	11.9
109 (no strainer)	20	.71	35	26	21	14.0	10.5
	30	.87	43	32	26	17.1	12.9
	40	1.00	50	37	30	19.8	14.9
110 (no strainer)	20	1.06	53	39	32	31	15.8
	30	1.30	64	48	39	26	19.3
	40	1.50	74	56	45	30	22

Table 6. Boom Height

Band Width	Height	
	80° Fan	95° Fan
8″	5″	4″
10″	6″	5″
12″	7″	6″
14″	8″	7″

Directed Spraying

Directed spraying is aiming a pesticide at a specific portion of a plant. Choosing nozzles for directed spraying is very similar to choosing them for broadcast treatments, except that the number of nozzles per row and the spacing of the rows become the variables. Nozzle manufacturers usually supply special charts for use in selecting nozzles for directed spraying.

The applicator knows:

- row spacing,
- number of nozzles to be used per row,
- pump pressure,
- sprayer speed,
- spray volume per acre.

Example:

- row spacing is 30 inches,
- there are two nozzles per row,
- pump pressure is 80 psi,
- sprayer speed is 4 mph,
- spray volume is 15 gpa.

Using Table 7, you should choose nozzle tip number 3-23.

Boomless Sprayers

Boomless sprayers have a single nozzle or multiple-tip cluster designed to produce a swath-like spray pattern. The swath is similar to that laid down by a boom sprayer.

Choosing tips for the cluster nozzles is similar to choosing them for a boom sprayer. You must determine the spray volume per acre you wish to apply. You must also choose the operating pressure and speed at which your sprayer performs best. Then use the charts in the nozzle manufacturer's catalogs to select the nozzle tips and spraying height which best fit your needs. The number of tips and the spraying height determine the width of the swath you will be spraying with each pass. You will have several nozzles from which to choose. Your decision should be based on:

- approximate swath width you wish to use (open field indicates wider swath; area with obstacles such as trees or buildings requires a narrower swath),
- drift hazard (higher spray heights and greater swath widths increase drift),
- single versus double side spraying.

Remember, the double tips will deliver twice the swath width and twice the output capacity in gallons per minute as single tips. However, at any given speed, the gallons per acre delivered by double tips is approximately the same as gallons-delivered by single tips.

Example: You wish to apply 15 gallons per acre. Your sprayer works best at 5 mph and 40 psi.

Table 8 indicates that tip C-4 will deliver 14.7 gpa at that speed and pressure. If the nozzle is set at a 36-inch spray height, the effective swath width is 27 feet. There are separate charts available for several different spray heights, which will allow you to choose from several nozzles, depending on the requirements of your job.

Table 7. Hollow Cone Tips

			Gallons per Acre—30″ Row Spacing									Gallons per Acre—40″ Row Spacing								
			One Nozzle per row			Two Nozzles per row			Three Nozzles per row			One Nozzle per row			Two Nozzles per row			Three Nozzles per row		
TIP NO.	Liquid Pressure in p.s.i.	Capacity in G.P.M. per Nozzle	3 MPH	4 MPH	5 MPH	3 MPH	4 MPH	5 MPH	3 MPH	4 MPH	5 MPH	3 MPH	4 MPH	5 MPH	3 MPH	4 MPH	5 MPH	3 MPH	4 MPH	5 MPH
	40	.08	5.3	4.0	3.2	10.5	7.9	6.3	15.8	11.9	9.5	4.0	3.0	2.4	7.9	5.9	4.7	11.8	8.8	7.1
	60	.10	6.6	4.9	4.0	13.2	9.9	7.9	19.8	14.8	11.9	4.9	3.8	3.0	9.9	7.4	5.9	14.8	11.1	8.9
	80	.11	7.3	5.4	4.4	14.5	10.9	8.7	22	16.3	13.1	5.4	4.1	3.3	10.9	8.2	6.6	16.3	12.3	9.8
2-13	100	.12	7.9	5.9	4.8	15.8	11.9	9.5	24	17.8	14.2	5.9	4.5	3.6	11.8	8.8	7.1	17.8	13.4	10.7
	150	.14	9.2	6.9	5.5	18.5	13.9	11.1	28	21	16.6	6.9	5.2	4.2	13.8	10.4	8.3	21	15.6	12.5
	250	.17	11.2	8.4	6.7	22	16.8	13.5	34	25	20	8.4	6.3	5.0	16.7	12.5	10.0	25	18.9	15.1
	400	.21	13.9	10.4	8.3	28	21	16.6	42	31	25	10.4	7.8	6.2	21	15.6	12.5	31	23	18.7
	40	.10	6.6	4.9	4.0	13.2	9.9	7.9	19.8	14.8	11.9	4.9	3.7	3.0	9.9	7.4	5.0	14.9	11.1	8.9
	60	.13	8.6	6.4	5.2	17.2	12.9	10.3	26	19.3	15.5	6.2	4.6	3.7	12.4	9.3	7.4	18.5	13.9	11.1
	80	.14	9.2	6.9	5.5	18.5	13.9	11.1	28	21	16.6	6.9	5.2	4.2	13.9	10.4	8.3	21	15.6	12.5
2-23	100	.16	10.6	7.9	6.3	21	15.8	12.7	32	24	19	7.7	5.8	4.6	15.4	11.6	9.2	23	17.3	13.8
	150	.19	12.5	9.4	7.5	25	18.8	15.0	38	28	23	9.2	6.9	5.5	18.3	13.7	11.0	27	21	16.5
	250	.23	15.2	11.4	9.1	30	23	18.2	46	34	27	11.3	8.4	6.8	23	16.9	13.5	34	25	20
	400	.28	18.5	13.9	11.1	37	28	22	55	42	33	13.9	10.4	8.3	28	21	16.7	42	31	25
	40	.12	7.9	5.9	4.8	15.8	11.9	9.5	24	17.8	14.2	5.8	4.4	3.5	11.7	8.8	7.0	17.5	13.1	10.5
	60	.14	9.2	6.9	5.5	18.5	13.9	11.1	28	21	16.6	6.9	5.2	4.2	13.9	10.4	8.3	21	15.6	12.5
	80	.16	10.6	7.9	6.3	21	15.8	12.7	32	24	19	7.9	5.9	4.8	15.8	11.9	9.5	24	17.0	14.4
3-23	100	.18	11.9	8.9	7.1	24	17.8	14.2	36	27	21	8.7	6.5	5.2	17.4	13.1	10.5	26	19.5	15.6
	150	.21	13.9	10.4	8.3	28	21	16.6	42	31	25	10.3	7.8	6.2	21	15.5	12.4	31	23	18.6
	250	.26	17.2	12.9	10.3	34	26	21	52	39	31	12.8	9.6	7.7	26	19.2	15.4	38	29	23
	400	.32	21	15.8	12.7	42	32	25	63	48	38	15.8	12.8	9.5	32	24	19.0	47	35	28

Table 8. Cluster Tips

Nozzle Number	Liquid Pressure in psi	Nozzle Capacity in GPM	Swath Width in Feet	(Spraying Height SH = 36″) Gallons per Acre at: 5 MPH	10 MPH	15 MPH
C1	30	.87	18	4.8	2.4	1.6
	40	1.0	18½	5.4	2.7	1.8
	60	1.2	18½	6.6	3.3	2.2
C2	30	1.7	23½	7.3	3.6	2.4
	40	2.0	24½	8.1	4.0	2.7
	60	2.4	24½	9.9	4.9	33
C4	20	3.5	26	13.2	6.6	4.4
	40	4.0	27	14.7	7.3	4.9
	60	4.9	27	18.0	9.0	6.0
C8	30	7.0	29	24	11.8	7.9
	40	8.0	30	26	13.2	8.8
	60	9.8	30	32	16.2	10.8
C15	30	13.0	30½	42	21	14.1
	40	15.0	31½	47	24	15.7
	60	18.4	31½	58	29	19.2
C30	30	26	32	42	40	27
	40	30	33	47	45	30
	60	36	33½	58	54	36

Air Blast Sprayers

Air blast sprayers use large quantities of air and smaller quantities of water to deliver the pesticide to the target. Some sprayers (especially those of smaller capacity) spray to only one side at a time and may require two passes per row. Other sprayers direct the spray to both sides and require only one pass between each crop row.

Air blast sprayers usually require a nozzle arrangement which permits a greater percentage of spray to be discharged from the upper half of the manifold. Usual recommendations are to select nozzle tips so that two-thirds (67 percent) of total spray volume discharged is from the top half. Even for row crop, field, and other broadcast spraying, the nozzles should be selected to direct the largest part of the spray into the upper half of the air stream.

You need to determine how many nozzles are needed to obtain the coverage on the crop you will be spraying.

(1) First, determine the number of nozzles you will be using on each manifold. This number depends on the type of equipment you will be using and the size, shape, and density of crop you will be spraying. The following examples will help you arrange nozzles on your sprayer manifold.

Two-side delivery in high trees with low branches:

- top vanes raised,
- top nozzles open,
- lower nozzles open.

Two-side delivery in medium trees with low branches:

- external vanes pointed at tree top,
- top nozzles closed to prevent deflection by external vanes,
- bottom nozzles open.

Two-side delivery in medium trees, pruned high:
- external vanes pointed at tree top,
- upper nozzles closed as required to prevent deflection by external vanes,
- lower nozzles shut off.

One-side delivery for high trees or overly dense foliage:
- close desired cover,
- external vane aimed at tree top,
- close top nozzles as required to prevent deflection by vane,
- close lower nozzles as required, depending upon height of lower branches.

Two-side delivery—young orchard or grove with widely spaced rows:
- external deflectors lowered in full down position,
- top nozzles closed, as required,
- lower nozzles closed, as required.

(2) Divide the desired gpm by the number of manifolds your equipment has. Some equipment has one manifold per side; other equipment contains two manifolds per side.

(3) Divide the number of nozzles you will be using on each manifold by 2. This allows you to determine the discharge rate for the upper half and lower half of the manifold separately. If your equipment has nozzles unevenly spaced along the manifold, consult your equipment manufacturer's information for the number and placement of nozzles directing spray to the top half of the tree. Normally the bottom 2, 3, or 4 nozzles cover the lower part of the tree.

(4) Multiply the discharge rate per manifold (in gpm) by 0.67 to find the discharge rate for the nozzles in the top section of each manifold (since 67 percent of the spray should be discharged to the top half of the tree).

(5) Multiply the discharge rate per manifold (in gpm) by 0.33 to find the discharge rate for the nozzles in the lower section of each manifold.

(6) Divide the gpm for the upper section of the manifold by the number of nozzles in that section to find the gpm you need for each nozzle.

(7) Divide the gpm for the lower section of the manifold by the number of nozzles in that section to find the gpm you need for each nozzle.

(8) Use nozzle manufacturer's charts to select the appropriate nozzles.

(9) Check the total capacity of your nozzle arrangement by using the following formula:

Number of nozzles in upper section × Capacity per nozzle
+ Number of nozzles in lower section × Capacity per nozzle
= Total capacity per manifold.

Total capacity per manifold × Number of manifolds = Discharge rate in gpm

Compare this rate with the discharge rate you wish to achieve.

Example:

Your equipment has the capacity to apply 14 gpm spraying two sides at 200 psi with one manifold per side. You need eight nozzles operating on each manifold for best coverage of the trees.

- $\frac{\text{Total discharge rate (14)}}{\text{Number of manifolds (2)}}$ = Discharge rate per manifold (7 gpm)

  $14 \div 2 = 7$

- $\frac{\text{Number of nozzles per manifold (8)}}{2}$ = Number of nozzles in upper (or lower) section (4)

  $8 \div 2 = 4$

- Discharge rate per manifold (7 gpm) × 0.67 = 4.7 gpm for upper portion

  $7 \times .67 = 4.7$

- Discharge rate per manifold (7 gpm) × 0.33 = 2.3 gpm for lower portion

  $7 \times .33 = 2.3$

- $\frac{\text{gpm for upper section (4.7)}}{\text{nozzles in section (4)}}$ = 1.2 gpm per nozzle in upper section

  4.7 ÷ 4 = 1.2

- $\frac{\text{gpm for lower section (2.3)}}{\text{nozzles in section (4)}}$ = 0.6 gpm per nozzle in lower section

  2.3 ÷ 4 = 0.6

- The nozzle chart (Table 9) indicates that you need nozzles 156-B (1.18 gpm) or 141A (1.23 gpm) for the upper portion. You would probably select 156-B because you want a larger droplet size, longer throw, and narrower spray pattern than the five hole core or whirler would deliver. The nozzle charts also indicate that you need nozzles 139-A (0.55 gpm) or 153-B (0.62 gpm) for the lower portion. You would probably select the 153-B because you want the wider angle lower in the tree.

Table 9. Mist Spray Nozzles

Nozzle Number		139-A	140-A	141-A	142-A	143-A	144-A	145-A	146-A
		Discharge Capacity, G.P.M.							
Pressure at Nozzle (p.s.i.)	40	.25	.34	.55	.76	1.10	1.52	1.93	2.70
	60	.30	.41	.67	.93	1.35	1.86	2.36	3.31
	80	.35	.48	.78	1.08	1.55	2.15	2.73	3.82
	90	.38	.52	.82	1.15	1.65	2.30	2.88	4.05
	100	.39	.53	.87	1.20	1.74	2.40	3.05	4.26
	150	.47	.65	1.06	1.47	2.13	2.94	3.73	5.22
	160	.50	.69	1.10	1.52	2.20	3.05	3.88	5.42
	175	.52	.71	1.15	1.58	2.31	3.17	4.05	5.65
	190	.54	.74	1.20	1.65	2.40	3.30	4.22	
	200	.55	.75	1.23	1.69	2.46	3.40	4.32	6.03
	300	.67	.92	1.51	2.08	3.02	4.16	5.28	7.39

NOTE: A-Series Nozzles have five-hole core or whirler.

Nozzle Number		151-B	152-B	153-B	154-B	155-B	156-B	157-B	158-B
		Discharge Capacity, G.P.M.							
Pressure at Nozzle (p.s.i.)	40	.16	.19	.29	.35	.44	.52	.61	.76
	60	.19	.23	.35	.42	.54	.63	.75	.93
	80	.22	.26	.40	.48	.62	.73	.89	1.07
	90	.23	.27	.42	.51	.66	.77	.92	1.14
	100	.25	.29	.45	.54	.70	.81	.97	1.21
	150	.29	.35	.54	.65	.85	.98	1.19	1.48
	160	.30	.36	.56	.67	.87	1.02	1.22	1.52
	175	.32	.37	.58	.70	.91	1.06	1.27	1.60
	190	.33	.39	.60	.73	.95	1.10	1.33	
	200	.34	.40	.62	.75	.97	1.18	1.36	1.71
	300	.41	.48	.75	.90	1.19	1.37	1.68	2.10
	400	.46	.55	.86	1.04	1.37	1.59	1.94	2.40

NOTE: B-Series Nozzles have two-hole core or whirler.

- Check the total capacity of your nozzle arrangement.

Number of nozzles in upper section (4) × Capacity per nozzle (1.18) = 4.7 gpm for upper section

$4 \times 1.18 = 4.7$

Number of nozzles in lower section (4) × Capacity per nozzle (0.62) = 2.5 gpm for lower section

$4 \times .62 = 2.5$

$4.7 + 2.5$ = Total capacity per manifold (7.2 gpm)

Capacity per manifold (7.2) × Number of manifolds (2) = 14.4 gpm

$4.7 + 2.5 \times 2 = 14.4$

This is slightly above the 14 gpm you need. You may compensate by driving slightly faster.

NOTE: The exact gpm you are seeking will rarely be on the chart. Try to choose nozzles closest to the gpm you need. For the upper portion, choose a size that delivers slightly more than you need. Then compensate by choosing slightly lower capacity nozzles for the lower portion, or vice versa.

Spray Gun Nozzles

Gun spraying usually is done by hand and is intended to wet surfaces thoroughly with spray material. In order to choose an appropriate spray gun nozzle, you must know the approximate operating pressure of your sprayer. Some guns are useful for pressures between 30 and 800 psi, but others are built only for pressures up to 200 psi or from 200 to 800 psi. The other variables are the spray angle which each nozzle delivers at various pressure settings and the maximum throw of each nozzle at different pressures.

You must decide which nozzle delivers spray at the appropriate angle and throw distances for your particular application job. Choose the tip according to the gallons per minute your sprayer will deliver and the pressure necessary to do the job. Nozzle capacities range from 0.25 gpm to 50 gpm at 30 to 800 psi, with ›z-throw distances of up to 60 feet.

Calibration at the Application Site

The first step in calibration is to check two important factors related to the nozzles:

- pressure at the nozzles, and
- nozzle flow rates.

Unless these two factors match the figures on the manufacturer's charts, your equipment will not deliver the specified amount of pesticide.

The charts from which you selected your nozzles are based on pressure at the nozzles. To check this, mount a pressure gauge close to the nozzles. Then compare that reading with the pressure reading at the control station pressure gauge. (After the test, remove the pressure gauge near the nozzles and plug the connection.)

Even new nozzles may deliver at rates which vary from the manufacturer's charts; variance in delivery rates can result in costly underdosing or overdosing. You can check nozzle flow rates by measuring the length of time needed to collect a quart of carrier from each nozzle. Using Table 10, you can convert this information to gallons per minute.

Next, you must test your equipment at the application site to determine whether it is delivering the pesticide at the desired rate. Several methods for testing various types of spray equipment are explained below. If you find that the equipment is not delivering at a rate that is within 5 percent of the desired gpm or gpa, you must make adjustments and do another test. Minor adjustments in gallons per acre or gallons per minute can be made in one of three ways:

- changing the pump pressure—Lower pressure means less spray delivered; higher pressure means more spray delivered. Only minor adjustments should be made, because a large pressure change will change the discharged particle size significantly.
- changing the sprayer speed—Slower speed means more spray delivered; faster speed means less spray delivered. This is a practical method for most small changes.
- changing nozzle tips—This is the preferred method for large changes in delivery rate.

Table 10. Rates of Flow

GPM	Seconds to collect 1 quart	GPM	Seconds to collect 1 quart
.05	300	.20	75
.06	250	.225	67
.07	214	.25	60
.08	188	.30	50
.09	167	.35	43
.10	150	.40	38
.11	136	.50	30
.12	125	.60	25
.13	115	.70	21
.14	107	.80	19
.15	100	.90	17
.17	88	1.0	15

Boom Sprayer Calibration

Install the nozzle tips in the nozzle bodies on the boom using the spacing and boom height appropriate for the nozzle tips. Align them carefully. Misalignment of nozzle tips is a common cause of uneven coverage. Do not use nozzles of different sizes and spray angles on the same boom except in special multiple-nozzle arrangements designed for directed spraying. Check the boom to be sure it is level. If it is not, the spray output pattern will be uneven.

Nozzle manufacturers usually recommend a 30 percent spray pattern overlap in broadcast boom spraying. The height of the boom alters the percentage of overlap of the spray pattern, so use the boom height recommended by the manufacturer. At that height, the spray angle built into the nozzles provides approximately the correct overlap. In band spraying, the boom height influences the width of the band the nozzle is delivering. Make adjustments in the boom height to achieve the desired band width with the angle of nozzle you have chosen.

Fill the spray tank with the carrier you will be using and operate the pump to fill the system. Operate the sprayer briefly on a paved surface such as a road or driveway, if possible, to check for:

- correct broadcast overlap or band pattern,
- streaks and uneven patterns caused by worn or partly plugged nozzles,
- uniform coverage.

Make any necessary adjustments and then refill the tank. The next step is to choose a calibration method. There are many different ways to calibrate sprayers. Here are two basic methods:

Nozzle Output Method

(1) Using Table 11 below, select the appropriate distance and mark it off in the field or area you will be spraying. For broadcast applications, use the nozzle spacing to determine the calibration distance. For band or directed applications, use the row spacing.

(2) Using the throttle setting and gear you wish to use, bring the sprayer up to speed. With the spraying system shut down, drive the measured distance and note the time in seconds that it takes.

(3) With the equipment in neutral, operate the spray system for the measured time and collect the nozzle discharge in a container graduated in ounces. For a broadcast boom with evenly spaced nozzles, catch the output from any nozzle along the boom. If more than one nozzle per row is used, catch the spray from all nozzles directed at a single row.

(4) The total discharge measured in ounces is equal to gallons per acre (gpa) applied. With either broadcast boom or band sprayer, the gpa is equal to the output from one nozzle. When more than one nozzle is used per row, the combined amount collected from all nozzles directed at the row is equal to the gpa.

Table 11. Calibration Distances

Row or Nozzle Spacing (inches)	Calibration Distance (feet)
40	102
38	107
36	113
34	120
32	127
30	136
28	146
26	157
24	170
22	185
20	204
18	227

Example: (Broadcast or Band Application):

The pressure you have selected is 30 psi. The nozzles are spaced 20 inches apart on the boom.

(1) The distance to mark off for 20-inch nozzle spacing is 204 feet.

(2) Select the gear and throttle setting, bring the sprayer up to speed, and measure the time needed to cover 204 feet.

(3) If it required 20 seconds to travel the 204 feet, set the pressure at 30 psi and catch one nozzle's output for 20 seconds.

(4) Measure the amount collected. The output in ounces is the amount applied in gallons per acre. If the nozzle output is 15 ounces, the sprayer applied 15 gallons per acre.

(5) Repeat steps 3 and 4 for each nozzle.

Example: (Directed Spray)

You want to spray a 32-inch row, using two nozzles per row (one on each side). The pressure to be used is 20 psi.

(1) The distance to travel for a 32-inch row is 127 feet.

(2) Select speed and drive the 127 feet. Measure the time in seconds.

(3) If it took 15 seconds, set the pressure at 20 psi and catch the output from one pair of nozzles for 15 seconds.

(4) Measure the quantity from the two tips. The amount measured in ounces represents the gallons per acre applied. If each tip delivers 5 ounces (a total of 10 for the pair), the sprayer output is 10 gallons per acre.

(5) Repeat steps 3 and 4 for each pair of nozzles on the boom.

Volume Output Method

Sometimes it is not practical to catch the flow from individual nozzles. Another method of calibration is to measure the volume of spray dispersed from the tank over a measured area. Your test area can be either one acre or part of an acre. Be sure to compare flow rate from individual nozzles along the boom before using this method.

First, you must determine the sprayed width for your boom sprayer.

The sprayed width for **broadcast** spraying is the distance (in feet) between the first and last nozzles on the boom, plus the distance (in feet) between two nozzles.

Example:

- nozzle spacing is 24 inches (2 feet).
- distance between the first and last nozzles on the boom is 18 feet.
- 18 feet + 2 feet = a 20-foot sprayed width.

The sprayed width for **band** spraying is equal to the number of bands (nozzles) multiplied by the band width (in inches). Divide by 12 to convert to sprayed width in feet.

Example:

- number of bands = 9
- band width = 10 inches

Number of bands (9) × band width (10″) = Sprayed width in inches (90″)

$$9 \times 10 = 90$$

$$\frac{90 \text{ inches}}{12} = \text{sprayed width in feet (7.5)}$$

$$90 \div 12 = 7.5$$

The sprayed width for **directed** spraying is equal to the number of rows sprayed multiplied by the row spacing (in inches). Divide by 12 to convert to sprayed width in feet.

Example:

- number of rows = 7
- row spacing = 40 inches

Number of rows (7) × Row spacing (40″) = Sprayed width in inches (280″)

$$7 \times 40 = 280$$

$$\frac{280 \text{ inches}}{12} = \text{Sprayed width in feet (23.3)}$$

$$280 \div 12 = 23.3$$

Spray-an-Acre Method—One type of volume output calibration involves spraying an entire acre:

(1) Completely fill the tank with water.

(2) Mark off one acre in the field to be sprayed. Use this formula to figure the distance you need to drive to cover one acre:

$$\text{Distance to drive for one acre} = \frac{43{,}560}{\text{sprayed width (in feet)}}$$

(3) Spray the measured acre at the speed and pressure appropriate for the nozzles you have selected.

(4) Completely refill the spray tank, using a container marked off in gallons. Carefully measure the quantity you add. The amount needed to completely refill the tank is the rate applied per acre.

Spraying Less Than One Acre—Another way to calibrate by the volume output method is to spray an area smaller than an acre:

(1) Stake out a test area in the field to be sprayed. The distance should be at least 1,000 feet.

(2) Fill the spray tank with water.

(3) Spray the measured run using the pressure and speed appropriate for the nozzles. Be sure the sprayer is at correct speed when you reach the test strip.

(4) Refill the tank to the initial level, carefully measuring the quantity you add.

(5) Calculate the rate of application. The method of calculation depends on whether you are making a broadcast application or a band application.

To figure the gallons per acre for broadcast spraying:

Find the area sprayed in the test run:

$$\frac{\text{Sprayed width} \times \text{distance in test run}}{\text{Square feet in one acre (43,560)}} = \text{Area sprayed (in acres)}$$

Then find the gallons per acre being sprayed:

$$\frac{\text{Gallons used in test run}}{\text{Area (in acres) sprayed in test run}} = \text{Gallons per acre}$$

Example:

- sprayed width = 20 feet
- distance in test run = 1,000 feet

- gallons used in test run = 8
- spray volume desired = 18 gpa

$$\frac{\text{Sprayed width (20')} \times \text{test run (1,000)}}{\text{43,560 sq. ft.}} = \text{Area sprayed (0.46 acre)}$$

$$20 \times 1{,}000 \div 43{,}560 = 0.46$$

$$\frac{\text{Gallons used (8)}}{\text{Area sprayed (0.46)}} = 17.4 \text{ gpa}$$

$$8 \div 0.46 = 17.4$$

This is within 5 percent of the 18 gallons per acre you wish to spray.

To figure the gallons per acre for band application:
Find area sprayed in the bands of the test area:

$$\frac{\text{Sprayed width (band width} \times \text{no. of bands)} \times \text{length of test run}}{\text{Square feet in one acre (43,560)}} = \text{Area sprayed in bands (in acres)}$$

Find gallons per acre being sprayed in the bands:

$$\frac{\text{Gallons used in test run}}{\text{Area sprayed in bands (in acres)}} = \text{Gallons per acre}$$

Example:

- sprayed width = 7.5 ft. (nine 10-inch bands),
- distance in test run = 1,000 ft.
- gallons used in test run = 1.8
- spray volume desired = 9 gpa (be sure to determine band rate)

$$\frac{\text{Sprayed width (7.5 ft.)} \times \text{length of test run (1,000 ft.)}}{\text{43,560}} = \text{Area sprayed in bands (0.17 acre)}$$

$$7.5 \times 1{,}000 \div 43{,}560 = 0.17$$

$$\frac{\text{Gallons used (1.8)}}{\text{Area sprayed in bands (0.17)}} = \text{Gallons per acre (10.6)}$$

$$1.8 \div 0.17 = 10.6$$

This is not within 5 percent of the 9 gallons per acre you wish to spray, so you must make adjustments and do another test.

Boomless Sprayer Calibration

Calibrate boomless sprayers using the volume output method. Use either the "spray an acre" or "spray part of an acre" technique to measure output of this kind of sprayer. The sprayed width is the effective swath width your sprayer produces with the nozzle tips and spray height you have chosen. Nozzle selection charts often specify the effective swath width produced by the nozzles at a given height. An overlap percentage may also be recommended. If you need to measure the effective swath width, spray water on a dry surface at the operating pressure and nozzle height you have chosen. Measure the sprayed width (in feet). The portion which is completely wet is your effective swath width. The width of the area on the fringe which is not completely wetted is the area you need to overlap on the next pass for complete coverage. These types of nozzles often require 50 percent overlap.

High Pressure (Hydraulic) Sprayer Calibration

High-pressure sprayers may be equipped with booms or with nozzles which spray a swath. When they are used in this way, they are calibrated in the same way as a low-pressure boom or boomless sprayer.

High-pressure sprayers also may be equipped with spray guns for treating livestock, orchards, nurseries, roadsides, or rights-of-way. Once the appropriate spray gun tip has been chosen and the flow rate has been checked, no further calibration is necessary.

Air Blast Sprayer Calibration

Since air blast sprayers are often used to apply a highly concentrated spray mixture, great care must be taken in calibrating the sprayer. With dilute mixtures, a variation of 3 gallons per minute in spray output has little effect on the amount of active ingredient delivered; however, with concentrate sprays, the same variation can cause a ten-fold or greater error in the application rate.

The most common error in air blast sprayer operation is traveling at the wrong speed. Too slow a rate of travel will result in overspraying and waste of time, fuel, money, and pesticide. Too fast a rate of travel will result in an inadequate spray deposit and poor pest control.

A maximum speed of 2 mph is recommended for most air blast applications. In cases of very dense foliage or large trees, a lower rate of travel (from $\frac{3}{4}$ to $1\frac{1}{2}$ mph) should be selected. Increased speed reduces the coverage to the tops and centers of trees, even though the liquid delivered per tree or per acre appears adequate.

The best method of selecting the optimum ground speed is to put water into the tank and make a test run in the area to be treated. Vary the rate of speed until the spray material is being blown through the trees in the desired pattern. In orchard, nursery, and forestry spraying, the water carrier must be blown completely through the trees. Field crop, mosquito, and related applications require uniform penetration across the swath width.

To determine sprayer speed in mph, measure the feet traveled in one minute and divide by 88. If the distance between trees is constant, you can count the number of trees passed in one minute and use this formula to compute speed:

$$\frac{\text{Tree spacing (tree center to tree center in feet)} \times \text{Number of trees passed per minute}}{\text{88 feet per minute}} = \text{Ground speed in mph}$$

Choosing the Spray Volume (Discharge Rate)

Air blast sprayers can deliver highly concentrated chemicals. They apply the normal amount of pesticide to the target, but with less water. The amount of chemical per tankful is 3, 5, or even 10 times the amount used with hydraulic sprayers, but only $\frac{1}{3}$ to $\frac{1}{10}$ as many gallons of total spray volume (water and pesticide) are applied. The amount of active ingredient that reaches the target should be the same as with dilute methods.

Sometimes the label or other sources specify the dosage increases necessary for air blast or mist blower equipment (3X, 5X, 10X, etc.). Many times, however, the applicator must choose the concentration to apply. Consider these factors in making your choice:

- The savings in water and labor are greatest when converting from dilute to 5X or 10X concentrates. Over 10X, the savings are negligible.
- High concentrate applications (over 5X) require extreme accuracy and ideal spraying conditions. Very small changes in rate of speed or nozzle output are magnified by the concentrations of the tank mixture.

Labels and other recommendations often list spray volume in terms of:

- pints/quarts/gallons/pounds of spray mixture per tree (dilute or concentrated),
- pints/quarts/gallons/pounds of spray mixture per acre (dilute or concentrated),
- gallons or pounds per acre of dilute spray (as applied by other equipment).

Depending on the requirements of your job, you may need to convert these spray volume recommendations in order to determine the correct discharge rate (in gallons per minute) for your air blast sprayer. Use the following formulas:

(1) When spray volume is given as gallons or pounds per tree in concentrate and trees are closely spaced so that continuous spraying is feasible:

- Determine the gallons of spray to apply to each tree **in each pass**. Since you spray the tree from both sides:

$$\text{Rate per tree per pass (or side)} = \frac{\text{Recommended rate per tree}}{\text{2 passes (sides) per tree}}$$

OR

$$\text{Rate per tree} = \tfrac{1}{2} \text{ the recommended rate}$$

- Determine the gpm you need for your sprayer to deliver the desired rate per tree per pass. At the rate of speed you have selected, determine the number of trees passed per minute (by counting or by using the following formula):

$$\text{Trees passed per minute} = \frac{\text{mph} \times 88 \text{ ft. per minute}}{\text{Tree spacing in feet}}$$

If your sprayer sprays on one side only, then:

$$\text{gpm} = \text{Trees passed per minute} \times \text{Spray volume in gallons per tree per pass}$$

If your sprayer sprays on two sides:

$$\text{gpm} = \text{Trees passed per minute} \times 2 \times \text{Spray volume in gallons per tree per pass}$$

Example:

- The label calls for 2 pints spray concentrate per tree (2 pints = ¼ or .25 gallons).
- Your spray equipment covers the tree thoroughly at 3 mph and sprays to one side only.
- The trees are spaced at 20-foot centers.

$$\frac{\text{Recommended rate per tree in gallons (0.25)}}{\text{passes per tree (2)}} = \text{Gallons per tree per pass (0.125)}$$

$$0.25 \div 2 = 0.125$$

$$\frac{\text{mph (3)} \times 88 \text{ ft/min}}{\text{tree spacing (20 ft)}} = \text{Trees passed per minute (13.2)}$$

$$3 \times 88 \div 20 = 13.2$$

$$\text{Trees passed (13.2)} \times \text{Spray volume in gallons (0.125)} = 1.65 \text{ gpm}$$

$$13.2 \times 0.125 = 1.65$$

(2) When spray volume is gallons per tree in concentrate, spaces exist between trees, and the air blast sprayer will be used to spot spray each tree:

- Determine the gallons of spray to apply per tree per side (as above).
- Find the time (in minutes) you require to pump the needed number of gallons into each side of each tree using the nozzles on your sprayer. The discharge rate is determined by filling the tank full or to a marked level with water. Bring blower and pump up to speed and run for 5 minutes. Measure the amount needed to refill the tank.

$$\text{gpm} = \frac{\text{Gallons pumped in test}}{\text{Minutes in test}}$$

If your sprayer delivers large quantities (15 or more gallons) per minute, reduce the test time to 1 or 2 minutes.

- Determine the number of minutes you need to spray each side of the tree:

$$\text{Minutes per side of tree} = \frac{\text{Gallons per side}}{\text{Gallons per minute}}$$

Example:

- The label calls for 3 gallons of concentrate spray per 50-foot elm tree.
- Your sprayer pumps 50 gallons in 5 minutes.

$$\frac{\text{3 gallons}}{\text{2 sides}} = \text{1.5 gallons per side of tree}$$

$$3 \div 2 = 1.5$$

$$\frac{\text{Gallons pumped in test (50)}}{\text{Minutes in test (5)}} = \text{gpm (10)}$$

$$50 \div 5 = 10$$

$$\frac{\text{Gallons per side (1.5)}}{\text{Gallons per minute (10)}} = \text{0.15 minutes (9 seconds) per side}$$

$1.5 \div 10 = 0.15$

(3) When the recommended spray volume is listed as pounds or gallons of dilute spray per acre:
You must convert the volume of dilute spray to volume of concentrate spray. There are two methods.

- volume of concentrate per tree,
- volume of concentrate per acre (the only choice when you will be spraying field crops, turf, or other nontree areas).

To convert recommendations for volume of dilute spray per acre to volume of concentrate per tree:

- Determine the gallons of **dilute** spray which conventional hydraulic sprayers would apply to each tree. Charts are available to guide you, or your experience with hydraulic equipment may help you to make the determination.
- Find the application rate per tree.

$$\frac{\text{Gallons per tree (dilute)}}{\text{Concentration to be used (?X)}} = \text{Gallons per tree (concentrate)}$$

- Since the tree is sprayed on two sides, figure the gallons to be applied to each side of the tree (gallons per pass).

$$\frac{\text{Gallons (concentrate) per tree}}{\text{Passes per tree (2)}} = \text{Gallons per pass (concentrate)}$$

- Determine the rate of speed which is best for your equipment.
- Determine the gpm needed. For a sprayer directing spray to **one** side:

$$\frac{\text{mph} \times 88 \text{ ft/min} \times \text{gallons per pass per tree}}{\text{Tree spacing}} = \text{gpm}$$

For a sprayer directing spray to **two** sides:

$$\frac{2 \times \text{mph} \times 88 \text{ ft/min} \times \text{gallons per pass per tree}}{\text{Tree spacing}} = \text{gpm}$$

Example:

- Label directions call for 1 pound per 100 gallons.
- Dilute spray volume = 12 gallons per tree.
- Concentration = 5X
- Sprayer speed = 2 mph
- Sprayer sprays to two sides.
- Tree spacing = 30 feet between centers.

$$\frac{\text{Gallons per tree (dilute) (12)}}{\text{Concentration (5)}} = 2.4 \text{ gallons per tree}$$

$12 \div 5 = 2.4$

$$\frac{\text{Gallons per tree (2.4)}}{\text{Number of passes (2)}} = 1.2 \text{ gallons per pass}$$

$2.4 \div 2 = 1.2$

$$\frac{2 \times \text{mph (2)} \times 88 \times 1.2 \text{ gal/pass}}{\text{Tree spacing (30 ft.)}} = 14 \text{ gpm}$$

$2 \times 2 \times 88 \times 1.2 \div 30 = 14$ gpm

To convert recommendations for volume of dilute spray per acre to volume of concentrate per acre (for tree spraying):

- Find gallons per acre (concentrate) you must apply:

$$\text{Gallons per acre (Concentrate)} = \frac{\text{Gallons per acre (dilute)}}{\text{Concentrate rate to be used}}$$

- Then determine gpm:

For sprayers applying to one side only:

$$\text{gpm} = \frac{\text{Gal. per acre} \times \text{mph} \times \text{tree spacing (ft)}}{1{,}000}$$

For sprayers applying to two sides:

$$\text{gpm} = \frac{2 \times \text{gal. per acre} \times \text{mph} \times \text{tree spacing (ft)}}{1{,}000}$$

Example:

You normally apply 1,760 gallons of dilute spray per acre. Your sprayer covers evenly at 2 mph and is spraying to two sides. Your trees are spaced on 24-foot centers. You wish to apply a 4X concentration.

$$\frac{\text{Gallons per acre dilute (1,760)}}{\text{Concentration (4X)}} = 440 \text{ gpa}$$

$$1760 \div 4 = 440$$

$$\frac{2 \times \text{gpa (440)} \times \text{mph (2)} \times \text{tree spacing (24)}}{1{,}000} = 42.2 \text{ gpm}$$

$$2 \times 440 \times 2 \times 24 \div 1000 = 42.2$$

To convert recommendations for volume of dilute spray per acre to **volume of concentrate per acre (for field, crop, turf, and other nontree spraying)**:

- Determine the swath width—follow equipment manufacturer's recommendations and the field conditions (wind speed and direction).
- Determine gallons (concentrate) to be applied per acre.

$$\text{Gallons per acre (concentrate)} = \frac{\text{Gallons per acre (dilute)}}{\text{Concentrate rate}}$$

- Determine gpm.

$$\text{gpm} = \frac{\text{Gallons per acre} \times \text{mph} \times 88 \text{ ft/min} \times \text{swath width}}{43{,}560}$$

Example:

- Label directions call for 200 gallons per acre dilute spray.
- Sprayer speed = 2.5 mph
- Concentration = 6X
- Swath width = 90 feet

$$\frac{\text{gpa dilute (200)}}{\text{Concentration (6)}} = 33.3 \text{ gpa (concentrate)}$$

$$200 \div 6 = 33.3$$

$$\frac{\text{gpa con. (33.3)} \times \text{mph (2.5)} \times 88 \text{ ft/min} \times \text{swath width (90)}}{43{,}560 \text{ gpm}} = 15 \text{ gpm}$$

$$33.3 \times 2.5 \times 88 \times 90 \div 43{,}560 = 15$$

Calibrating Granular Applicators and Dusters

Granular Application Equipment

There are many types of granular application equipment. Gravity-feed applicators may have one long hopper with a sliding gate or auger which regulates the flow to the multiple outlets. The granules drop straight down to the target surface from the outlets, so the swath width is equal to the width of the hopper. Other equipment uses air blast or whirling discs to distribute the granules in swaths much wider than the machines. To determine the swath width, you must measure the actual swath on a hard surface.

Band applicators usually are a modification of the gravity-feed equipment. Granules drop through tubes and are released just above the soil to form bands of a specific width. For band applicators, the swath width is the number of bands multiplied by the band width in feet.

Soil injectors are band applicators with the tubes releasing the granules in furrows which are then covered. Ram-air equipment (agricultural aircraft) uses a combination of air flow and gravity to deliver the granules to the target site.

In all types of granular equipment, the amount of granules applied per unit of area depends on the size of the adjustable opening, the speed at which the equipment travels (or the speed of the hopper agitator), the roughness of the surface of the application site (except for aerial application), and the granular formulation chosen.

Different formulations have different flow rates depending on the size, weight, shape, and texture of the granules. Environmental factors such as temperature and humidity also alter granular flow rates. (High temperature and humidity slow the flow rate, and vice versa.)

Because so many variables can affect the delivery rate, you must calibrate your equipment for each batch of product you use and for each new field condition.

Granular equipment which is not motorized delivers granules at a rate geared to the turns of the hopper agitator, which is in turn geared to the revolutions of the wheels. The faster the equipment is moved, the faster the release of granules, and vice versa. As a result, equipment speed does not affect the amount of granules deposited per unit area. The only way to change the application rate in this type of equipment is by changing the feed gate settings.

Motorized granular equipment distributes the granules at a constant rate independent of the speed of the equipment. The dosage rate per acre (or other unit area) depends on both the metered opening and the equipment speed. Minor adjustments in flow rates can be made by altering the rate of speed. (Faster speed means fewer granules delivered per area). Larger adjustments should be made by altering the equipment settings.

Consult the equipment manual for manufacturer's recommendations for approximate settings for the granules being applied. If the equipment is motorized, select the speed by using manufacturer's suggestions and taking into consideration the condition of the application site. Soft, muddy, or uneven surfaces and small areas with many obstacles dictate slower speeds.

Calibrate your equipment using one of the two methods described below. If the application rate differs more than 5 percent from the desired rate, you should adjust the equipment and recalibrate.

Broadcast Granular Applicators

Run a precalibration check on the equipment:

- First, fill the hopper to a predetermined height or weight. Settle the material by driving a short distance or by shaking or striking the hopper; then refill the hopper.
- Set the flow rate as recommended by the equipment manual.
- Turn on the applicator and operate on a hard surface to check for uniform distribution along the swath width.

The next step is to determine whether the equipment is metering granules at the rate per acre you need. Calibrate the equipment by determining the amount of granules distributed over a measured area. You may use either of two methods:

- the calibration pan method,
- the volume output method.

Calibration Pan Method

Multiple outlet broadcast spreaders, band applicators, and soil injection equipment often can be calibrated by collecting the granules in calibration pans graduated in ounces.

If the dosage is given in pounds per 1,000 linear feet of row:

- Mark off 1,000 feet in the field you wish to treat.
- Collect the granules discharged from one tube or opening during the 1,000-foot test run. If the equipment is motorized, bring it up to the speed you have selected before beginning the test run.

OR

Make the test run at the speed you have selected, but do not operate the applicator. Note the time (in seconds) it takes to complete the test run. Then with the equipment standing still, collect the granules discharged for that measured time.

- The amount of granules collected (in ounces or pounds) is the rate per 1,000 linear feet. (If you wish to use only a 100-foot test run, the amount of granules collected multiplied by 10 is the dosage per 1,000 linear feet.)

Volume Output Method

The volume output method of calibration can be done in one of two ways:

Treat an acre at the speed and setting recommended by the equipment manual. To determine your rate of application, catch the granules in calibration pans or measure the amount of granules needed to refill the hopper.

OR

Treat less than an acre. Stake out a test area in the field to be treated. The total test run should be at least 1,000 feet.

- Treat the test area at the speed and setting you have chosen.
- Catch the granules in a pan, or refill the hopper and measure the amount added.
- Calculate the rate of application:

$$\frac{\text{Swath width} \times \text{distance in test run (in ft.)}}{\text{Square feet in an acre (43,560)}} = \text{Area (in acres) treated in test}$$

$$\frac{\text{Pounds used in test run}}{\text{Area (in acres) treated in test run}} = \text{Pounds per acre}$$

Example:

- swath width = 15 feet
- test run = 1,000 feet
- amount used in test run = 5 pounds
- amount needed per acre = 15 pounds

$$\frac{\text{Swath width (15')} \times \text{test run (1,000')}}{\text{43,560 sq. ft.}} = \text{Area treated (0.34 acre)}$$

$$15 \times 1{,}000 \div 43{,}560 = 0.34$$

$$\frac{\text{Pounds in test run (5)}}{\text{Area treated (0.34)}} = \text{Pounds per acre (14.7)}$$

$$5 \div 0.34 = 14.7$$

That is within 5 percent of the specified rate.

Band Granular Applicators

Use the methods described above to calibrate band applicators.

However, if the label directions give the rate in **pounds per acre broadcast**, then you must use the following formula to determine the rate per acre in bands:

$$\frac{\text{Band width} \times \text{Pounds per acre (broadcast)}}{\text{Row spacing}} = \text{Pounds (band) per acre}$$

Example:

- label rate = 12 pounds per acre (broadcast)
- band width = 6 inches
- row spacing = 30 inches

$$\frac{\text{Band width (6")} \times \text{12 pounds per acre (broadcast)}}{\text{Row spacing (30")}} = \text{2.4 pounds per acre}$$

$$6 \times 12 \div 30 = 2.4$$

If the label directions list **pounds to apply per 1,000 linear feet**, you must use this formula to determine your rate:

$$\frac{\text{Total pounds used in test run}}{\text{Number of rows in swath}} = \text{Pounds used per row in test run}$$

$$\frac{\text{Pounds used per row (in test run)} \times 1{,}000 \text{ ft.}}{\text{Distance traveled in test run}} = \text{Pounds per 1,000 linear feet}$$

Example:

- number of bands or rows covered in test run = 8
- distance traveled in test = 3,000 feet
- pounds used in test = 2.3

$$\frac{\text{Pounds used in test (2.3)}}{\text{Number of rows (8)}} = \text{Pounds used per row in test run (.287)}$$

$2.3 \div 8 = .287$

$$\frac{\text{Pounds used per row (.287)} \times 1{,}000 \text{ ft.}}{\text{Distance traveled in test run (3,000 ft.)}} = \text{Pounds per 1,000 linear feet (.095 or 1.5 oz.)}$$

$.287 \times 1{,}000 \div 3{,}000 = .095$

Dust Application Equipment

To calibrate dusters for use in ground application, follow the directions given above for calibrating granular application equipment.

Calibrating Other Equipment

Calibrating Seed Treaters

Dust Treaters

Set the seed hopper gate to release the required pounds per dump by rotating the hand wheel on the side of the hopper. Adjust the counterweight on the weight pan to trigger the dumping mechanism when the required weight of seeds is in the pan. Run the treater with the determined seed weight, but catch the pesticide dust in a measuring cup as it comes off the vibrating feeder. Speed up or slow down the feeder until the correct rate of pesticide dust is coming off the vibrator belt for each batch. These seed treaters are somewhat difficult to calibrate accurately and they cause pesticide dust to escape into the operator's working environment.

Liquid and Slurry Seed Treaters

Liquid and slurry seed treaters coat seeds with pesticides in liquid form. The pesticide mixture may be a slurry formed from wettable powder formulations, or it may be a liquid formed from soluble powders, flowables, emulsifiable concentrates, and similar formulations.

The amount of pesticide mixture applied by these treaters is adjusted by two means:

- the size of the metering cup or bucket,
- the concentration of the pesticide mixture.

Step 1. Determine how much liquid your treater's metering cup or bucket will dump into the seed each time the weighted seed pan trips. The cups or buckets are available in three sizes (15cc, 23cc, or 46cc). The smaller cup size is for large seed sizes, and vice versa. Label directions or machine calibration instructions will list the appropriate cup size for the seed to be treated.

Step 2. Set the seed flow hopper gate to release the correct weight of seed. Different settings on the gate are related to the different types of seed to be treated and their different flow patterns. Run seed slowly into the treater until the weighted seed pan dumps seed into the treater. Shut off the treater immediately and weigh the amount of seed that was dumped. Note the setting of the weight on the weight balance arm and the weight of the grain dumped. Record for future use.

Step 3. Determine the number of dumps per bushel by dividing the weight per dump into the bushel weight of your seed. For example, if a treater dumps 6 pounds of wheat each time the seed pan trips and a bushel weighs 60 pounds, there would be 10 dumps per bushel.

Step 4. Determine how much of the liquid or slurry you are applying per bushel of seed. To do this, multiply the amount of chemical your metering cup dumps into the seed (Step 1) by the number of dumps per bushel (Step 3). Since most metering cup capacities are measured in cc, while the chemical recommendations are in ounces per bushel, divide the result by 29.57 to give the liquid ounces per bushel applied.

$$\frac{\text{Metering cap capacity (in cc)} \times \text{dumps per bushel}}{29.57\text{cc}} = \text{Ounces of liquid applied per bushel}$$

Example:

$$\frac{46\text{cc} \times 10 \text{ dumps}}{29.57} = \frac{460}{29.57} = 15.6 \text{ oz. liquid per bushel}$$

$$46 \times 10 \div 29.57 = 15.6$$

Step 5. The pesticide label or expert recommendations will list the appropriate amount of pesticide to add per gallon of water or per bushel to achieve the correct concentration. This will be listed as pounds or pints of product per gallon of water or ounces per bushel. If directions are given only in ounces per bushel, you must convert to ounces per gallon. Divide the ounces in a gallon (128) by the number of ounces of liquid your treater applied per bushel. Then multiply the result by the ounces of the chemical you want to apply to each bushel.

$$\frac{128 \text{ (oz. per gal.)} \times \text{oz. chemical desired per bushel}}{\text{oz. liquid applied per bushel}} = \text{oz. of chemical to add to 1 gallon of water}$$

Example:

- Ounces of liquid your treater applies per bushel = 15.6
- Ounces of chemical to be applied per bushel = 1.5

$$\frac{128 \times 1.5}{15.6} = 12.3 \text{ ounces of chemical to add to one gallon of water}$$

$$128 \times 1.5 \div 15.6 = 12.3$$

NOTE: For additional information, see the calibration instruction manual furnished with each machine by the manufacturer.

Calibrating Soil Fumigation Equipment

Soil fumigation equipment can be calibrated by using the volume output method described for sprayers. Use the following formulas:

$$\text{Test area sprayed} = \frac{\text{Swath width} \times \text{distance in test run}}{\text{Square feet in an acre (43,560)}}$$

$$\text{Gallons per acre} = \frac{\text{Gallons used in test run}}{\text{Area (in acres) sprayed in test run}}$$

For band applications, the swath width is the band width (in inches) multiplied by the number of bands. Divide by 12 to find the swath width in feet.

Soil fumigant rates sometimes are listed as ounces per 100 or 1,000 linear feet traveled. You can use the following formula:

$$\frac{\text{Total ounces used in test run}}{\text{Number of rows in swath}} = \text{ounces used per row in test run}$$

$$\frac{\text{Ounces used per row in test run} \times 100 \text{ (or 1,000) feet}}{\text{Distance traveled in test run}} = \text{Ounces per 100 (or 1,000) feet}$$

Soil fumigant rates are sometimes listed as feet traveled per pint of fumigant delivered. Then:

- with orifice pressurized, keep the unit stationary and operate the pump or pressure system at the equipment manual's suggested setting,
- time how long (in seconds) it takes to collect 1 pint of fumigant from the orifice,
- determine how fast you need to travel:

$$\frac{\text{Ft. per pint specified on label}}{\text{Collection time for one pint}} = \text{Speed (feet per second)}$$

$$\frac{\text{Speed (feet per second)}}{1.45} = \text{Miles per hour}$$

If the speed is too fast or slow for your ground conditions and equipment, change settings and recalibrate.

Calibrating Airplanes and Helicopters

This equipment is highly specialized and should be calibrated according to equipment manufacturer's instructions or with guidance from Extension, university, or other professional personnel. The basic volume output method can be used for this equipment also:

(1) Fill the tank or hopper to a known level.
(2) Apply pesticide over a known area (acre or part of an acre).
(3) Measure quantity of pesticide needed to refill tank or hopper.
(4) Figure rate per acre.

Calibrating Aquatic Application Equipment

Aquatic application equipment should be calibrated according to the equipment manufacturer's instructions or with guidance from Extension, university, or other professional personnel. The volume output method can be successfully used for aquatic equipment, but you must figure whether to base the rate on:

- water surface area to be treated,
- bottom surface area to be treated, or
- total volume of water to be treated.

Then proceed to:

(1) Fill tank or hopper to known level.
(2) Apply pesticide to a specific area (acres of surface or bottom area or acre-feet of volume).
(3) Measure quantity of pesticide needed to refill tank or hopper.
(4) Figure output per area treated (acres or acre-feet).

Diluting Pesticides Correctly

Unless you have the correct amount of pesticide in your tank mix, even a correctly calibrated sprayer can apply the wrong dose of pesticide to the target.

Formulations such as wettable and soluble powders, emulsifiable concentrates, and flowables are sold as concentrates and must be diluted in the spray tank with an appropriate carrier. Water is the most common carrier, but kerosene, oil, and other liquids are sometimes used. The label or other recommendations will tell you:

- how much to dilute the formulation, and
- how much of the dilute pesticide to apply per unit of area.

Mixing Soluble and Wettable Powders

Pounds Per 100 Gallons

Directions for wettable or soluble powders may be given in pounds of pesticide formulation per 100 gallons of carrier. You must know the capacity in gallons of your sprayer tank (or the number of gallons you will be adding to your spray tank if the job requires only a partial tank load). Then use the following formula:

$$\frac{\text{Gallons in tank} \times \text{lbs. per 100 gal. recommended}}{\text{100 gallons}} = \text{Pounds needed in tank}$$

Example:

Your spray tank holds 500 gallons. The label calls for 2 pounds of formulation per 100 gallons of water. How many pounds of formulation should you add to the tank?

$$\frac{\text{500 gallons} \times \text{lbs. per 100 gallons (2)}}{\text{100 gallons}} = \text{Pounds needed in tank (10)}$$

$$500 \times 2 \div 100 = 10$$

You should add 10 pounds to the tank.

Example:

You need to spray only one acre and your equipment is calibrated to spray 60 gallons per acre. The label calls for 2 pounds of formulation per 100 gallons of water. How many pounds of formulation should you add to the tank to make 60 gallons of finished spray?

$$\frac{\text{Gallons in tank (60)} \times \text{lbs. per 100 gallons (2)}}{\text{100 gallons}} = \text{1.2 lbs. (19 oz.) needed in tank}$$

$$60 \times 2 \div 100 = 1.2$$

Number of pounds to add is 1.2 or 19 oz.

Pounds Per Acre

The label may list the recommended dosage as pounds per acre. If the job requires a full tank, you must know how many gallons your equipment applies per acre and the spray tank capacity. Use these formulas:

$$\frac{\text{Gallons in tank}}{\text{Gallons applied per acre}} = \text{Acres sprayed per tankful}$$

$$\text{Acres sprayed per tank} \times \text{Pounds formulation per acre} = \text{Pounds form. needed in tank}$$

Example:

Your sprayer applies 15 gallons per acre and your tank holds 400 gallons. The label rate is 3 pounds of formulation per acre.

$$\frac{\text{Gallons in tank (400)}}{\text{Gallons per acre (15)}} = \text{26.7 acres sprayed per tankful}$$

$$400 \div 15 = 26.7$$

$$\text{Acres sprayed per tankful (26.7)} \times \text{Pounds formulation per acre (3)} = \text{Pounds needed in tank (80.1)}$$

$$26.7 \times 3 = 80.1$$

Add 80 pounds of pesticide formulation to the tank.

If the job requires less than a full tank, you must know how many acres you wish to treat and how many gallons your sprayer is pumping per acre. You must figure both the number of gallons needed in the tank and the pounds of formulation to add. Use these formulas:

$$\text{Gallons per acre} \times \text{Acres to be treated} = \text{Gallons needed in tank}$$

$$\text{Acres to be treated} \times \text{Pounds formulation per acre} = \text{Pounds form. needed in tank}$$

Example:

You wish to spray $3\frac{1}{2}$ acres and your equipment is applying 15 gallons per acre. The label rate is 3 pounds per acre.

Gallons per acre (15) × Acres to be treated ($3^1/_2$) = Gallons needed in tank (52.5)

$15 \times 3.5 = 52.5$

Acres to be treated ($3^1/_2$) × Pounds formulation per acre (3) = Pounds formulation ($10^1/_2$) needed in tank

$3.5 \times 3 = 10.5$

If the recommended dosage is given as **pounds of active ingredient** per acre, you must first convert that figure to **pounds of formulation** per acre. Use the following formula:

$$\frac{\text{Pounds of active ingredient per acre} \times 100}{\text{Percent of active ingredient in formulation}} = \text{Pounds form. per acre}$$

Then follow the formulas listed above under "pounds per acre" to find the pounds of formulation to add to your tank.

Example:

You wish to apply 2 pounds of active ingredient per acre. Your formulation is 80 percent WP.

$$\frac{\text{Pounds of a.i. per acre (2)} \times 100}{\text{\% a.i. in formulation (80)}} = 2.5 \text{ pounds formulation per acre}$$

$2 \times 100 \div 80 = 2.5$

If the recommended rate is a **percentage of active ingredient in the tank**, another formula is necessary. First find the number of gallons of spray in the spray tank (either the tank capacity or gallons needed for job if less than tank capacity). Then:

$$\frac{\text{Gallons of spray in tank} \times \text{\% active ing. wanted} \times \text{Weight of carrier (lbs. per gal.)}}{\text{\% active ingredient in formulation}} = \text{Pounds form. to add to tank}$$

Example:

Your mist blower directions call for a spray containing 1.25 percent active ingredient. You need to mix 40 gallons of spray for the job. The pesticide is a 60 percent SP and you will use water as the carrier.

$$\frac{\text{Gallons of spray (40)} \times \text{\% active ing. needed (1.25)} \times \text{Weight of water/gal (8.3)}}{\text{\% active ingredient in formulation (60)}} = 6.9 \text{ pounds form. needed in tank}$$

$40 \times 1.25 \times 8.3 \div 60 = 6.9$ lbs.

Mixing Liquid Formulations

Dosages for liquid formulations (EC, F, etc.) are often listed as **pints, quarts, or gallons per 100 gallons** or **per acre**. Use the pounds per 100 gallons and pounds per acre (above) for making these calculations. Substitute the appropriate liquid measure for "pounds" in the formulas.

Example:

The label rate is 2 pints of pesticide formulation per 100 gallons of water. Your spray tank holds 300 gallons.

$$\frac{\text{Gallons per tank (300)} \times \text{pints per 100 gal. (2)}}{\text{100 gallons}} = 6 \text{ pints form. needed in tank}$$

$300 \times 2 \div 100 = 6$

Example:

Your sprayer applies 22 gallons per acre and your tank holds 400 gallons. The label rate is $1^1/_2$ quarts per acre.

$$\frac{\text{Gallons in tank (400)} \times \text{quarts per acre (1.5)}}{\text{Gallons per acre (22)}} = 27.3 \text{ qts. needed in tank}$$

$400 \times 1.5 \div 22 = 27.3$

If the recommendation for the liquid formulation is listed as **pounds of active ingredient per acre**, you must first convert that figure to **gallons of formulation** to **apply per acre**. The label of a liquid formulation always tells how many pounds of active ingredient are in one gallon of the concentrated formulation (4 EC has 4 pounds of active ingredient per gallon; 6 EC contains 6 pounds per gallon, etc.).

$$\frac{\text{Pounds of active ingredient needed per acre}}{\text{Pounds of active ingredient per gallon of formulation}} = \text{Gallons of formulation per acre}$$

Example:

The recommendation is for 1 pound of active ingredient per acre. You purchased an 8 EC, which contains 8 pounds of active ingredient per gallon. Your tank holds 500 gallons and is calibrated to apply 25 gallons per acre.

$$\frac{\text{Pounds a.i. to apply per acre (1)}}{\text{Pounds a.i. per gallon (8)}} = \text{1/8 gallons (1 pint) per acre}$$

$1 \div 8 = .125\ (1/8)$

$$\frac{\text{Gallons in tank (500)}}{\text{Gallons per acre (25)}} = \text{Acres per tankful (20)}$$

$500 \div 25 = 20$

Acres per tankful (20) × gallons per acre ($^1/_8$ or .125) = Gallons to add to tank (2.5)

$20 \times .125 = 2.5$

If the recommended rate is a **percentage of active ingredient in the tank**, use this formula:

$$\frac{\text{Gallons of spray} \times \text{\% a.i. wanted} \times \text{Weight of carrier (lbs/gal)}}{\text{lbs. a.i. per gallon of formulation}} = \text{Gallons of form. to add}$$

Example:

You wish to make 100 gallons of a 1 percent spray, using water as the carrier. You have a 2 EC formulation (2 pounds active ingredient per gallon). How many gallons of the 2 EC should you add to the 100 gallons of water in the tank?

$$\frac{\text{Gallons of spray (100)} \times \text{\% a.i. wanted } (1 \div 100) \times \text{Weight of water (8.3)}}{\text{lbs. a.i. per gallon of formulation (2)}} = \text{Gallons of form. to add (4.15)}$$

$100 \times .01 \times 8.3 \div 2 = 4.15$ gals.

Mixing Concentrates for Air Blast Sprayers or Mist Blowers

If the dosage recommendations are listed as pounds or gallons per acre or pounds or gallons per 100 gallons of carrier for use in boom or hydraulic sprayers, you will need to convert the dosage to the concentration factor you have chosen (usually 2×, 3×, 4×, 5×, or 10×). Simply follow the steps listed above for the dry or liquid formulation you are using. The **last** answer should be multiplied by the concentration factor.

Pounds or gallons of formulation per tank × Concentration factor = Pounds or gallons formulation per tank in concentrate form

Example:

The label lists the dosage as 4 pounds formulation per 100 gallons of water for dilute application. Your air blast sprayer tank holds 600 gallons. You wish to apply a 5× concentration.

$$\frac{\text{Gallons per tank (600)} \times \text{Lbs. per 100 gallons recommended (4)}}{\text{100 gallons}} = \text{Lbs. needed in tank for hydraulic sprayer (24)}$$

$600 \times 4 \div 100 = 24$

Pounds formulation per tank for hydraulic sprayer (24) × Concentration wanted (5×) = Pounds of formulation to add to air blast tank (120)

$24 \times 5 = 120$

4) Measure a distance of 660 ft. (1/8 mile) in this area.

5) Fill hoppers and attach containers (sacks, buckets) to each hopper to catch granules separately from each hopper.

6) Drive the test run at the same speed to be used later in actually treating the field.

7) Remove the collecting containers and weigh each one (in pounds); all should weigh about the same.

8) Add the weights (in pounds) of granules released from each hopper, multiply by 66 and divide by the effective swath width. This gives the number of pounds of granular material applied to each acre. If this is not the desired amount, adjust the equipment and repeat the calibration.

Example 3

The applicator's rig applies material in six 12-inch bands. In the calibration run on a 660-ft. course, each hopper put out: 0.11 lb, 0.12 lb, 0.11 lb, 0.12 lb, 0.12 lb. 0.13 lb. Because the amounts are roughly the same, the operator adds them and gets 0.71 lb. To determine the weight of granules released on an acre of land, he completes this calculation:

$$\frac{0.71 \text{ lb. in test} \times 66}{6 \text{ ft. effective swath}} = 7.81 \text{ lbs/A}$$

The 66 in the above formula converts amounts needed to treat 660 ft. of test course to amounts needed for a full acre (660 ft. × 66 ft. = 43,560 sq. ft. = 1 acre).

Area Measurements

To determine how much pesticide you will need to do a job, you must measure the area to be treated. If the area is a rectangle, circle, or triangle, simple formulas may be used. Determining the area of an irregularly shaped site is more difficult.

The following examples will help you in computing the area of both regularly and irregularly shaped surfaces.

Regularly Shaped Areas

Rectangles

The area of a rectangle is found by multiplying the length (L) by the width (W).

Area = Length × Width

Example:

40 × 125 = 5,000 sq. ft.

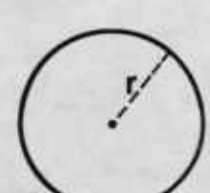
Circles

The area of a circle is the radius (one-half the diameter) squared and then multiplied by 3.14.

Area = 3.14 × radius squared

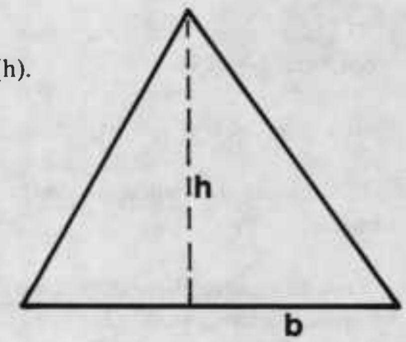
Example:

35 × 35 × 3.14 = 3846.5 sq. ft.



Triangles

The area of a triangle is one-half the base (b) multiplied by the height (h).



$$\text{Area} = \frac{b \times h}{2}$$

Example:

b = 55′
h = 53′

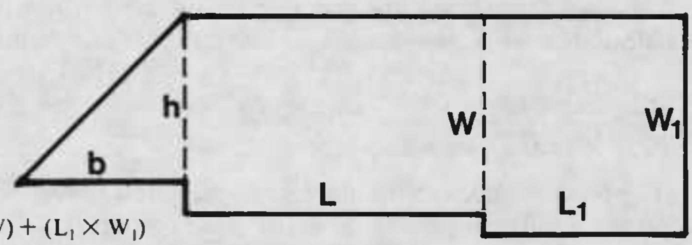
$55 \times 53 \div 2 = 1457.5$ sq. ft.

Irregularly Shaped Areas

Irregularly shaped areas often can be reduced to a combination of rectangles, circles, and triangles. Calculate the area of each and add them together to obtain the total area.

Example:

b = 25′
h = 25′
L = 30′
W = 42′
L_1 = 33′
W_1 = 31′



$\text{Area} = (b \times h \div 2) + (L \times W) + (L_1 \times W_1)$

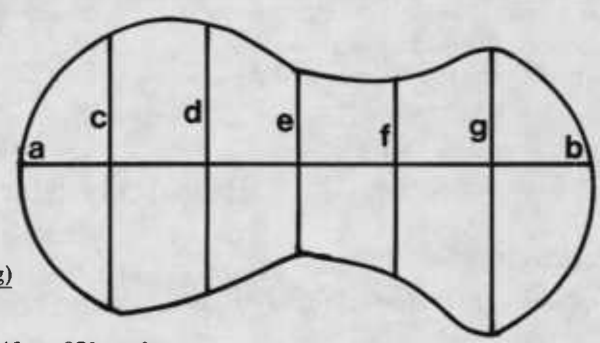
$25 \times 25 \div 2 = 312.5$ $\quad 30 \times 42 = 1260$ $\quad 31 \times 33 = 1023$

$312.5 + 1260 + 1023 = 2595$ sq. ft.

Another way is to establish a line down the middle of the property for the length, and then measure from side to side at several points along this line. Areas with very irregular shape require more side to side measurements. The average of the side measurements can be used as the width. The area is then calculated as a rectangle.

Example:

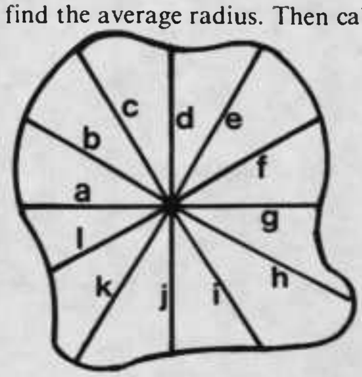
ab = 45′
c = 22′
d = 21′
e = 15′
f = 17′
g = 22′



$$\text{Area} = (ab) \times \frac{(c + d + e + f + g)}{5}$$

$22 + 21 + 15 + 17 + 22 \div 5 \times 45 = 873$ sq. ft.

A third method is to convert the area into a circle. From a center point, measure distance to the edge of the area in 10 to 20 increments. Average these measurements to find the average radius. Then calculate the area, using the formula for a circle.



Example:

$$\text{Radius} = \frac{a + b + c + d + e + f + g + h + i + j + k + l}{12}$$

Area = 3.14 × radius squared

$10 + 12 + 16 + 15 + 11 + 12 + 10 + 9 + 13 + 12 + 13 + 16 \div 12$
$= 12.42$ (radius)

$12.42 \times 12.42 \times 3.14 = 484.1$ sq. ft.

Laws and Regulations

Laws and Regulations

Pesticide application has become more complex in recent years. The number of different kinds of pesticides available for use has increased greatly. Effects on wildlife and the environment are known to be important considerations in pesticide use. New highly poisonous pesticides require special equipment and safety measures. To help protect the public, the environment, and the applicator, new laws and regulations have been adopted.

FIFRA

A law passed by Congress in 1972 and substantially amended in 1974 and 1978 (called by its initials—FIFRA*) regulates the registration, manufacture, transportation, and use of pesticides. The law affects you, the applicator, in many ways. Most importantly, it provides that:

- all pesticides must be used only as directed on the label,
- all pesticide uses must be classified as "restricted" or "general",
- persons who buy or use restricted-use pesticides must be certified as competent pesticide applicators or must be directly supervised by a certified applicator,
- persons who do not obey the law will be subject to penalties (fines and jail terms).

Use Inconsistent With the Label

An applicator may not use any pesticide in a manner not permitted by the labeling. You must use the pesticide only on the plants, animals, or sites specified in the directions for use. You may not use higher dosages, higher concentrations, or more frequent applications. You must follow directions for use, safety, mixing, diluting, storage, and disposal—as well as restrictions on reentry and days to harvest, slaughter, and grazing.

The law **does** allow you to:

- apply a pesticide at any dosage, concentration, or frequency **less** than that listed on the labeling,
- apply a pesticide against any target pest not listed on the labeling **if** the application is to a crop, animal, or site that is listed,
- use any equipment or method of application which is not prohibited by the labeling,
- mix a pesticide or pesticides with a fertilizer if the mixture is not prohibited by the labeling,
- mix two or more pesticides, if all the dosages are at or below the recommended rate.

*Federal Insecticide, Fungicide, and Rodenticide Act, as amended. Original law regulating pesticides was enacted in 1947.

Classification of Pesticide Uses

Every use of every pesticide will be classified by the U. S. Environmental Protection Agency as either "general" or "restricted". Many times either all the uses of a particular formulation are classified as restricted or all of them are classified as general. Sometimes, however, certain uses of a formulation are restricted and other uses of the same product are not. In these cases the directions for use for the two classifications must be clearly separate from one another. Entirely different packaging and labeling often are used.

A pesticide (or some of its uses) will be classified as "general use" if it is not likely to harm humans or the environment when used as directed on the label.

A pesticide (or some of its uses) will be classified as "restricted use" if it could cause human injury or environmental damage unless it is applied by competent persons (certified applicators) who have shown their ability to use these pesticides safely and effectively.

Classification of pesticides and pesticide uses may be based on:

- the potential for poisoning of humans,
- the type of formulation,
- the way the pesticide is used,
- the place in which the pesticide is used,
- the potential for harm in the environment.

When a pesticide is restricted, the label will say "Restricted Use Pesticide" in a box on a prominent part of the front panel. When a pesticide is classified for general use, the words "General Classification" will appear immediately below the heading "Directions for Use."

NOTE: Although EPA has classified many pesticide products and uses, some pesticides have not yet been classified. Applicators should pay close attention to the signal words and human and environmental hazard statements on each product. The absence of a "Restricted-Use Pesticide" statement does not mean that the product is not hazardous; it may simply mean that the pesticide has not yet been classified.

Certification of Applicators

Persons who are not certified pesticide applicators may not purchase or use restricted pesticides unless they are directly supervised by a certified applicator.

Certification requires training or testing for competency in the safe and effective handling and use of these pesticides.

Your state or a federal agency will conduct the training and/or tests for certification. Your state may impose stricter standards than those required by FIFRA. The U.S. Environmental Protection Agency requires each state to maintain a program to assure that certified applicators have current certification. Check with your state to determine the requirements you need to meet.

Many adjoining states have developed agreements to allow certification in one state to be accepted in the nearby states or throughout a region. If you will be operating in more than one state, you should check with the proper authorities to determine whether separate training and/or testing for certification is necessary for each state.

There are two types of certified pesticide applicators—private applicators and commercial applicators.

Private Applicators

Private applicators are persons who use or supervise the use of restricted-use pesticides in producing an agricultural commodity on property owned or rented by themselves or their employer, or on the property of another person with whom they trade services. Examples of private applicators are farmers, ranchers, floriculturists, and orchardists. Private applicators are trained and/or tested in the safe use and handling of pesticides and pest control practices associated with agricultural operations.

Commercial Applicators

Commercial applicators are persons who use restricted-use pesticides for hire on property other than their own, and government workers (public operators) who apply pesticides in their jobs. Commercial applicators are trained and tested in the general areas of safe use and handling of pesticides and then receive further training in one or more specific categories of application, including:

- agricultural pest control (plant or animal),
- forest pest control,
- ornamental and turf pest control,
- seed treatment,
- aquatic pest control,
- right-of-way pest control,
- industrial, institutional, structural, and health-related pest control,
- public health pest control,
- regulatory pest control,
- demonstration and research pest control.

Several states have different or additional categories for commercial applicators. These include, for example, aerial application, wood preservation, and use of antimicrobials.

You must determine which categories best fit your business needs. It is illegal to apply a restricted-use pesticide in a category in which you are not certified.

Penalties

If you violate the law or regulations enacted under FIFRA, you are subject to civil penalties. They can be as much as $5,000 for each offense ($1,000 for private applicators). Before EPA can fine you, you have the right to ask for a hearing in your own city or county. Some violations of the law may also subject you to criminal penalties. These can be as much as $25,000 or one year in prison, or both, for commercial applicators; $1,000 and/or 30 days in prison for private applicators.

Registration

Every pesticide which is bought, sold, or used in the United States must, by law, be registered by the U. S. Environmental Protection Agency. EPA approves not only the product itself, but also each separate use for which it is intended, and the product label. You are responsible for applying only those pesticides which are registered. You may encounter three major types of registration:

- federal registration,
- special local needs registration,
- emergency exemptions from registration.

Federal EPA registrations are the most familiar. Most pesticide uses are registered this way. Look for the official EPA registration number (which must appear on the label) to be sure you are buying an approved product.

Special local needs registrations (known as SLN or 24(c) registrations) are becoming more common. They allow a state, under some conditions, to register **additional uses** for a federally-registered pesticide. These registrations often involve adding application sites, pests, or alternate control techniques to those listed on the federally registered label.

The registrant must provide supplemental labeling for each SLN registration. The applicator must have a copy of an SLN label in his possession in order to apply the pesticide for that purpose. The registration number of an SLN label will include the initials "SLN" and the standard two-letter abbreviation code for the state which issued the registration. These registrations are legal only in the state or local area specified in the labeling. Any application in another state or region is subject to civil and criminal penalties. Extension personnel, pesticide dealers, and other professionals will help keep you informed of SLN registrations which pertain to your work.

Emergency exemptions from registration are used when an emergency pest situation arises for which no pesticide is registered. If both federal and SLN registrations would take too long to enact, an emergency registration can be used. Known as "Section 18 exemptions," these registrations are handled by the highest governing official involved —usually a state governor or federal agency chief. This provision allows the sale and use of a product for a nonregistered purpose for a specified period of time. Strict controls and record keeping are required for all these emergency uses. You must understand all of the special requirements and responsibilities involved whenever you use pesticides with emergency exemptions. The agency which has granted the emergency exemption will supply you with the necessary rates, safety precautions, and other vital information.

Residues and Tolerances

The pesticide which remains in or on food or feed is called a **residue**. Many times a long-lasting residue is desirable for long-term pest control. Residues which remain in food or feed at harvest or slaughter, however, are carefully monitored to avoid hazards to the humans and domestic animals which will eat them.

EPA sets residue **tolerances** for all crop and animal products intended for food or feed. A tolerance is the maximum amount of pesticide residue which may remain on or in treated crops and animals that are to be sold for food or feed. These tolerances are determined by extensive testing. To insure safety, the levels usually are set at least 100 times lower than the amount known to be hazardous. If the residue exceeds the tolerance, the food or feed may not be marketed or sold.

The Food and Drug Administration monitors food and feed for tolerance violations. FDA sets tolerances for residues resulting from pesticides applied to food or feed after harvest. This agency may condemn and seize any products exceeding the tolerances and may prosecute violators.

The Meat Inspection Division of the U.S. Department of Agriculture monitors pesticide tolerances in animals and animal products.

A pesticide applicator cannot measure residues on crops and livestock, because such measurements require highly specialized equipment and techniques. Only by following label instructions exactly can you be sure that treated products will have residues well below tolerance level when marketed. Especially important are instructions on correct dosages and on minimum days to harvest, slaughter, or grazing.

Other Regulations

Transportation

Shipment of pesticides and other dangerous substances across state lines is regulated by the federal Department of Transportation (DOT). DOT issues the rules for hauling these materials. DOT standards tell you which pesticides are dangerous to man and create a health hazard during transportation.

If you ever haul pesticides between states, you should know that:

- They must be in their original packages. Each package must meet DOT standards.
- The vehicle must have a correct sign. Manufacturers must put the correct warning signs on each package.
- The pesticides may not be hauled in the same vehicle with food products.
- You must contact DOT immediately after each accident:
  a) when someone is killed,
  b) when someone is injured badly enough to go to a hospital, or
  c) when damage is more than $50,000.
- You must tell DOT about all spills during shipment.

State and local laws may require you to take additional precautions while transporting pesticide products.

Aerial Application

Application of pesticides from airplanes is regulated by the Federal Aviation Administration (FAA) and may be regulated by your state. FAA judges both the flying ability of pilots and the safety of their aircraft. FAA rules, too, say that an aerial applicator may not apply any pesticide except as the label directs.

Worker Safety

The Occupational Safety and Health Act of 1970 is administered by the Occupational Safety and Health Administration (OSHA) in the Department of Labor. It requires anyone with 11 or more workers to keep records and make reports. The records must include all **work-related** deaths, injuries, and illnesses. Minor injuries needing only first aid treatment need not be recorded. A record must be made if the injury involves:

- medical treatment,
- loss of consciousness,
- restriction of work or motion, or
- transfer to another job.

This law also requires investigation of employee complaints that may be related to pesticide use, reentry, or accidents.

Pesticide Safety

Pesticide Safety

Most pesticides are designed to poison pests. Unfortunately, many pesticides are also poisonous to people. Many people in all walks of life have pesticide residues in their bodies. Pesticide applicators and their families are regularly exposed to far greater than normal contact with pesticides. Therefore, it is important to do everything possible to keep exposure to an absolute minimum.

You also want to protect your workers and other people from pesticide injuries. Most pesticide accidents result from careless practices or lack of knowledge about safe handling of pesticides. The time you spend to learn about and to use safe procedures is an investment in the health and safety of yourself, your family, and others.

Protecting Your Body

Some pesticides are so highly toxic that accidental exposure to them without proper protection can sicken or kill humans. Other pesticides are much less toxic; large exposures to these poisons would be necessary to cause illness. Even slightly toxic pesticides can irritate the nose, throat, eyes, and skin of some people. You should know how to protect yourself, your workers, and other persons from harmful exposure to the pesticides you are applying.

Pesticides can enter the body in three major ways:

- through the mouth (orally),
- through the skin and eyes (dermally),
- through the lungs (by inhalation).

People may be poisoned without realizing the seriousness of the exposure—especially if pesticides enter through the skin and lungs.

Oral poisoning can be caused by:

- not washing hands before eating, drinking, smoking, or chewing,
- mistaking the pesticide for food or drink,
- accidentally applying pesticides to food,
- carelessly splashing pesticide into the mouth.

Dermal poisoning can be caused by:

- not washing hands after handling pesticides or their containers,
- splashing or spraying pesticides on unprotected skin or eyes,
- wearing pesticide-contaminated clothing (including boots and gloves),
- applying pesticides in windy weather,
- wearing inadequate protective clothing and equipment during mixing or application.

Inhalation poisoning can be caused by:

- prolonged exposure to pesticides in closed or poorly ventilated spaces,
- accidentally breathing vapors from fumigants and other toxic pesticides,
- breathing fumes, dust, or mist during application without appropriate protective equipment,
- inhaling fumes present immediately after a pesticide is applied (reentering the area too soon),
- not having a good seal on your respirator or using an old or inadequate cartridge or canister.

People can be exposed to pesticides in two major ways:

- acute exposure, and
- chronic exposure.

Acute exposure is a single incident of exposure to a pesticide. Usually the symptoms of poisoning begin quickly and leave little doubt about the cause of the illness. Acute exposure is usually due to an accident such as:

- splashing a pesticide into the mouth,
- spilling or spraying a pesticide onto your clothing, or
- being contaminated by broken equipment.

Chronic exposure is repeated exposure to pesticides over a period of time. Chronic exposure may go unnoticed since some pesticides may persist in the body for a long time without any obvious signs or symptoms of poisoning. If you continue to be exposed to these pesticides, residues in your body may increase. An additional risk is that even low-level chronic exposure may lead to serious illness. Chronic exposure most often occurs in the workplace because of:

- faulty or inadequate protective clothing or equipment,
- early reentry,
- inadequate cleanup of clothing and body, or
- contaminated working conditions.

What You Should Wear

To prevent pesticides from entering the body, you must wear protective clothing and equipment. You should follow all advice on protective clothing or equipment which appears on the label. However, the lack of any statement or the mention of only one piece of equipment does not rule out the need for additional protection. No safety recommendations can cover all situations. Your common sense and knowledge of pesticide toxicity should help you assess the hazard and select the kind of protection you need.

Protective Clothing

Body Covering

Any time you handle pesticides, you should wear at least:

- a long-sleeved shirt and long-legged trousers, or
- a coverall-type garment.

They should be made of woven or laminated fabric, manufactured for this purpose. When handling pesticide concentrates or very toxic materials, you also should wear at least a liquid-proof apron.

Gloves

When you handle concentrated or highly toxic pesticides, wear gloves. For liquid formulations, liquid-proof neoprene gloves are best. They should be long enough to protect the wrist. Gloves should not be lined with a fabric. The lining absorbs chemicals and is hard to clean. For most jobs, sleeves should be outside of the gloves to keep pesticides from running down the sleeves and into the gloves. But if you will be working with your hands and arms overhead, put the gloves outside of the sleeves.

Hat

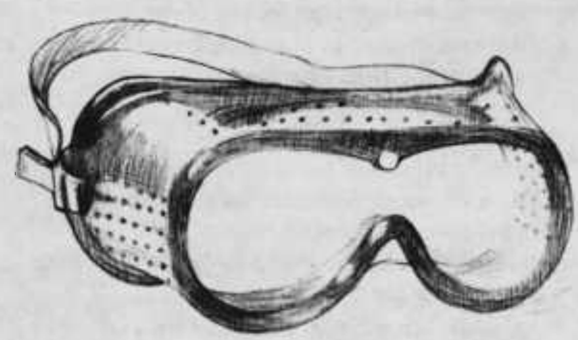
Wear something to protect your head. A wide-brimmed hat will help keep pesticides off your neck, eyes, mouth, and face. Most special coveralls have an attached protective hood. Hats should not have a cloth or leather sweatband. They should be easy to clean or disposable. When you will be exposed to liquid pesticides, wear a liquid-proof hat. Plastic "hard hats" with plastic sweatbands are liquid-proof and are cool in hot weather.

Shoes and Boots

Sturdy shoes and socks are sufficient for some pesticide applications. Neoprene or rubber boots are a wise precaution with many pesticide applications because canvas, cloth, and leather shoes can readily absorb pesticides. If you will be handling liquid concentrates or highly toxic pesticides (those with "DANGER" on the label), neoprene or rubber boots are necessary. Wear unlined boots with trouser legs outside the boots so the pesticide will not run down the leg and collect in the boot.

Goggles or Face Shield

Wear goggles or a face shield when there is any chance of getting pesticide in your eyes. Eyes readily absorb pesticides and the temporary blindness caused by an accident may delay or prevent self-treatment. You can wear goggles alone or with a respirator.



Protective Clothing for Fumigant Application

When handling or applying fumigants, be sure to check the label for directions on how to best protect yourself. If the label does not give specific instructions, then you should wear at least gloves, shoes or boots, and a long-sleeved shirt and long-legged trousers made from tightly woven fabric. Some fumigants readily penetrate rubber, neoprene, and leather. These fumigants may be trapped **inside** the gloves, boots, or liquid-proof suit and cause severe skin irritation or lead to poisoning through skin absorption. The labels on these fumigants will specify the appropriate protective clothing to be worn while handling them.

Care of Clothing

Wear clean clothing daily. If clothes get wet with pesticides, change them immediately. If they get wet with pesticide concentrates or highly toxic pesticides, destroy them. A toxic residue may remain even after washing. Do not store or wash contaminated clothing with the family laundry. Wash hats, gloves, and boots daily, inside and out. Hang them to dry. Test gloves for leaks by filling them with water and gently squeezing.

Wash goggles or face shields at least once a day. Wear neoprene headbands, if possible. Elastic fabric headbands often absorb pesticides and are difficult to clean. Have some spares so you can replace them as necessary.

Protective Equipment

The respiratory tract—the lungs and other parts of the breathing system—is much more absorbent than the skin. You must wear an approved respiratory device when the label directs you to do so. Even if the label does not require it, you should always wear a respiratory protective device:

- if the pesticide you are mixing or applying has a label precautionary statement such as "do not breathe vapors or spray mist", or "harmful or fatal if inhaled,"
- during calibration and adjusting of equipment if you are using pesticides with the above precautionary statements,
- if you will be exposed to a pesticide for a long time,
- if you are working in an enclosed area.

If you still have trouble breathing while wearing a respiratory device, see your physician to find out whether you have a respiratory problem.

Cartridge Respirator

You should wear this kind of respirator when you will be intermittently exposed to a pesticide.

The inhaled air is drawn through both a fiber filter pad and a cartridge to absorb pesticide vapors. Most harmful vapors, gases, and particles are removed. These half-face masks cover the mouth and nose. To cover the eyes also, use one that is combined with goggles, or wear separate goggles.

Canister Respirator (Gas Mask)

You should wear this kind of respirator when you will be continuously exposed to a pesticide.

The canister has longer-lasting absorbent material and filters than the cartridge respirator. Gas masks usually provide full-face protection. Neither cartridge nor canister respirators will protect you from high concentrations of vapor, and neither kind is effective when the oxygen supply is low; for example, during fumigation inside buildings, railroad cars, holds of ships, or grain bins.

Supplied-Air Respirator

You may use this kind of respirator when mixing or applying pesticides:

- when the oxygen supply is low,
- when you are exposed to high concentrations of highly toxic pesticides.

You must work close to a supply of clean air, since this type of respirator works by pumping clean air through a hose to the face mask.

Self-Contained Breathing Apparatus

You should wear this kind of respirator under the same conditions as the supplied-air respirator. It does about the same thing. The difference is that you carry cylinders of air or oxygen with you, usually on your back. This lets you move more freely and over a wider area than you can with a supplied-air respirator. Seek training from competent instructors before using self-contained breathing equipment. These devices contain a limited air supply, which may be used up even more quickly in high temperatures or with excessive exertion.

Positive Pressure Respirator

Both chemical cartridge and chemical canister respirators rely on the wearer's ability to draw air through the filters in normal breathing. To be effective, these "negative-pressure" respirators must be tightly sealed to the face. A positive-pressure respirator uses a lightweight blower to draw the contaminated air through the filter. It forces the clean air into a loose-fitting helmet-like head covering. The outflow prevents contaminants from entering the helmet. The filtered air circulates over the head, neck, and upper body of the applicator, providing some cooling.

Positive-pressure respirators are available as lightweight backpacks, or they may be mounted on or in application equipment where the power is supplied by the vehicle's electrical systems. Some vehicle-mounted units provide cool filtered air to the applicator.

Respiratory Devices for Use With Fumigants

Fumigants readily become gases. They pose the greatest hazard of poisoning through inhalation. Exposure to even small concentrations of the fumigant as a gas can cause severe injury and death. Special precautions are necessary during handling and application. Use a supplied-air respirator, or at least a canister respirator with an organic vapor canister. Wear a respirator during application and reentry if any exposure to the fumigant gas is likely. In enclosed areas such as bins, vaults, and chambers there may be insufficient oxygen to sustain life. Use supplied-air respirators or a self-contained breathing apparatus and never work alone.

Selection and Maintenance

Use only those respirators which carry a seal of approval for pesticide use from the National Institute for Occupational Safety and Health (NIOSH) and the Mine Safety and Health Administration (MSHA). Read the manufacturer's instructions on the use and care of any respirator and its parts before you use it.

A negative-pressure respirator must fit the face well. Long sideburns, a beard, or glasses may prevent an adequate seal.

When applying pesticides, change filters, cartridges, and canisters if you have trouble breathing or if you smell pesticides. Remove and discard filters, cartridges, and canisters after use. Then wash the facepiece with detergent and water, rinse it, and dry it with a clean cloth. Store it in a clean, dry place away from pesticides.

The useful life of a cartridge or canister depends on:

- the amount of absorbent material it contains,
- the concentration of contaminants in the air,
- the breathing rate of the wearer,
- the temperature and humidity.

Operation and maintenance requirements for positive-pressure respirators are similar to those for cartridge and canister respirators. The filter has a longer working life than those in cartridges or canisters, but it should be replaced after about 150 hours of use or when the amount of air being supplied to the applicator drops noticeably. The exposed parts of these respirators also need to be washed and dried after each use.

Protective Clothing and Equipment Guide

FORMULATION	Label Signal Word		
	CAUTION	WARNING	DANGER
Dry	Long-legged trousers and long-sleeved shirt; shoes and socks.	Long-legged trousers and long-sleeved shirt; shoes and socks; wide-brimmed hat; gloves.	Long-legged trousers and long-sleeved shirt; shoes and socks; hat; gloves; cartridge or canister respirator if dusts in air or if label precautionary statement says: "Poisonous or fatal if inhaled."
Liquid	Long-legged trousers; long-sleeved shirt; shoes and socks; wide-brimmed hat.	Long-legged trousers and long-sleeved shirt; shoes and socks; wide-brimmed hat; rubber gloves. Goggles if required by label precautionary statement. Cartridge or canister respirator if label precautionary statement says: "Do not breathe vapors or spray mists," or "Poisonous if inhaled."	Long-legged trousers and long-sleeved shirt, rubber boots, wide-brimmed hat, rubber gloves, goggles or face shield. Canister respirator if label precautionary statement says: "Do not breathe vapors or spray mists," or "Poisonous if inhaled."
Liquid (when mixing)	Long-legged trousers; long-sleeved shirt; shoes and socks; wide-brimmed hat; gloves; rubber apron.	Long-legged trousers and long-sleeved shirt; shoes and socks; wide-brimmed hat; rubber gloves; goggles or face shield; rubber apron. Respirator if label precautionary statement says: "Do not breathe vapors or spray mist," or "Poisonous (or fatal or harmful) if inhaled."	Long-legged trousers and long-sleeved shirt, rubber boots, wide-brimmed hat, rubber gloves, goggles, rubber apron, canister respirator.
Liquid (prolonged exposure to spray, or application in enclosed area)	Long-legged trousers and long-sleeved shirt, boots, rubber gloves, water-proof wide-brimmed hat.	Water-repellent, long-legged trousers and long-sleeved shirt, rubber boots, rubber gloves, rubber apron, water-proof wide-brimmed hat, face shield, cartridge or canister respirator.	Water-proof suit, rubber boots, rubber gloves, water-proof hood or wide-brimmed hat, face shield, canister respirator.

Personal Cleanup

Any time you spill a pesticide on yourself, wash immediately. When you finish working with pesticides or pesticide-contaminated equipment, take a shower. Wash your body and hair thoroughly with detergent and water. Work clothing should be changed daily. Place used clothing away from your other clothes and away from the family laundry. The pesticides remaining on your work clothes could injure persons who touch them. Do not allow children or pets to play in them. Be sure that the person who will be laundering your work clothes knows of the potential danger. Do not launder work clothes with the family laundry. Do not wash contaminated gloves, boots, respirators, or other equipment in streams or ponds. The pesticides could poison aquatic life or harm people, livestock, or wildlife.

Reentering Treated Areas

Unprotected persons should not enter an area immediately after a pesticide application. The waiting period is called the **reentry interval**. Workers not wearing proper protective clothing must always wait at least until sprays have dried or dusts have settled before entering an area treated with any pesticides. Some highly toxic carbamate and organophosphate pesticides have specific reentry times set by law. These times must be listed on the pesticide label. Some states have set even longer reentry times for some pesticides due to climatic conditions and other special hazards in their area.

If you are in charge of a pesticide application, you are responsible for warning workers and other people that an area has been treated with pesticides. You must either tell the people or put up warning signs, or you may do both. These signs must be placed at the usual point of entry to the areas or on bulletin boards where the workers normally gather for work instructions. If you have reason to believe that a person is not able to read, you must make a reasonable effort to make sure that person understands the warning. If necessary, you must arrange for these warnings to be given in other languages.

The warnings must include:

- areas, buildings, or fields which have been treated,
- length of time unprotected persons should stay out of areas (reentry interval), and
- what to do in case of exposure.

The above guidelines **will not** be listed on the label. However, you, the applicator, are responsible for seeing that they are followed. The only exceptions are mosquito abatement and related public pest control programs and livestock and other animal treatments.

Handling Pesticides Safely

Transportation of Pesticides

You are responsible for the safe transport of pesticides in your possession. The safest way to haul pesticides is in the back of a truck. Secure all containers to prevent breakage and spillage. Keep the pesticides away from food, feed, livestock, pets, and passengers.

Pesticides should be transported only in correctly labeled containers. Be sure to keep paper and cardboard packages dry. If any pesticide is spilled in or from the vehicle, clean it up right away using correct cleanup procedures. Do not leave pesticides unattended. You are responsible if accidents occur.

Pesticide Storage

As soon as pesticides arrive, store them in a safe place. The storage area should be in a cool, dry, well-ventilated and well-lighted room or building that is insulated to prevent freezing or overheating. Be sure that the area is fireproof, with a cement floor. Keep the area locked to prevent entry by children and other unauthorized persons and post warning signs on doors and windows.

The area should be supplied with detergent, hand cleaner, and water; absorbent materials, such as absorbent clay, sawdust, and paper to soak up spills; a shovel, broom, and dustpan; and a fire extinguisher rated for ABC fires.

The storage building or area should be located away from where people and animals live. This will avoid or minimize harm to them in case of fire or flooding.

Store all pesticides in the original containers. Do not store them near food, feed, seed, or animals. Store paper containers off the floor. Check every container for leaks or breaks. If one is leaking, transfer the contents to a container that has held exactly the same pesticide. If one is not available, use a clean container of similar construction and label it correctly. Clean up any spills. Keep an up-to-date inventory of the pesticides you have.

Mixing and Loading Pesticides

Studies have shown that pesticide applicators are most often exposed to harmful amounts of pesticides when handling concentrates.

Workers involved in mixing and loading undiluted highly toxic pesticides are exposed to a high risk of accidental poisoning. Pouring concentrates from one container to another is the most hazardous activity.

Safety Guidelines

By observing some simple precautions, you can reduce the risks involved in this part of your job. It is important to keep livestock, pets, and people out of the mixing and loading area. Do not work alone at night, or when using highly toxic pesticides. Choose a place with good light and ventilation. Be particularly careful not to mix or load pesticides at night or indoors unless lighting and ventilation are adequate.

Before handling a pesticide container, put on protective clothing and equipment. Each time you use a pesticide, read the directions for mixing. Do this before you open the container. This is essential—directions, including amounts and methods, often change.

Do not tear paper containers to open them. Use a sharp knife. Clean the knife afterwards, and do not use it for other purposes. When pouring a pesticide from the container, keep the container and pesticide below eye level. This will avoid a splash or spill on your goggles or protective clothing.

If you splash or spill a pesticide while mixing or loading, stop right away and remove contaminated clothing. Wash thoroughly with detergent and water as quickly as possible. Then clean up the spill.

When mixing pesticides, measure carefully. Use only the amount called for on the label and mix only the amount you plan to use.

When loading pesticides, stand so the wind does not blow them toward your body. To prevent spills, close containers after each use.

Closed Handling Systems

Closed handling systems can reduce the applicator's exposure to concentrated pesticides. A closed handling system is a series of interconnected equipment which allows the applicator to remove a pesticide from its original container, rinse the empty container, and transfer the pesticide and rinse solution to the spray tank without contacting the pesticide.

Closed system handling has several advantages and disadvantages.

Advantages:

- increased applicator safety,
- less need for protective clothing and equipment (waterproof clothing and respirators can be uncomfortable, especially in hot weather),
- reduction of spills and more accurate measurement. This reduces overdosing and underdosing and may result in savings to the applicator.

Disadvantages:

- equipment is cumbersome,
- equipment is not usable with all pesticide containers because of variations in drum openings, shapes, and sizes,
- many steps involved in the system—all must be done in proper sequence.

The systems now available are designed to remove the pesticide concentrate from the original container in one of two ways:

- gravity,
- suction.

Gravity systems are sometimes called "punch and drain" systems. The unopened pesticide container is inserted into a chamber, which is then sealed. A punch cuts a large opening in the container, allowing all of the material to drain into the mixing tank. A water nozzle attached to the punch sprays the inside of the container to rinse it thoroughly. The rinse water also drains into the mixing tank. The rinsed container is then removed for disposal. A limitation of this system is that only full container quantities can be used. It is not possible to use part of the pesticide in a container and store the rest.

Suction systems use a pump to remove the pesticide through a probe inserted into the container. Some containers are equipped with built-in probes. The pesticide is transferred to the mixing tank by hose and pipe. When the container is empty, it and the transfer system are rinsed with water. The rinse water is added to the mixing tank.

To allow the use of only part of the pesticide in the container, the system must have a way to measure the amount of pesticide suctioned into the mixing tank, and must allow the probe to remain in the container until all the pesticide is used and the container and probe can be rinsed. Some probes have a breakaway head which allows the head to stay and the probe to be withdrawn and reused.

In some systems, it is not possible to reseal partially emptied containers. Another disadvantage of suction systems is that highly viscous pesticides (those which pour like molasses) are difficult to move by suction.

Closed handling systems are not yet easily obtained. The ones in operation are for use only with liquid formulations. They are often custom-made, using components from several commercial sources. Closed handling systems may become more widely available, since one state (California), now requires their use with all highly toxic products. At least two products (Galecron and Fundal) require the use of closed system equipment for mixing.

Two techniques are under development to reduce the need for handling dry concentrates. One is a closed handling system similar to those used for liquid formulations. The other is soluble packaging. Soluble bags or containers allow an applicator to put the entire package (pesticide and container) into the tank. The container dissolves in the solvent in the tank. Disadvantages of soluble packaging include the risk of releasing the concentrate if the packaging is exposed to water during shipping and the possibility of "splashback" as containers are added to the tank.

Pesticide Application

The safety of yourself and others should be a major concern during any pesticide application. Follow all label directions carefully, and observe these basic safety guidelines.

Wear the correct protective clothing and equipment. Wear waterproof clothing if you will be working in drift, spray or runoff. Do not wipe your gloves on your clothing; this will contaminate your clothing and may soak through to your skin. Never eat, drink, smoke, or chew while handling or applying pesticides. Wash your face and hands thoroughly first. If you feel ill, do not try to finish the job. Get out of the area fast and get help.

If you will be working outdoors, choose application equipment, formulations, and additives that will minimize drift and runoff. Do not apply pesticides during or just before expected high winds or heavy rains. Try to spray downwind from sensitive areas such as beehives, residential areas, waterways, and nontarget crops and livestock.

If you are working indoors, be sure you have adequate ventilation or wear a supplied-air respirator. Be sure that nontarget food and feed, toys, and pets are removed from the area to be treated. Failure to do this is a misuse of the pesticide. Choose application techniques, equipment, and formulations that minimize exposure to persons and nontarget animals who may have to reenter treated areas to live or work.

To prevent spillage and possible poisonings, check all application equipment for leaking hoses, pumps, or connections; and plugged, worn, or dripping nozzles. Do not blow out clogged nozzles, hoses, or lines with your mouth. Do not allow children, pets, or unauthorized persons to touch application equipment or pesticide containers or to enter storage areas. Correctly calibrate your equipment before use. Try to use all the pesticide in your tank or hopper. If you have some left over, use it for other labeled uses.

Before application, you must clear the area of all unprotected persons. By law, the application of a pesticide—either directly or through drift—must not expose workers or other persons.

Cleaning Equipment

Never leave pesticide equipment at the application site. When the tank or hopper is empty, return the equipment to the area designated for equipment cleanup. Mixing, loading, and application equipment must be cleaned as soon as you finish using it. Clean both the inside and outside, including nozzles. Only trained persons should do this job. They should wear correct protective clothing.

Sometimes you may need to steam-clean equipment or use special cleaning agents. In other cases, water and detergent may be enough.

Have a special area for cleaning. It is best for the area to have a wash rack or concrete apron with a sump to catch contaminated wash water. Dispose of sump wastes as you would excess pesticides. Keep drainage out of water supplies and streams.

Equipment sometimes must be repaired before it is completely cleaned. Warn the person doing the repairs of the potential hazards.

Disposal

Excess Pesticides

EPA recommends ways to dispose of excess pesticides. Consult local authorities for procedures in your area. Consult the label for disposal instructions or precautions. If you have excess pesticides:

- Use them up as directed on the label.
- Take the pesticides to a landfill operating under EPA or state permit for pesticide disposal. (Most solid waste landfills are not suitable.)
- If you cannot dispose of them right away, safely store the pesticides until you can.

Containers

Do not leave pesticides or pesticide containers at the application site. Never give pesticide containers to children to play with or adults to use. Leftover pesticides should be kept in tightly closed containers in your storage facility.

Always triple rinse empty containers of liquid pesticides as follows:

1. Empty the container into the tank. Let it drain an extra 30 seconds.
2. Fill it one-fifth to one-fourth full of water.
3. Replace the closure and rotate the container. Invert the container so the rinse reaches all the inside surfaces.
4. Drain the rinse water from the container into the tank. Let the container drain for 30 seconds.
5. Repeat steps 2 through 4 at least two more times for a total of three rinses. Remember to empty each rinse solution into the tank.

Burnable Containers

- You may burn small numbers of them if permitted by state and local regulations.
- You may take them to a landfill operating under EPA or state permit for pesticide disposal.
- You may bury them singly in open fields. Bury them at least 18 inches below the surface. Be careful not to pollute surface or subsurface water.

Nonburnable Containers (metal, plastic, or glass)

- Rinse the containers three times.
- Many large containers in good shape can be reused by your supplier. Return them to your supplier, a pesticide manufacturer or formulator, or a drum reconditioner.
- You can send or take them to a place that will recycle them as scrap metal or dispose of them for you.
- All rinsed containers may be crushed and buried in a sanitary landfill. Follow state and local standards.
- If it is not possible to rinse containers, take them to a landfill operating under EPA or state permit for pesticide disposal.

Containers Which Held Organic Mercury, Lead, Cadmium, Arsenic, or Inorganic Pesticides

- Rinse them three times and bury them in a sanitary landfill. Use rinse water in spray tank or on other labeled targets.
- If they are not rinsed, take them to a landfill operating under EPA or state permit for pesticide disposal.

Cleanup of Pesticide Spills

Minor Spills

Keep people away from spilled chemicals. Rope off the area and flag it to warn people. Do not leave unless someone is there to confine the spill and warn of the danger. If the pesticide was spilled on anyone, wash it off immediately.

Confine the spill. If it starts to spread, dike it up with sand or soil. Use absorbent material such as soil, sawdust, or an absorbent clay to soak up the spill. Shovel all contaminated material into a leakproof container for disposal. Dispose of it as you would excess pesticides. Do not hose down the area, because this spreads the chemical. Always work carefully and do not hurry.

Do not let anyone enter the area until the spill is completely cleaned up.

Major Spills

The cleanup of a major spill may be too difficult for you to handle, or you may not be sure of what to do. In either case, keep people away, give first aid if needed, and confine the spill. Then call Chemtrec, the local fire department, and state pesticide authorities for help.

Chemtrec stands for Chemical Transportation Emergency Center, a public service of the Manufacturing Chemicals Association. Its offices are located in Washington, D. C. Chemtrec provides immediate advice for those at the scene of emergencies.

Chemtrec operates 24 hours a day, seven days a week, to receive calls for emergency assistance. For help in chemical emergencies involving spills, leaks, fire, or explosions, call toll-free 800-424-9300 day or night. This number is for **emergencies** only.

If a major pesticide spill occurs on a highway, have someone call the highway patrol or the sheriff for help. (Carry these phone numbers with you.) Do not leave until responsible help arrives.

Report all major spills by phone to your state pesticide authority. You also may need to notify other authorities:

If the spill is on a state highway, call

- the highway patrol, or
- the state highway department.

If the spill is on a county road or a city street, call:

- the county sheriff, or
- city police.

If food is contaminated, notify:

- state or federal food and drug authorities, or
- city, county, or state health officials.

If water is contaminated, notify:

- state health officials,
- regional, state, or federal water quality or water pollution authorities, and,
- the state fish and game agency.

County agricultural extension offices have these phone numbers.

First Aid and Pesticide Poisoning Recognition

First Aid

Get medical advice quickly if you or any of your fellow workers have unusual or unexplained symptoms starting at work or later the same day. Do not let yourself or anyone else get dangerously sick before calling your physician or going to a hospital. It is better to be too cautious than too late.

First aid is the initial effort to help a victim while medical help is on the way. If you are alone with the victim, make sure the victim is breathing and is not being further exposed to the poison before you call for emergency help. Apply artificial respiration if the victim is not breathing.

Read the first aid instructions on the pesticide label, if possible. Follow those instructions. Do not become exposed to poisoning yourself while you are trying to help. Take the pesticide container (or the label) to the physician. Do not carry the pesticide container in the passenger space of a car or truck.

Poison on skin:

- Act quickly.
- Remove contaminated clothing and drench skin with water.
- Cleanse skin and hair thoroughly with detergent and water.
- Dry victim and wrap in blanket.

Chemical burn on skin:

- Wash with large quantities of running water.
- Remove contaminated clothing.
- Cover burned area immediately with loose, clean, soft cloth.
- Do not apply ointments, greases, powders or other drugs in first aid treatment of burns.

Poison in eye:

- Wash eye quickly but gently.
- Hold eyelid open and wash with gentle stream of clean running water.
- Wash for 15 minutes or more.
- Do not use chemicals or drugs in the wash water. They may increase the extent of injury.

Inhaled poison:

- Carry victim to fresh air immediately.
- Open all doors and windows so no one else will be poisoned.
- Loosen tight clothing.

Apply artificial respiration if breathing has stopped or if the victim's skin is blue. If patient is in an enclosed area, do not enter without proper protective clothing and equipment. If proper protection is not available, call for emergency equipment from your fire department.

Poison in mouth or swallowed:

- Rinse mouth with plenty of water.
- Give victim large amounts (up to 1 quart) of milk or water to drink.
- Induce vomiting only if instructions to do so are on the label.

Procedure for inducing vomiting:

- Position victim face down or kneeling forward. Do not allow victim to lie on his back, because the vomitus could enter the lungs and do additional damage.
- Put finger or the blunt end of a spoon at the back of victim's throat or give syrup of ipecac.
- Collect some of the vomitus for the physician if you do not know what the poison is.
- **Do not** use salt solutions to induce vomiting.

Do not induce vomiting:

- If the victim is unconscious or is having convulsions.
- If the victim has swallowed a corrosive poison. A corrosive poison is a strong acid or alkali. It will burn the throat and mouth as severely coming up as it did going down. It may get into the lungs and burn there also.
- If the victim has swallowed an emulsifiable concentrate or oil solution. Emulsifiable concentrates and oil solutions may cause severe damage to the lungs if inhaled during vomiting.

Pesticide Poisoning Recognition

Pesticides can poison humans as well as the target pests. Some pesticides are highly toxic to humans; only a few drops in the mouth or on the skin can cause severe injury. Other pesticides are less toxic, but overexposure to them will cause injury. You should know the kinds of injury most likely to be caused by the pesticides you use.

You also should be on the alert for the two kinds of clues to pesticide poisoning. Some are feelings that only the person who has been poisoned can notice—such as nausea or headache. These are **symptoms**. Others, like vomiting, can be noticed by someone else. These are **signs**. You should know:

- what your own symptoms might mean, and
- what signs of poisoning to look for in your coworkers and others who may have been exposed.

Pesticides which are chemically similar to one another cause the same type of injury to humans. This injury may be mild or severe, depending on the specific pesticide involved and the amount of overexposure. But the **pattern** of injury caused by each chemical group is usually the same.

There are two major types of pesticide poisoning injuries:

- external irritants,
- internal poisons.

External irritants cause redness, blisters, and rash on skin, and swelling and a stinging sensation in eyes, nose, mouth, and throat. Some pesticide groups are irritating to nearly all people; others cause irritation only to sensitive individuals.

Internal poisons injure organs or other systems inside the body. The poison enters the body directly through swallowing or indirectly by absorption during breathing or through the skin. Some pesticide groups cause both external irritation and internal poisoning injuries.

The chart on the following pages lists the major chemical groups of pesticides. For each group, the chart tells:

- action of the poison on the human system,
- some signs and symptoms of internal exposure,
- degree of external irritation,
- signs and symptoms of chronic exposure (if any),
- type of pesticide.

The chart is designed only as a guide. Many of the signs and symptoms listed are similar to other illnesses which you might experience, such as the flu or even a hangover. If you have been working with pesticides and then develop suspicious signs and symptoms, call your physician or the nearest poison control center. Only a physician can diagnose pesticide poisoning injuries.

Ask your physician or poison control center to obtain the latest edition of "Recognition and Management of Pesticide Poisonings," by Donald P. Morgan, M.D., Ph.D. It is available through the U.S. Environmental Protection Agency or from the U.S. Government Printing Office (No. EPA-540/9-80-005, January 1982).

NOTE: Some applicators working with cholinesterase-inhibiting pesticides in the carbamate or organophosphate family routinely take atropine tablets to prevent poisoning. This is not a sound medical practice. Atropine is itself a potent toxin and could lead to poisoning injuries. Atropine also can mask the early signs and symptoms of cholinesterase poisoning and dangerously delay proper diagnosis and treatment.

Numbers following each pesticide on the list below refer to numbers on the "Effects" chart which begins on the page 56.

Effects of Pesticide Chemicals on the Human Body

Chart key refers to the number on the chart in which the pesticide is covered.

Pesticides Index

Effects of Pesticide Chemicals on the Human Body

Chemical Family	Action on Human System	Internal Exposure
1. Organophosphates	Inhibits acetylcholinesterase (an enzyme) in the tissues.	Headache, dizziness, weakness, shaking, nausea, stomach cramps, diarrhea, sweating.
2. Carbamates	Reversible changes in acetylcholinesterase enzyme of tissues.	Headache, dizziness, weakness, shaking, nausea, stomach cramps, diarrhea, sweating.
3. Organochlorines (Chlorinated Hydrocarbons)	Disrupt function of nervous system, mainly the brain.	Headache, dizziness, weakness, shaking, nausea, excitability, disorientation.
4. Pentachlorophenol	Toxic to liver, kidneys, and nervous system.	Headache, weakness, nausea, excessive sweating.
5. Nitrophenolic and Nitrocresolic Pesticides	Toxic to liver, kidneys, and nervous system.	Headache, weakness, thirst, excessive sweating, feeling of overall illness. Yellow stain of skin, hair and urine is characteristic.
6. Chlorophenoxy Pesticides	Irritant to lung, stomach and intestinal linings. Injure liver, kidney, and nervous system.	Prompt vomiting, burning sensation in stomach, diarrhea, muscle twitching.
7. Paraquat and Diquat	Injure skin, nails, cornea, liver, kidney, linings of stomach and intestine, and respiratory system.	Burning pain, nausea, vomiting, and diarrhea.
8. Thiocarbamates and Dithiocarbamates	Low human toxicity.	Nausea, vomiting, diarrhea, weakness, and nasal stuffiness.
9. Pyrethrins and Pyrethroids	Very low human toxicity.	Slight toxic reaction.
10. Arsenical Pesticides	Toxic to liver, kidney, brain, bone marrow, and nervous system.	Headache, burning stomach pain, vomiting, diarrhea, dizziness. Garlic odor on breath and feces.
11. Coumarins, Indandiones, and Other Anticoagulants	Prevents blood from clotting.	Usually no reaction if low accidental dose ingested.
12. Sodium Fluoroacetate	Extremely toxic. Affects heart tissue and brain.	Stomach pain, vomiting, hallucination, nervousness.

External Exposure	Chronic Exposure	Type of Pesticide
Minimal rashes but readily absorbed through the skin.	Loss of appetite, weakness, weight loss, and general feeling of sickness.	Insecticides, acaricides
Minimal rashes but readily absorbed through the skin.	Loss of appetite, weakness, weight loss, and general feeling sickness.	Insecticides, acaricides
Minimal rashes but readily absorbed through the skin.	Some buildup in the fat tissues. May cause nervousness, weakness, and shaking.	Insecticides and acaricides (HCB is a fungicide)
Highly irritating to skin, eyes, nose and throat.	Weight loss, weakness, anemia.	Herbicides, defoliants, molluscicides, germicides, fungicides, and wood preservatives.
Moderately irritating sensations to skin, eyes, nose, and throat.	Weight loss	Herbicides
Moderately irritating to eyes, skin, and lungs.	Do not remain in body; passed out within hours or days.	Herbicides
Irritates and injures skin and nails.		Herbicides
Irritating to skin, eyes, nose, and throat.		Fungicides
Swelling of mouth and throat, irritating to nose, throat, eyes.	Accumulates in body. Chronic headaches, dizziness, stomachaches, salivation, low fever, garlic breath.	Rodenticides, insecticides, acaricides, marine antifouling compounds, desiccants, herbicides, fungicides.
Minimal		
Minimal		Rodenticides

Chemical Family	Action on Human System	Internal Exposure
13. Zinc Phosphide	Highly toxic: severe intestinal irritation; severe injury to liver, kidneys, nervous system, and heart.	Intense nausea, stomach pain, excitement, chills, cough.
14. Yellow Phosphorus	Highly toxic; blood system injury; injury to liver, nervous system, heart, and kidneys.	Breath has garlic odor; feces may glow and smoke from phosphorus fumes; vomiting and diarrhea; burning pain in throat, stomach, and intestines.
15. Strychnine and Crimidine	Acts directly on cells in the brain and spinal cord to cause convulsions.	Blue skin color; violent convulsions.
16. Vacor, DLP-787	Very toxic; injures nervous system, brain, and area around heart.	Nausea, vomiting, diarrhea, stomach cramps, chills, confusion, weakness, chest pains.
17. Red Squill	Low toxicity.	Prompt vomiting and nausea.
18. ANTU and Norbormide	Selectively toxic to rats; toxic to humans only in huge suicidal doses.	Blue skin, labored breathing.
19. Sulfur Dioxide, Formaldehyde, Chloropicrin, and Acrolein	Strong irritant of lungs and throat.	Headache, dizziness, nausea, wheezing, cough.
20. Methyl Bromide, Ethylene Oxide and Propylene Oxide	Serious injury to lungs; injures nervous system.	Coughing of frothy fluid; severe shortness of breath, drowsiness, shaking, weakness.
21. Halocarbons	Injures heart muscles; also injures lungs, brain, liver, and kidney.	Shock, drowsiness, shaking, weakness.
22. Carbon disulfide	Injury to nervous system.	Dizziness, headache, nausea, and disorientation.
23. Phosphine	Injures lungs, liver, kidneys, and nervous system.	Weakness, shaking, vomiting, cough, difficulty in breathing, intense thirst.
24. Metal Phosphides	Injures lungs, liver, kidneys, heart, and nervous system.	Nausea and vomiting followed by weakness, shaking, and dizziness.
25. Sulfuryl Fluoride	Injures lungs and kidneys.	Muscle twitching, convulsions.
26. Hydrogen Cyanide, Acrylonitrile, and Sodium Cyanide	Injury to brain and heart tissues.	Headache, nausea, constriction of throat, dizziness, nervousness. Sudden unconsciousness.
27. 4-Amino-Pyridine	Disrupts nervous system functions.	Thirst, nausea, dizziness, weakness, excessive sweating.

External Exposure	Chronic Exposure	Type of Pesticide
Minimal		Rodenticides
Dermal exposure usually low; irritates nose and throat.		Rodenticides
Minimal		Rodenticides
Minimal		Rodenticides
Minimal	Excreted rapidly; not retained in body.	Rodenticides
Minimal		Rodenticides
Severe irritation of eyes, nose, throat. Blisters on skin.		Fumigants
Irritates eyes, nose, and throat.	Lack of coordination.	Fumigants
Irritates eyes, nose, and throat. Blisters and redness on skin.	Liver damage, weight loss, and jaundice.	Fumigants
Irritates eyes, nose, and throat.	Pain; tingling and weakness of arms and legs; loss of mental functions.	Fumigants
Irritates eyes, nose, and throat.	Pain in eyes and nose; nosebleeds; abdominal pain.	Fumigants
Irritants		Fumigants
Irritant	Injury to kidneys and lungs.	Fumigants
Irritant		Fumigants, rodenticides
		Avicides

Chemical Family	Action on Human System	Internal Exposure
28. Chlordimeform	Bladder injury.	Abdominal and back pain; painful urination; blood in urine.
29. Copper Salts and Organic Complexes	Injures intestinal lining, brain, liver, kidneys, and blood.	Prompt vomiting; burning pain in chest; diarrhea, headache, sweating.
30. Cycloheximide	Irritates stomach and intestine; injury to kidneys, brain lining, and nervous system.	Excitement, tremors, salivation, diarrhea.
31. Endothall	Damages heart, blood vessels, nervous system, and intestinal lining.	Convulsions, shock, lack of coordination.
32. Nicotine Sulfate	Injures nervous system.	Nausea, headache, diarrhea, dizziness, shaking, abdominal pain, lack of coordination, sweating, salivation.
33. Phenylmercuric Salts	Injures nervous system and kidneys.	Delirium, muscle weakness, lack of coordination.
34. Sodium Chlorate	Injury to intestinal lining, nervous system, and kidneys.	Swelling of mouth and throat; pain in esophagus, stomach, and intestine; restlessness.
35. Acetamides	Irritants	
36. Acetanilides	Irritants	
37. Aliphatic Acids	Irritant	
38. Alumino fluoride Salt	Irritant	
39. Benzene	Irritant	Mild lung irritation caused by hexachlorobenzene.
40. Benzoic Acid and Benzilic Acid Derivatives	Irritant	
41. Benzonitriles	Irritant	Moderately irritating to lungs.
42. Dithio carbamates	Do *not* inhibit cholinesterase; mild irritants.	
43. Carbanilate	Irritant	
44. Dicarboximides	Irritant	

External Exposure	Chronic Exposure	Type of Pesticide
Skin rash; sweet taste in mouth.		Insecticides, miticides
Irritates skin and eyes; damages mucous membranes.		Fungicides
Minimal		Fungicides
Irritating to eyes, skin, and mucous membranes.		Herbicides, algicides
Minimal but readily absorbed through the skin.		Insecticides
Minimal	Weakness and lack of coordination in arms and legs; difficulty in talking and swallowing.	Fungicides
Irritant		Herbicides, defoliants.
Moderately irritating to skin and eyes.		Herbicides
Mild irritants; propachlor is a skin irritant and sensitizer.		Herbicides
Skin and eye irritants.		Herbicides
Slight irritant of eyes, nose, and skin.		Insecticide
Skin irritation caused by pentachloronitrobenzene.	Blood changes caused by hexachlorobenzene.	Fungicides, insecticides
Irritating to skin.		Insecticides, herbicides
Moderately irritating to skin.		Fungicides, herbicides
Mild irritant to skin, eyes, nose, and throat.	-	Herbicides, fungicides
Irritant and skin sensitizer.		Herbicides
Skin irritant.		Fungicides

Chemical Family	Action on Human System	Internal Exposure
45. Dinitrotoluidine Compounds	Irritant	
46. Oxadiazolinone	Irritant	
47. Phthalate	Irritant	
48. Picolinic Acid Derivative	Irritant	Irritates lungs.
49. Pyridazinone	Irritant	
50. Phosphonomethyl Glycine	Irritant	Irritates lungs.
51. Thiadiazin(ol)	Irritant	Vomiting, diarrhea, shaking, and weakness causes by bentazon herbi-cides.
52. Triazines	Irritant	
53. Uracils	Irritant	Irritating to lungs.
54. Urea Derivatives	Irritant	

External Exposure	Chronic Exposure	Type of Pesticide
Slightly to moderately irritating to skin, eyes, nose, and throat		Herbicides
Irritating to skin and eyes.		Herbicides
Mild irritant.		Herbicides
Irritating to skin, eyes, nose, and throat.		Herbicides
Slightly irritating.		Growth Retardant
Irritates eyes.		Herbicides
Moderately irritating to skin, eyes, nose, and throat.		Herbicides, fungicides
Mildly irritating to skin, eyes, nose, and throat.		Herbicides
Irritating to skin, eyes, nose, and throat.		Herbicides
Moderately irritating to skin, eyes, nose, and throat.		Herbicides, insecticides

Other Terms Used in Pest Control

Other Terms Used in Pest Control

Some of these words have several meanings. Those given here are the ones that relate to pest control.

Abrasion: The process of wearing away by rubbing.

Abscission: The separation of fruit, leaves, or stems from a plant.

Absorption: The process by which a chemical is taken into plants, animals, or minerals. Compare with adsorption.

Activator: A chemical added to a pesticide to increase its activity.

Adherence: Sticking to a surface.

Adsorption: The process by which chemicals are held on the surface of a mineral or soil particle. Compare with absorption.

Adulterated: Any pesticide whose strength or purity falls below the quality stated on its label. Also, a food, feed, or product that contains illegal pesticide residues.

Aerobic: Living in the air. The opposite of anaerobic.

Aerosol: An extremely fine mist or fog consisting of solid or liquid particles suspended in air. Also, certain formulations used to produce a fine mist or smoke.

Agitation: The process of stirring or mixing in a sprayer.

Alkaloids: Chemicals present in some plants. Some are used as pesticides.

Anaerobic: Living in the absence of air. The opposite of aerobic.

Animal Sign: The evidences of an animal's presence in an area.

Antagonism: The loss of activity of a chemical when exposed to another chemical.

Antibiotic: A substance which is used to control pest microorganisms.

Antidote: A practical treatment for poisoning, including first aid.

Aqueous: A term used to indicate the presence of water in a solution.

Arsenicals: Pesticides containing arsenic.

Aseptic: Free of disease-causing organisms.

Bait Shyness: The tendency for rodents, birds, or other pests to avoid a poisoned bait.

Bipyridyliums: A group of synthetic organic pesticides which includes the herbicide paraquat.

Botanical Pesticide: A pesticide made from plants. Also called plant-derived pesticides.

Broadleaf Weeds: Plants with broad, rounded, or flattened leaves.

Brush Control: Control of woody plants.

Carbamate: A synthetic organic pesticide containing carbon, hydrogen, nitrogen, and sulfur.

Carcinogenic: Can cause cancer.

Carrier: The inert liquid or solid material added to an active ingredient to prepare a pesticide formulation.

Causal Organism: The organism (pathogen) that produces a specific disease.

Chemosterilant: A chemical that can prevent reproduction.

Chlorinated Hydrocarbon: A synthetic organic pesticide that contains chlorine, carbon, and hydrogen. Same as organochlorine.

Chlorosis: The yellowing of a plant's green tissue.

Cholinesterase: A chemical catalyst (enzyme) found in animals that helps regulate the activity of nerve impulses.

Concentration: The amount of active ingredient in a given volume or weight of formulation.

Contaminate: To make impure or to pollute.

Corrosion: The process of wearing away by chemical means.

Crucifers: Plants belonging to the mustard family, such as mustard, cabbage, turnip, and radish.

Cucurbits: Plants belonging to the gourd family, such as pumpkin, cucumber, and squash.

Deciduous Plants: Perennial plants that lose their leaves during the winter.

Deflocculating Agent: A material added to a suspension to prevent settling.

Degradation: The process by which a chemical is reduced to a less complex form.

Dermal: Of the skin; through or by the skin.

Dermal Toxicity: Ability of a chemical to cause injury when absorbed through the skin.

Diluent: Any liquid or solid material used to dilute or carry an active ingredient.

Dilute: To make thinner by adding water, another liquid, or a solid.

Dispersing Agent: A material that reduces the attraction between particles.

Dormant: State in which growth of seeds or other plant organs stops temporarily.

Dose, Dosage: Quantity of a pesticide applied.

Emulsifier: A chemical which aids in suspending one liquid in another.

Emulsion: A mixture in which one liquid is suspended as tiny drops in another liquid, such as oil in water.

Fungistat: A chemical that keeps fungi from growing.

GPA: Gallons per acre.

GPM: Gallons per minute.

Growth Stages of Cereal crops: (1) Tillering—when additional shoots are developing from the flower buds. (2) Jointing - when stem internodes begin elongating rapidly. (3) Booting - when upper leaf sheath swells due to the growth of developing spike or panicle. (4) Heading - when seed head is emerging from the upper leaf sheath.

Hard (water): Water containing soluble salts of calcium and magnesium and sometimes iron.

Herbaceous Plant: A plant that does not develop woody tissue.

Hydrogen-Ion Concentration: A measure of acidity or alkalinity, expressed in terms of the pH of the solution. For example, a pH of 7 is neutral, from 1 to 7 is acid, and from 7 to 14 is alkaline.

Immune: Not susceptible to a disease or poison.

Impermeable: Cannot be penetrated. Semipermeable means that some substances can pass through and others cannot.

Lactation: The production of milk by an animal, or the period during which an animal is producing milk.

LC50: The concentration of an active ingredient in air which is expected to cause death in 50 percent of the test animals so treated. A means of expressing the toxicity of a compound present in air as dust, mist, gas, or vapor. It is generally expressed as micrograms per liter as a dust or mist but in the case of a gas or vapor as parts per million (ppm).

LD50: The dose of an active ingredient taken by mouth or absorbed by the skin which is expected to cause death in 50 percent of the test animals so treated. If a chemical has an LD50 of 10 milligrams per kilogram (mg/kg) it is more toxic than one having an LD50 of 100 mg/kg.

Leaching: Movement of a substance downward or out of the soil as the result of water movement.

Mammals: Warm-blooded animals that nourish their young with milk. Their skin is more or less covered with hair.

Miscible Liquids: Two or more liquids that can be mixed and will remain mixed under normal conditions.

MPH: Miles per hour.

Mutagenic: Can produce genetic change.

Necrosis: Localized death of living tissue such as the death of a certain area of a leaf.

Necrotic: Showing varying degrees of dead areas or spots.

Nitrophenols: Synthetic organic pesticides containing carbon, hydrogen, nitrogen, and oxygen.

Noxious Weed: A plant defined as being especially undesirable or troublesome.

Oral: Of the mouth; through or by the mouth.

Oral Toxicity: Ability of a pesticide to cause injury when taken by mouth.

Organic Compounds: Chemicals that contain carbon.

Organochlorine: Same as chlorinated hydrocarbon.

Organophosphate: A synthetic organic pesticide containing carbon, hydrogen, and phosphorus; parathion and malathion are two examples.

Ovicide: A chemical that destroys eggs.

Pathogen: Any disease-producing organism.

Penetration: The act of entering or ability to enter.

Phytotoxic: Harmful to plants.

Pollutant: An agent or chemical that makes something impure or dirty.

PPB: Parts per billion. A way to express the concentration of chemicals in foods, plants, and animals. One part per billion equals 1 pound in 500,000 tons.

PPM: Parts per million. A way to express the concentration of chemicals in foods, plants, and animals. One part per million equals 1 pound in 500 tons.

Predator: Any animal that destroys or eats other animals.

Propellant: Liquid in self-pressurized pesticide products that forces the active ingredient from the container.

PSI: Pounds per square inch.

Pubescent: Having hairy leaves or stems.

RPM: Revolutions per minute.

Safener: A chemical added to a pesticide to keep it from injuring plants.

Seed Protectant: A chemical applied to seed before planting to protect seeds and new seedlings from disease and insects.

Soil Sterilant: A chemical that prevents the growth of all plants and animals in the soil. Soil sterilization may be temporary or permanent, depending on the chemical.

Soluble: Will dissolve in a liquid.

Solution: Mixture of one or more substances in another in which all ingredients are completely dissolved.

Solvent: A liquid which will dissolve a substance to form a solution.

Spreader: A chemical which increases the area that a given volume of liquid will cover on a solid or on another liquid.

Sticker: A material added to a pesticide to increase its adherence.

Surfactant: A chemical which increases the emulsifying, dispersing, spreading and wetting properties of a pesticide product.

Susceptible: Capable of being diseased or poisoned; not immune.

Susceptible Species: A plant or animal that is poisoned by moderate amounts of a pesticide.

Suspension: Finely divided solid particles mixed in a liquid.

Synergism: The joint action of two or more pesticides that is greater than the sum of their activity when used alone.

Target Pest: The pest at which a particular pesticide or other control method is directed.

Tolerance: (1) The ability of a living thing to withstand adverse conditions, such as pest attacks, weather extremes, or pesticides. (2) The amount of pesticide that may safely remain in or on raw farm products at time of sale.

Toxicant: A poisonous chemical.

Trade Name: Same as brand name.

Vapor Pressure: The property which causes a chemical to evaporate. The lower the vapor pressure, the more easily it will evaporate.

Vector: A carrier, such as an insect, that transmits a pathogen.

Viscosity: A property of liquids that determines whether they flow readily. Viscosity usually increases when temperature decreases.

Volatile: Evaporates at ordinary temperatures when exposed to air.

Wetting Agent: A chemical which causes a liquid to contact surfaces more thoroughly.

Square Feet vs. Acre Mixing

The label dosage rate is sometimes given in pounds, pints, quarts, or gallons per 1,000 square feet. If you have calibrated your equipment in terms of 1,000 square feet, you must adjust the formulas above from an acre to 1,000 square feet. The following formulas may be used with either liquid or dry formulations:

$$\frac{\text{Gallons per tank}}{\text{Gallons applied per 1,000 sq. ft. by equipment}} = \text{Number of 1,000 sq. ft. sections sprayed per tankful}$$

Number of 1,000 sq. ft. sections sprayed per tankful × Pints, quarts, gallons, or pounds of formulation per 1,000 sq. ft. = Amount of formulation to add to tank

However, if you have calculated the area you are to treat in acres, you must convert the 1,000-square-foot rate to rate per acre as follows:

$$\frac{\text{43,560 (sq. ft. in acre)}}{\text{1,000 sq. ft.}} = 43.5$$

Pints, quarts, gallons, or pounds per 1,000 sq. ft. × 43.5 = Pints, quarts, gallons, or pounds of formulation to apply per acre

To convert from the rate per acre to the rate per 1,000 square feet (or 100 square feet):

$$\frac{\text{Pints, qts., gals., or lbs. of formulation recommended per acre}}{\text{43.5 (435 for 100 sq. ft.)}} = \text{Pints, qts., gals., or lbs. formulation per 1,000 sq. ft. (or 100 sq. ft.)}$$

Area Measurements

To determine how much pesticide you will need to do a job, you must measure the area to be treated. If the area is a rectangle, circle, or triangle, simple formulas may be used. Determining the area of an irregularly shaped site is more difficult.

The following examples will help you in computing the area of both regularly and irregularly shaped surfaces.

Regularly Shaped Areas

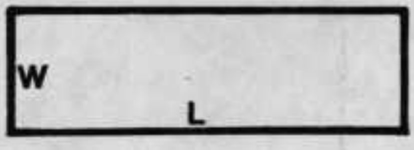
Rectangles

The area of a rectangle is found by multiplying the length (L) by the width (W).

Area = Length × Width

Example:

40 × 125 = 5,000 sq. ft.



Circles

The area of a circle is the radius (one-half the diameter) squared and then multiplied by 3.14.

Area = 3.14 × radius squared

Example:

35 × 35 × 3.14 = 3846.5 sq. ft.

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