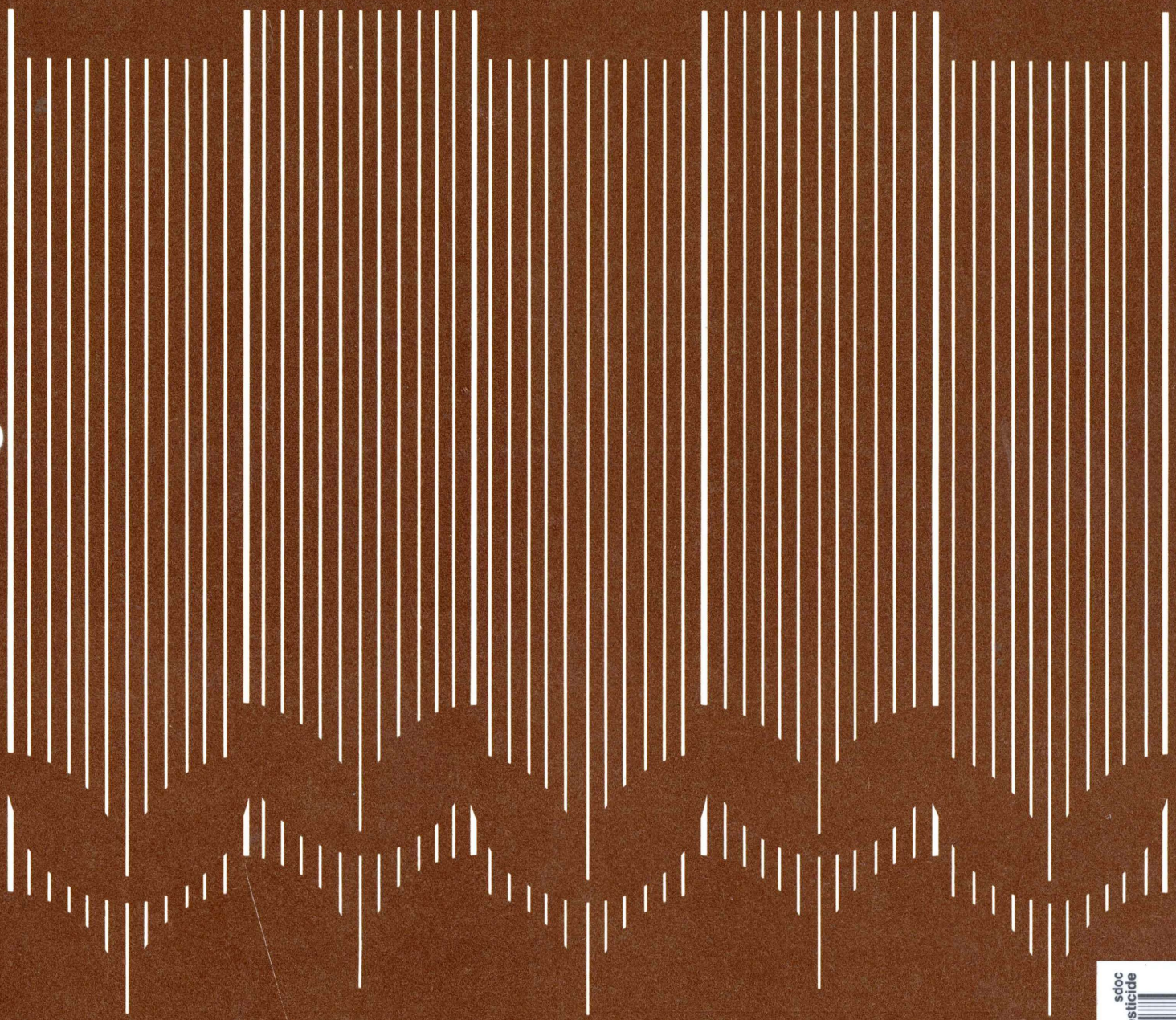
Pesticide Applicator Certification

The Iowa Core Manual

Apply Pesticides Correctly



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Preface

Revised from *Apply Pesticides Correctly—A Guide for Commercial Applicators* published by the U.S. Environmental Protection Agency. Revision prepared by Iowa State University Extension staff members: Wendy Wintersteen, entomology associate; Jerald DeWitt, Integrated Pest Management coordinator; Richard Fawcett, weed scientist; Donald Lewis, entomologist; and Robert Nyvall, plant pathologist. In addition, this manual includes information adapted from Cooperative Extension Service publications from the University of California, Michigan State, and North Carolina State universities.

No endorsement is intended by Iowa State University Cooperative Extension Service of companies or their products mentioned nor is criticism implied of similar companies or their products not mentioned.

Introduction

This guide includes:

- the federal and state laws that apply to pesticide use;
- the most common features of pests, how they develop, and the kinds of damage they do;
- methods to control pests and how to combine these methods for the best results;
- how pesticides work;
- how pesticide labels can help the applicator;
- how to use pesticides so they will not harm individuals or the environment; and
- how to choose, use, and care for equipment.

Careful study of this guide will be preparation for taking the written exam(s) to obtain certification.

Private or Commercial Applicator?

There are two types of pesticide applicators: private and commercial. To determine which classification covers your situation, read the following definitions.

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 employers, or on the property of other persons with whom they trade services. Private applicators wishing to use restricted use pesticides must be certified. Certification involves either passing a written examination or attending a training session conducted by the Iowa State University Extension Service.

Commercial applicators are persons who apply pesticides for hire on property other than their own, and government workers (public applicators) who apply pesticides in their jobs. Commercial applicators must pass an examination demonstrating competence in applying restricted and general use pesticides to obtain certification.

Laws and Regulations

Pesticide application has become more complex in recent years. The number of different kinds of pesticides available 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.

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) As Amended

Passed by Congress in 1972 and substantially amended in 1974 and 1978, FIFRA regulates the registration, manufacture, transportation, and use of pesticides.

Here are the parts of the law that concern applicators most:

- It states that all pesticide uses must be classified as either general or restricted.
- It requires an applicator to be certified as competent to use any of the pesticides classified for restricted use.
- It provides penalties (fines and jail terms) for people who do not obey the law.

Classification of Pesticides

Manufacturers must register every pesticide with the Environmental Protection Agency (EPA). By law, when each pesticide is registered, all its uses must be classified. EPA must decide whether each use is a general or a restricted one.

Under the law, pesticide uses that will damage the environment very little or not at all when applied as the label directs can be classified as general uses.

Uses that could cause damage even when applied as directed on the label must be classified as restricted uses. These uses may be carried out only by someone who is certified or under a certified person's supervision.

Some uses may be general under some conditions and restricted under others.

Certification of Applicators

As a result of FIFRA, the pesticide applicator training program was developed to enable private and commercial applicators to obtain certification. The certification training program is based on the minimum amount of knowledge that an individual must have to properly apply a pesticide. In order to demonstrate competency, private applicators should possess practical knowledge of the pest control problems and practices associated with agricultural operations. Applicators should be able to recognize common pests, understand labels and labeling, apply pesticides according to label directions, and be able to recognize poisoning symptoms.

Commercial applicators must exhibit competency in those areas of pest control where they plan to make applications of any pesticide. Broad-based practical knowledge must be demonstrated in the areas of label and labeling comprehension, safety, the environment, pests, pesticides, equipment, application techniques, supervision, and laws and regulations. See pages 4-5 for details on how to become certified in Iowa.

Prohibited Actions

An applicator may not use any pesticide in a manner not permitted by the labeling. A pesticide may be used only on the plants, animals, or sites specified in the directions for use. It may not be used in higher dosages, higher concentrations, or more frequent applications. Directions for use, safety, mixing, diluting, storage, and disposal must be followed, as well as restrictions on reentry and days to harvest, slaughter, and grazing.

FIFRA, 1978 Amendments

Amendments made to FIFRA in 1978 now allow:

- application of a pesticide in any dosage, concentration, or frequency **less** than that listed on the labeling;
- application of 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 of any equipment or method of application that is not prohibited by the labeling;
- mixing a pesticide or pesticides with a fertilizer if the mixture is not prohibited by the labeling;
- mixing two or more pesticides if all the dosages are at or below the recommended rate.

Penalties

Violation of the legal provisions established in FIFRA may bring about civil penalties that can be as much as $5,000 for each offense. Before an EPA fine is levied, you have the right to ask for a hearing in your own city or county. Violation of the law may also subject one to criminal penalties that can be as much as $25,000 or 1 year in prison, or both.

Special Labels

Federal law (FIFRA) provides two methods for special labeling of pesticides. Section 24(C), special local need registration, is requested by the pesticide manufacturer and approved by the Iowa Department of Agriculture. The approving state must show that there is a local need for the pesticide and that the pesticide is more effective or less hazardous than the currently registered products. The duration for this special label is 5 years.

Section 18, emergency exemption from registration, is requested by the Iowa Secretary of Agriculture and approved by the EPA. The state must show that a pest outbreak has or is about to occur and no pesticide is registered that can

provide control. The duration for this special label is usually less than 1 year.

Special Review
Formally known as RPAR (the rebuttable presumption against registration), Special Review is a process that provides a risk benefit analysis of pesticides for which legitimate questions of use have been raised. Special review leads to a decision to take no action against the product, to restrict some or all uses of the product, or to initiate cancellation of the product.

Other Federal 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 tells which pesticides are dangerous to people 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 tell DOT about all spills during shipment.

State and local laws may require additional precautions.

Aerial Application
Application of pesticides from airplanes is regulated by the Federal Aviation Administration (FAA) and may be regulated by individual states. FAA judges both the flying ability of pilots and the safety of their aircraft. FAA rules 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 (DOL). 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. But a record must be made if the injury involves medical treatment, loss of consciousness, restriction of work or motion, or transfer to another job.

Residues
The pesticide that stays in or on raw farm products or processed foods is called a residue. EPA sets residue tolerances under regulations authorized by the Federal Food, Drug, and Cosmetic Act. A tolerance is the concentration of a pesticide that is judged safe for human use. Residues in processed foods are considered to be food additives and are regulated as such.

Tolerances are expressed in parts per million (ppm). One ppm equals one part (by weight) of pesticide for each million parts of farm or food product. Using pounds as a measure, 50 ppm would be 50 pounds of pesticide in a million pounds of the product. The same pesticide may have a different tolerance on different products. It might be 50 ppm on grapes and 24 ppm on apples.

If too much residue is found on a farm or food product, the product may be seized or condemned by the Iowa Department of Agriculture.

The label will tell how many days before harvest the pesticide may be applied. Follow the label exactly to avoid breaking the law.

Iowa Pesticide Act
The Iowa Pesticide Act as amended by the 65th General Assembly regulates pesticides by requiring the registration of all pesticide products sold in Iowa and by requiring that individual pesticide applicators be certified as competent to apply pesticides. In addition to the certification of applicators, all persons (companies) engaged in the business of applying pesticides must be licensed by the Iowa Department of Agriculture.

Please note that two similar but separate regulatory actions are needed prior to regulated pesticide application in Iowa: licensing and certification. As stated above, companies are licensed, individuals are certified. This will be further discussed on pages 5-7.

Other features of the Iowa Pesticide Act state that misuses of pesticides have now become legal violations. Licensed or certified pesticide applicators could have their licenses or certifications revoked, suspended, or denied as a result of any violation of the act.

The amendments to the Iowa Pesticide Act expand the authority of seizures to include the issuance of written stop sale, stop use, and removal orders. The Department of Agriculture has the authority to investigate pesticide accidents and incidents or loss arising from the use or misuse of pesticides. The finding of these investigations may be made available to the person claiming damage and to the person who is alleged to have caused the damage.

How to Become Certified to Apply Pesticides in Iowa

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, 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.

Private applicators wishing to use restricted-use pesticides must become certified. Private applicators who apply general-use pesticides only do not need to be certified. Certification involves either passing a written examination demonstrating competence in applying pesticides or showing proof of attending training sessions conducted by Iowa State University Extension Service. Each individual pesticide applicator not under the direct supervision of a certified applicator must become certified to use restricted-use pesticides. Each individual private pesticide applicator will pay a $5 certification fee to the Iowa Department of Agriculture and receive a private applicator certification card upon becoming certified.

Recertification. The Iowa Department of Agriculture requires recertification of each private pesticide applicator every third year. Recertification involves paying a $5 recertification fee and either taking and passing a written examination or attending a training session conducted by the Iowa State University Extension Service. Individuals wishing to become certified or recertified should contact their local county extension office concerning dates and places of the training sessions and examinations.

Commercial applicators
Commercial applicators are persons who apply pesticides for hire on property other than their own, and government workers (public applicators) who apply pesticides in their jobs.

Commercial pesticide applicators and public pesticide applicators must pass an examination demonstrating competence in applying pesticides before receiving a pesticide applicator certification card and before a pesticide applicator's license is issued to the company. Each individual commercial pesticide applicator not under the direct supervision of a certified applicator must take and pass the written examination to demonstrate competence to apply pesticides.

Commercial applicators are trained and tested in the general area of safe use and handling of pesticides, as discussed in this manual, and then receive further training and testing in one or more specific categories of application, including:

1A	Agricultural Weed Control
1B	Agricultural Insect Control
1C	Agricultural Crop Disease Control
1D	Fruit and Vegetable Pest Control
1E	Animal Pest Control
2	Forest Pest Control
3	Ornamental and Turf and Greenhouse Pest Control
4	Seed Treatment
5	Aquatic Pest Control
6	Right-of-Way Control
7A	General and Household Pest Control
7B	Termite Pest Control
7C	Fumigation
7D	Community Insect Control
8	Public Health Pest Control
9	Regulatory Pest Control
10	Demonstration and Research Pest Control

Any person engaged in aerial applications of pesticides must demonstrate competency in broad-based practical pest control and in the category-specific standards for the area(s) of application desired. Because of the use of categories of application it may be necessary for an applicator to become certified in more than one category in order to legally apply restricted-use pesticides.

Each individual commercial pesticide applicator and public pesticide applicator will pay a $10 certification fee to the Iowa Department of Agriculture for each time certified. The applicator may take more than one written examination over different certification classifications without having to pay additional certification fees.

To prepare for written examinations, study this manual as well as the appropriate category manual(s). These manuals can be obtained from county extension offices or from Publications Distribution, Iowa State University, Ames, Iowa 50011. When ordering a category manual from Publications Distribution, give the specific category number and check prices before ordering.

Written examination(s) may be taken on any weekday, Monday through Friday, that state offices are open, preferably before 3 p.m. No appointment is needed. The location of the Pesticide Section of Iowa Department of Agriculture is the Wallace State Office Building, 900 East Grand Ave., Des Moines, Iowa 50319.

Written examinations will also be given in the outlying areas of the state each year. Pesticide applicators should keep in touch with their local county extension offices for specific dates and places.

The Core Manual exam has 75 multiple choice questions. At least 60 questions must be answered correctly to pass. Each category exam has 25 multiple choice questions, with at least 20 correct answers needed to pass. A person who fails an exam will not be able to repeat it on that same day.

If a person passes only some of the exams taken, the Department of Agriculture will keep those scores on record for about a year. Therefore, repeat exams are needed only on those previously failed. It is not necessary to repeat the entire series.

Recertification. The Iowa Department of Agriculture requires recertification of each individual pesticide applicator every third year. Recertification involves paying a $10 recertification fee and attending a recertification training session before present certification expires. If certification is allowed to expire, passing the written examination is required for recertification.

Reciprocity Between States. Individuals from surrounding states should contact the Iowa Department of Agriculture to determine if certification obtained in their home state is applicable in Iowa. Each request for certification based on reciprocity is considered on an individual basis.

How to Obtain an Iowa Pesticide Company License

Companies engaged in the business of applying pesticides to the lands or properties of another must be licensed by the Iowa Department of Agriculture. A company may be a person who is the sole owner and operator. In addition, pesticide dealers distributing restricted use pesticides are required to be licensed.

New Applicants

New applicants (companies) are to request pesticide applicator license forms from the Pesticide Section of Iowa Department of Agriculture, Wallace State Office Building, 900 East Grand Ave., Des Moines, Iowa 50319, 515/281-8591.

Each individual certified must be listed on the license application form. An owner-operator must list himself or herself. Other companies should list each individual who is employed by the company responsible for applying pesticides. In addition, show the classifications of pesticide application each individual will be doing.

The Iowa Pesticide Act requires that at least one individual from a company take and pass a written certification examination before the Secretary of Agriculture issues a pesticide company license.

License Renewal

Application to renew a pesticide applicator's license will automatically be sent to each pesticide company licensed the previous calendar year. This is handled by computer and will be sent like an annual billing.

Fees. Whether using the new form or the renewal form to apply for a pesticide applicator's license, attach a check made out to the Iowa Department of Agriculture in the amount of $25 to cover the annual pesticide applicator license fee.

Public pesticide applicators are exempt from payment of the annual license fee.

Proof of Financial Responsibility

In addition to buying an annual license, an applicant for a pesticide company license must file with the Iowa Department of Agriculture proof of financial responsibility either in the form of a certificate of liability insurance or a surety bond. The minimum amount of liability coverage acceptable is $50,000 each for property damage and public liability insurance, including loss for damage arising out of the actual use of any pesticide (chemical coverage). The proof of financial responsibility may be submitted with the application for a pesticide applicator's license or requested from the insuring or bonding company who in turn would supply the Department of Agriculture with a certificate of insurance or surety bond.

Nonresident Pesticide Applicators

Any nonresident (person or company) applying for a pesticide applicator's license in this state shall file a written power-of-attorney designating the Secretary of State as the agent of the nonresident upon whom service of process may be made in the case of any suit against the nonresident applicator. The written power-of-attorney must be filed with the Iowa Secretary of State before issuance of the pesticide application license to the nonresident.

Recordkeeping

The Iowa Pesticide Act requires that commercial pesticide applicators maintain records of each pesticide applied for three years after application. These records must include, but are not limited to:

- the name of the applicator
- the name of the landowner or customer;
- an adequate and precise description of the land area involved in outdoor treatment and the exact address or location of any building(s) treated;
- the date of application;
- the pesticide product used;
- the quantity of pesticide used and the rate of application;
- the direction and estimated velocity of the wind at the time of application to any outdoor area.

In addition to meeting the State of Iowa requirements of keeping application records for three years, keeping records of pesticide use is a wise precaution. Records can establish proof of proper use in damage suits, and can also provide information to trace residue or damage problems resulting in liability cases.

Records can also help pesticide applicators save money. They allow applicators to compare the results obtained from different pesticides. Applicators can improve their pest control practices and efficiency, too. Records help to reduce pesticide misuse. Careful records from year to year help guide applicators in buying only the amount of pesticides they will need. In this way, applicators can reduce winter carryover.

The more information on record, the more useful the records will be. Applicators should carry a notebook with them in the field. All the

information is right there with them, and they need not try to memorize all the necessary items. They should fill in the recommended form to be sure they get all the necessary data every time. On page 8 is a suggested spray record sheet for pesticide applicators.

Pesticide dealers licensed to sell restricted use pesticides must keep a record of every sale of restricted use pesticide. While there is no specific record keeping procedure, the most acceptable method is to list on the invoice for restricted pesticides the certification number of the applicators who purchased it.

Iowa Bee Rule

In June 1980, the Bee Rule took effect in Iowa. Honey bees are beneficial insects and an important aspect of Iowa's agriculture. The ruling establishes cooperation between pesticide applicators and beekeepers to prevent unnecessary bee kills.

Pesticide applicators must contact the County ASCS (Agricultural Stabilization and Conservation Service) to obtain all apiary locations within a two mile radius of the field being sprayed. The applicator will be given the names and addresses of beekeepers who have hives in the area.

The beekeepers must be notified by the applicator not less than 24 hours and not more than 72 hours prior to the time of an application of pesticides toxic to bees. If the beekeeper cannot be reached, call the Office of the State Apiarist 515/281-5736.

In case of emergency, call 515/281-3561. This number is to be used **only** after office hours or on weekends.

Iowa Department of Water, Air, and Waste Management

The department was established by the 69th General Assembly, 1981, and merged in 1983 with the Department of Environmental Quality, Natural Resources Council, and certain water programs of the State Health Department. The central office is in Des Moines, and six regional offices are located in Manchester, Mason City, Spencer, Atlantic, Des Moines, and Washington.

The department's responsibilities include monitoring the quality of groundwater and surface water, and permitting and inspecting water supply facilities and wastewater treatment plants. The department also monitors air quality, establishes standards, and controls the emission of air pollutants. In addition, the agency enforces state laws prohibiting open dumping and regulates the construction and operation of sanitary landfills. Finally, the department ensures the proper handling of hazardous wastes and responds to spills of chemicals. Information on disposal may be obtained by calling 515/281-8690. Spills must be reported within six hours by calling a 24-hour number 515/281-8694.

Suggested Spray Record Sheet

Licensee _____ Address _____ Phone _____

Customer _____ Address _____ Phone _____

Crop or other target treated _____

Number of acres or other units treated _____

Pest(s) controlled and developmental state _____

Severity of infestation, infection, etc. _____

Stage of crop growth (if applicable) _____

Date and time pesticide was applied _____

Soil condition (if applicable) _____
(wet, dry, cloddy, etc.)

Temperature _____ Humidity _____ Cloud cover _____ Wind direction and speed _____

Pesticide used _____ EPA Reg. No. _____
(name of product and formulation)

How pesticide mixed (if applicable) _____
(active ingredient per gallon, etc.)

Application equipment used _____

Pesticide application rate _____
(active ingredient per acre or other unit treated)

Total amount of pesticide applied _____
(gallons or pounds per acre or other unit treated)

Specific location of application (if applicable): Twp _____ Sect. _____ ¼ Sect. _____

Map of treated area (if applicable)

Pests

The first step in solving any problem is to understand what is causing it. In this case, the first step is to recognize the pests that must be controlled.

We favor certain plants and animals that provide us food and fiber. But we also provide good growing conditions for other plants and animals that harm them and us. These living things that compete with us for food and fiber, or attack us directly, are pests. The living plant or animal a pest depends on for survival is called the host.

Pests can be put into five main groups: insects (plus mites, ticks, and spiders), weeds, plant disease agents, mollusks, and vertebrates.

Most applicators know most of the pests they see on the job. But sometimes unfamiliar pests may appear. Identification aids, publications, and pictures are available, but the best thing to do is to contact local experts. Ask the Cooperative Extension Service or a competent consultant for help.

Insects

Insects thrive in more environments than any other group of animals. They live not only on the earth's surface but within the soil and in water. They are at home in deserts, rain forests, hot springs, snow fields, and dark caves. They eat the choicest foods on our table. They can even eat the table.

This large number of insects can be divided into three categories according to their importance to us:

• Species of minor importance include 99 percent of all species. They are food for birds, fish, mammals, reptiles, amphibians, and other insects. Some have aesthetic value.

• Beneficial insects are a small but important group that includes 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 bumble bees and honey bees, some moths, butterflies, and beetles. Without pollinators, many kinds of plants could not grow or produce food. Honey from honey bees is food for humans. Secretions from some insects are made into dyes and paints. Silk comes from the cocoons of silkworms.

• Destructive insects are those that usually come to mind when insects are mentioned; this category actually 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.

Recognizing Common Features of Insects

All adult insects have two things in common—they have six jointed legs and three body regions. But how do you tell one insect from another? The most important parts to look at are wings and mouthparts. Some insects have no wings. Others have two or four. The wings vary in shape, size, thickness, and structure. Insects with chewing mouthparts have toothed jaws that bite and tear the food. Insects with piercing-sucking mouthparts have long beaks that they force into a plant or animal to suck out fluids or blood.

Almost all insects change in shape, form, and size during their lives. This change is called metamorphosis. It may be a gradual change, involving little more than an increase in size or it may be a very dramatic one in which the adult bears little if any resemblance to the young.

In simple metamorphosis the insect that hatches from the egg looks like a miniature copy of the adult. The juvenile forms are called nymphs. These nymphs, which have no wings, go through several growing stages before changing into winged adults. Examples are cockroaches, lice, termites, aphids, and scales.

Other insects undergo complete metamorphosis. They go through four stages. The larva hatches from an egg. It is a worm, caterpillar, grub, or maggot. This is the stage in which these insects grow the most and do the most damage. When full grown, the larva changes into a pupa. During this stage it changes to the adult. The adult stage usually has wings. Examples are the beetles, butterflies, flies, mosquitoes, fleas, bees, and ants.

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.

Weeds

A weed is simply a plant out of place. Weeds are a problem for several reasons. They reduce crop yields, increase costs of production, and reduce quality of crop and livestock products. Some cause skin irritation and hay fever or are poisonous to humans, livestock, and wildlife. They spoil the beauty of turf and landscape plants.

Recognizing Common Features of Weeds

Controlling weeds requires knowledge of how they grow. One important feature is the length of their life cycles.

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 may be grasslike (crabgrass and foxtail) or broadleaved (pigweed and cocklebur).

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

Winter annuals are plants that grow from seeds that sprout in the fall. They grow, mature, produce seed, and die before summer. Examples are 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 the first year. In the second year they mature, produce seed, and die. Examples are mullein, burdock, and bull thistle.

Perennials

Plants that live more than two years and may live indefinitely are perennials. During the winter, many lose their foliage and the stems of others may die back to the ground. Some grow from seed. Others produce tubers, bulbs, rhizomes (below-ground rootlike stems) or stolons (above-ground stems that produce roots). Examples include johnsongrass, field bindweed, dandelion, and plantain.

Creeping perennials produce seeds but also produce rhizomes and stolons. Examples are Bermuda grass, johnsongrass, and field bindweed.

Simple perennials normally reproduce by seeds. But root pieces may produce new plants following mechanical injury during cultivation. Dandelions, plantain, trees, and shrubs are in this category.

Diseases

A plant disease is any harmful condition that makes a plant different from a normal plant in its appearance or function.

Recognizing Common Features of Plant Diseases

Plant diseases are divided into two groups based on their cause.

Abiotic Plant Diseases

These are caused by nonliving agents and cannot be passed from one plant to another. The causes can include such things as nutrient deficiency, extreme cold or heat, toxic chemicals (air pollutants, some pesticides, salts, too much fertilizer), mechanical injury, and lack of or too much water.

Biotic Plant Diseases

These are caused by microscopic living agents that live and feed on or in plants. They can be passed from one plant to another. The most common causes of parasitic diseases are fungi, bacteria, viruses, and nematodes. The less common microorganisms such as mycoplasms, rickettsia-like bacteria, spiroplasms, and viroids can also cause disease. A few seed-producing plants can cause plant diseases too.

Three things are required before a parasitic disease can develop: a susceptible host plant, a parasitic agent, and an environment favorable for parasite development.

Fungi are microscopic plants that lack chlorophyll; therefore, they cannot make their own food. There are more than 100,000 different kinds of fungi. Not all are harmful, and many are helpful to man. While fungi are microscopic, the fruiting structures of some are known as mushrooms and may become quite large. Most fungi reproduce by spores, which function about the same way seeds do. Fungi may attack a plant both above and below the soil surface.

Fungus diseases include apple scab, anthracnose of beans, smut in corn, and powdery mildew on landscape plants.

Bacteria are microscopic, one-celled plants. They usually reproduce by simply dividing in half. Each half becomes a fully developed bacterium. Bacteria can build up fast under ideal conditions. Some can divide every 30 minutes. Fire blight of pears, halo blight of beans, and bacterial leaf spot on peaches are examples of diseases caused by bacteria.

Viruses are so small that they cannot be seen with the unaided eye or even with an ordinary microscope. They are generally recognized by their effects on plants. Viruses easily overwinter in bulbs, roots, cuttings, and seeds. Many viruses are carried from plant to plant by insects, usually aphids or leafhoppers. Some viruses are transmitted when machines or people touch healthy plants after touching diseased plants. A few are transmitted in pollen. At least one virus is transmitted by a fungus. A few are transmitted by nematodes. Wheat streak mosaic, tobacco mosaic, and corn dwarf are examples of diseases caused by viruses.

Nematodes are small, usually microscopic, roundworms, commonly found in the soil. Many nematodes are harmless but others attack a wide variety of crops. Some species attack the above-ground plant parts, such as leaves, stems, and seeds, but most species feed on or in the roots. They may feed on one root location or they may move through the roots. Nematodes usually do not kill plants, but reduce growth and plant health. They may weaken the plant and make it susceptible to other disease agents.

All nematodes that are parasites on plants have a hollow feeding spear. They use it to puncture plant cells and feed on the cell contents. Nematodes may develop and feed either inside or outside of a plant. Their life cycle includes an egg, four larval stages, and an adult. Most larvae look like adults, but are smaller. The females of some, such as root knot and cyst nematodes, become fixed in the plant tissue. Their bodies become swollen and rounded. The root knot nematode deposits its eggs in a mass outside of its body. The cyst nematode keeps part of its eggs inside its body after death. They may survive there for many years.

Development of Plant Diseases

A parasitic disease depends on the life 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. This step is called inoculation. If conditions are favorable for disease development, the parasite will infect or penetrate the plant. When the parasite begins to live on host tissue, the tissue is injured or killed resulting in a symptom. At this stage, the plant is diseased. Many parasites may live on a plant without harming it, therefore not causing disease.

A plant responds to parasites through overdevelopment, underdevelopment, or death of tissue. Overdevelopment of tissues includes such conditions as galls, swellings, and leaf curls. Underdevelopment of tissue is seen in stunting, lack of chlorophyll, and incomplete development of organs. Death of tissue is evidenced by blights, leaf spots, wilting, or cankers.

Identifying Plant Diseases

It is not always possible to tell one plant disease from another just by looking at the plant itself. Because many disease agents cause similar injury, other evidence is needed. Identifying the cause is a better way to identify the disease. A microscope or magnifying lens is usually necessary to see such things as fungus spores, nematodes or their eggs, and bacteria. More training is needed to find and identify the cause of a disease than is needed to observe the effects.

Mollusks—Snails and Slugs

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.

Land snails and slugs are soft-bodied and have two pairs of antennaelike 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 rasplike tongue. They may eat entire seedlings. As they move, snails and slugs leave a slimelike mucous trail that 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.

Vertebrate Pests

All vertebrate animals have jointed backbones: mammals, birds, reptiles, amphibians, and fish. Most vertebrate animals are not pests but 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 that prey on livestock and poultry cause costly losses to ranchers each year. Large numbers of roosting birds can soil populated areas.

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.

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.

Pest Control

An orderly process of decision making must be followed in order to plan and carry out a pest control program. The principal elements of any plan are:

- 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 the applicator and the environment.
- Know the correct use of the methods.
- Know local, state, and federal regulations that apply to the situation.

Integrated Pest Management

Integrated Pest Management is a philosophy of pest control where all available strategies are utilized and optimum yields are realized with the least amount of environmental impact. Integrated Pest Management is a program that emphasizes not only pest control but pest prevention whenever possible. In an Integrated Pest Management program, the grower limits chances of a pest problem by such tactics as timing of tillage, selecting resistant crops, using pesticides judiciously, and other integrated concepts. In IPM, several major strategies work together to manage insects, diseases, nematodes, and weeds while complementing a sound fertility and crop management program. These major strategies are crop management and cultural practices, field scouting, economic thresholds, and an integration of chemical and biological control.

Crop management and cultural practices disrupt the pest environment. These methods include selecting resistant crop varieties, timing of planting and harvesting, tillage practices, water and fertilizer management, and crop rotation.

Field scouting is simply monitoring the crop and pest conditions on a regular basis throughout the year. By scouting the field on a regular basis, the grower can predict if pest control measures are justified.

Under an IPM system, management decisions to prevent loss are based on:

- economic threshold levels,
- economic injury levels, and
- integrated control methods.

Economic threshold level refers to the condition where the number of pests present will economically justify a treatment program to prevent significant loss.

Economic injury level refers to the point at which pests will cause economic damage to crops.

In a good IPM program, chemical control is as important as non-chemical controls such as biological control, cultural control, and so on. Management strategies are employed to encourage the maintenance of biological control agents. Often, IPM is confused with biological control. Although there are times in an IPM program when pesticides are not necessary, the purpose of IPM is not to replace pesticides with biological control but rather to use pesticides when justified and when they complement the total crop management program.

Basically, IPM is a risk reducing program. It takes the guesswork out of managing pests. The bottom line is that IPM will save the grower time, money, and energy.

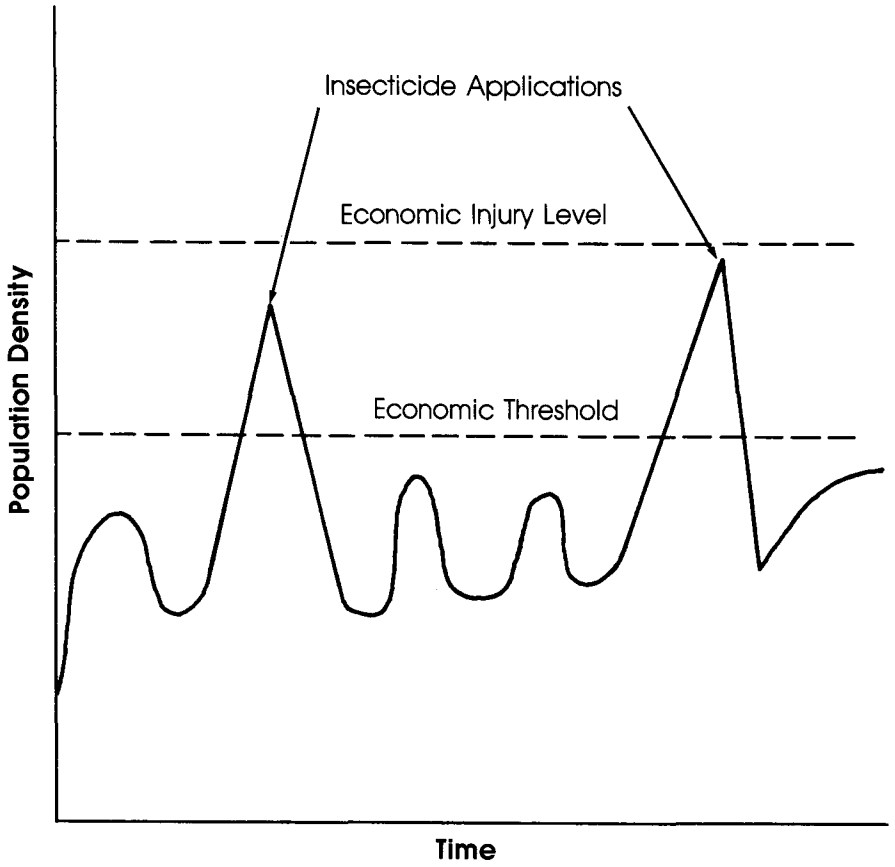


Figure 1. Economic thresholds and injury levels.

The implementation of an IPM pest management practice can result in the judicious use of pesticides and fertilizers in a sound management program. Products are employed only with the knowledge there is an economic return and their use is based on the latest research data. By using pesticides and fertilizers to the best of our knowledge, we limit the amount of agricultural chemicals applied to cropland in Iowa and further reduce the risk of transport of these products to waters.

Pest Control Methods

Many pest control methods have been known and used for years to reduce pest populations. But some methods, what we call them, and the way we put them together are new. Here are the most important pest control methods:

Resistant Varieties

Some crops, animals, and woods resist pests better than others. Some crops and woods are immune to certain pests. By using resistant types, we make the environment less favorable for pests. This makes it easier to keep pests below harmful levels. 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 naturally occurring enemies of the pest: parasites, predators, and disease agents (pathogens). Most biological control agents occur naturally. Releasing more of a pest's enemies into the target area can supplement this natural control and is called augmented biological control. Biological control also includes methods by which the pest is biologically altered, as in the production of sterile males and the use of pheromones and juvenile hormones.

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 may 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.

Sanitation practices and certain structural modifications help to suppress some pests by removing sources of food and shelter. Other forms of sanitation that 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.

Mechanical-Physical Control

Devices and machines used to directly control pests are called mechanical controls. Some physical methods and examples of their use are:

- traps for rats, mice, and birds,
- barriers to protect against termites, rodents, and flies,
- light to attract or repel pests,
- sound to kill, attract, or repel pests,
- heat to kill pests,
- cold to kill pests,
- radiation to sterilize or kill pests,
- electrocution to kill pests, and
- handpicking to eliminate pests.

Legal Control

Legal controls result from federal, state, or local laws and regulations. They include quarantines, inspections, embargoes, and compulsory crop or product destruction.

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 that 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.

Putting It All Together

The combination of methods selected depends on the kind and amount of control needed. The three main types of controls are prevention, suppression, and eradication.

Prevention involves keeping a pest from becoming a problem and includes the use of sanitation, treated seed, pesticides, cultural controls, quarantines, seed certification, and resistant plants, animals, or wood.

Suppression involves reducing pest numbers or damage to an acceptable level and includes sanitation, pesticides, cultural controls, and resistant plants, animals, or wood.

Eradication involves destroying or removing a pest completely from a crop, an area, or a geographic region.

Integrated Pest Management at Iowa State

Extension's Integrated Pest Management (IPM) program at Iowa State University is investigating the various factors that affect pest populations. The IPM project began in 1979 with about 2,800 acres of corn, soy-

beans, and alfalfa being monitored in the Spencer, Des Moines, and Davenport extension areas. By 1983, the project was expanded to more than 20,000 acres located in each of the 12 extension areas. College students who serve as interns are employed each summer to take the field counts of pest populations.

The IPM program also has established a number of services available to growers and agribusiness specialists for pest control. A statewide computer system, based in Ames, handles the data collected by IPM interns in the field throughout the state. The pest information collected in the monitored fields is used to form models for predicting pest populations in various crops, to determine economic thresholds, and to select control alternatives.

The information released by the IPM computer system is available to growers through Fonfacs. This is a recorded message available by calling 515/294-8354—not a toll-free number. Fonfacs is updated daily and gives information on pest levels and recommendations for treatment. IPM information is made available daily over live radio (WOI-AM) at 12:15 p.m. and through public television by the Agricultural Infodata Service. Several radio stations call Fonfacs and broadcast the message during farm broadcasts. Pest information is also available daily to personal computer users via the Iowa Crop Advisory Network (ICAN). Information on accessing this network can be obtained by contacting the IPM office, 103 Bessey Hall, Iowa State University, Ames, Iowa 50011, 515/294-8352.

Several publications related to IPM are available through Publications Distribution, ISU, Ames, Iowa 50011. The *Integrated Pest Management Decision Guide* (IPM-22) has information on scouting, pest identification, and control strategies as well as program printouts for the programmable calculator. The *Insect, Weed and Plant Disease Newsletter* is released weekly and offers information on statewide pests on crops, livestock, and ornamentals. A subscription ($15.00) is available through Publications Distribution.

Each year IPM also provides a number of scout training meetings across Iowa. Local county extension offices have dates and locations.

One goal of the IPM project is to encourage the development of IPM firms in Iowa. Services vary from scouting of rootworm beetles to a complete crop management package. Per acre costs range from $2.50 to $7.00 depending on the services. A list of crop consultants is available (IPM-24) from the local county extension office. Several co-ops also are offering service to their customers and provide limited scouting services for growers.

Integrated Pest Management will continue to increase in importance since economical crop production depends on sufficient pest control.

For more information about IPM programs and services contact:

Jerry DeWitt
103 Bessey Hall
Iowa State University
Ames, Iowa 50011
515/294-8352

Pesticides

After considering all available control methods, the decision may be that a pesticide is needed. Here are some things to know in order to choose the right pesticide and use it most effectively.

Pesticides are chemicals used to destroy, prevent, or control pests. They are also used to attract or repel pests and to regulate plant growth or remove or coat leaves.

Here are the types and uses of pesticides.

Insecticide controls insects and other related pests such as ticks and spiders.

Miticide controls mites.

Acaricide controls mites, ticks, and spiders.

Nematicide controls nematodes.

Fungicide controls fungi.

Bactericide controls bacteria.

Herbicide controls weeds.

Rodenticide controls rodents.

Avicide controls birds.

Piscicide controls fish.

Molluscicide controls mollusks, such as slugs and snails.

Predacide controls vertebrate pests.

Repellent keeps pests away.

Attractant lures pests.

Plant Growth Regulator stops, speeds up, or otherwise changes normal plant processes.

Defoliant removes unwanted plant growth without killing the whole plant immediately.

Desiccant dries up plant leaves and stems and insects.

Antitranspirant coats the leaves of plants to reduce unwanted water loss (transpiration).

The Nature of Pesticides

Pesticides can be grouped according to their chemical nature.

Inorganic Pesticides
These are made from minerals, most frequently arsenic, copper, boron, lead, mercury, sulfur, tin, and zinc. Examples: lead arsenate, Bordeaux mixture, and Paris green

Synthetic Organic Pesticides
These are man-made pesticides containing carbon, hydrogen, and one or more other elements such as chlorine, phosphorous, and nitrogen. Examples: 2,4-D, atrazine, captan, parathion, and malathion.

Plant-Derived Organic Pesticides
These are made from plants or plant parts. Examples: rotenone, red sqill, pyrethrins, strychnine, and nicotine.

Living Microorganisms
These are viruses, bacteria, and fungi produced by man. Examples: the bacterium *Bacillus thuringiensis* and the polyhedrosis virus.

How Pesticides Work

Pesticides also can be grouped according to what they do. Many synthetic organic pesticides work in more than one way. Read the label to find out what each pesticide will do.

Protectants applied to plants, animals, structures, and products to prevent entry or damage by a pest.

Sterilants make pests unable to reproduce.

Contacts kill pests simply by contacting them.

Stomach poisons kill when swallowed.

Systemics are taken into the blood of an animal or sap of a plant and kill the pest without harming the host.

Translocated herbicides kill plants by being absorbed by leaves, stems, or roots and moving throughout the plant.

Fumigants are gases that kill when they are inhaled or otherwise absorbed by the pest.

Anticoagulants prevent normal clotting of blood.

Selectives are more toxic to some kinds of plants or animals than to others.

Nonselectives are toxic to most plants or animals.

Pheromones affect pests by changing their behavior.

Using Pesticides

Terms that describe when and how to use pesticides are used in labeling. They also are found in leaflets and bulletins available at county or area extension offices or from specialists at Iowa State University. Knowing and understanding these terms will help you get the best results from pesticides with the least possible harm to you and the environment.

When To Use
Preemergence is used before crop or weeds emerge. The term may also refer to use after crops emerge or are established but before weeds emerge.

Preplant is used before the crop is planted.

Postemergence is used after the crop or weeds have emerged.

How To Use
Band application is to a strip over or along a crop row or on or around a structure.

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

Broadcast calls for uniform application to an entire, specific area.

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

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

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

Drench calls for saturating the soil with a pesticide or oral treatment of an animal with a liquid pesticide.

Foliar is application to the leaves of plants.

In-furrow calls for application to or in the furrow in which a plant is planted.

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

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

Sidedress is application along the side of a crop row.

Soil application is applied to the soil rather than to vegetation.

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

Soil injection is application beneath the soil surface.

Spot treatment means application to a small area.

Accuracy Is Important

The **rate** and **time** of application of pesticides are critical. Most pesticides work at very low rates. If too much is used it can harm or even kill the plant or animal you wish to protect. Pesticides work best when applied at specific times. Applying them before or after the correct time reduces or even eliminates their effectiveness.

Since all these chemicals work in small amounts, be careful to treat only the intended target. Avoid contaminating anything else as a result of drift or residue in application equipment or soil.

Factors Affecting Pesticide Activity

Soil Factors

Organic matter in soils limits pesticide activity. Soils with high organic matter content may need higher rates of pesticides for good pest control. Follow label instructions.

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

Climatic Factors

Soil moisture and rain affect the way pesticides work and how long pesticides stay on soil and plants. Pesticides work best with moderate soil moisture. Wetness may keep the pesticide from contacting the soil particles and rain causes soluble pesticides to leach down through the soil. Rain is good when preemergence pesticides are applied to the surface because it carries them down into the soil to the pests. But rain during or soon after over-the-top foliar applications is not good because it may wash pesticides off the leaves.

Humidity and temperature also affect the way pesticides work. Herbicides work best when plants are growing fast. High relative humidity and optimum temperatures usually cause this fast growth. High temperatures cause some soil pesticides to evaporate quickly. Low temperatures may slow down or stop the activity of some pesticides.

Light may break down some pesticides if they are left on the soil surface for a long time.

Pesticide Resistance

The ability of pests to resist poisoning must be considered 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 sensitive pests. Some pests avoid the pesticide while others are able to withstand its effects. Pests that are not destroyed pass along to their offspring the trait that allowed them to survive.

When one pesticide is used repeatedly in the same place, the pest population sometimes builds up its resistance. Some pests have become practically immune to poisoning by certain pesticides.

Not every pesticide failure is caused by pest resistance, however. There must be the correct pesticide, the correct dosage, and the correct application.

Plant Growth Regulators, Desiccants, Defoliants, and Antitranspirants

These change normal plant processes.

Plant Growth Regulators

All plant parts are made up of tiny cells that continually multiply and grow. Plant growth regulators speed up, slow down, or otherwise affect cell growth and reproduction. They are used to decrease preharvest drop, increase fruit firmness, reduce scald, delay water core (water soaked area around core of fruit), increase red color, thin fruit, and increase flowering. They reduce fruit cracking, promote uniform bearing of fruit, control plant height, prevent or delay sprouting of tubers, and promote dense growth of landscape plants. They also promote earlier flowering, prevent seed formation, induce branching, reduce suckering, hasten fruit maturity, increase seed yield, and control excessive growth.

Desiccants and Defoliants
These often are called harvest-aid chemicals, because they help the farmer harvest his crop. Both are used to get rid of leaves, stems, and weeds in such crops as cotton, soybeans, and potatoes.

Antitranspirants
By reducing water loss, they can prevent winter damage, maintain color in evergreens, protect against salt damage, help protect transplants, and prevent needle drop on Christmas trees.

Types of Formulations

Active ingredients are the chemicals in a pesticide product that do the work. Active ingredients can rarely be used in the form in which they were made. They usually must be changed or mixed with something else. Other ingredients may be added to make them convenient to handle and safe, easy, and accurate to apply. These are the inert ingredients. This mixture of active and inert ingredients is called a **pesticide formulation.** Some formulations are ready for use but others must be diluted with water or a petroleum solvent.

Following are the most common types of liquid and dry formulations, Cooperative Extension Service recommendations, and the labels and labeling may refer to the formulations as abbreviated.

Liquid Formulations

Emulsifiable Concentrates (EC or E)
This formulation can be mixed with water to form an emulsion. Each gallon of an EC usually contains 2 to 8 pounds of active ingredient. Diluted ECs usually need little agitation in the spray tank.

ECs can damage some crops, so these crops may require a different formulation of the active ingredient such as a wettable powder or a dust.

Solutions (S)
High Concentrates are special formulations that usually contain 8 or more pounds of active ingredient per gallon. They may contain only the active ingredient itself. Most are designed to be used as is or diluted with oil or petroleum solvents. They contain chemicals that allow them to spread and stick well. Ultra low volume (ULV) concentrate materials should be used without further dilution.

Low Concentrate formulations usually contain less than 2 pounds of active ingredient per gallon. Most are solutions in highly refined oils that need no further dilution. The label will give directions for use, as for controlling household and industrial pests, mothproofing, livestock sprays, or space sprays in barns.

Flowables (F or L)
Some active ingredients can be made only as a solid or, at best, a semisolid. These are finely ground and put into a liquid along with other substances that make the mixture form a suspension. They are **flowable solids.** Flowables can be mixed with water. They seldom clog spray nozzles and need only moderate agitation. Most of them handle as well as EC formulations.

Aerosols (A)
These are liquids that contain the active ingredient in solution in a solvent. More than one pesticide may be in these formulations. Most aerosol formulations have a low percentage of active ingredient. They are made for use only in fog- or mist-generating machines and are used in structures, greenhouses, and barns for insect control.

Liquified Gases
Some fumigants are gases that become liquid when placed under pressure. The pressure may be either high or low, depending on the product. Some nematicides, insecticides, fungicides, and rodenticides are formulated this way. These formulations are applied by injecting them directly into the soil, releasing them under tarps, or releasing them into a structure such as a grain storage elevator.

Some other active ingredients remain liquid in an ordinary container but turn into a gas or vapor when or after they are applied. These formulations do not require storage under pressure. They must be put into the soil or confined in a space before they turn to gas. Otherwise, they could be lost into the air.

Dry Formulations

Dusts (D)
Most dust formulations are ready for use on seeds, plants, or animals. They contain an active ingredient plus a very fine or powdered dry inert substance such as talc, clay, nut hulls, or volcanic ash.

The amount of active ingredient usually ranges from 1 to 10 percent.

All the ingredients are ground into fine, uniform particles. Inert ingredients are often added so the formulation will store and handle well. Some active ingredients are prepared as dusts because they are safer for crops in that form. Dusts always must be used dry. They can easily drift into nontarget areas.

Dust concentrates are available for further dilution with dry inert ingredients before they are ready to use.

Granules (G)
Granular formulations are dry. Most are made by applying a liquid formulation of the active ingredient to coarse particles (granules) of some porous materials such as clay, corn cobs, or walnut shells. Granule particles are much larger than dust particles. The pesticide is absorbed into the granule, or coats the outside of it, or both. Inert ingredients may be added to make the formulation handle well. The amount of active ingredient ranges from 2 to 40 percent. Granular formulations are safer to apply

than ECs or dusts. They are most often used as soil treatments, and may be applied either directly to the soil or over plants. They do not cling to plant foliage, but they may be trapped in the whorls of some plants. Granular formulations, like dusts, should always be used dry. Never mix them with water.

Wettable Powders (WP or W)
These are dry, finely ground pesticide formulations. They look like dusts. But unlike dust they are made to mix with water. Most wettable powders are much more concentrated than dusts. They contain 15 to 95 percent active ingredient—usually 50 percent or more. Wettable powders form a suspension rather than a true solution when added to water. Good agitation is needed in the spray tank to maintain the suspension. Good wettable powders spray well and do not clog nozzles. They are abrasive to pumps and nozzles. Most wettable powders are safer for use on plants than ECs are.

Soluble Powders (SP)
Soluble powders also are dry formulations. But when they are added to water, they form true solutions. Agitation in the spray tank may be needed to get them to dissolve but after that, no more agitation usually is needed. The amount of active ingredient in an SP is usually above 50 percent.

Baits (B)
A bait formulation is an edible or attractive substance mixed with a pesticide. The bait attracts pests and the pesticide kills them when they eat the formulation. Baits usually are used to control rodents and insect pests. They can be used in buildings or outdoors. The amount of active ingredient in most bait formulations is quite low, usually less than 5 percent.

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 against adding adjuvants.

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

Emulsifiers allow petroleum-based pesticides (ECs) 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 adhere to the treated surface for a longer period of time.

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 that 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 that are not compatible can result in 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), or 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 expertise. Be careful with do-it-yourself mixes that could cost time and money.

Labels and Labeling

Each time you buy a pesticide, you also receive instructions to tell you how to use it. Those instructions are the labeling.

The words labeling and label seem alike but they do not mean the same thing.

Labeling is all information from the company or its agent about the product, including such things as the label on the product, brochures, flyers, and information handed out by the dealer.

The label is the information printed on or attached to the container of pesticides. This label means many things. To the manufacturer, it is a "license to sell." To the state or federal government, it is a way to control the distribution, storage, sale, use, and disposal of the products. To the buyer or user, it is a main source of facts on how to use the product correctly and legally. It is a way to tell users about special safety measures needed.

Some labels are easy to understand; others are complicated. But all will tell how to use the product correctly.

Parts of the Label

Brand Name

The brand name is the one used in ads. The brand name shows up plainly on the front panel of the label and is the most identifiable name for the product.

Type of Formulation

Different types of pesticide formulations (such as liquids, wettable powders, and dusts) require different methods of handling. The label tells what type of formulation the package contains. The same pesticide may be available in more than one formulation.

Common Name

Many pesticides have complex chemical names. Some have been given a common name to make them easier to identify. For instance, carbaryl is the common name for 1-naphthyl N-methylcarbamate. A chemical made by more than one company will be sold under several brand names, but you may find the same common name or chemical name on all of them.

Ingredient Statement

Every pesticide label must list what is in the product, written so that you can see quickly what the active ingredients are. The amount of each active ingredient is given as a percentage by weight or as pounds per gallon of concentrate. It can be listed by either the chemical name or the common name. The inert ingredients need not be named, but the label must show what percent of the contents they include.

Net Contents

The net contents number tells how much is in the container. It can be expressed in gallons, pints, pounds, quarts, or other units of measure.

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.

Registration and Establishment Numbers

A registration number must be on every pesticide label showing that the product has been registered with the federal government. It usually is found on the front panel of the label and will be written as "EPA Registration No. 0000." The establishment number tells what factory made the chemical. This number does not have to be on the label, but will be somewhere on each container.

Signal Words and Symbols

To do their job, most pesticides must control the target pest. By their nature, they are toxic. Therefore, some may be hazardous to people. You can tell the toxicity of a product by reading the signal word and looking at the symbol on the label.

Signal Words

This tells approximately how toxic the material is to people. The signal

Table 1. Signal Words

Signal Warning	Toxicity	LD_{50} milligram/kilogram Oral	LD_{50} milligram/kilogram Dermal	Approximate Amount Needed to Kill the Average Person
Danger	Highly toxic	0-50	0-200	Taste to a teaspoonful
Warning	Moderately toxic	over 50 to 500	over 200 to 2,000	Teaspoonful to 2 tablespoons
Caution	Low toxicity or comparatively free from danger	over 500 to 5,000	over 2,000 to 20,000	One ounce to one pint
No signal word required	Relatively nontoxic	over 5,000	over 20,000	Over one pint

words that follow are set by law. Each manufacturer must use the correct one on every label.

Precautionary Statement Hazards to Humans (and Domestic Animals)
This section tells the ways in which the product may be poisonous to man and animals. It also tells of any special steps to take to avoid poisoning, such as the kind of protective equipment needed.

If the product is highly toxic, this section will inform physicians of the proper treatment for poisoning.

Environmental Hazards
Pesticides are useful tools but wrong or careless use could cause undesirable effects. To help avoid this, the label contains environmental precautions to read and follow. For example:

- "This product is highly toxic to bees exposed to direct treatment or to residues on crops."
- "Do not contaminate water when cleaning equipment or when disposing of wastes."
- "Do not apply where runoff is likely to occur."

Labels may contain broader warnings against harming birds, fish, and wildlife.

Physical and Chemical Hazards
This section tells of any special fire, explosion, or chemical hazards that the product may pose.

Statement of Practical Treatment
If swallowing or inhaling the product or getting it in the eyes or on the skin would be harmful, the label tells emergency first aid measures. It also tells what types of exposure require medical attention.

Figure 2. Sample specimen label.

PRECAUTIONARY STATEMENTS
HAZARDS TO HUMANS
(& DOMESTIC ANIMALS)
DANGER

ENVIRONMENTAL HAZARDS

PHYSICAL OR CHEMICAL HAZARDS

DIRECTIONS FOR USE

It is a violation of Federal law to use this product in a manner inconsistent with its labeling.

RE-ENTRY STATEMENT
(If Applicable)

CATEGORY OF APPLICATOR

STORAGE AND DISPOSAL

STORAGE

DISPOSAL

CROP:

RESTRICTED USE PESTICIDE

FOR RETAIL SALE TO AND APPLICATION ONLY BY CERTIFIED APPLICATORS OR PERSONS UNDER THEIR DIRECT SUPERVISION

PRODUCT NAME

ACTIVE INGREDIENT: _____ %
INERT INGREDIENTS: _____ %

TOTAL: 100.00 %

THIS PRODUCT CONTAINS LBS OF PER GALLON

KEEP OUT OF REACH OF CHILDREN

DANGER — POISON

STATEMENT OF PRACTICAL TREATMENT

IF SWALLOWED
IF INHALED
IF ON SKIN
IF IN EYES

SEE SIDE PANEL FOR ADDITIONAL PRECAUTIONARY STATEMENTS

MFG BY
TOWN, STATE
ESTABLISHMENT NO.
EPA REGISTRATION NO.

NET CONTENTS

CROP:

CROP:

CROP:

CROP:

CROP:

WARRANTY STATEMENT

The pesticide label is the most important information to take to the physician when someone has been poisoned.

Statement of Use Classification
Every pesticide label must show whether the contents are for general use or restricted use. EPA puts every product use into one of these two classes. The classification is based on the hazard of poisoning, the way the pesticide is used, and its effect on the environment.

General Use
If a pesticide will harm the applicator or the environment very little or not at all when used exactly as directed, it will be labeled a general use pesticide, and the label says: "General classification."

Restricted Use
A restricted use pesticide is one that could cause some human injury or environmental damage even when used as directed on the label. The label on these products says: "Restricted use pesticide for retail sale to and application only by certified applicators or persons under their direct supervision."

The restricted use statement must be at the top of the front panel of the label.

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

The use instructions tell:

- the pests the product is registered to control (Labels use common names for pests. Knowing these names will help to choose the proper pesticide and find control information);
- the crop, animal, or other item the product can be used on;
- whether the product is for general or restricted use;
- in what form the product should be applied;
- how much to use;
- where the material should be applied;
- when it should be applied.

Misuse Statement
This section reminds that it is a violation of federal law to use a product in a manner inconsistent with its labeling. Do not use a product on a crop or for a pest not listed on the label. Do not use it at more than the recommended rate. Before the product could be registered, EPA required the manufacturer to conduct many tests to be sure the label directions were correct. Following them exactly, will give the best results the product can give and avoid breaking the law.

Reentry Statement
If required for the product, this section tells how much time must pass before a pesticide-treated area is safe for entry by a person without protective clothing. Consult local authorities for special rules that may apply.

Category of Applicator
If required for the product, this section will limit use to certain categories of commercial applicators.

Storage and Disposal Directions
Every pesticide should be stored and disposed of correctly. This section will tell how to store and dispose of the product and empty containers.

Using Pesticides Safely

Protecting Humans

Pesticides are toxic. They can cause injury. The product's hazard—the danger that injury will occur to humans—depends on the toxicity of the active ingredient plus the exposure to the product during use.

How Pesticides Enter the Body

Pesticides may enter the human body through the skin, the mouth, the lungs, and the eyes. Even where the chemical is not absorbed by the body, certain pesticides may cause significant injury to skin and eye tissue.

Children under 10 are the victims of at least half of the accidental pesticide deaths in this country. If pesticides were always cared for correctly, children would never touch them.

Many accidental pesticide deaths are caused by eating or drinking the product. But some mixers, loaders, and applicators die or are injured when they breathe a pesticide vapor or get a pesticide on their skin. Repeated exposure to small amounts of some pesticides can cause sudden severe illness.

Most pesticides can enter the body through the skin. More may enter the body this way than through accidental swallowing or inhaling while working. With some pesticides, skin contact alone can cause death.

To help prevent **all** accidents with pesticides:

- Use and store pesticides away from children and other untrained persons.
- Take care to follow directions. Products for restricted use need special care. The label is the guide.

Dermal Exposure

Absorption through the skin is the most common route of poisoning of agricultural workers. Absorption may occur as the result of a splash, spill, or drift when mixing, loading, applying, or disposing of pesticides. It may also result from exposure to large amounts of residue on a crop or when cleaning or repairing contaminated equipment.

The degree of dermal absorption hazard depends on the dermal toxicity of the pesticide, the extent of the exposure, the way the pesticide is formulated, and the site of contamination. In general, wettable powders, dusts, and granular pesticides are not as readily absorbed through the skin and other body tissues as are the liquid formulations such as the emulsifiable concentrates. Certain areas of the body, such as the scrotum, absorb pesticides very thoroughly and rapidly. Don't take chances. If a pesticide is splashed or spilled, wash immediately. It is also important to wash hands thoroughly before smoking, eating, or using the bathroom.

Oral Exposure

If a pesticide is swallowed, it may result in serious illness, severe injury, or even death. Pesticides may be consumed by accident, through carelessness, or they may be consumed intentionally. The most frequent cases of accidental oral exposure occur where pesticides have been taken from the original labeled container and put into an unlabeled bottle or food container.

Poisoning as a result of oral exposure to pesticides is almost always due to inexcusable carelessness. Follow these rules:

- Always store a pesticide in its original labeled container.
- Never use the mouth to clear a spray line or nozzle or to begin siphoning a pesticide.
- Never eat, drink, or smoke until after leaving the work area and washing thoroughly.

Respiratory Exposure

Respiratory exposure is particularly hazardous because pesticides can be rapidly absorbed by the lungs. Vapors and extremely fine particles pose the most serious risks. In addition, pesticides can be inhaled in sufficient amount to cause serious damage to nose, throat, and lung tissue.

The risk of poisoning is generally low when dilute sprays are applied with conventional application equipment, due primarily to the relatively large droplet sizes produced. When low-volume equipment is being used to apply concentrated material, the risk is increased substantially because of the smaller droplets produced. There is significant risk when mixing and loading dust or powder formulations. Application in confined spaces (e.g. during treatment of stored grain) is particularly hazardous. Protection from respiratory exposure is provided by gas masks and other respiratory devices.

Eye Exposure

The tissues of the eye are particularly absorbent. Besides the potential for chemical injury to the eye itself, some pesticides may be absorbed in sufficient amounts through the eye to result in serious or even fatal illness. Eye protection is needed when measuring or mixing pesticide concentrates and when applying highly or moderately toxic materials. Protective shields or goggles should also be used whenever there is a chance that sprays or dusts may come into contact with the eyes. These pieces of protective equipment should be kept available and clean at all times.

It should now be obvious that pesticides can enter the body in solid, liquid, or gaseous form. It is particularly important to remember that highly concentrated and highly toxic chemicals, especially liquids

and gases, present the greatest danger. If not removed immediately, most liquid concentrates can readily penetrate the unbroken skin and cause sickness. The longer a pesticide remains on skin or in the eyes, or the longer it is inhaled, the greater the risk that serious damage will occur.

Toxicity of Pesticides
Knowing the toxicity of a pesticide means knowing how poisonous it is. The toxicity of a pesticide must be measured in more than one way. Many pesticides are dangerous after one large dose. Some pesticides, however, are dangerous after small, repeated doses.

Measuring Pesticide Toxicity
Finding the toxicity of pesticides to humans is not easy. Obviously humans cannot be test animals. Other animals, usually rats, are used. However, just because a pesticide is very poisonous to rats does not necessarily mean it is also very poisonous to dogs, cows, people, or wildlife. Likewise, a pesticide that is relatively nontoxic to rats is not always safe to other animals. Toxicity studies are only guidelines. They are used to estimate how poisonous a pesticide is compared to another pesticide.

Acute toxicity is how poisonous a pesticide is to an animal (or human) after a single exposure. A pesticide with a high acute toxicity is deadly if even a very small amount is absorbed. Usually poisonous comparisons of pesticides are on the basis of acute toxicity, which is also the basis for the warning statements on the label. Acute toxicity may be measured as acute oral toxicity, acute dermal toxicity, and acute inhalation toxicity.

LD_{50} is a standard toxicological term that means single lethal dose (deadly amount) for 50 percent of a population of test animals, usually rats, mice, or rabbits. LD_{50} values are measured from 0 up and are given as a single oral dose, a single dermal dose, or both. The lower the LD_{50} value, the more toxic the pesticide. Most LD_{50} values are given on a basis of milligrams of pesticide per kilogram of body weight of test animal. However, most people cannot readily relate to the metric units of weight, milligram and kilogram, and LD_{50} values based on ounces of pesticide per 100 pounds of test animal would be more meaningful. Therefore, in order to convert LD_{50} values given in milligrams per kilogram to values given in ounces per 100 pounds, the value given in milligrams per kilogram should be divided by 625.

For example, malathion has an oral LD_{50} of 1375. This means that if 1375 milligrams of technical or concentrate malathion per kilogram of body weight were fed to each animal of a test population, approximately 50 percent of the animals would be killed as a result. Dividing the 1375 figure given in milligrams per kilogram by 625 results in an LD_{50} value in ounces per 100 pounds; $1375 \div 625 = 2.2$. Therefore, the probable lethal oral dose of technical malathion for a 200-pound human would be 2 times 2.2 or 4.4 ounces. The word "probable" is stressed because toxicological data obtained from specific animal studies do not necessarily apply to humans or other species of animals.

Acute inhalation toxicity is measured by LC_{50}. LC means "lethal concentration." "Concentration" is used instead of "dose" because the amount of pesticide inhaled from air is being measured. LC_{50} values are measured in milligrams per liter. Liters are metric units of volume similar to a quart. The lower the LC_{50} value, the more poisonous the pesticide.

Chronic toxicity is how poisonous a pesticide is to an animal (or human) after small, repeated doses over a period of time. It is possible to be poisoned without ever getting a large dose of pesticide. Chronic toxicity is measured as chronic oral toxicity, chronic dermal toxicity, and chronic inhalation toxicity. Chronic toxicity is very important because some pesticides can remain in the body for a long time. If exposed often to these pesticides, they may remain in the body and build up.

There is no standard measure like LD_{50} for chronic toxicity studies. Often, the length of the experiment in days, months, or years, and the amount of each dose, is stated. For example, a study of chronic oral toxicity might appear as follows: "8 milligrams of pesticide were fed to rats daily for two years. No symptoms of poisoning appeared."

The chronic toxicity of organophosphate and carbamate pesticides is measured by cholinesterase levels in the blood. A low level of cholinesterase means danger. If an individual's cholinesterase level is abnormally low, that person should stay away from organophosphates and carbamates until the level is normal again.

Most pesticides can cause severe illness, or even death, if misused. But every registered pesticide can be used safely with proper care.

Symptoms of Pesticide Poisoning
It is important to know what kinds of sickness are caused by the pesticides used, as well as the conditions under which each one may cause illness.

Both symptoms and signs serve as clues to pesticide poisoning. Feelings that only the person who has been poisoned can notice—such as nausea or headache—are symptoms. Conditions such as vomiting that also can be noticed by someone else are signs. Know what personal symptoms might mean, and what signs to look for in co-workers and others who may have been exposed.

All pesticides in the same chemical group cause the same kind of sickness. This sickness may be mild or severe, depending on the pesticide and the amount absorbed. But the pattern of illness caused by one type of pesticide is always the same. Having some of the signs and symptoms does not always indicate poisoning since other illnesses may cause similar signs and symptoms; headache and a feeling of being unwell, for example. It is the pattern of symptoms that makes it possible to tell one kind of sickness from another.

Get medical advice quickly if unusual or unexplained symptoms appear at work or later the same day. A person who may have been poisoned should not be left alone. Do not let anyone get dangerously sick before calling a physician or going to a hospital. It is better to be too cautious than too late. Take the container (or the label) of the pesticide to the physician.

Synthetic Organic Pesticides
Organophosphates. These pesticides injure the nervous system. The signs and symptoms go through stages. They normally occur in this order:

- Mild Poisoning: fatigue, headache, dizziness, blurred vision, too much sweating and salivation, nausea and vomiting, and stomach cramps or diarrhea.
- Moderate Poisoning: unable to walk, weakness, chest discomfort, muscle twitches, constriction of pupil of the eye, and earlier symptoms become more severe.
- Severe Poisoning: unconsciousness, severe constriction of the pupil of eye, muscle twitches, secretions from mouth and nose, breathing difficulty, and death if not treated.

Illness may be delayed a few hours. But if signs or symptoms start more than 12 hours after exposure to the pesticide, it is probably some other illness. Check with a physician to be sure.

Carbamates. The only carbamates likely to make you ill on the job act almost like organophosphates, producing the same signs and symptoms. But the injury they cause can be corrected more easily by a physician. For this reason, most carbamates are safer than organophosphates. The label will warn you of the danger.

Nitrophenols and Pentachlorophenol. The signs and symptoms of skin exposure include redness, burning, and blisters. The signs and symptoms of poisoning include: headache, nausea, gastric distress, restlessness, hot feeling, flushed skin, sweating, deep and fast breathing, fast beating of the heart, fever, ashen color, collapse, and coma.

Severe poisoning usually runs a rapid course. One usually dies or is almost well within 24 to 48 hours.

Fumigants and Solvents. Too much exposure to these compounds may make a person seem drunk. Repeated exposure to the fumigant methyl bromide has caused permanent internal injury without early signs or symptoms of poisoning. It is possible to absorb a fatal dose before symptoms appear.

Inorganic Pesticides
Large single doses of most inorganic pesticides cause vomiting and stomach pain. The signs and symptoms depend on the mineral from which the pesticide is made, but in nearly all cases the illness is long lasting.

Plant-derived Pesticides. Some plant-derived pesticides are very toxic. Technical pyrethrum may cause allergic reactions. Some rotenone dusts irritate the respiratory tract. Nicotine is a fast-acting nerve poison about as dangerous as parathion. Other plant-derived pesticides are strychnine and red squill.

First Aid Procedures for Pesticide Poisoning
Read the directions in the "Statement of Practical Treatment" on each pesticide label. These instructions can save your life and the lives of your employees.

If you get a pesticide on your skin:
Remove the pesticide as quickly as possible. Remove all contaminated clothing. Prompt washing may prevent sickness even when the spill is very large. Do not forget hair and fingernails. Water-wettable powders or suspensions are easy to remove with plain water. So are most emulsifiable concentrates and emulsions. Solutions of pesticides in petroleum oil or other solvents are harder to remove without soap or detergent. Detergents work better. Washrooms and emergency field washing facilities should have detergents rather than plain soap.

If you inhale a pesticide:
Get to fresh air right away.

If you splash a pesticide into your mouth and swallow it:
Rinse your mouth with plenty of water. Go or be taken to a physician immediately. It is sometimes dangerous to cause vomiting; follow label directions.

Preventive Medicine and Pesticide Poisoning
Organophosphate pesticides are involved in more cases of occupational poisoning and death than any other single group of pesticide. Therefore, pesticide applicators using carbamate and organophosphate pesticides on a regular basis should consider having their blood tested to find their normal or base level of a chemical called cholinesterase. This chemical is necessary for the nervous system, and without it, the poison victim will die. Both carbamate and organophosphate pesticides attack this chemical in the blood and make it useless.

Once a pesticide applicator's base level of cholinesterase has been determined by a doctor, a simple blood test will show if there has been overexposure to either an organophosphate or carbamate pesticide and if further contact with these pesticides should be avoided until the cholinesterase level has returned to normal. In severe cases, antidotes must be given. Pesticide applicators working with highly toxic carbamate and organophosphate pesticides should have their cholinesterase levels tested at regular intervals throughout the spray season.

Medical Antidotes
By law, highly toxic pesticides must have instructions for the physician on the label in case of a pesticide poisoning. Such instructions will include information on medical antidotes if such information is available. Remember that medical antidotes can be very dangerous if misused. They should never be used as a preventive treatment and should be prescribed and given only by a qualified physician.

In cases where instructions for the physician are not given on the pesticide label, a poison control center or poison treatment center should be contacted.

Universal Antidotes
The best first aid is to dilute the poison as quickly as possible and to neutralize the acid or alkali causing the burns. It is very important that the victim get to a hospital without delay. The following are some universal antidotes for pesticide poisoning:

• For acids or alkali: give patient water or preferably milk. One to two cups for victims under 5 years of age, up to a quart for patients over 5 years of age. Milk is better than water because it dilutes and helps neutralize the poison. Water only dilutes the poison.
• For acids only: If sure the poison is an acid, give the patient milk of magnesia (one tablespoon to one cup of water), baking soda, or chalk in water.
• For alkali only: If sure the poison is an alkali, give the patient lemon juice or vinegar.

Universal Sponge
Universal sponges should be used to absorb excess poisons only after first aid suggestions for the corrosive or noncorrosive poisons are followed.

Activated charcoal absorbs many poisons at a high rate. Mix it with water into a thick soup for the victim to drink. Activated charcoal is found in aquarium filters or is available from a drug store. Grosafe is a commercial preparation of activated charcoal sold for use on pesticide spills or overdoses on crops and soil. In a poisoning emergency, this product may be substituted for a pharmaceutical grade of activated charcoal and fed to the victim.

A homemade universal sponge for poison is a mixture of four tablespoons of toast (burnt black), two tablespoons of strong tea (instant ice tea mix will do), and two tablespoons of milk of magnesia. This is used to absorb and neutralize most poisons.

First Aid Kit for Field and On-the-Job Use
A well-equipped, readily available first aid kit can be important in a pesticide emergency. Make up a kit from a lunch pail, tool box, or a sturdy wooden box. It should have a tight-fitting cover with a latch so that it will not come open or allow pesticides to leak inside. Label it clearly with paint or waterproof marker. A first aid kit for field and on-the-job use should include:

• A small plastic bottle of a common detergent. It is used to quickly wash pesticides off the skin.
• A small plastic container of salt. Salt is used with water to induce vomiting or to aid a person in shock.
• A box or plastic container of baking soda or a bottle of milk of magnesia. Mix with water to neutralize acidic chemicals that have been swallowed.
• A plastic bottle of lemon juice or vinegar to be used with water to neutralize basic or alkali chemicals that have been swallowed.
• A small package or bag of activated charcoal. Mixed with water and swallowed, activated charcoal acts as an absorber of all pesticides.
• A shaped plastic airway for mouth-to-mouth resuscitation.
• A thermos or plastic bottle (at least one pint capacity) of clean water. If there is no clean water in an emergency, use any pond or stream water available.
• Simple bandaids, bandages, and tape. All cuts and scrapes should be covered to prevent pesticide from easily entering the body.
• Several dimes should always be taped to the inside cover of the first aid kit for emergency phone calls.
• A small, plastic empty jar with a tight-fitting lid is useful as a drinking glass for the victim to induce vomiting or for feeding activated charcoal. It can also be used for collecting vomitus to take to the doctor.

Iowa Poison Information Centers
Iowa has five Poison Control Centers that anyone can call at any hour for information regarding proper treatment of pesticide poisoning.

Des Moines
515/283-6212
Iowa Methodist Medical Center
(Blank Memorial Hospital)
1200 Pleasant Street
Des Moines 50308

Dubuque
319/589-9099
Mercy Medical Center
Mercy Drive
Dubuque 52001

Fort Dodge
515/573-3101 (x-5757)
Trinity Regional Hospital
Poison Information Center
Kenyon Road
Fort Dodge 50501

Iowa City
800/272-6477
800/272-6103
University of Iowa Hospital
Poison Information Center
Iowa City 52240

Waterloo
319/235-3893
Allen Memorial Hospital
1825 Logan Avenue
Waterloo 50703

Protective Clothing

Body Covering. When handling pesticides, wear at least a long-sleeved shirt and long-legged trousers, or a coverall type garment. They should be made of closely woven fabric. When handling pesticide concentrates or very toxic materials, wear a liquid-proof raincoat or apron. Wear trousers outside of the boots to keep pesticides from getting inside.

Gloves. Generally, when handling concentrated or highly toxic pesticides, wear liquid-proof neoprene gloves. However, some fumigants are readily absorbed by neoprene. The label will tell what kind of gloves to use. They should be long enough to protect the wrist. Gloves should not be lined with a fabric. The lining is hard to clean if a chemical gets on it. Sleeves should be outside of the gloves to keep pesticides from running down the sleeves and into the gloves.

Hat. Wear something to protect the head. A wide-brimmed, waterproof hat will protect neck, eyes, mouth, and face. It should not have a cloth or leather sweatband. These sweatbands are hard to clean if chemicals get on them. Plastic "hard hats" with plastic sweatbands are good.

Boots. Generally, wear unlined neoprene boots. However, some fumigants are readily absorbed by neoprene boots so follow label instructions.

Goggles or Face Shield. Wear goggles or a face shield when there is any chance of getting pesticides in the eyes. Wear goggles alone or with a respirator.

Care of Clothing. Wear clean clothing daily. If clothes get wet with spray, change them right away. If they get wet with pesticide concentrates or highly toxic pesticides, destroy them. They are hard to get clean by normal methods. 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. Elastic fabric headbands often absorb pesticides and are difficult to clean. Have spares and replace them often, or use neoprene headbands.

Respiratory Protective Devices

The respiratory tract—the lungs and other parts of the breathing system—is much more absorbent than the skin. Wear an approved respiratory device when the label directs. Follow the label instructions on respiratory protection.

A respirator will be needed if exposed to a pesticide for a long

Cartridge Respirator

Supplied Air Respirator

Canister Respirator

Self-contained Breathing Apparatus

Figure 3. Types of respirators.

time, if the pesticide used is highly toxic, or if working in an enclosed area.

Chemical Cartridge Respirator. Wear when exposed to intermittent concentrations of a toxic pesticide.

The inhaled air comes through both a filter pad and a cartridge made 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.

Chemical Canister Respirator (Gas Mask). Wear when exposed to a continuous concentration of a toxic pesticide.

The canister has longer lasting absorbing material and filters than a cartridge respirator. Gas masks usually protect the face better than cartridge types, but neither kind protects during fumigation or when the oxygen supply is low, as in a silo.

Supplied Air Respirator. Wear when the oxygen supply is low, when exposed to high concentrations of highly toxic pesticides in enclosed areas, as in fumigation, or when work can be done close to a supply of clean air. Clean air is pumped through a hose to the face mask.

Self-contained Breathing Apparatus. Wear this kind of respirator under the same conditions as the supplied air respirator. It operates in similar fashion but cylinders of air or oxygen are carried, usually on the back. Movement is easier and possible over a wider area than with a supplied air respirator.

Selection and Maintenance. Specific types of cartridges and canisters protect against specific chemical gases and vapors. Be sure to choose one made for the pesticide being used. Use only those approved by the National Institute for Occupational Safety and Health (NIOSH), or the Mining Enforcement and Safety Administration (MESA).

The respirator must fit the face well. Long sideburns, a beard, or glasses may prevent a good seal. Before using, read the manufacturer's instructions on the use and care of the respirator and its parts.

When applying pesticides, change filters, cartridges, and canisters if breathing trouble occurs, or if pesticides are smelled. Remove and discard filters, cartridges, and canisters after use. Then wash the face piece with detergent and water, rinse and dry with a clean cloth. Store in a clean, dry place away from pesticides.

The useful life of a cartridge or canister depends on the amount of absorbent material, the concentration of contaminants in the air, the breathing rate of the wearer, and the temperature and humidity.

If breathing trouble occurs while wearing a respiratory device, see a physician to find out whether a respiratory problem exists.

Protecting the Environment

The environment includes our surroundings and its many forms of life. Every plant or animal is affected by other plants or animals in the environment. Factors like rain, temperature, and wind are part of the environment. We cannot do much about them, but we can control some other things, including the use of pesticides.

Many people consider pesticides a tool for preserving or improving the environment. Others feel that they cause pollution. As a weed is a "plant out of place," a pesticide sometimes can be a "tool out of place." Correct use prevents pollution by pesticides.

How Pesticides Harm the Environment

Using pesticides in a way other than as directed on the label can injure plants and animals, leave illegal residues, and damage the environment in many other ways.

Any pesticide can cause harm if not chosen and used with care. Here are some ways damage can occur.

Direct Kill of Nontarget Organisms Do not let a pesticide contact anything except the target area. Pesticides are sometimes applied over a large area. Targets are such things as mosquitoes, forest insects, and weeds. Many nontarget plants and animals within the treated area may be harmed. Plan area projects with great care to avoid irreparable damage to the environment.

Drift from herbicides can kill nearby crops and landscape plants. Bees may be killed and other pollinators if treating a crop while they are working in a field. Parasites and predators that help control harmful insects could also be killed.

Runoff from a sprayed field can kill fish in a nearby stream or pond. Life in streams can be wiped out by careless tank filling or draining and improper container disposal.

All of these kills can result in lawsuits, fines, and loss of certification.

If more than one pesticide will control the target pest, choose the one that is the least hazardous to the environment and most useful for a particular situation. Ask a Cooperative Extension Service to help make this choice.

Insecticides and Honey bees. The number of reported honey bee kills has increased greatly in Iowa during the last few years due to the increased number of insecticide applications made to alfalfa for alfalfa weevil and leafhopper control and to field corn for adult corn rootworm control. Losses of bees to

pesticides can be minimized by understanding several basic principles:

- Apply proper rates and follow label recommendations.
- Ground application is safer than aerial application.
- Avoid excessive drift.
- Emulsifiable concentrates are safer than wettable powders.
- Granules are least hazardous to the bees.
- Safest applications are before 7 a.m. and after 7 p.m.

Persistence and Accumulation
Not all pesticides act the same after application.

Pesticides that break down quickly remain on the target or in the environment only a short time before being changed into harmless products. Some are highly toxic. Others are fairly harmless.

Pesticides that break down slowly may stay in the environment without change for a long time. Often this is good, because it means long term control. These are called persistent pesticides. Most of them are not broken down easily by microorganisms and are only slighly soluble in water.

Some persistent pesticides can injure sensitive crops planted on the same soil the next year. But they seem to be of little hazard to the environment beyond the treated soil. Other persistent pesticides can build up in the bodies of animals, including humans. They may build up until they are harmful to the animal itself or to the meat eater that feeds on it. These are called accumulative pesticides.

Pesticide Movement in the Environment
Pesticides become problems when they move off target. This may mean:

- drifting out of the target area as mist or dust,
- moving on soil through runoff or erosion,
- leaching through the soil,
- being carried out as residues in crops and livestock,
- evaporating and moving with air currents.

Soil and Pesticides
Persistent pesticides may limit future planting since a farmer can only plant crops that the pesticide will not kill or contaminate.

Even pesticides directed at plants or animals can move to the soil if they are washed or brushed off. Or they may be worked into the soil with dead plant parts.

Air and Pesticides
Pesticides in the air cannot be controlled. The pesticides can settle into water, crops, trees, houses, or barnyards. The winds can carry them hundreds of miles. Even gentle breezes can carry them away from the target.

Water and Pesticides
Water is necessary for all life but it is not safe to drink or bathe in polluted water.

Most fish and other aquatic life can survive only slight changes in their environment. Even tiny amounts of many pesticides can harm them or destroy the food they live on. They may die at once, or there may be chronic effects. The behavior of an animal can be changed so that predators can more easily catch and kill it. Pesticide-contaminated eggs may not hatch.

Pesticides in water also may harm other wildlife. Polluted irrigation water can harm crops, soil, and livestock. It can cause illegal residues in crops, milk, and meat.

Pesticides may be applied directly to water when controlling some pests. It can be done safely by choosing the pesticides carefully, making sure they are registered for the use intended, and applying them when and as directed.

Water can be polluted if the wrong pesticide is used or applied carelessly.

Pesticides can reach water directly as a result of drift, spills, application to waterways (ditches and streams), and incorrect disposal methods.

Pesticides also may reach water indirectly. This happens because of erosion, runoff, and leaching. In fact, most pesticide movement through air or soil ends up in water.

Benefits of Careful Use
Pesticides help the environment when they are used correctly. Most important, they can help produce better quality and higher yields of food, fiber, and timber by reducing damage from pests.

Be a responsible pesticide applicator. Weigh carefully the advantages and disadvantages of each pesticide use. Choose the pesticide that will do the least damage while giving good control. Finally, plan each part of the job carefully from beginning to end.

Safe Use Precautions

Most parts of the job may involve some risk of pesticide injury:

- hauling pesticides,
- storage,
- mixing,
- calibrating equipment before use,
- loading,
- applying,
- repairing equipment,
- working in pesticide-treated crops and buildings,
- cleaning application equipment after use,
- disposing of surplus pesticides and empty containers,
- cleaning up spills, and
- cleaning protective clothing and equipment.

Some of these tasks are done indoors. All require some safety measures to prevent harm to people, animals, and plants as well as to soil and water outside the target area.

To prevent harm from pesticides, follow safety precautions and use common sense. The following paragraphs cover the minimum safety steps to take.

Before Buying a Pesticide
The first and most important step in choosing a pesticide is to know what pest to control. Then find out which pesticides will control it. There may be a choice of several. Common sources of information are the Iowa State University Extension Service, the U.S. Department of Agriculture, and pesticide manufacturers and dealers.

At the Time of Purchase
Read the label of the pesticide to find out:

- restrictions on use,
- if this is the correct chemical for the problem,
- if the product can be used safely under the conditions,
- environmental precautions needed,
- if the formulation and amount of active ingredient are right for the job,
- if the right equipment is available to apply the pesticide,
- if the right protective clothing and equipment is used, and
- how much pesticide is needed.

Before Application
Read the label again to find out:

- the protective equipment needed to handle the pesticide,
- the specific warnings and first aid measures,
- what it can be mixed with,
- how to mix it,
- how much to use,
- safety measures,
- when to apply to control the pest and to meet residue tolerances,
- how to apply,
- the rate of application, and
- special instructions.

Transportation of Pesticides
You are responsible for the safe transport of your pesticide.

The safest way to carry pesticides is in the back of a truck. Fasten down all containers to prevent breakage and spillage.

Keep pesticides away from food, feed, and passengers.

Pesticides should be in a correctly labeled package.

Keep paper and cardboard packages dry.

If any pesticide is spilled in or from the vehicle, clean it up right away. Use correct cleanup procedures.

Do not leave unlocked pesticides unattended. The user is responsible if accidents occur.

Pesticide Storage
The label tells how to store the product. As soon as pesticides arrive, correctly store them in a locked and posted place. Children and other untrained persons should not be able to get to them.

The storage place should keep the pesticides dry, cool, and out of direct sunlight. It should have enough insulation to keep the chemicals from freezing or overheating.

The storage place should have fire-resistant construction, including a cement floor, an exhaust fan for ventilation, good lighting, and a lock on the door.

Keep the door locked when the building is not in use.

The storage building should be away from where people and animals live. This will avoid or minimize harm to them in case of fire.

Store all pesticides in the original containers.

Do not store them near food, feed, seed, or animals.

Check every container often for leaks or breaks. If one is damaged, transfer the contents to a container that has held **exactly** the same pesticide. Clean up any spills correctly.

Keep an up-to-date inventory of the pesticides on hand.

Mixing and Loading Pesticides
Keep livestock, pets, and people out of the mixing and loading area.

Do not work alone, especially at night.

Work outdoors. Choose a place with good light and ventilation. Do not mix or load pesticides indoors or at night unless there is good lighting and ventilation.

Before handling a pesticide container, put on the correct protective clothing and equipment.

Each time a pesticide is used, read the directions for mixing before opening the container. **This is essential.** Directions, including amounts and methods, are often changed.

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 taking a pesticide out of the container, keep the container and pesticide below eye level. This will avoid a splash or spill on goggles or protective clothing. Do the same thing when pouring or dumping any pesticide.

If a pesticide is splashed or spilled while mixing or loading:

- Stop right away.
- Remove contaminated clothing.
- Wash thoroughly with detergent and water. Speed is essential.
- Clean up the spill.

When mixing pesticides, measure carefully. Use only the amount called for on the label. Mix only the amount to be used.

When loading pesticides, stand so the wind blows across the body from the right or left to avoid contamination.

To prevent spills, replace all pour caps and close containers after use.

Pesticide Application
Wear the correct protective clothing and equipment.

To prevent spillage of chemicals, check all application equipment for leaking hoses, pumps or connections; and plugged, worn, or dripping nozzles.

Use water to correctly calibrate spray equipment before use. Before starting a field application, clear all livestock and people from the area to be treated.

Drift is the movement of spray droplets or dust particles away from the target area. Drift increases as droplet or particle size decreases and as wind speed increases. It can be minimized by spraying at low pressure, using the largest practical nozzle openings, and spraying during the calmer parts of the day.

Vaporization is the evaporation of an active ingredient during or after applicaton. Pesticide vapors can cause injury far from the site of applicaton. High temperatures increase vaporization. Reduce vaporization by choosing non-volatile chemical formulations and spraying in the cooler parts of the day.

Cleaning Equipment
Mixing, loading, and application equipment must be cleaned as soon as it is finished being used. Clean both the inside and outside, including nozzles. Only trained persons should do this job. They should wear correct protective clothing.

Sometimes equipment may need to be cleaned with steam or special cleaning agents. In other cases, hot 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 good sump. This will catch all contaminated wash water and pesticides. Dispose of sump wastes by burning or burial as with 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 possible hazards.

Disposal

Excess Pesticides
There are several alternatives for the disposal of organic pesticides. They may be used for other purposes as directed on the label. Or they may be buried in a specially designated landfill or burned in a specially designed pesticide incinerator. If it is not possible to properly dispose of the excess promptly, store them according to the label directions and the suggestions in the Pesticide Storage section of this manual.

Consult the Iowa Department of Water, Air, and Waste Management for state regulations regarding pesticide disposal. The number to call is 515/281-8690.

Containers
Before disposing of pesticide containers, they must be triple rinsed.

- Empty the container in the spray tank and let it drain for 30 seconds.
- Fill the container one-fifth to one-fourth full of water.
- Replace the closure and rotate the container. Upend the container so the rise reaches all the side surface.
- Drain the rinse water from the container into the spray tank and let it drain for 30 seconds after emptying.
- Repeat the procedure at least two more times.

There is an alternative to the rinse, pour, and drain routine, which can be tedious and time-consuming, especially during the busiest season. An inexpensive jet-spray device is available that attaches to a hose and is inserted through the bottom of a container to make a vent. A 60-second spray is equivalent to triple rinsing. Other alternatives may also be available.

The EPA recommendations for disposal of triple rinsed pesticide containers are based on contents and construction material.

Containers that held organic or metallo-organic pesticides but **not** organic mercury, lead, cadmium, or arsenic compounds may be disposed of in the following ways:

Containers that will burn may be buried in a specially designated landfill or buried singly in open fields. In the fields, bury containers at least 18 inches below the surface, being careful not to pollute surface or subsurface water. Burn small numbers of them as directed by state and local regulations or burn them in a special pesticide incinerator.

There are several alternatives for the disposal of containers that will not burn. For example, many large containers in good shape can be reused by the supplier. Return them to the pesticide manufacturer or formulator, or drum reconditioner. Send or take containers to a place that will recycle them as scrap metal or dispose of them.

All rinsed containers may be crushed and buried in a sanitary landfill, following state and local standards. They may also be buried in the field.

Containers that held organic mercury, lead, cadmium, or arsenic or inorganic pesticides may be disposed of by triple rinsing the containers and burying them in a sanitary landfill.

Consult the Iowa Department of Water, Air, and Waste Management for state regulations regarding pesticide container disposal. The number to call is 515/281-8690.

Pesticide Spills
In the event of a pesticide spill, the following actions must be taken:

Contain the spill, preventing any draining of the chemical off the property. If possible, use an absorbent material to soak up the spill, such as soil, sawdust, or a special product made for the purpose.

Shovel all contaminated material into a leakproof container for disposal. Dispose of it as you would excess pesticides. Do not hose down the area. This spreads the chemical.

Put something on the spill to stop the chemical action. It may be possible to use common household bleach or a solution of lye or ammonia. If not sure what to use, call the chemical manufacturer. Always work carefully. Do not hurry.

Report the spill to the agencies listed below.

Environmental Protection Agency
Public Law 92-500 requires immediate notification of the appropriate agency of the U.S. Government of discharge of oil or hazardous substances. Any such person who fails to notify immediately such agency of such discharge shall, upon conviction, be fined not more than $10,000 or imprisoned for not more than one year, or both. All major pesticide spills should be immediately reported to the Environmental Protection Agency. The telephone number to call in the four-state area of Iowa, Missouri, Kansas, and Nebraska is 816/374-3778. The following information should be reported:

- Name, address, and telephone number of persons reporting,
- Exact location of spill,
- Name of company involved and location,
- Specific pesticide spilled,
- Estimated quantity of pesticide spilled,
- Source of spill,
- Cause of spill,
- Name of body of water involved, or nearest body of water to the spill area, and
- Action taken for containment and cleanup.

Iowa Department of Water, Air, and Waste Management
All major pesticide spills in Iowa should be reported by telephone to the Iowa Department of Water, Air, and Waste Management 515/281-8694 within 6 hours of occurence or discovery.

Sheriff or Police
The spill could also be reported to the sheriff or police. The initial report of the pesticide spill must be followed by a written report to the Department of Water, Air, and Waste Management within 5 days.

Safe-Entry Times
It may be dangerous for an unprotected person to enter an area immediately after some pesticides have been used. The time that must pass before the area is safe for a person without protective clothing is called a safe-entry time, or reentry period. This time is given on the label of each pesticide that may cause a reentry problem. It varies according to the pesticide applied and the crop or area treated. These times have been set to allow harmful pesticide residues to break down or disappear. Reentry may pose special problems in some areas. Check with local authorities for any special rules that may apply.

Application Equipment

The pesticide application equipment used is important to the success of the pest control job. First select the right kind of application equipment. Then use it correctly to suit the needs and, finally, take good care of it. This is true whether hand-carried, tractor-drawn, self-propelled, or aircraft-mounted equipment is used.

New equipment and techniques are continually being developed in an effort to maximize the efficiency and safety of pesticide applications. We have already noted that many problems of current concern such as drift, nonuniform coverage, failure of a pesticide to effectively reach the target organism, and selective control are at least partially solvable through the development of new application techniques and equipment.

A number of significant developments have occurred in recent years and, while we don't expect that they will immediately revolutionize application practices, some of them may play increasingly important roles in the coming years.

New Herbicide Application Techniques

A number of new techniques, based on similar principles and designed for similar purposes, have recently been developed for herbicide applications. The new techniques are designed to provide selective, post-emergence control of problem weeds that either escaped or were not susceptible to previous control methods and they are designed to provide effective control at relatively low application rates.

These techniques are effectively only if the problem weeds are significantly taller than the crop at some time during the growing season. They achieve maximum effectiveness against the widest spectrum of weeds if used with a systemic, nonselective herbicide that is effective at low dosages. Indeed, it was the introduction of Roundup, which meets these requirements, that was largely responsible for the development of these application techniques. Roundup controls both grasses and broadleaves and it translocates downward in the plant. Wetting a small part of the top of a weed is often enough to kill the entire plant.

Some problems have been encountered, however, in using these techniques for the control of certain broadleaves, particularly velvetleaf and milkweed. In general, broadleaves are less susceptible than grasses to Roundup. The relatively low dosages applied using these methods have sometimes been insufficient to provide effective control.

Sprayers

A sprayer should be designed to do the job planned, durable, and convenient to fill, operate, and clean.

Hand Sprayers

Hand sprayers are for professional application of pesticides in structures and can be used for small jobs around the home and garden. They can be used in restricted areas where a power unit would not work.

Advantages: Economical, simple, easy to use, clean, and store.

Limitation: Frequent lack of good agitation and screening for wettable powders. Keep WP's in suspension by shaking the sprayer.

Low Pressure Field Sprayers

These sprayers are designed to deliver low to moderate volume at 15 to 50 psi. Most are used for treating field and forage crops, pastures, fence rows, and structures. They also may be used to apply fertilizer-pesticide mixtures.

Advantages: Medium to large tanks, low cost, light weight, and versatility.

Limitations: Low gallonage output limits their use when high volume is required low pressure limits pesticide penetration, and agitation is limited.

High Pressure Sprayers

Often called hydraulic sprayers, they are designed to deliver large volumes at high pressure. They are used to spray fruits, vegetables, trees, landscape plants, and livestock. When fitted with the correct pressure regulators, they can be used at low pressures. Applications usually are made at high gallonages (usually 100 or more per acre). Even though very large tanks are used, they may need to be filled often.

Advantages: Well built, usually have mechanical agitation, and last a long time even when using wettable powders.

Limitations: High cost, large amounts of water, power, and fuel needed, high tire loads, and high pressure which makes a spray that drifts easily.

Air Blast Sprayers

These units use a high speed, fan-driven air stream to break the nozzle output into fine drops that move with the air stream to the target. The air is directed to either one or both sides as the sprayer moves forward. These sprayers are used in applying pesticides to landscape plants, fruits, vegetables, and for biting fly control. Most air blast sprayers can be adapted to apply either high or low volumes of spray.

Advantages: Good coverage and penetration, low pump pressures, and mechanical agitation.

Limitations: Drift hazards, chance of overdosages, difficult to use in small areas, and hard to confine discharge to limited target areas.

Ultra Low Volume (ULV) Sprayers
These deliver undiluted pesticides from the air, on the ground, or in buildings.

Advantages: No water is needed and equal control with less pesticide.

Limitations: Does not provide for thorough wetting, hazards of using high concentrates, chance of overdosage, and small number of pesticides that can be used this way.

Recirculating Sprayers
A fairly recent development, recirculating sprayers come in two basic types: box and broadcast.

With the **box-type sprayer,** three or four streams of herbicide are directed parallel to the ground above the crop canopy. It may be rear- or front-mounted. The streams are aimed across the row into a catch basin.

Broadcast or trough-type sprayers were first sold under the trade name "Spray Sickle" but are now manufactured by several companies. These sprayers are front-mounted either on tractors or high-clearance equipment. They consist of a series of nozzles pointing backward toward a common trough or catch basin positioned above the crop canopy and are used in broadcast fashion much like standard spray equipment.

Advantages: All spray not intercepted by weeds is pumped from the catch basin back to either the spray tank or directly into the nozzles, and may be mounted on tractors or high-clearance equipment.

Limitation: Splashing may cause problems on sensitive crops.

Sprayer Parts

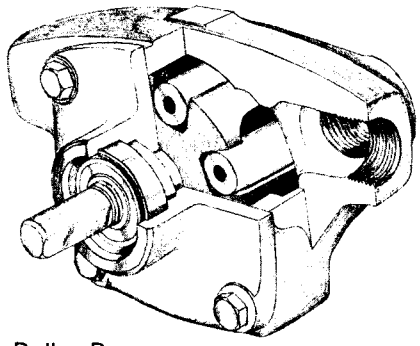
Tanks
Tanks should have large openings for easy filling and cleaning. They should allow straining during filling and have mechanical or hydraulic agitation. The tank should be made of corrosion-resistant material such as stainless steel or glass reinforced plastic. If made of mild steel, it should have a protective plastic lining or coating. The tank should have a good drain. The outlets should be sized to the pump capacity. If dual tanks are used, 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.

Flush out the tank, pump, lines, and nozzles after each day's use and each separate pesticide use. If switching to another pesticide where contamination must be prevented, wash out with detergent and water two or three times and then flush with water. Phenoxy herbicides such as 2,4-D are hard to remove. After using them, either follow the special cleaning procedures noted on the pesticide label or avoid using the same sprayer for any other product. Keep tank clean inside and out. Tighten or repair all leaky tank seals or fittings. Make sure sight gauges can be read.

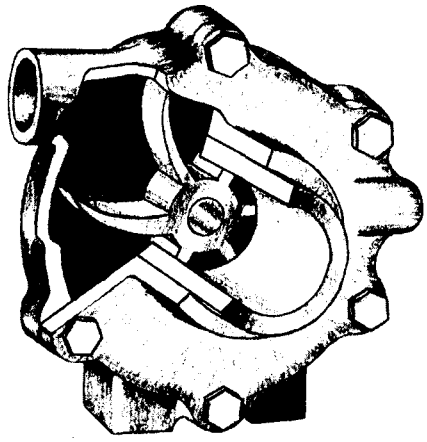
Pumps
The pump must be adequate for all the spraying pressures used. It must provide enough flow to supply all nozzles, allow for hydraulic agitation when needed, and leave a reserve to allow for loss of flow due to wear.

Pumps should resist corrosion and abrasion. Centrifugal pumps provide high volume at low pressure. They are not self-priming. Piston and diaphragm pumps provide moderate to high volumes at high pressure. They are self-priming. Roller and gear pumps provide moderate volume at low to moderate pressure. They are self-priming in most equipment. Do not use wettable powder formulations in gear pumps. If pressures above 75 psi are needed, piston pumps are more likely to provide them over a long period of time.

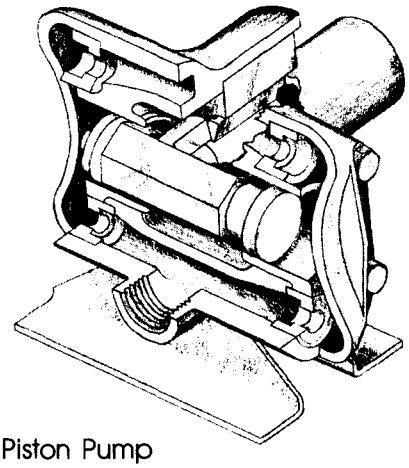
A pump can be damaged if operated dry or with a restricted inlet. Follow the manufacturer's recommendations for pump operation. Keep all shields in place.



Roller Pump



Centrifugal Pump



Piston Pump

Figure 4. Types of sprayer pumps.

Strainers (Filters)
Proper filtering of the pesticide protects the working parts of the sprayer and avoids time loss and misapplication due to clogged nozzle tips.

Filtering should be progressive, with the largest mesh screen in the suction line between the tank and the pump. Put a smaller mesh screen in the high pressure line between the pump and the pressure regulator. Put the finest mesh screen nearest the nozzles. Do not use a screen in the suction line of a centrifugal pump.

Clean strainers after each use. Replace them if there is deterioration. Strainers are the best defense against nozzle and pump wear and nozzle clogging. Use nozzle screens as large as nozzle sizes permit. Screen opening should be less than nozzle opening.

Hoses
Select synthetic rubber or plastic hoses that have burst strength greater than the peak operating pressures, resist oil and solvents present in pesticides, and are weather-resistant.

Suction hoses should resist collapse. They should be larger than pressure hoses. All fittings on suction lines should be as large or larger than the line itself.

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

Pressure Gauges
These serve as the monitor of the spraying job. They must be accurate and have only the range needed for the work. For example, a 0-60 psi gauge with 2-pound gradations would be enough for most low pressure sprayers.

Check frequently for accuracy against an accurate gauge. Do not use them under too much pressure. Keep glass faces clean and intact. Use gauge protectors to protect against corrosive pesticides and pressure surges.

Pressure Regulators
The pressure regulator must have a working range that is about the same as the range of pressure planned.

Agitators
Make sure the sprayer has enough agitation. If it does not, the pesticide application rate may vary greatly as the tank is emptied. Bypass agitation may be good enough for solutions and emulsions. Use a jet applicator or mechanical agitator for wettable powders. Mechanical agitation is the surest way to get good agitation. It is expensive initially and is harder to maintain. Hand sprayers must be shaken frequently.

Control Valves
These should be large enough to not restrict flow. They should be easy to reach. On-off action should be quick and positive. Be able to cut off all flow or flow to any section of the spraying system. There are many different kinds of control valves. Be sure to know how to operate and maintain the ones on all owned equipment.

Nozzles
A nozzle is made up of four major parts: the body, the cap, the strainer (screen), and the tip or orifice plate. It 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 that 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 ensure proper operation.

The nozzle helps control the rate and pattern of distribution. These things depend on the nozzle design or type, its operating pressure, the size of the opening, its discharge angle, and its distance from the target.

The basic nozzle types are described in the following paragraphs.

Solid Stream. A type used in handguns to spray a distant target and for crack and crevice treatment in buildings. Also a type used in a nozzle body to apply pesticides in a narrow band or inject them into the soil.

Flat Fan. There are three types of flat fan nozzles. The regular flat fan nozzle makes a narrow oval pattern with lighter edges. It is used for broadcast spraying. This pattern is designed to be used on a boom and to be overlapped 30 to 50 percent for even distribution.

The even flat fan nozzle makes a uniform pattern across its width. It is used for band spraying and for treating walls and other surfaces.

The flooding nozzle makes a wide-angle flat spray pattern. It works at lower pressures than the other flat fan nozzles. Its pattern is fairly uniform across its width and is used for broadcast spraying.

Hollow Cone. There are two types: the core and disk and the whirl chamber. The pattern is circular with both, with tapered edges and little or no spray in the center. It is used for spraying foliage.

Solid Cone. This nozzle produces a circular pattern with the spray well distributed throughout the pattern. It is used for spraying foliage.

Atomizing nozzle. This one makes a fine mist from liquid pesticides and is used indoors in special situations.

Broadcast. This nozzle forms a wide flat fan pattern. It is used on boomless sprayers and to extend the effective swath width when attached to the end of a boom.

General Information
Many spraying jobs could be done by more than one nozzle type or pattern. Here are some general guidelines:

- For weed control: regular flat fan, flooding fan, even flat fan, and hollow cone.
- For disease control: hollow cone and solid cone.
- For insect control outdoors: regular flat fan, hollow cone, and solid cone.
- For insect control indoors: even flat fan, solid stream, and atomizing.
- To minimize drift: flooding fan, whirl chamber hollow cone; keep operating pressures below 30 psi.

Nozzles are available in many materials. Here are the main features of each kind.

- Brass: inexpensive, wears quickly from abrasion, and probably the best material for minimal use.
- Stainless steel: will not corrode, and resists abrasion, especially if it is hardened.
- Plastic: resists corrosion and abrasion, and swells when exposed to some solvents.
- Aluminum: resists some corrosive materials, and is easily corroded by some fertilizers.
- Tungsten carbide and ceramic: highly resistant to abrasion and corrosion, and expensive.

Keep nozzles in good working condition. For most boom applications, select nozzles of uniform type and size.

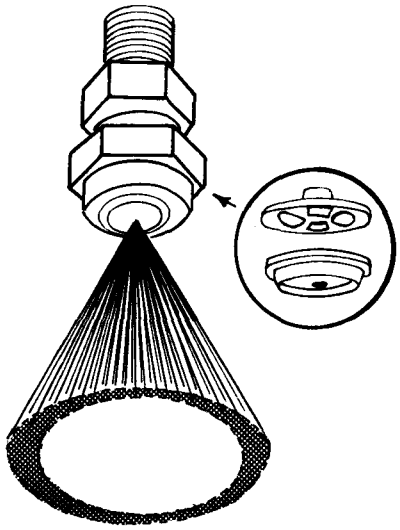


Figure 6. Hollow cone nozzle.

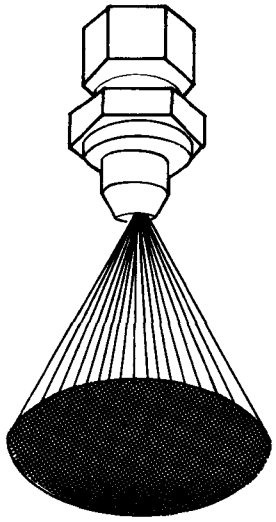
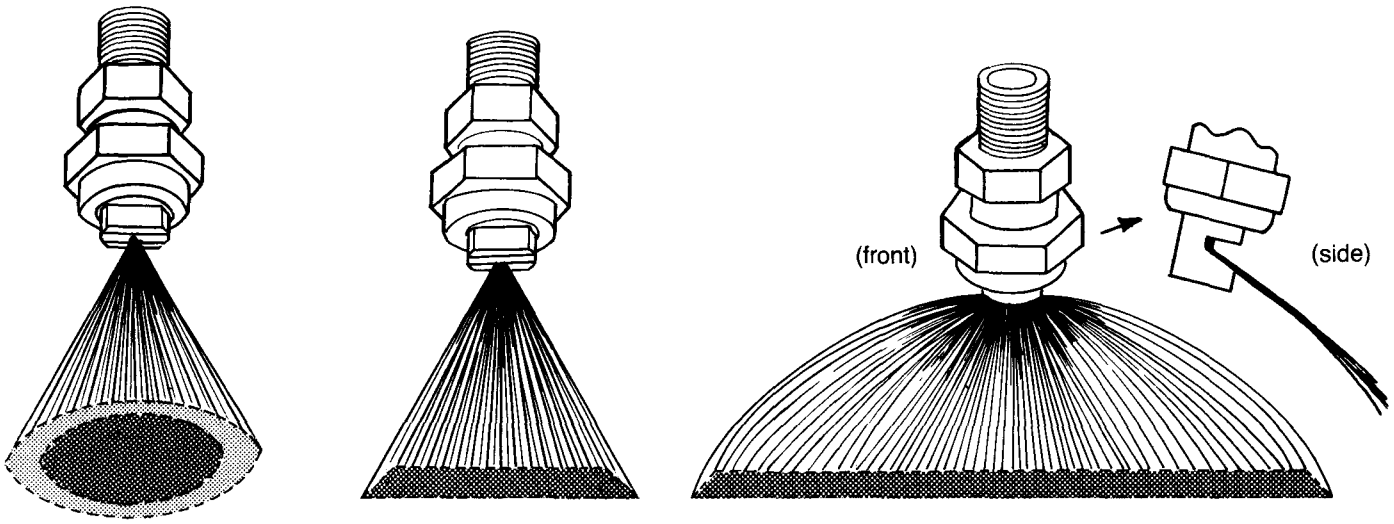


Figure 7. Solid cone nozzle.



Regular Flat Fan Nozzle Even Flat Fan Nozzle Flooding Fan Nozzle

Figure 5. Three types of flat fan nozzles.

Nozzle caps should not be overtightened. Adjust nozzle distance and spacing to suit the target. Follow the nozzle manufacturer's instructions and the pesticide label. Allow for crop or weed height if necessary. Check each nozzle for uniform flow using water and a jar marked in ounces. Replace any nozzles having faulty spray patterns. A good check is to spray on asphalt pavement. Watch for streaks as speed increases or as spray dries.

Clean nozzles only with a toothbrush or wooden toothpick.

Controlled Droplet Applicators
Although the standard hydraulic spray nozzle has proven effective over the years, it does have significant drawbacks. It relies on pressure to break the spray solution into droplets and in so doing produces an extremely wide range of droplet sizes. The smaller droplets are highly susceptible to drift and the larger ones provide inefficient coverage and are subject to runoff from treated plant surfaces. Although hydraulic nozzles normally produce a relatively small percentage of large drops, they may contain the greatest amount of spray volume.

The diameter of spray droplets is measured in microns. A micron is 1/1000 of a millimeter (approximately 0.0004 inches). It has been shown that drops smaller than 50 microns are highly susceptible to drift under normal conditions and that the ideal range for general spray applications is from 80 to 150 microns.

Substantial research has been directed toward the development of nozzles that produce a majority of droplets in this general size range. The most promising are nozzles that use spinning disks, cups, or screens. The controlled droplet applicator (CDA) used most widely today is manufactured by Micron Sprayers and is commonly referred to as a rotary spray nozzle. It uses a spinning cup that has small grooves extending radially up the inner wall. The nozzle is gravity-fed from the spray tank and is powered by a small electric motor.

The spray solution initially forms a pool at the bottom of the spinning cup. It is then moved up the grooves on the inside of the cup by centrifugal force and, when it reaches the edge of the cup, is distributed in a hollow-cone pattern. When they leave the cup, the spray droplets are flung out parallel to the ground and then fall almost vertically onto the crop.

Rotary spray nozzles generate relatively uniform droplets, with the average size ranging from 40 to 250 microns depending on cup diameter, speed, and flow rates.

Tests have indicated that rotary nozzles can provide equivalent control with less volume of spray solution and less drift. The pesticide is applied in three gallons of solution or less per acre. This obviously results in substantial reductions in water equipment. There have also been claims that more efficient coverage and reduced spray drift would allow significant reductions in the amount of pesticide applied; the evidence to date, however, is not conclusive. It should be pointed out that, since rotary nozzles do not apply the spray under pressure, canopy penetration in crops such as soybeans may not be satisfactory. A substantial amount of additional research needs to be done before we can make a judgment on the potential value of these applicators.

While one of the principal advantages of rotary nozzles is the use of less spray volume, keep in mind that you cannot use a volume less than that specified on the label unless it is based on an appropriate recommendation.

Operation and Maintenance
The operator's manuals for spray equipment will tell exactly how to use and care for it. After each use, rinse out the entire system. Remove and clean nozzles, nozzle screens, and strainers. Check for leaks in lines, valves, seals, and tank both after filling with water and during running.

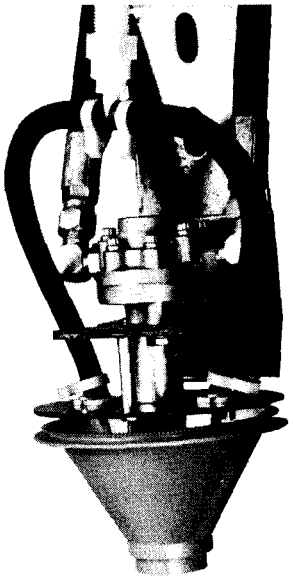


Figure 8. Hydraulically driven rotary nozzle.

Be alert for nozzle clogging and changes in nozzle patterns. If nozzles clog or other trouble occurs in the field, avoid contamination 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.

Store sprayers correctly after use. But first, rinse and clean the system. Then fill tank almost full with clean water. Add a small amount of new light oil to the tank. Coat the system by pumping tank contents out through nozzles or handgun. Drain the pump and plug its openings or fill the pump with light oil or antifreeze. Remove nozzle screens and store in light oil or diesel fuel.

Dusters and Granular Applicators

Hand Dusters
Like hand sprayers, hand dusters are for professional use in structures and can be used in gardens. They

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

Advantages: the pesticide is ready to apply, and good penetration in confined spaces.

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

Power Dusters
Power dusters use a powered fan or blower to propel the dust to the target. They range from knapsack or backpack types to those mounted on or pulled by tractors. Their capacity in area treated per hour compares favorably with some sprayers.

Advantages: simply built, easy to maintain, and low in cost.

Limitations: drift hazards, high cost of pesticide, and application may be less uniform than with sprays.

Selecting a Duster
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 keep the dust cloud well away from the user.

Granular Applicators
Several types are available. Hand-carried knapsack and spinning disk types are used for broadcast coverage. Mounted equipment is available for applying bands over the row in row crops. Mounted or tractor-drawn machines may be used for broadcast coverage.

Advantages: eliminates mixing, is low in cost, minimizes drift, and is less hazardous to applicator.

Limitations: high cost for pesticide, limited use against some pests because granules won't stick to most plants, need to calibrate for each granular formulation, and poor lateral distribution, especially on side slopes.

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

Use and Maintenance
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 cloud that may form.

Watch banders 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.

Fumigant Applicators
One type is needed to handle low pressure fumigants. Another type is needed to handle high pressure fumigants that are kept liquid only by storage in pressure vessels.

The low pressure fumigators are gravity or pump fed units. Most high pressure units use the pressure generated by the fumigant or a compressed gas to force the fumigant into the soil or space being fumigated.

Selection
Methods of choosing equipment to apply low pressure fumigants are similar to those for choosing a low pressure sprayer. But corrosion-resistant pumps, tanks, fittings, nozzles, and lines are essential. High pressure fumigators must be able to withstand the internal pressure created by the fumigant. Select equipment with pressure or flow regulators that ensure constant delivery rates.

Use and Maintenance
Keep the units in good repair. Make sure there are no leaks. Replace hoses and fittings as soon as signs of deterioration appear. Lines and fittings should not be located near the operator. Empty all lines after application. To avoid contamination and corrosion, flush the units after use. Carefully follow all precautions on the fumigant label.

Aerosol Generators and Foggers
Aerosol generators utilize atomizing nozzles, spinning disks, and small nozzles at high pressure.

Fogs are usually generated by thermal generators using heated surfaces.

Advantages: efficient distribution of liquid pesticides in enclosed spaces, efficient distribution of liquid pesticides in dense foliage, and some devices automatic in operation.

Limitations: aerosols and fogs extremely sensitive to drift, and repeated application needed to maintain effectiveness.

Selection
Choose an aerosol generator according to where it will be used: indoors or outdoors. Aerosol and fog generators are manufactured for many special uses. Truck- and trailer-mounted machines are for use outdoors. Most hand-operated or permanently mounted automatic machines are for use indoors.

Use and Maintenance
In general, use and care for an aerosol generator is the same as for 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.

Selective Applicators

Selective applicators are not the answer to all weed problems, but they do provide excellent and economic control for many tall, problem weeds. Keep in mind, however, that the application can be made only after weeds have grown significantly taller than the crop. By this time most crop loss from competition may already have occurred and driving through the field this late in the season may be impractical. Use of these techniques should not be considered as primary weed control practices but only as supplementary methods where regular cultural and chemical control measures have failed.

At the present time, Roundup is the only herbicide registered for use with these applicators, although other translocated herbicides are being tested.

Roller Applicator

This is a recently developed type in which herbicide solution is trickled onto a carpet-covered roller that turns as the equipment is driven across the field. The herbicide is "wiped" onto weeds that contact the roller. The roller or drum measures 8 to 10 inches in diameter and rotates at about 50 rpm. The herbicide solution is applied manually to the carpet either through a drop boom or low pressure nozzles. A wiper constructed of belting runs against the drum to even the solution on the carpet.

Advantage: eliminates drift and splash.

Limitation: if roller becomes wet, herbicide may drip on crop and cause damage.

Rope-wick Applicator

The recently developed applicator is essentially the same as the roller except that it does not rotate. It consists of a section of polyvinylchloride pipe (usually 3 to 4 inches in diameter) with pieces of soft rope arranged in an overlapping pattern. The rope should provide a constant, high wicking rate and should be selected with care. A recent study by the Monsanto Corporation and the Nebraska Agricultural Experiment Station found that a rope with a diamond-braided polyester covering and an acrylic yarn core (Gulf Rope and Cordage Co. "Pistachid") had the highest wicking rate of those tested. The herbicide solution is placed inside the pipe and the pieces of rope become wet through wick actions.

Advantages: drips very little, relatively easy and inexpensive to build, and uses only a small amount of herbicide.

Limitation: in dense stands, treated weed stems may contact crop leaves and cause severe injury.

Calibration

Adjusting equipment to apply the desired rate of pesticide is necessary to ensure that each pesticide is used safely, with best results, and as directed on the label. The basic equipment needed includes a measuring cup, tape measure, watch with second hand, and flags or stakes for marking distances; for granular applications, a small scale and plastic bags are needed in addition to the other items.

Calibration of Field Sprayers

To apply a pesticide evenly and accurately, the sprayer must move at a constant speed. It also must operate at a constant pressure. Each nozzle must be clean and at the right height. All nozzles must be of the correct type and size for the job, with each nozzle in the system delivering its rated amount of pesticide.

The rate a sprayer is operating can be adjusted in three ways:

- Change the pressure. Lower pressure means less spray delivered; higher pressure means more spray delivered. This is not a good method, because a pressure change may change the nozzle pattern and droplet size. Pressure must be increased four times to double the output.
- Change the speed of the sprayer. Slower speed means more spray delivered, faster speed means less spray delivered. This method is practical for small changes in delivery rate. Driving half as fast will double the delivery rate.
- Change the nozzle tips to change the amount delivered. The larger the hole in the tip, the more spray delivered. This is the best method for making major changes in the delivery rate.

There are many ways to calibrate equipment. The preferred methods differ according to the kind of equipment used. Here is one basic method that will allow calibration in a minimum amount of time for either broadcast or band application:

1. First, fill the sprayer tank at least half full of water. This will simulate actual spraying conditions.

2. Determine the nozzle spacing or band width in inches and measure the appropriate distance in the field according to the following table:

Broadcast nozzle spacing or band width (inches)	Travel distance (feet)
7	583
14	408
20	204
30	136
36	113
38	107
40	102

3. In the field, measure and state the distance to be traveled. Select the tractor gear and mark the throttle or speedometer setting to be used during the spraying operation. Start the tractor 25 feet behind the starting point and start timing when crossing the start line. Stop timing at the designated distance. Record the travel time in seconds.

4. Set the pressure at the reading to be used to spray the field.

5. With the sprayer stationary and with just water in the sprayer tank, collect water from each nozzle at the pre-set pressure for the number of seconds it took to travel the prescribed distance. If there is more than a 5 percent variation from the average, the nozzle tip should be changed.

6. The ounces collected per nozzle equal the number of gallons per acre the sprayer will produce.

7. The sprayer is now calibrated. Next, determine the amount of pesticide to add to the spray tank. Know the recommended rate of chemical application, the capacity of the spray tank, and the calibrated output of the sprayer. The examples below do not imply endorsement of a particular product or brand name.

Example: In broadcast application, Lasso will be applied at the rate of 3 quarts per acre. The sprayer has a 200-gallon tank and is calibrated to apply 20 gallons per acre.

• Determine the number of acres that can be sprayed with each tankful:

$$\text{Acres/tankful} = \frac{\text{tank capacity}}{\text{spray rate}}$$

$$= \frac{200}{20}$$

$$= 10 \text{ acres}$$

• Determine the amount of pesticide to add to each tankful: Amount per tankful = acres per tankful × rate per acre = 10 × 3 = 30 quarts. Therefore, 30 quarts of Lasso must be added to each tankful applied.

Example: For band application, a fonofos recommendation calls for 1 pound of active ingredient per acre in a 7-inch band over corn rows 40 inches apart. The sprayer has a 300-gallon tank and is calibrated to apply 30 gallons per acre. How much Dyfonate 4-EC (4 pounds/gallon) should be added to the spray tank?

• First, determine the volume of spray applied per field acre. The sprayer is calibrated to apply 30 gallons per acre (broadcast rate)—but it will be treating only a portion of each acre. Determine the spray volume per field acre using the following formula:

$$\text{Broadcast spray rate} \times \frac{\text{band width}}{\text{row space}}$$

= spray rate/field acre

$$30 \text{ gal} \times \frac{7 \text{ in}}{40 \text{ in}}$$

= 5.25 gal of spray/field acre

• Determine the number of field acres that can be sprayed with each tankful:

$$\frac{\text{tank capacity}}{\text{spray rate}} = \text{acres/tankful}$$

$$\frac{300}{5.25} = 57 \text{ acres/tankful}$$

• Determine the amount of product needed per acre:

$$\frac{1 \text{ lb a.i./A}}{4 \text{ lb a.i./gal}}$$

= ¼ (or .25) gal of product/acre (1 qt)

If row spacing is different from that designated on the label or in the extension recommendation, convert to the appropriate application rate using the following formula:

$$\text{Product/acre} \times \frac{\text{designated row spacing}}{\text{own row spacing}}$$

If, for instance, in the present example, row spacing were 36 inches rather than 40 inches, the amount of product needed per acre would be:

$$1 \text{ qt} \times \frac{40 \text{ in}}{36 \text{ in}}$$

= 1.1 qt (35 ou) of product/acre

• Determine the amount of pesticide to add to each tankful:

Acres/tankful × rate/acre = amount/tankful

= 57 × 1

= 57 qt (14¼ gal) of Dyfonate 4-EC needed for each tankful

Calibration of Granular Applicators

The application rate of granular applicators depends on the size of the metering opening, the speed of the agitator or rotor, travel speed, the roughness of the field, and the flowability of the granules. Granules flow at different rates depending on size, density, type of granule, temperature, and humidity. A different applicator setting may be necessary for each pesticide applied; variations in flow rate can also occur with the same product from day to day or from field to field. It is, therefore, important to calibrate frequently in order to maintain the proper application rate.

Apart from the actual setting of the metering opening, ground speed is the most significant factor affecting the application rate. The ground speed during calibration and application must be the same, and the speed must remain constant. Even though gravity-flow applicators use a rotating agitator whose speed varies with ground speed, the flow of granules through the opening is not necessarily proportional to speed. A speed change of one mile per hour may cause a significant variation in the application rate.

It is important to keep in mind that, in addition to affecting the flow rate, high humidity may cause clumping of some granules leading to a nonuniform application and, in some cases, to actual clogging of the equipment.

The method chosen for calibrating a granular applicator depends largely on the type of equipment and method of application, as well as the way in which the application rate is expressed. The following method is simple and will allow calibrating for granular insecticides in a 7-inch band width or for infurrow applications. This method is only applicable for insecticides applied at the rate of 1 pound active ingredient per 13,068 linear-foot row.

1. Measure and mark a distance of 1,000 feet in the field.

2. Based on the granular formulation applied at 1 pound active ingredient per 13,068 linear-foot row, the amount of insecticide to apply is listed in the table below.

Formulation	Ounces of product/ 1,000 linear ft of row
10 g	12.2 oz.
15 g	8.2 oz.
20 g	6.1 oz.

3. Fill the hoppers, turn the applicator on, and operate them until all are feeding. Then turn them off, disconnect the drop tubes and attach a container (e.g. plastic bag or plastic jar) to the outlet of each applicator; the weight of each container must be known unless it is negligible. Calibration must be done with the same brand granules that will be used during application.

4. Drive the measured distance, operating at the speed that will be used during application.

5. Weigh and record the amount of material collected from each hopper with the recommended application rate. Adjust the setting of any unit that is not within 5 percent of the recommended rate and recalibrate.

Additional information on spraying equipment and calibration is in the following publications available from county extension offices or from Publications Distribution, Iowa State University, Ames, Iowa 50011.
Pm-1101a, *Spraying Equipment—Nozzles*
Pm-1101b, *Spraying Equipment—Pumps*
Pm-1101c, *Spraying Equipment—Tanks and Agitators*
Pm-1101d, *Spraying Equipment—Strainers, Booms, Flow Control Devices*
Pm-617, *Pesticide Calibration*

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