BUREAU OF LAND MANAGEMENT PESTICIDE APPLICATOR STUDY GUIDES

ALL STUDY GUIDES

Updated/Corrected: January 2005

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PESTICIDE APPLICATOR
STUDY GUIDE

GENERAL

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BUREAU OF LAND MANAGEMENT PESTICIDE APPLICATOR HANDBOOK

1st Edition

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Disclaimer

The author has made every attempt to provide up-to-date, scientific information for both the novice and experienced pesticide applicator. Many sources of information have been gleaned to acquire the suggestions and guidelines found in this manual. Information or suggestions for the use of specific pesticides, or for a specific pest control problem, are not included. Only current recommendations should be used, along with making sure you are using a current pesticide label.

The information contained in this publication is supplied with the understanding that there is no intended endorsement of a specific product or practice, nor is discrimination intended toward any product or practice included in or omitted from this publication.

Due to constantly changing laws and regulations, as well as differing state laws and regulations, the author assumes no liability for the suggestions contained herein. The user assumes all such responsibility in following these and other pest control practices involving pesticides.

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INTRODUCTION

This manual was developed as a reference and testing material for training Bureau of Land Management (BLM) personnel involved with pesticide applications. This manual does not replace BLM Manuals H-9011 and H-9011-1, Chemical Pest Control.

BLM Manual 9011 - CHEMICAL PEST CONTROL – An Overview

BLM Manual 9011 sets forth the Bureau of Land Management (BLM) policy responsibilities, and guidance for conducting chemical pest control program under an integrated pest management approach (IPM) on lands administered by the BLM. The objective is to provide procedures and guidelines for planning and implementing the use of pesticides in an integrated pest management (IPM) approach, and conducting assigned responsibilities for management of a chemical pest control program on lands administered by the BLM so as to assure maximum protection to the environment and human health.

Authority

A. **Federal Land Policy and Management Act of 1976** (43 U.S.C. 1701 1712) - This act states that the BLM must manage public lands according to the principles of multiple use and sustained yield. These principles are further qualified in the act by the statutory duty that the BLM prevent unnecessary degradation of the public lands.
B. **Public Rangelands Improvement Act of 1987** (43 U.S.C. 1901 et seq.) - This act states the BLM must manage, maintain and improve public lands suitable for livestock grazing so that they become as productive as feasible.
C. **The Federal Insecticide Fungicide and Rodenticide Act** as amended (Public Law 92-516) - This act requires all pesticides be registered with the Environmental Protection Agency (EPA). The Federal Environmental Pesticide Control Act (FEPCA) of 1972 amends the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), and requires the basis for registration as to whether or not a pesticide causes unreasonable adverse effects on humans or the environment. The act also makes it illegal to use a registered pesticide in a manner inconsistent with its labeling. It also requires the certification of all personnel who supervise or apply restricted pesticides. The degree of certification must meet the classification requirements for proper storage transportation or disposal of pesticides. The responsibility for administering the act is vested in the Environmental Protection Agency (EPA).
D. **Superfund Amendments and Reauthorization Act of 1986** (42 U.S.C. 11001), also known as the Emergency Planning and Community Right-to-Know Act - provides that workers must be given information such as Material Safety Data

Sheets (MSDS) and technical data sheets on pesticides that they will be handling or applying.

E. **Carlson Foley Act of 1968** (P.E. 90-583) – Provides the authorization for reimbursement of expenses to State or local agencies for weed control on Federal lands.
F. **Federal Noxious Weed Act of 1974** (7 U.S.C. 2801-2813) as amended by Sec. 15, Management of Undesirable Plants on Federal Lands 1990 - This bill requires that each Federal Agency: (1) designate a lead office and person trained in the management of undesirable plants; (2) establish and fund an undesirable plant management program; (3) complete and implement cooperative agreements with State agencies; and (4) establish integrated management systems to control undesirable plant species.
G. **Departmental Manual 517** - Prescribes the Department's guidance for the use of pesticides on the lands and waters under its jurisdiction and for compliance with the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) as amended.
H. **National Environmental Policy Act (NEPA)** (40 CFR Parts 100-1508) - Provides that all Federal Agencies perform an analysis of the potential impacts their proposed action will have on all affected environments.

Responsibility

A. The Director and Deputy Director. The Director and Deputy Director formulates BLM policy within limits delegated by the Secretary of the Interior, assuring that BLM chemical pest control programs conform with the Department of the Interior policy and receive necessary review. This responsibility is exercised through the Assistant Director, Land and Renewable Resources.
B. The Chief, Division of Renewable Resources and Planning. Acting for the Assistant Director, Land and Renewable Resources, the Chief is responsible for overseeing the chemical pest control program and also reviews and monitors the implementation actions on land administered by the BLM.
C. Other Washington Office Division Chiefs are responsible for coordinating and ensuring that specific guidelines are met and provide for the Chemical Pest Control Program in their area of responsibility.
D. State Directors. State Directors are responsible for ensuring adherence to BLM policy and procedures developed in this Manual Section, and overseeing the chemical pest control program on BLM lands within their States.
E. District Managers. District Managers are responsible for planning and implementing a Chemical Pest Control Program within their area of responsibility in conformance with BLM and State Office policy and procedures.
F. Area Managers. Area Managers are responsible for planning and implementing a Chemical Pest Control Program within their area of responsibility in conformance with BLM and State Office policy and procedures.

References

See BLM Manual Sections 6830 - Animal Damage Control; 6840 - Threatened and Endangered Species; 9012 - Expenditure of Rangeland Insect Pest Control Funds; 9015 - Integrated Weed Management; and BLM Handbooks 9011 and H-9011-1 - Chemical Pest Control; 9014 – Use of Biological Control Agents On Public Lands; 9220 – Integrated Pest Management.

Policy

Policies governing the use of chemical pest control on lands administered by the BLM are as follows:

A. All users must conform to basic policy statements as outlined in the Department of the Interior Pesticide Use Policy (517 DM 1).
B. All proposed uses of chemical pest control methods on public lands are to be reviewed and studied thoroughly to evaluate the need for such uses and to determine the possible impacts each may have on the ecosystem and total environment.
C. All alternatives available through integrated pest management (IPM) are to be explored. Integrated pest management (IPM) methods include, but are not limited to prevention, education, biological, cultural, mechanical, and chemical methods.
D. EPA-registered pesticides are considered safe for use when applied in conformance with current label guidelines and restrictions. These pesticides and the other methods of pest management available through integrated pest management (IPM) are effective and environmentally sound tools when applied correctly.
E. Given a variety of viable alternatives the most cost effective method shall be chosen.
F. Only pesticides that have been analyzed and approved through National Environmental Protection Act (NEPA) documentation can be used in chemical pest control on BLM lands.

Files and Record Maintenance

Establish and maintain files in accordance with BLM Manual Section 1270 and disposed of in accordance with Manual Section 1272. See BLM Handbook 8-9011-1 or chapter 11 of this manual for a description of record keeping requirements and specific filing instructions.

Guidelines For Conducting Chemical Pest Control Programs.

When BLM consents to a chemical pest control program on lands administered by BLM at the request of individuals, organizations, or other Federal Agencies; and if the control work is accomplished by another Federal Agency, that agency must provide information for submission of a Pesticide Use Proposal (PUP – See Chapter 11) and receive the approval of the Authorized BLM official. All other chemical pest control programs, including those done under BLM proposals, cooperative projects, on right-of-ways, or by lessees and concessionaires, and other activities and authorizations issued pursuant to a permit, must be submitted for review and approval in PUP format that is in conformance with the procedures below. Those agencies, lessees, cooperators, and other authorized land users may be subject to punitive measures by failure to submit such proposals. Upon completion of an application of a pesticide, a Pesticide Application Record (PAR) must be completed within 24 hours. This record must be kept for 10 years in project files at the field office or at the station level.

Review and Coordination

A. Office of Environmental Affairs (OEA). The Department of the Interior, OEA, requires all pesticide proposals meeting the criteria as described in 517 DM 1 to be submitted to them for review.
B. Division of Range. The Division of Range coordinates all pesticide use proposals and forwards to OEA those projects requiring review by OEA officials. For those offices without trained and certified personnel, the Washington Office (WO) Chief, Division Renewable Resources and Planning gives final approval to all proposed projects that conform to Departmental and BLM policy.
C. State Director. The State Director coordinates all pesticide use proposals for his/her State and forwards to the Division of Range those proposals requiring review and approval by the Chief, Division of Range or OEA.

Planning

A. Manage chemical pest control programs on BLM lands consistent with and integrated into land management planning documents.
B. In addition to conforming to Departmental policy, an environmental analysis is prepared for each proposal. If this analysis indicates that an environmental impact statement is necessary, then it must also be prepared.

   1. Identifying and Organizing Objectives
      a. Weigh benefits of control against the environmental, economic, and values that may be threatened.
      b. Determine scope of project and integrate into the plan positive measures for protecting wildlife and other values.
      c. Determine for each target pest all possible courses of action and evaluate relative merits for controlling the pest with the least adverse effect on the environment. This integrated pest management (IPM) approach must be followed in arriving at the decision to use a chemical pesticide.
      d. Any program involving the use of chemical pest control is submitted as a pesticide use proposal (PUP) for review on a fiscal year basis to allow time for review and approval for inclusion in the annual work plan. Other submissions may be made on an emergency basis. For further details on Program Submission, Implementation, and Reports, refer to BLM Handbook (H-9011-1).

2. Coordinating with Other Agencies. Specialists of the United States Department of Health and Human Services, the United States Department of Agriculture, the United States Department of the Interior (Fish and Wildlife Service), and the Environmental Protection Agency provide consultation and assistance on problems of medical, agricultural, and environmental importance (i.e., disease and pest management, quarantine control, fish and wildlife protection) upon request. Personnel in BLM State Offices coordinate and request consultation and assistance as needed from local agency representatives. For further guidance in Animal Damage Control, see BLM Manual Section 6830, and Grasshopper, Mormon Cricket Control, see BLM Manual Section 9012.

3. Seeking Public Involvement. Before a decision is made to proceed with a chemical pest control project, the public shall be invited to review and comment on the site-specific analyses for the project. The public is to be notified of the final decision for a site-specific project as soon as it has been made. Notice methods include local newspapers, district and resource are public notices, and public rooms are used to distribute public information concerning proposed BLM actions.

4. Employing Protective Measures. Establish definite boundaries for the treatment area and leave a buffer strip along streams, near residences, and other sensitive areas. See page 35. Width depends on the pesticide used, method of application, climatic conditions, and form applied. Adhere to protective measures described on the label of the pesticide planned for use and refer to H-9011-1 for further guidance.

5. Training and Certification.

    a. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1972, as amended, P.L. 92-516 requires that all personnel applying restricted-use pesticides (RUP) to be certified in the use of these pesticides or be under the direct supervision of certified applicators. Additionally, it will be the policy of the BLM that all non-restricted pesticides be applied by certified applicators or under the direct supervision of a certified applicator. All personnel involved in planning, reviewing, supervising, or applying pesticides must be properly trained to handle pesticides and pesticide application equipment. This ensures that control measures are applied with maximum safety, efficiency, and economy. Continued training, periodic examinations, and appropriate certification of personnel are required to safeguard against misuse, prevent contamination of the environment, and protect public lands.
    b. It is the responsibility of the Washington Office to ensure adequate training and certification. The Assistant Director, Land and Renewable Resources, has the responsibility for all pesticides used within BLM. For further details, refer to the BLM Handbook H-9011-1.

Monitoring

Monitoring means the periodic measuring of the changes, over a period of time, from the introduced chemicals in various parts of the environment. For further details on monitoring refer to BLM Handbook H-9011-1.

Safety Plan - Pesticide Applications.

Project personnel and safety officers must be constantly alert to detect any unsafe practices. The officer in charge of the project and the District base radio operator must keep copies of a site-specific safety plan. The designated Contracting Office's Authorized Representative, inspector, or project officer is in charge, and the safety officer enforces the safety rule outlined. For further details on Safety Plans - Pesticide Applications, refer to BLM Handbook (H-9011-1).

Threatened and Endangered Species

Before a chemical pest control program may be initiated, a survey of the area for threatened or endangered species must be made. The BLM Manual Section 6840 encompasses the BLM policy for all endangered species.

Chapter 1 - PESTS AND PESTICIDES

Terms To Know

Active ingredient------------ Also known as a.i. or AI. Part of a pesticide formulation responsible for the pesticidal effect (killing, repelling or altering behavior).
Adjuvants ------------------- Additives that are added to a spray mixture to increase performance or offset certain application problems like water quality, drift and pH.
Annuals --------------------- Plants that live for one growing season only.
Apoplast -------------------- The major pathway for water and nutrients to move in a plant from the soil upward and into the leaves through the xylem.
Axil ------------------------- The angle formed by a leaf or branch with the stem.
Biennials -------------------- Plants that live for two growing seasons.
Chlorosis ------------------- Yellowing or blanching of plant parts that are normally green.
Carrier ---------------------- Liquid or solid used to dilute a pesticide's active ingredient <u>during the manufacture</u> of a pesticide formulation. Often confused with Diluent.
Contact pesticide------------ Provides control when targeted pest comes in physical contact with it. For plants, a contact herbicide kills only the part of the plant that makes contact.
Creeping root systems ------ Root modified for food storage and vegetative reproduction. Roots that penetrate deeper into the soil and are more resistant to control.
Diluent --------------- ---------Anything used to reduce the concentration of a pesticide formulation <u>at the time of application.</u>
Emulsifier ------------------ Adjuvant added to a pesticide formulation to permit petroleum-based pesticides to mix with water
Epinasty -------------------- Curling or bending of plant parts.
Eradication------------------ Destroying an entire pest population in an area.
Fibrous root system --------- A fine, densely branching root, which absorbs moisture and nutrients from the soil. This is a typical root system for most grasses.
Foliar ----------------------- Applied to the leaves of a plant.
Formulation----------------- Pesticide product as sold by the manufacturer, usually a mixture of active and inert ingredients. May be either a liquid or dry formulation.
Habitat---------------------- The place where a plant or animal lives, feeds, and breeds.
Host------------------------- The living plant or animal that a pest depends on for survival.
Inert ingredients ------------ Often called **carrier**, are added to the active ingredient of a pesticide product to make it suitable for storage, handling or application. Has no pesticidal effect.
Life cycle ------------------- Series of stages an organism passes through during its lifetime.
Metamorphosis-------------- The series of changes through which insects and insect-like organisms pass in their growth from egg to adult.
Mode of action-------------- The overall manner in which a pesticide affects a pest at the tissue or cellular level. Most commonly used to refer to herbicides.
Necrosis --------------------- Death or decay of tissue.
Nodes ----------------------- Slightly enlarged portion of stem or root where new growth occurs.
Nonpersistent pesticide ----- A pesticide that breaks down quickly after it is applied.
Nonselective pesticide------- A pesticide that is toxic to most plants or animals.
Parasite --------------------- An organism that lives and feeds on or in an organism of another species, which it usually injures.
Pathogen--------------------- Any disease-producing organism.
Perennial -------------------- Plants that live two or more years.

Persistent --------------------- Remaining active in the environment for at least one or more growing seasons giving continued protection against the pest.

Pesticide ---------------------- An economic poison defined in most state and federal laws as any substance used for controlling, preventing, destroying, repelling, or mitigating any pest.

Phloem ------------------------ Living tissue that transports sugars symplastically from site of photosynthesis to sites of storage or utilization.

Photosynthesis---------------- A chemical reaction in plants by which carbon dioxide and water combine to produce oxygen and the sugars. This is accomplished by light acting on light-sensitive pigments called chlorophylls.

Plant disease ----------------- Any harmful condition that makes a plant different from a normal plant in its appearance or function.

Postdirected------------------ Applied directly to weeds in a band or strip after emergence.

Postemergence--------------- Applied after the weed emerges from the soil.

Predator ---------------------- Any animal that destroys or eats other animals.

Pre-emergence--------------- Applied before the weeds emerge from the soil.

Preplant incorporated ------ (PPI) Incorporated into the soil before the crop is planted, and by definition, before weed emergence.

Prevention-------------------- Keeping a pest from becoming a problem.

Rainfastness------------------ Ability to resist the effects of rainfall. Usually expressed as the number of hours needed between time of application and rainfall or irrigation to ensure sufficient absorption of herbicide into a plant.

Rhizomes --------------------- Underground, horizontal roots often capable of growing roots at new nodes to grow new plants. Quackgrass is said to have a rhizomatous root system.

Rosette ----------------------- A group of leaves radiating from about the same point, often at ground level at the base of a very short stem, or at the tip of longer stems.

Selective pesticide----------- More toxic to some kinds of plants and animals than to others.

Slurry ------------------------ A mixture of a pesticide and a small portion of its diluent, usually in a small container (2 – 5 gallons) prior to adding to a spray tank.

Stolon ------------------------ Above ground horizontal stem that may produce roots. Bermudagrass is said to be stoloniferous.

Stomach poison ------------- A pesticide that kills when it is eaten by the pest.

Suppression ------------------ Reducing pest numbers or damage to an acceptable level.

Symplast ---------------------- The major pathway for sugars to move from the leaves downward to the roots and shoot tips of a plant.

Systemic pesticide ---------- Pesticide that needs to be ingested or taken up into the tissues of a target pest. The ability of a pesticide to be taken up by a plant or animal. When the insect feeds on this plant or animal, it ingests the systemic pesticide and is killed.

Taproot ----------------------- The main, downward-growing root of a plant, which grows deeply and produces lateral roots along its length. Dandelions and most biennial weeds have taproots.

Terrestrial-------------------- In reference to land.

Tolerance--------------------- Ability to withstand the effects of a pesticide without adverse effects.

Toxicant ---------------------- Substance that is poisonous to living organisms.

Translocated herbicide ----- A pesticide that kills plants by being absorbed by leaves, stems, or roots and moving throughout the plant.

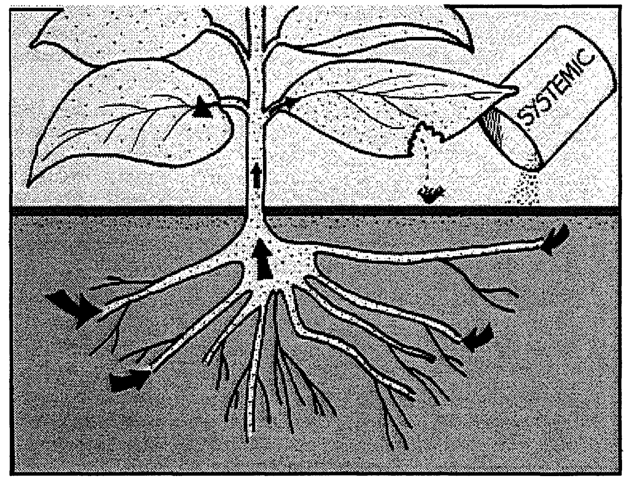
Tubers ------------------------ Thickened, underground, fleshy growth arising from stems or roots.

Vertebrate-------------------- An animal with a jointed backbone.

Volatility---------------------- Pesticide loss through evaporation.

Xylem ------------------------- Non-lining tissue in a plant that conducts water and minerals apoplastically from roots to shoots.

A pesticide is any chemical that is used to kill, control, repel or adversely alter the behavior of pests. The pests may be insects, plant diseases, weeds, birds, or ground squirrels. Therefore, insecticides, fungicides, herbicides, avicides, rodenticides and many other "-cides" are all types of pesticides. The suffix "-cide" means to kill.



The term **active ingredient (a.i.)** is often used to describe the chemical part of a pesticide formulation that produces the desired effect on the pest. For purposes of trade and registration pesticide manufacturers designate a **brand** or **trade** name for each product. The trade name is the name under which the pesticide is marketed and sold. Because active ingredients have complex **chemical names**, many are given a shorter **common name**. Only common names that are officially accepted by the EPA may be used in the ingredient statement on the pesticide label. Roundup™ is the brand or trade name for the herbicide containing the active ingredient, glyphosate, the common name. Some pesticides must only **contact** (touch) the pest to be deadly; others must make contact with all growing surfaces and be absorbed before they can be effective (**systemic**). Others pesticides must be swallowed or absorbed.

This chapter will give you some basic knowledge about destructive pests, their life cycles, and how they commonly develop and spread. The accurate detection, identification, and diagnosis of pest problems is a science where experience is important. When you find a pest or pest problem you cannot identify, seek a professional opinion.

When you have identified a pest, you must decide how to manage it. If control is necessary, decide whether you need to **prevent** the pest from becoming a problem, **suppress** the numbers of pests or the level of their damage, or **eradicate** the entire pest population. Then, using what you have learned about integrated pest management, choose the methods that will do a cost-effective job of managing the pest while causing the least possible harm to people and the environment.

WEEDS AND HERBICIDES

Any plant can be considered a weed when it is growing where it is not wanted. Weeds become a problem when they compete with desirable plants for water, nutrients, light, and space. Most terrestrial weeds are either grasses, sedges, or broadleaf plants.

Grasses

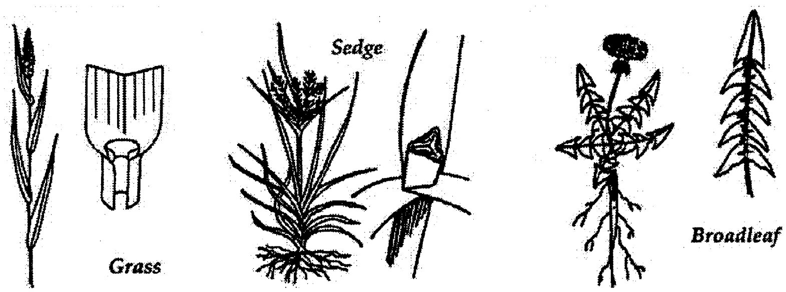
Grass seedlings have only one leaf as they emerge from the seed. Their leaves are generally narrow and upright with parallel veins. Grass stems are round and may be either hollow or solid. Most grasses have fibrous root systems. The growing point on seedling grasses is sheathed and located below the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

Sedges

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

Broadleaf weeds

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



Development Stages

All plants have four stages of development:

- **seedling** -- small, delicate plantlets.
- **vegetative** -- fast growth; production of stems, roots, and leaves. Uptake and movement of water and nutrients is **fast** and thorough.
- **seed production** -- energy directed to producing flowers and seed. Uptake of water and nutrients is **slow** and is directed mainly to flower, fruit, and seed structures.
- **maturity** -- **little or no** energy production or movement of water and nutrients.

Life Cycles Of Plants

Annuals

Plants with a one-year life cycle are **annuals**. They grow from seed, mature, and produce seed for the next generation in one year or less. They are grass-like (crabgrass and foxtail) or have broad leaves (burdock and houndstongue). There are two types of annuals:

- **Summer annuals** are plants that grow from seeds that germinate in the spring. They grow, mature, produce seed, and die before winter. Examples: crabgrass, foxtail, common cocklebur, pigweed, and common lambsquarters.
- **Winter annuals** are plants that grow from seeds that germinate in the fall. They grow, mature, produce seed, and die before the following summer and include downy brome, many mustards and chickweed.

Biennials

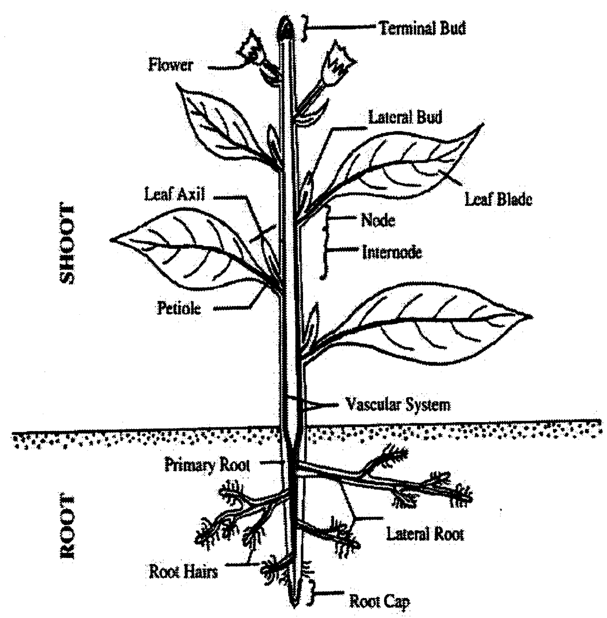
Plants with a two-year life cycle are **biennials**. They grow from seed and develop a heavy root (taproot) and compact cluster of leaves (rosette) the first year. In the second year, they mature, produce seed, and die. Examples: mullein, burdock, and many large thistles.

Perennials

Plants that live more than two years are **perennials**. Some perennial plants mature and reproduce in the first year and then repeat the vegetative, seed production, and maturity stages for many following years. In other perennials, the seed production and maturity stages may be delayed. Some perennial plants die back each winter; others, such as deciduous trees, may lose their leaves, but do not die back to the ground. While most perennials grow from seed, many species also produce tubers, bulbs, rhizomes or stolons. Examples of perennials are leafy spurge, field bindweed, dandelion, and Canada thistle. Perennials can also be further classified as:

- **Simple perennials** normally reproduce by seeds or from taproots. However, root pieces that may be left by cultivation may produce new plants. Examples: dandelions, plantain, spotted knapweed, trees, and shrubs.
- **Bulbous perennials** may reproduce by seed, bulblets, or bulbs. Wild garlic produces seed and bulblets above ground and bulbs below ground.
- **Rhizomatous and creeping perennials** produce seeds but also produce rhizomes, stolons, or roots modified for food storage and vegetative reproduction (creeping roots). Examples: Johnson grass, Bermuda grass, field bindweed, leafy spurge and Canada thistle.

Principal Parts of a Vascular Plant



Weed Control Strategy

Weed control is nearly always designed to **prevent** or **suppress** a weed infestation. Eradication usually is attempted only in regulatory weed programs and in relatively **small, confined areas**, where total control is feasible.

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

While there are many methods of weed control (mechanical, cultural, biological) herbicides tend to be used most often. Herbicides are pesticides used to control unwanted plants and are categorized by their selectivity and mode-of-action.

Herbicide Selectivity

The susceptibility or tolerance of different plants to herbicides is called **herbicide selectivity**. Several factors affect a plant's susceptibility to herbicides:

- **Growing points** – Growing points that are sheathed or located below the soil surface are not reached by contact herbicides.
- **Leaf shape -** Herbicides tend to bounce or run off narrow, upright leaves. Broad, flat leaves tend to hold the herbicide longer.
- **Waxy cuticle -** Sprays applied to leaves may be prevented from entering by a thick, waxy cuticle. The waxy surface also may cause a spray solution to form droplets and run off the leaves.
- **Leaf hairs -** A dense layer of leaf hairs holds the herbicide droplets away from the leaf surface, allowing less of the herbicide to be absorbed into the plant. A thin layer of leaf hairs causes the chemical to stay on the leaf surface longer than normal, allowing more chemical to be absorbed into the plant.
- **Size and age -** Young, rapidly growing plants are more susceptible to herbicides than are larger, more mature plants.
- **Deactivation -** Certain plants can stop the action of herbicides and are less susceptible to injury from these chemicals. Such plants may become dominant over a period of time if similar herbicides are used repeatedly. Grasses can tolerate herbicides such as 2,4-D, dicamba (Banvel™, Clarity™) and picloram (Tordon™) because they can metabolize these herbicides faster than broadleaf plants. These types of herbicides are known as **selective herbicides**. These same grasses, as well as broadleaf plants, are in turn controlled by the **nonselective herbicides** such as glyphosate (Roundup™) and paraquat (Gramoxone™).
- **Stage in life cycle -** Seedlings are very susceptible to herbicides and to most other weed control practices. Plants in the vegetative and early bud stages are generally very susceptible to translocated herbicides. As low-growing rosettes, biennials tend to be more susceptible during their first year of growth. Plants with seeds or in the maturity stage are the least susceptible to most chemical weed control practices.
- **Timing of stages in the life cycle -** Plants that germinate and develop at different times than non-target species may be susceptible to carefully timed herbicide applications without risk of injury to other desirable plants.

HERBICIDES

Mode of Action

Herbicide mode-of-action is the manner in which herbicides affect plants at the tissue or cellular level. Herbicides with the same mode-of-action will have the same translocation (movement) pattern and produce similar injury symptoms. Within a plant, herbicides move either in the **symplast**, the major pathway for sugars from the leaves to move downward through the phloem to the roots and shoot tips; or in the **apoplast**, the major pathway for water and nutrients from the soil to move upward through the xylem and into the leaves. Movement with a plant occurs faster through the xylem.

Herbicides are also classified as **soil-applied** and affect only roots and shoots; or as **contact** herbicides; those that do not move, kill very quickly but only kill the part of the plant they touch.

Soil Applied Herbicides

Root inhibitors such as the herbicides trifluralin, (Treflan™), ethalfluralin (Sonalan™) and pendimethalin (Prowl™) belong to the Dinitroanilines, also known as "yellow" herbicides. These herbicides inhibit the steps in plant cell division and affected roots are relatively few in number and club shaped. Except for oryzalin (Surflan™), these compounds have water solubility less than one part per million and bind to soil particles so they are unlikely to leach. Losses mainly occur through volatilization and photodegradation on soil surfaces. Therefore, incorporation into the soil by mechanical mixing or by overhead irrigation soon after application is routinely suggested.

Shoot Inhibitors, EPTC (Eptam™), acetochlor (Harness™) are soil applied for control of seedling grasses, some broadleaves and suppression of some perennials from tubers and rhizomes. Injury appears as malformed (twisted), dark green shoots and leaves on injured young plants. Grass crops with some tolerance to these compounds can be protected from injury with other chemicals (safeners and protectants).

Shoot and Root Inhibitors are preplant incorporated, preemergence and sometimes early postemergence for control of annual grasses, and some annual broadleaves in small seeded legumes, established woody species, established turf, established herbaceous perennials. Herbicides in this group include pronamide (Kerb™) and dichlobenil (Casoron™).

Foliar-Applied, Symplastically Translocated Herbicides

Plant Growth Regulators disrupt hormone balance and protein synthesis. Chlorosis, stoppage of growth, and distorted new growth (epinasty) are typical symptoms and are evident on new growth first. The plants die slowly. Examples of the plant growth regulators include 2,4-D, picloram (Tordon™), dicamba (Banvel™, Clarity™), clopyralid (Stinger™, Curtail™), and fluroxypyr (Starane™).

Amino Acid Synthesis Inhibitors prevent plants from producing specific amino acids, the key building blocks for normal plant growth and development. Symptoms include yellowing of new growth and death of treated plants in days to weeks. Glyphosate (Roundup™) and sulfosate (Touchdown™) are herbicides that affect the production of aromatic amino acids while the sulfonylurea (SU) herbicides such as sulfometuron (Oust™), metsulfuron-methyl (Ally™, Escort™); and the imidazolinone herbicides such as imazapyr (Arsenal™) and imazethapyr (Pursuit™) affect other sites of amino acid production. High soil pH greatly increases the persistence of the SU herbicides while pHs below 6.8 increase chemical degradation of the herbicide. Dry weather and cool temperatures in particular, and possibly low pH and high organic matter, contribute to persistence of the imidazolinones in the soil.

Lipid Synthesis Inhibitors prevent the formation of fatty acids, components essential for the production of plant lipids. Lipids are vital to the integrity of cell membranes and to new plant growth. Leaves yellow, redden and sometimes wilt. Seedling grasses tend to lodge by breaking over at the soil surface. Included in this group are the grass herbicides sethoxydim (Poast™) and clethodim (Select™).

Pigment Inhibitors prevent plants from forming photosynthetic pigments. New growth turns white and is sometimes tinged with pink or purple. New growth initially appears normal except for the conspicuous lack of green and yellow pigments. Clomazone (Command™), fluridone (Sonar™) and amitrole are examples of this herbicide group.

Upwardly Mobile Only Herbicides, Apoplastically Translocated

Photosynthesis Inhibitors inhibit the photosynthetic process and translocate apoplastically. Movement is upward with water in the plant, moving through the plant from the soil and evaporating into the atmosphere at the leaf surfaces. Symptoms develop from bottom to top on plant shoots (older leaves show most injury; newer leaves least injury). Chlorosis first appears between leaf veins, along the margins, followed by necrosis of the tissue. Any potential control of established perennials must come from continued soil uptake and not movement downward through the plant from the shoots. Foliar activity alone can provide only shoot kill. Herbicides in this chemical group have excellent soil activity. Soil persistence varies from weeks to months depending on compound and dose and soil pH. Soil mobility varies from low to high depending on the compound and soil characteristics. Herbicides in this grouping include atrazine, simazine and tebuthiuron (Spike™).

Non-translocated (Contact Herbicides)

The use of **Cell Membrane Destroyers** such as paraquat (Gramoxone™) and diquat results in rapid disruption of cell membranes and very rapid kill. These compounds are activated by sunlight to form oxygen compounds (hydrogen peroxide) that destroys plant tissue by rupturing plant cell membranes. This results in a rapid browning (necrosis) of plant tissue.

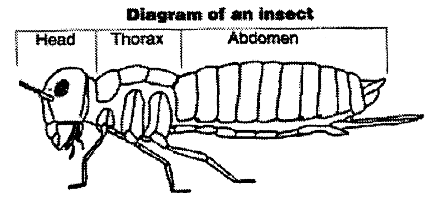
Rapid destruction of cell membranes prevents translocation to other regions of the plant. Severe injury is evident hours after application as water-soaked areas that later turn yellow or brown. Maximum kill is attained in a week or less. Partial coverage of a plant with spray results in spotting and/or partial shoot kill. New growth on surviving plants will be normal in appearance. Foliar activity alone can provide only shoot kill.

The mode-of-action of a herbicide also influences how a herbicide is applied. For example, contact herbicides that disrupt cell membranes, needs to be applied to leaf tissue after a plant has emerged (postemergence). Also, it is necessary to have good coverage of the vegetation by contact herbicides. In contrast, most seedling growth inhibitors need to be applied to the soil prior to plant growth to effectively control newly germinated seedlings (preemergence).

To be effective, herbicides must:

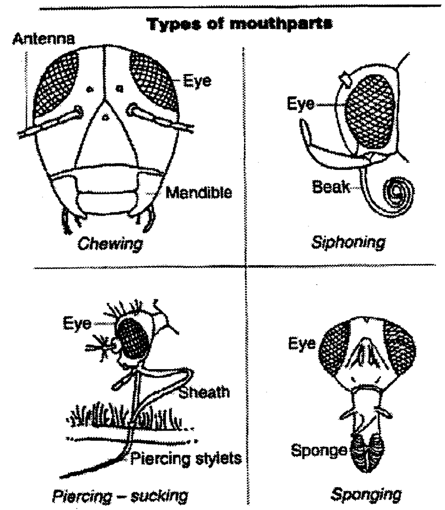
- adequately contact plants so good coverage by the spray mixture is essential,
- be absorbed by plants,
- move within the plants to the site of action, without being deactivated,
- reach toxic levels at the site of action.

INSECTS AND INSECTICIDES



There are more kinds of insects on earth than all other living animals combined. The large number of insects can be divided into three categories according to their importance to people:

Species of ecological importance -- About 99 percent of all species are in this category. They do not directly help or harm people, but they are crucial in the food web. They are food for birds, fish, mammals, reptiles, amphibians, aquatic life, and other insects. Some remove animal wastes and dead plants and animals, returning nutrients to the environment. Some are considered beautiful.



Beneficial insects -- In this small but important group are the pollinators and predators that feed on harmful insects, mites, and weeds. Without pollinators, many kinds of plants could not grow. Examples are ladybird beetles, some bugs, ground beetles, tachinid flies, praying mantids, and many tiny parasitic wasps.

Destructive insects -- Although this is the category that usually comes to mind when insects are mentioned, it includes the fewest species. These are the insects that suck out plant juices, bore into stems and spread disease. This category includes aphids, beetles, fleas, mosquitoes, caterpillars, and termites. Forest insects tend to become problems in weak, slow-growing stands of trees. Forest insect defoliators include forest tent caterpillars, tussock moth, spruce budworm and gypsy moths. Wood-boring insects channel into the tree bark and cambium layer and lower the quality of the wood. This can also lead to secondary damage by plant diseases such as fungi. Some range plants and trees are over-wintering hosts for destructive insects that transmit plant diseases to agricultural crops.

Insect Physical Characteristics

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

Head - The head has antennae, eyes, and mouthparts. **Antennae vary in size and shape and can aid in identifying some pest insects.** Insects have compound eyes made up of many individual eyes. These compound eyes enable insects to detect motion, but they probably cannot see clear images. **Mouthparts are also used to identify insects.** The four general types of mouthparts are:

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

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

Thorax - The thorax contains the three pairs of legs and (if present) the wings. **The various sizes, shapes, and textures of wings and the pattern of the veins are also used to identify insect species.** The forewings take many forms. In the beetles, they are hard and shell-like; in the grasshoppers, they are leathery. The forewings of flies are membranous; those of true bugs are part membranous and part hardened. Most insects have membranous hindwings, but the wings of moths and butterflies are membranous and covered with scales.

Abdomen - The abdomen is usually composed of 11 segments, but 8 or fewer segments may be visible. Along each side of most of the segments are openings (called spiracles) through which the insect breathes. In some insects, the tip end of the abdomen has a tail-like appendage.

Important Insect Orders

Insects are classified into the animal kingdom. Each kingdom is then further divided into increasingly smaller groups based on similarities. The standard groups in a typical complete classification of species are (the example is for a honey bee, *Apis mellifera* Linnaeus):

KINGDOM (Animal)
PHYLUM (Arthropoda)
CLASS (Insecta)
ORDER (Hymenoptera)
FAMILY (Apidae)
GENUS (*Apis*)
SPECIES (*mellifera*)

Of the 31 insect orders, there are 9 that contain most of the destructive insects.

1. Coleoptera – Beetles, weevils
2. Diptera – Flies, mosquitoes
3. Hemiptera – True bugs, assassin bugs, stink bugs, bed bugs, lygus bugs
4. Homoptera – Aphids, leafhoppers
5. Hymenoptera – Wasps, bees, ants, sawflies
6. Lepidoptera – Butterflies and moths
7. Orthoptera – Grasshoppers
8. Siphonaptera – Fleas
9. Thysanoptera - Thrips

Life Cycles of Insects

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

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

When the young first hatches from an egg, it is either called a larva, nymph, or naiad, depending on the species. After feeding for a time, the young grows to a point where the skin cannot stretch further; the young sheds its skin (molts) and new skin is formed.

The number of these developmental stages (called instars) varies with different insect species and, in some cases, may vary with the temperature, humidity, and food supply. The heaviest feeding generally occurs during the final two instars.

The mature (adult) stage is when the insect is capable of reproduction. Winged species develop their wings at maturity. In some species, mature insects do not feed, and in some species the adults do not feed on the same material as the immature forms.

No metamorphosis

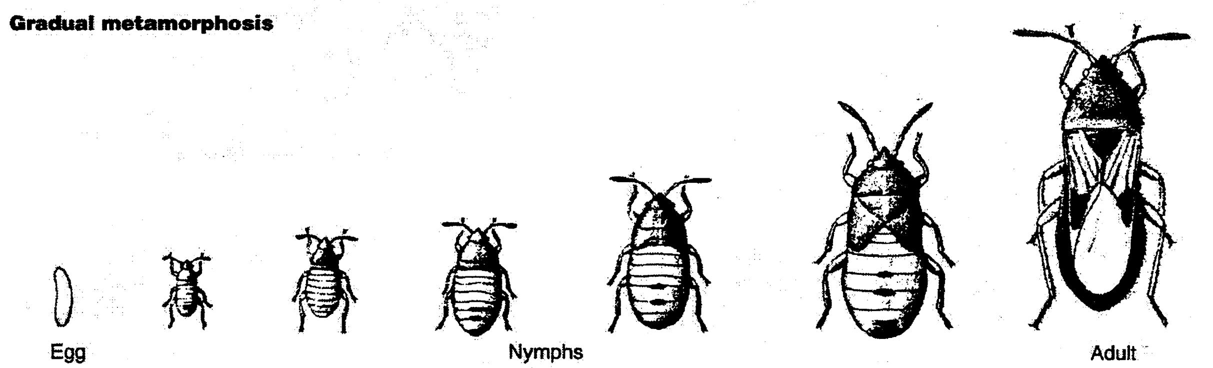
Between hatching and reaching the adult stage, some insects do not change except in size. The insect grows larger with each successive instar until it reaches maturity. Examples are silverfish, firebrats, and springtails. The food and habitats of the young (called nymphs) are similar to those of the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

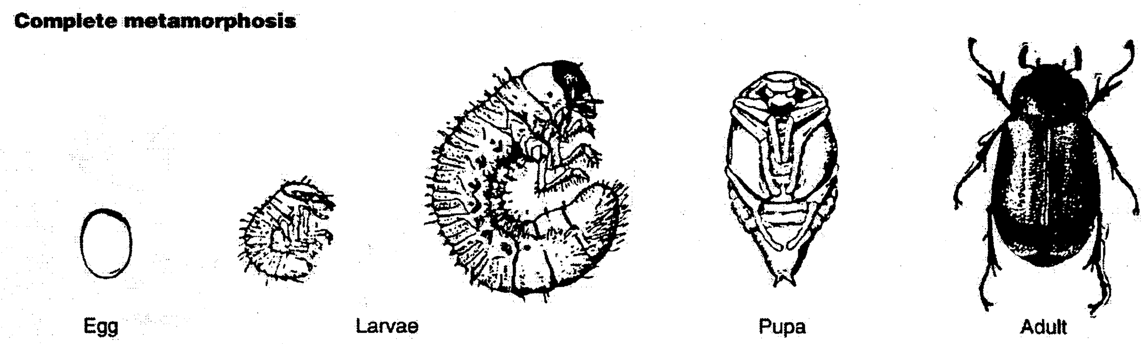
Gradual metamorphosis

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

Incomplete metamorphosis

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





Complete metamorphosis

The insects with complete metamorphosis pass through four stages of development: egg, larva, pupa, and adult. The young are called larvae, caterpillars, maggots, or grubs and are entirely different from the adults. They usually live in different situations and in many cases feed on different foods than adults. Examples are the beetles, butterflies, flies, mosquitoes, fleas, bees, and ants. The army cutworm larvae cause serious damage in small grains while the adults, known as miller moths, are not considered destructive pests at all. Grizzly bears actually consume the adult miller moths in the absence of high quality forage during July and August.

Larvae hatch from the egg and grow larger, passing through one to several instar stages (called molting). Moth and butterfly larvae are called caterpillars and some beetle larvae are called grubs. Most fly larvae are called maggots. Caterpillars often have legs but maggots and weevil grubs are legless. Beetle larvae usually have three pairs of legs. The pupa is a resting stage during which the larva changes into an adult with legs, wings, antennae, and functional reproductive organs. Some insects form a cocoon during this stage.

Insect Control Strategies

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

To successfully control insects and insect-like pests, you need a thorough knowledge of their habitats, feeding habits, and life cycle stages. Environmental conditions, such as humidity, temperature, and availability of food, can affect the length of the life cycle by altering the growth rate of the insects. A favorable environment (usually warm and humid) can shorten the time of development from egg to adult.

You must carefully monitor pest populations and take management action at a time when you are most likely to succeed. For example, timing may be essential when you need to control an internal feeder before it enters the plant. It is particularly useful to know the life cycle stages in which the pests are most vulnerable:

- In the **egg and pupal stages**, insects may be difficult to control, because these stages are inactive. The pests are not feeding, are immobile, and often are in hard-to-reach areas such as under the ground, in cocoons or cases, and in cracks or crevices.
- In the **late instar and adult stages**, insects may be controlled with moderate success. Because of their size, the insects are easiest to see in these stages and usually are causing the most destruction. However, larger insects are often more resistant to pesticides, and adults already may have laid eggs for another generation.
- The **early larval or nymph stages**, when insects are small, active, and vulnerable, is when you usually can achieve the best control.

INSECTICIDES

Often the word "insecticide" is confused with the word "pesticide." It is, however, just one of many types of pesticides. At the beginning of World War II, insecticide selection was limited to arsenic-based compounds, petroleum oils, nicotine, pyrethrum, rotenone and cyanide gas. World War II opened the chemical era with the introduction of synthetic organic insecticides.

There are many groups of insecticides, both contact and systemic. The most widely used are the organochlorines, organophosphates, carbamates, pyrethroids, spinosyns, insect growth regulators and botanicals.

Organochlorines

The organochlorines contain carbon (thus organo-), hydrogen, and chlorine, making them highly persistent. The oldest group of the organochlorines contained DDT with more than 4 billion pounds being used between 1940 and 1973, when the U.S. Environmental Protection Agency canceled all uses. Only a few organochlorines survive in today's pesticide arsenal. The organochlorines destroy the balance of sodium and potassium ions within the nervous system in a way that prevents normal transmission of nerve impulses, both in insects and mammals. They can also be very persistent in the environment. Other organochlorines include, lindane, dieldrin, endrin and chlordane; most of which are no longer registered for use in the U.S.

Organophosphates

Organophosphates (OPs) are phosphorous-containing insecticides. Because of their similarity to the "nerve gases", the OPs are more toxic other groups of insecticides. Since they are chemically relatively non-persistent, they have been used as substitutes for the persistent organochorines.

In insects, the OPs work by poisoning the central nervous system. In mammals, the organophosphates inhibit cholinesterase, an essential enzyme of the nervous system responsible for proper nerve/muscle control. With the OPs, this inhibition is irreversible and results in rapid twitching of voluntary muscles, paralysis and possible death. The drugs atropine and 2-PAM are used to counter the effects of OP poisoning.

Common organophosphate insecticides include: parathion, malathion, Di-syston™ (disulfoton), Dursban™ (chlorpyrifos), Reldan™ (chlorpyrifos - methyl) and Cygon™ (dimethoate).

Carbamates

The carbamates, derivatives of carbamic acid, have a mode-of-action is similar to the OPs. They also affect mammals in that their mode of action is that of inhibiting cholinesterase. Only the drug atropine is used to counter the effects of carbamate poisoning.

The first successful carbamate insecticide was Sevin™ (carbaryl), introduced in 1956. Two distinct qualities have made it the most popular carbamate: its very low mammalian oral and dermal toxicity (cholinesterase inhibition by carbamates is reversible) and an exceptionally broad spectrum of insect control. Other carbamates are methomyl (Lannate™), carbofuran (Furadan™), aldicarb (Temik™), and propoxur (Baygon™).

Pyrethroids

Natural pyrethrum, from chrysanthemum plants, is seldom used because of its cost and instability in sunlight. Recently, synthetic pyrethrums (pyrethroids) have become available and are very stable in sunlight and generally effective against most insect pests at very low rates. The pyrethroids include permethrin (Ambush™ and Pounce™), bifenthrin (Capture™), lambda-cyhalothrin (Warrior™), cypermethrin (Ammo™), and cyfluthrin (Tempo®). All of these are photostable and do not undergo photolysis (splitting) in sunlight. And because they have minimal volatility they provide extended residual effectiveness, up to 10 days under optimum conditions. Pyrethroids affect both the peripheral and central nervous system of the insect and initially stimulate nerve cells to produce repetitive discharges and eventually cause paralysis.

Nicotinoids

The nicotinoids are a new class of insecticides with a mode of action modeled after the natural compound nicotine. Imidacloprid was first registered in the U.S. in 1992 and is primarily marketed under the trade names Admire™ and Gaucho™. The nicotinoids act on the central nervous system of insects resulting in rapid death.

Spinosyns

Spinosyns are the newest class of insecticides, represented by spinosad (Tracer™, Spintor™). Spinosad is a fermentation by-product of a soil-inhabiting microorganism and is effective as a broad-spectrum material for most caterpillar pests at low rates. Spinosad acts by disrupting the binding of the acetylcholine, a chemical essential for proper nerve function.

Insect Growth Regulators

Rather than acting like a regular "poison," insect growth regulators (IGRs) interfere with insect development and are taken up more by ingestion than by contact. Their greatest value is in the control of caterpillars and beetle larvae. Dimilin™ (diflubenzuron) is a common IGR that acts on the larval stages of insects by blocking the synthesis of chitin, their hard outer covering.

Botanicals

Botanical insecticides are natural insecticides derived from plants. **Pyrethrum,** extracted from the chrysanthemum flowers, was used in the early 19th century to control body lice. Pyrethrum acts on insects with phenomenal speed causing immediate paralysis, thus its popularity in fast knockdown household aerosols. However, unless it is formulated with one of the synergists most of the paralyzed insects recover to once again become pests.

Synergists Or Activators

Synergists are not considered toxic or insecticidal, but are used with insecticides to enhance the activity of the insecticides. The most common synergist is piperonyl butoxide used to enhance the action of the fast knockdown insecticides such as pyrethrum, allethrin, and resmethrin against flying insects. Synergists simply bind to certain enzymes in the pest and prevent them from degrading the toxicant.

PLANT DISEASES

Diseases in plants may be caused by a) viruses, b) bacteria, c) fungi, d) nematodes or e) parasitic plants like mistletoe. Nematodes are small, unsegmented worms. Since they live in the soil, pesticides used to control them (nematicides) are usually applied before planting. Nematodes cause small knots on the roots and kill the tips of feeder roots. Symptoms of nematode damage include yellowing of leaves, stunting and general decline of the plant.

The most important forest diseases in terms of future production include the fungal rusts, root rots and dwarf mistletoe. Fungicides are chemicals used to control the fungi that cause molds, rots, and plant diseases. Because fungi do not "swallow" in the normal sense, all fungicides work by coming in contact with the fungus. Therefore, most fungicides are applied over a large surface area. Some fungicides may be systemic in that the plant to be protected and must be absorbed by the plant. The fungicide then moves throughout the plant, killing the fungi.

RODENTICIDES

Rodenticides are chemicals used to control pocket gophers, ground squirrels, rats, mice, bats and other rodents. Chemicals that control other mammals, birds (avicides), and fish (piscicides) are also grouped in this category by regulatory agencies. Most rodenticides are stomach poisons and are often applied as baits. Rodenticides are usually applied in limited areas such as runways, known feeding places, or as baits.

PESTICIDE FORMULATIONS

The manner in which a pesticide comes from the manufacturer is known as its **formulation**. A single pesticide may be sold in more than one kind of product formulation (e.g., liquid, granular, dust) and in various concentrations.

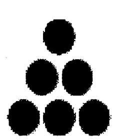
A pesticide formulation consists of one or more chemicals:

(1) The **active ingredient** or "a.i." is the part of a pesticide formulation that produces the desired effect on the pest. The name of the active ingredient is listed on the label and its concentration is expressed in percentage and often as the amount of a.i. per gallon.

(2) The **inert ingredients,** often called **carriers**, are added to the active ingredient of a pesticide product to make it suitable for storage, handling or application. Examples of inert ingredients are talc in a dust formulation or a petroleum distillate in an emulsifiable concentrate formulation. These ingredients are not specifically listed on the pesticide label but the concentration of inert ingredients is expressed as a percentage

Types of Formulations

Pesticides formulations can be divided into three main groups: dry, liquid and gas.



Dry
Dusts or Powders,
Granules, Pellets, Tablets,
Particulates
Dry Flowables

Liquids
Suspensions (Flowables),
Solutions, Emulsifiable
Concentrates

Gases
Fumigants sold as
liquids or solids

DRY FORMULATIONS

WETTABLE POWDERS (WP): The a.i. is combined with a finely ground dry carrier. Other ingredients that enhance the ability of the powder to suspend in water are also added. WP's are mixed with water for application as a spray. **Examples: Sevin 50 W®, , Kerb 50W®**
<u>Advantages:</u> Usually low costs * Easy to store and transport * Lower toxicity to plants than EC's and other liquid formulations * Easily measured and mixed * Less skin and eye absorption than EC's and other liquid formulations. <u>Disadvantages:</u> Inhalation hazard when pouring and mixing * Requires good and constant agitation (usually mechanical) in the spray tank * Difficult to keep suspended in backpack applications * Abrasive to many pumps and nozzles * Visible residues.

WATER SOLUBLE PACKETS/BAGS (WSP,WSB): Preweighted amounts of WP or SPs are packaged in water-soluble plastic bags that dissolve in water. **Examples: Ammo WSB®, Thiodan WSB®**
<u>Advantages:</u> Reduce mixing and handling hazards associated with highly toxic pesticides * Limited risks associated with inhalation or handling undiluted pesticide as long as packets are not opened. <u>Disadvantages:</u> Packets dissolve when exposed to water * Bags or packets are usually premixed at a specific rate.

FLOWABLES (F OR FL): A liquid formulation consisting of a finely ground active ingredient suspended in a liquid and then mixed with water for application. **Examples: Seed Treatments, Bravo 720®, Furadan 4F®**
<u>Advantages:</u> Easy to handle and apply * Seldom clogs nozzles. <u>Disadvantages</u>: Require moderate agitation * May leave visible residue.

DRY FLOWABLES OR WATER DISPERSABLE GRANULES (DF OR WDG): Like WPs but a.i. is formulated on a granule instead of powder. **Examples: Escort DF®, Ally®, Amber®**
<u>Advantages:</u> Easier to mix than WPs * Less exposure to fine dusts. <u>Disadvantages:</u> Needs agitation * Difficult to keep suspended in backpack applications.

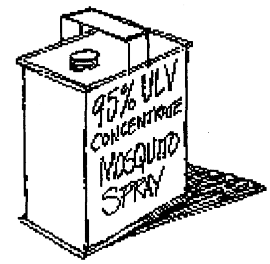
GRANULES OR PELLETS (G, P or XP for eXtruded Pellet): Most often used for soil applications. The a.i. is coated onto or absorbed into large, coarse particles such as clay pellets or granules. **Examples: Spike 20P®, Counter 15G®, Escort XP®**
<u>Advantages:</u> Ready to Use (RTU); no mixing * Drift hazard is low as particles settle quickly * Weight carries formulation through foliage to soil target * Simple application equipment. <u>Disadvantages:</u> Won't stick to foliage * Dust from application equipment might present hazard to applicator * More expensive than WPs or ECs * May need to be incorporated into soil *May need moisture to activate the active ingredient (ai).

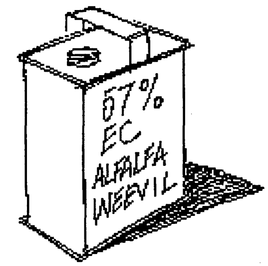
SOLUBLE POWDERS (SP): A dry formulation that is mixed with water for application that dissolves readily and forms a true solution. Example: **Carzol SP®**
<u>Advantages</u> Little agitation required. Read the label. <u>Disadvantages:</u> Not many products available because few active ingredients are soluble in water.

DUSTS (D): Low percentage of a.i. on a very fine dry inert carrier (chalk, clay or talc). Most are ready-to-use (RTU) Can drift easily.

FORMULATIONS - LIQUID

EMULSIFIABLE CONCENTRATE (E OR EC): Liquid formulation containing: the a.i., one or more solvents and an emulsifier to aid in mixing with water. **Examples: 2,4-D ester, Curtail M®, Treflan EC®, Fargo EC®**





<u>Advantages:</u> Easy to handle, store and transport * Usually a high concentration of a.i. per unit - more cost effective * Little agitation required. Will not usually settle out or separate when equipment is turned off * Little residue remains * Relatively non-abrasive.

<u>Disadvantages:</u> High concentration makes it easy to over- or underdose through mixing or calibration errors * More of a hazard to non-target plants and animals * Easily absorbed through skin of plants and animals * Solvents may cause rubber or plastic hoses, gaskets, or pump parts to deteriorate. May cause swelling in some plastic nozzles.

LOW VOLUME OR ULTRA LOW VOLUME (LV OR ULV): A liquid formulation usually applied small doses with specialized equipment usually with aircraft. Diluted with a small quantity of a specified carrier, usually 1 gallon per acre or less.

<u>Advantages</u>: Uses less product.
<u>Disadvantages</u>: Usually not suited to standard ground application equipment.

SOLUBLE LIQUID (S): A liquid formulation in which the active ingredient readily dissolves in water. Consists of the a.i. and additives. **Examples: Tordon 22K®, Krenite S , Roundup®**

<u>Advantage:</u> Will not separate or settle out when mixed with water.
<u>Disadvantage:</u> Few in number.

OTHER FORMULATIONS

MICROENCAPSULATION (ME OR M): Particles of pesticides (either dry or liquid) surrounded by a plastic-like polymer coating. The formulation product is mixed with water and applied as a spray. Once applied, the capsule slowly releases the pesticides. Then encapsulation process can prolong the active life of the pesticide by providing a time release of the active ingredient. **Example: Penncap M™**

<u>Advantages</u>: Increased safety to applicator. Easy to mix, handle and apply.
<u>Disadvantages:</u> Constant agitation necessary in tank. Some bees may pick up the capsules and carry them back to the hive, where the released pesticide may poison the entire hive.

Selecting a Formulation

1. What is the target pest or pests?
   - How will the formulation affect non-target plant and animal species? Because of the addition of solvents and emulsifiers, EC formulations may affect non-target species more than a WP or DF formulation.
   - How will the formulation influence the compatibility of other pesticides? Because of the addition of solvents and emulsifiers, EC's may combine better with other pesticides in a mixture. Always read the label for compatibility restrictions and conduct a compatibility test if in doubt.

2. What application equipment is best suited for certain formulations?
   - EC's may cause hoses and pump parts to deteriorate over time. WP's may cause roller pumps to wear.
   - Is the equipment best suited certain formulations? Centrifugal and diaphragm pumps may be best suited for WP's but may need mechanical agitation in the tank to keep the products suspended. WP and DF formulations may not stay suspended in backpack sprayers.

3. What concerns are there for the safety of the applicator and other people?
   - Is the active ingredient I need to use for a particular pest available in different formulation? This consideration may limit human exposure potential. Perhaps a highly toxic pesticide is available in water soluble packets (WSP) that would limit handling exposure.

MIXING PESTICIDE FORMULATIONS

Always read the pesticide label before you mix pesticide formulations. For example, some labels prohibit the mixing of a pesticide with a liquid fertilizer. Some labels require that you mix two or more pesticides in a given sequence. In the absence of such guidelines, a way to remember the sequence for mixing solid and liquid formulations is W-A-L-E.

1. Fill the spray tank 1/4 full of water and begin agitation. Add any compatibility adjuvants or other additives used to counteract hard water conditions (water conditioners, ammonium sulfate, etc.)
2. Begin the W-A-L-E sequence:
3. Add **W**ettable Powders (WP), then **W**ater dispersible granules (W or WDG) or Dry Flowables (DF).
4. **A**gitate until the W's are uniformly dispersed, meanwhile adding water until 80 to 90% of the desired volume is achieved.
5. Add flowable **L**iquids (L).
6. **E**mulsifiable Concentrates (EC) and surfactants go in last.
7. Top off the tank, continue agitation until the pesticides are properly mixed.

It is better to mix liquids with liquids or dry formulations with dry formulations, rather than a liquid with a wettable powder. Small quantities of dry formulations often mix easier if a slurry is made first. And when mixing into cold water, slurry dry herbicides first. Mixing of a dry product directly into contact with an oil-based adjuvant or oil based EC formulations will cause encapsulation of the dry formulation and cause uneven suspension of the tank mixture.

PESTICIDE COMPATIBILITY

Often, two or more pesticides are mixed together to control more than one pest during the same application. However, some pesticides may be chemically incompatible and a chemical reaction between them may result in loss of pesticide activity, increased toxicity to the applicator, or injury to the treated surface. Wettable powders may form lumps or liquids may settle into layers or form solids that settle out. The label often lists compatibilities of the pesticide involved. Always read the pesticide label for any compatibility and mixing restrictions.

Compatibility Test For Pesticide Mixtures

WARNING: Always wear personal protective equipment (PPE) when pouring or mixing pesticides. Perform this test in a safe area away from food and sources of ignition. Pesticides used in this test should later be applied to a labeled site. Rinse all utensils and jars and dispose of the rinse water (rinsate) onto a site listed on the pesticide label. Do not use utensils or jars for any other purpose after they have contacted pesticides. Mark these containers clearly!

Step 1. Use two clean, clear quart-size jars. If using a compatibility agent, add 1/3 teaspoon of the agent to one of the quart jars. Mix well then add the pesticide(s) to the jars in the proper order (WALES). Use the following table for the amounts of carrier (diluent) to add to both jars.

Output of sprayer (GPA)	=	Amount of carrier (diluent) to add to jar
10 GPA	=	6 oz (One tablespoon is ½ ounce)
15 GPA	=	10 oz
20 GPA	=	13 oz
25 GPA	=	1 pint (16 oz)
30 GPA	=	19 oz
40 GPA	=	26 oz

Use 1 teaspoon of an EC for each quart recommended per acre.
Use 1 ½ teaspoon of a WP for each pound recommended per acre.

Step 2. Tighten the lids and shake the jar vigorously. Feel the sides of the jar to determine if the mixture is giving off heat. If so, the mixture may be undergoing a chemical reaction and the pesticides should not be combined. Let the mixture stand for about 15 minutes and feel again for unusual heat.

If scum forms on the surface, if the mixture clumps, or if any solids settle to the bottom (except for wettable powders), the mixture probably is not compatible. Finally, if no signs of incompatibility appear, test the mixture on a small area where it is to be applied.

WATER QUALITY & PESTICIDE PERFORMANCE

Hard Water and pH

Minerals and certain pH levels in spray water can diminish the effectiveness of many pesticides. Mineral ions such as calcium, magnesium, salts and carbonates, commonly found in hard water, can bind with the active ingredients of some pesticides, especially the salt-formulation herbicides such as Roundup® (glyphosate), Poast® (sethoxydim), Pursuit® (imazethapyr), and Liberty® (glufosinate) resulting in poor weed control. The use of water-conditioning additives can give hard water minerals something to bind with other than the herbicide. In addition, some ammonium sulfate-based adjuvants can be used to offset hard water problems.

Extreme pH levels in the spray mixture can cause some pesticides to break down prematurely. This is primarily true for the organophosphate insecticides that can break down into inactive compounds in a matter of hours or minutes in alkaline situations (pH>7). The insecticide Cygon® (dimethoate) loses 50 percent of its pest control power in just 48 minutes when mixed in water of pH 9. At a pH of 6, however, it takes 12 hours for degradation to progress to that extent. By contrast, the sulfonyl urea (SU) herbicides tend to break down more rapidly where the pH is below 7. At low pHs, the herbicide 2,4-D is an uncharged molecule. At higher pH, 2,4-D tends to become more anionic or negatively charged which can affect its movement in the environment as well as its absorption into a plant. It pays to know your water pH and check product labels for such limitations before using pesticides.

As a general rule-of-thumb, the optimum pH for spraying most pesticides is slightly acidic (pH 5 to 7) which creates an environment that is more favorable for the uptake of herbicides The sulfonyl urea (SU) herbicides being the exception as they will break down in acidic environments. Leaf coatings also often have a high pH that can contribute to poor performance with certain herbicides. The use of a buffering or acidifying adjuvant can stabilize or lower the pH of a spray solution thereby improving the stability of the pesticide being used.

Always read the pesticide label to determine if there are any hard water or pH effects that may affect your pesticide application

ADJUVANTS

Adjuvants are spray solution additives that improve the performance of a spray mixture. Examples of adjuvants include:

- compatibility agents - used to aid mixing two or more herbicides in a common spray solution.
- drift retardants - used to decrease the potential for herbicide drift.
- suspension aids - used to aid mixing and suspending herbicide formulations in solution.
- spray buffers- used to change the spray solution acidity.
- surfactants.

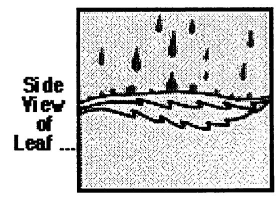
Types of Adjuvants

Adjuvants are generally classified by their uses rather than by their chemistry.

1. Surfactants and Wetting Agents
2. Oil-based Surfactants
3. Fertilizer-based Surfactants
4. Utility Adjuvants

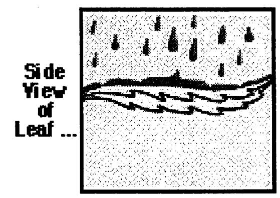
Surfactants

Surfactants (**Surf**ace-**Act**ing-**Agents)** are a broad category of adjuvants that are added to a spray mixture to facilitate and enhance the mixture's absorbing, emulsifying, dispersing, spreading, sticking, wetting and penetrating properties. Because of the high surface tension of water, spray mixture droplets maintain their roundness and can sit on the leaf hairs or leaf surface without much of the mixture actually contacting the leaf.



Without Adjuvants

Because postemergence herbicide effectiveness is greatly influenced by plant factors such as age and the growing conditions, herbicide performance can vary. A way to minimize the variations in postemergence herbicide performance is to use a surfactant in the spray solution.



With Adjuvants

Non-ionic surfactants (NIS) are composed of alcohols and fatty acids that do not produce either negative or positive electrical charges while in solution and therefore are compatible with most pesticides. Non-ionic surfactants are all-purpose and the most widely recommended.

Silicone-based surfactants are increasing in popularity due to their superior spreading ability. Some of these surfactants are a blend of non-ionic surfactants (NIS) and silicone while others are entirely silicone. The combination of a NIS and a silicone surfactant can increase absorption into a plant so that the time between application and rainfall can be shortened (increased rainfastness). Applicators are urged to exercise caution when applying silicone-based surfactants. The surfactant's extreme spreading ability may lead to droplet coalescence and subsequent runoff. Even so, silicone-based surfactants have the potential to give good coverage by chemical rather than by the physical means of using high volumes of carrier.

Oil-based Surfactants

The addition of oils as surfactants in spray solutions is a relatively common practice, depending on the type of herbicide and the weeds involved. It is important to note that not all oils provide the same effectiveness. Oil-based surfactants promote the penetration of a pesticide spray either through a waxy plant cuticle (skin) or through the tough chitinous shell of insects. Crop oils also may be important in helping make less water-soluble herbicides, such as Poast® (sethoxydim), Fusilade® (fluaziprop-butyl) and atrazine, more soluble.

In general, three types of oils are commonly referred to as surfactants: vegetable seed oils, crop oil concentrates, and esterified seed oils.

Vegetable seed oils are a blend of vegetable oil (cottonseed, soybean) and other surfactants. These surfactants exhibit good crop tolerance but do not have good spreading, sticking, or pest-penetrating properties.

Crop oil concentrates are a blend of paraffinic oil (petroleum based-80-85%) and the non-ionic surfactants (15-20%.) The purpose of the NIS in this mixture is to emulsify the oil in the spray solution and lower the surface tension of the overall spray solution. These surfactants exhibit good spreading and penetrating properties but crop tolerance may be a problem.

Methylated and esterified seed oils (MSO and ESO) are comprised of a methyl or ethyl esters of vegetable seed oil (sunflower, soybean, corn, canola) combined with a surfactant/emulsifier. These spray solution additives have good spreading and pest-penetrating properties and convey good crop tolerance. However, these additives generally are more expensive than vegetable seed oils or crop oil concentrates.

Fertilizer-based Surfactants

Nitrogen-based surfactant blends consist of combinations of various forms of nitrogen and surfactants and are used with herbicides recommending the addition of ammonium sulfate or 28 percent nitrogen. Research has shown that the addition of ammonium sulfate to spray mixtures enhances herbicidal activity on a number of hard-to-kill broadleaf weeds. Fertilizers containing ammonium nitrogen may also increase the effectiveness of certain polar, weak acid herbicides such as Banvel® (dicamba), Roundup® (glyphosate), Poast® (sethoxydim), Pursuit® (imazethapyr), and 2,4-D amine. It is thought that the ions in the fertilizer tie up hard water ions and also alter leaf pH thereby enhancing herbicidal action. It should also be noted that fertilizers applied with herbicides may cause crop injury. Fertilizers should only be used with herbicides as indicated on the pesticide label or where experience has proven acceptability.

Special Purpose or Utility Adjuvants

The special purpose or utility adjuvants are used to offset or correct certain conditions associated with mixing and application such as impurities in the spray solution (hard water), detrimental pH levels, drift, and compatibility problems between pesticides and liquid fertilizers. These adjuvants include acidifiers, buffering agents, water conditioners, anti-foaming agents, compatibility agents, dispersants and drift control agents.

PESTICIDE RESISTANCE

Insecticide-resistant insects, fungicide-resistant diseases and antibiotic-resistant bacteria were discovered long before herbicide-resistant weeds. The reason that weeds were the last pest category to show resistance is that they set seed and reproduce only once a year while insects can reproduce two and three times a year. This increases the possibility that naturally resistant insects will be produced since exceptionally large populations result in a wide variety of types, or genetic diversity, within the population. With most control measures (insecticides, herbicides or antibiotic drugs), small groups in the pest population (one in a million, billion, etc.) are naturally tolerant. Once the susceptible pests are killed off, only the tolerant ones will reproduce to product more resistant pests.

Identifying Pesticide Resistance

As pesticide applicators learn about pesticide resistance, an unfortunate side effect is that some pesticide failures resulting from bad weather, improper timing and improper applications are considered pesticide-resistance problems. Do not suspect pesticide resistance unless a failure fits the following traits:

- The same pesticide was used year after year.
- One pest, which normally should be controlled, is not controlled although other similar pests are controlled.
- A pest is spreading rapidly even though controls are used.
- Healthy pests are mixed with controlled pests (of the same species).

If you suspect pesticide resistance you should:

- Use pesticides with different modes-of-action to control the escaped pest. By varying the mode-of-action you are providing more pathways to control the pest and not just one.
- Do not allow resistant pests to reproduce. Do not let weeds go to seed.
- Use non-chemical practices such as cultivation, variety selection, etc. It takes longer for pests to overcome non-genetic methods of control.

Chapter 2
PESTICIDES IN THE ENVIRONMENT

Terms To Know

Adsorption characteristics (K_{oc}) --- The K_{oc} describes the relative affinity or attraction of the pesticide to soil material and, therefore, its mobility in soil.
Drift ------------------------------------ Movement of pesticides away from the target area.
Groundwater ------------------------- A region within the earth that is saturated with water.
Half life ($T_{½}$) -------------------------- A measure of pesticide degradation or persistence.
K_{oc} --------------------------------------- See Adsorption characteristics.
Hydrolysis ------------------------------ Chemically broken down by the addition of water.
Leaching -------------------------------- Transporting pesticides by percolating water.
Metabolized -------------------------- Living process by which a pesticide is changed into one or more different chemicals within a living organism.
Partition coefficient ----------------- See Adsorptive Characteristic and K_{oc}.
Persistence ---------------------------- Remaining in original form without breaking down.
Photolysis/photodegradation ------- Chemical decomposition using light energy.
Runoff ----------------------------------- Movement of pesticide across a land surface.
Soil permeability --------------------- To flow or spread through openings in the soil.
Soil organic matter (OM) ---------- Decaying plant and animal residues in the soil.
Soil texture --------------------------- Proportions of sand, silt, and clay.
Soil pH ---------------------------------- Measure of acidity or alkalinity on scale of 0 –14 respectively with 7 being neutral.
Water solubility ---------------------- Solubility is measured in mg/l of the pesticide in water at room temperature (20 or 25°C). It is generally the solubility of the pure (active ingredient) that is measured, not the formulated product.
Volatilization ------------------------- Evaporation potential and increases with air temperature and the vapor pressure of the pesticide. Occurs more rapidly in wet than in dry soils.

Once applied a pesticide, may be:

1. absorbed into the target pest,
2. bound to soil particles,
3. leached through the soil, or
4. broken down by UV light (photodecomposition).

A basic knowledge of a pesticide's chemical properties and its interaction with soil, water and air is the key to understanding how a pesticide will react in the environment. The ideal outcome is for a pesticide to stay on target, kill or repel the targeted pest, and then break down into harmless components that can be safely dissipated throughout the environment.

PESTICIDE MOBILITY

Pesticide mobility results in the redistribution of a pesticide either within the application area or its movement off-site. Mobility is affected by a pesticide's chemical properties as well as environmental and site characteristics such as soil texture, soil organic matter, weather and amount of water present.

The first step to understanding how pesticides react in the environment is to first understand two basic properties of pesticide chemistry.

1. Water Solubility
2. Adsorption to Soil

WATER SOLUBILITY

Water solubility describes the amount of pesticide that will dissolve into water. It is measured in either parts per million (ppm) or its equivalent, milligrams per liter (mg/l); the maximum number of milligrams that will dissolve in one liter of water. **The higher a pesticide's water solubility, the more likely it will move with water**. These values are most useful as a means of comparison and how much that actually dissolves in the field may differ due to temperature and the presence of other chemicals. Solubility of weak-acid or weak-base pesticides is also affected by pH.

Water Solubilities of Some Common Pesticides at 68°F		
Common Name	**Trade Name**	**Solubility**
Pendimethalin	Prowl	0.5 ppm
2,4-DB	Butyrac	40 ppm
Picloram	Tordon	430 ppm, 430 mg/L
2,4-D	Many	900 ppm
Clopyralid	Stinger, Curtail	1,000 ppm
Tebuthiuron	Spike	2,300 ppm
Glyphosate	Roundup	12,000 ppm
Dicamba (salt)*	Banvel, Clarity	400,000 ppm
The EPA "flags" any pesticide with a water solubility of > 30 ppm as a potential leacher.		
* Dicamba salt is a weak acid. Solubility may be affected by soil pH.		

ADSORPTION TO SOIL

Simply being water-soluble does not mean that a pesticide will **leach through** the soil profile or move across the land into surface water as **runoff.** Most pesticides will bind or be adsorbed by the organic matter fraction of soils. Organic matter is a complex mixture made up largely of decayed plant and animal material that coats soil particles in the surface layers of a soil profile.

Soil organic matter content can vary considerably among soil types, locations and with depth. To reduce some of this variability and provide a method for comparing the binding ability, pesticide adsorption is often expressed as **organic carbon partition coefficients** or simply $\mathbf{K_{oc}}$.

Pesticide K_{oc} values reflect how tightly pesticides will adsorb to organic matter in soils and provides a universal index for comparing adsorption. **Pesticides with higher K_{oc} values have a greater tendency to be adsorbed to soil organic matter and are less likely to leach** or be lost in runoff water.

K_{oc} Values					
K_{oc} < 50		**50 < K_{oc} < 5000**		**K_{oc} > 5000**	
Weakly Adsorbed		**Moderately adsorbed**		**Strongly adsorbed**	
May leach or runoff		**High potential for runoff**		**Runoff loss with sediment**	
Dicamba (Banvel™)	2	Tebuthiuron (Spike™)	80	Glyphosate	
Clopyralid (Stinger™)	6	Imazapyr (Arsenal™)	100	(Roundup™)	24,000
Picloram (Tordon™)	16	2,4-D ester	100	Paraquat	1,000,000
2,4-D amine	20				
Metsulfuron (Escort™)	35				

Generally, pesticide solubility and adsorption are inversely related; as solubility increases, adsorption generally decreases. Notable exceptions to this rule include the pesticides paraquat and glyphosate (Roundup®). Although these compounds are quite soluble, their chemical structure makes them adhere tightly to soils.

PESTICIDE FATE

In general, pesticide fate processes can be separated into three major categories:

1. Adsorption - binds pesticides,
2. Transfer processes - move pesticides,
3. Degradation processes - break pesticides down.

ADSORPTION

As discussed earlier, many soil factors influence pesticide adsorption. Soils high in organic matter or clay are more adsorptive than coarse sandy soils. In part this occurs because a clay or organic soil has a greater particle surface area or number of sites onto which pesticides can bind. Soil moisture also influences adsorption. Because water molecules compete with pesticides for binding sites on soil particles, wet soils tend to adsorb less pesticide than dry soils. Pesticides may also adsorb onto plant materials such as litter in no-till or minimum-till fields, the bark of trees, or thatch in turf. These organic layers may prohibit pesticide movement to target areas deeper in the soil.

TRANSFER

Pesticide transfer is sometimes essential for controlling pests. For example, certain pre-emergence herbicides (those applied prior to plant growth) must move within the soil to reach the germinating weed seeds. But too much movement can move a pesticide away from the target pest and can lead to reduced pest control, injury of non-target species including humans, and contamination of surface water and groundwater. Pesticides can be transferred in five ways:

1. Volatilization,
2. Runoff,
3. Leaching,
4. Absorption,
5. Crop removal.

Volatilization

Volatilization is the conversion of a solid or liquid into a gas. Once volatilized, a pesticide can move with air currents away from the treated surface. The **vapor pressure** of pesticides is an important factor in determining if a pesticide will volatilize (See Chapter 9 - Drift). Environmental factors such as high temperature, low relative humidity and the lack of air movement also tend to increase volatilization. A pesticide tightly adsorbed to soil particles is less likely to volatilize; therefore, soil conditions such as soil texture, organic matter content, and moisture also influence pesticide volatilization. Different pesticide formulations also can help reduce volatilization. Granular (G), flowable (F), and wettable powders (WP) are less susceptible to volatilization than emulsifiable concentrates (EC) and soluble powders (S).

Runoff And Leaching

Runoff is the movement of water across a sloping soil surface at a faster rate than it can enter the soil profile. Runoff water can carry pesticides in the water itself or by being bound to eroding soil particles. Over-irrigation and poor timing of pesticide applications can lead to the accumulation of excess surface water and subsequent pesticide runoff. Runoff can also occur if a pesticide is applied to a saturated soil, resulting from a previous rain or irrigation.

Leaching is the movement of pesticides through the soil profile and depends, in part, on the chemical and physical properties of the pesticide. For example, a pesticide held strongly to soil particles by adsorption is less likely to leach. The persistence, or longevity of a pesticide also influences the likelihood of leaching. A pesticide that is rapidly broken down by degradation processes is less likely to leach because it may remain in the soil for only a short time. Soil factors that influence leaching include texture, organic matter and soil permeability. Permeability is a function of soil texture, structure, and pore space. Highly permeable, coarse, sandy soils have large pores that allow water and pesticides to move rapidly between soil particles during rainfall or irrigation. In medium and fine-textured soils, water moves more slowly, allowing more time for pesticide adsorption and degradation. Soil permeability also increases when there are large channels produced by plant roots, earthworms, soil cracks, and the burrowing of smaller animals.

Absorption

Ab**s**orption, not to be confused with a**d**sorption, is the uptake of pesticides into plants and animals. Once absorbed into plants, pesticides are metabolized or remain inside the plant until the tissues decay or when the crop is harvested.

Crop Removal

Crop removal transfers pesticides and pesticide residues from the treatment site. Although harvesting is more typically associated with food and feed products, it is easy to forget that pesticides can be transferred by: (1) moving soil that contains adsorbed pesticides and (2) other plant parts that have absorbed pesticides (grass clippings). The pesticides can then be leached from the "crop" to later cause non-target damage.

PESTICIDE DEGRADATION (Persistence)

The persistence of pesticides after they are applied and enter the environment are influenced by air, temperature, oxygen, moisture, soil pH, sunlight, enzymes, soil moisture, water pH, soil texture, and organic matter present. The time it takes to reduce or deactivate a pesticide concentration by one-half of its previous concentration is called half-life (T½). Half-life values in subsoils and in ground water are usually much higher due to a lack of sunlight and scarcity of microorganisms with **increasing soil depth**. Pesticides leached to lower depths, persist longer in the environment. The EPA considers a pesticide with soil half-life of greater than 21 days as having a potential for causing water concerns due to the pesticide's longevity.

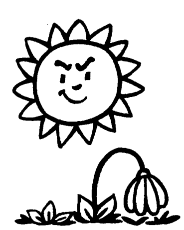
PESTICIDE PERSISTENCE IN SOILS		
Low Persistence (half-life less than 30 days)	**Moderate Persistence (half-life 30 to 100 days)**	**High Persistence (half-life greater than 100 days)**
Clopyralid (Curtail™)	Clopyralid (Curtail™)	Clopyralid (Curtail™)
Dicamba (Banvel™)	Carbofuran (Furadan™)	Picloram (Tordon™)
Malathion	Glyphosate (Roundup™)	Metsulfuron Methyl (Ally™ Escort™)
2,4-D	Triclopyr (Garlon™)	
Clopyralid's half-life is 15 to 287 days depending upon environmental conditions.		

Degradation processes convert most pesticide residues to inactive, less toxic, and harmless compounds and include:

1. **Microbial degradation** is the breakdown of pesticides by fungi, bacteria, and other microorganisms that use pesticides as a food source. Soil conditions such as moisture, temperature, aeration, pH, and the amount of organic matter affect the rate of microbial degradation because of their direct influence on microbial growth and activity.

2. **Chemical degradation** is the breakdown of pesticides by processes that do not involve living organisms and includes temperature, moisture and pH. Because of a lack of heat and oxygen in the water-saturated layers of the lower soil profile, degradation is much slower than at the surface. In northern states, the season influences groundwater temperatures from 5 to 10 feet below the ground surface. Groundwater below 10 to 15 feet maintains a constant temperature of 50° to 53° F. These low temperatures greatly reduce the rate of degradation. One of the most common pesticide degradation reactions is hydrolysis, a breakdown process where the pesticide reacts with water. Depending on the pesticide, this may occur in both acid and alkaline conditions. Many organophosphate and carbamate insecticides are particularly susceptible to hydrolysis under alkaline conditions (pH >7). Some herbicides such as the sulfonyl ureas (SU) degrade under acidic conditions (pH<7).

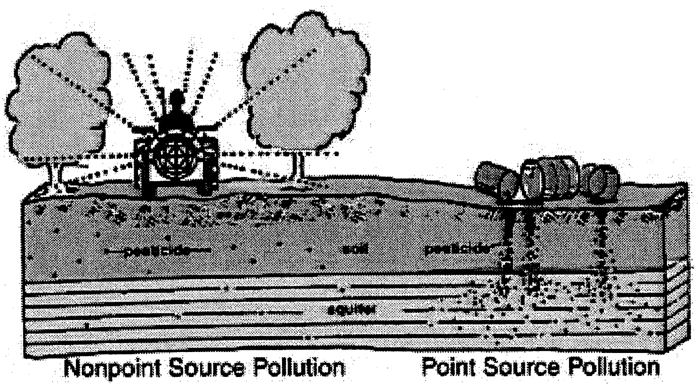
3. **Photodegradation** is the breakdown of pesticides by sunlight. Photodegradation can destroy pesticides on foliage, on the soil surface, and even in the air. This is why it is a good idea to line dry clothing that has been exposed to pesticides. Factors that influence pesticide photodegradation include the intensity of the sunlight, properties of the application site, the application method, and the properties of the pesticide.



FACTORS AFFECTING GROUNDWATER CONTAMINATION

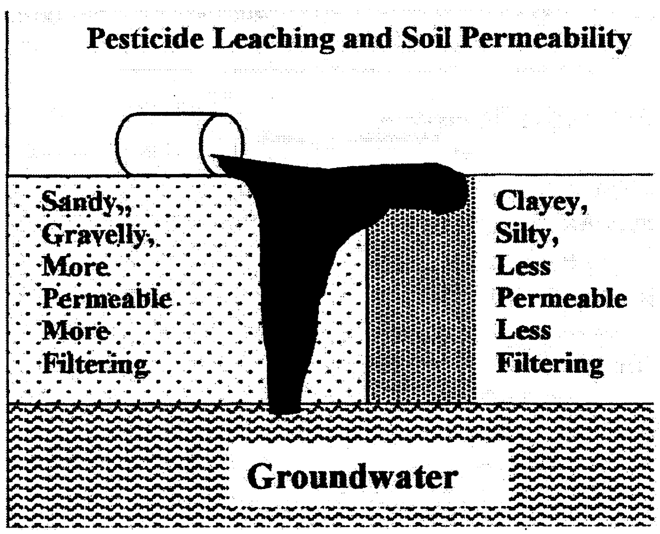
Groundwater lies below the soil surface and fills the pore spaces in and around sand, gravel, and other materials. Groundwater moves through water-saturated zones called **aquifers** with the upper level of the aquifer being called the **water table** that fluctuates throughout the year depending on use and recharge. Contamination of groundwater occurs when unwanted substances move through fractures or the soil profile to the saturated zone.

Generally, the groundwater "flow" rate is only <u>several feet per year</u> except in permeable sand and gravel aquifers where the movement may be <u>one or two feet per day</u>. In some cases, it may take several years for groundwater and dissolved substances to move a mile. Because of the slow rate of degradation of substances in groundwater, contamination at one location may show up years later in a different location. Pesticides that enter groundwater can come from either **point sources** or from **non-point sources**. Point sources are small, easily identified objects or areas of high pesticide concentration, such as tanks, mixing/loading sites at wellheads, containers, or spills. Non-point sources are broad, undefined areas in which pesticide residues are present.



Pesticide properties that influence groundwater contamination by pesticides include solubility, adsorption, volatility, and the potential for degradation. Information on other pesticides can be found on pesticide labels, Environmental Protection Agency (EPA) fact sheets, electronic pesticide databases and from the pesticide manufacturer.

Soil properties that affect pesticide movement into groundwater include texture, permeability, and organic matter content. Soil texture is the relative proportions of sand, silt, and clay and affects movement of water through soil therefore affecting the movement of dissolved chemicals such as pesticides. If rainfall is high and soils are **permeable**, water carrying dissolved pesticides may take only a few days to percolate downward to groundwater.



In arid and/or high mesa regions, groundwater may lie several hundred feet below the soil surface, and leaching of pesticides to groundwater may be a much slower process.

Groundwater quality is most vulnerable in areas where **permeability** of geologic layers is rapid. Carbonate bedrock, such as limestone, can make groundwater particularly susceptible to contamination because it is easily dissolved by water to form solution channels and depressions in the land surface (sinkholes). These sinkholes can provide a direct connection between the soil surface and the groundwater. Contaminated water that drains into a sinkhole can readily enter groundwater because the soil that lines the bottom of a sinkhole is often thin and provides little filtering of pollutants. Areas with high rates of rainfall or irrigation may have large amounts of water percolating through the soil and, therefore, are highly susceptible to leaching of pesticides, especially if the soils are highly permeable.

ENVIRONMENTAL RISK INDICATORS FOR PESTICIDES

There is an increasing need among users of pesticides, consumers and policy makers to get more insight into the risk that pesticides pose to the environment. For this purpose various risk estimation models have been developed to describe the environmental risk of pesticides.

TRIGGER VALUES

In this simplest of risk estimation methods, pesticides are presumed to have ground water contamination potential if environmental fate studies trigger multiple criteria for both mobility and persistence. Trigger values are based strictly on laboratory data. Further refinements of ground water assessment of the pesticide should consider additional field parameters such as application rate, soil, and target crops. The following values are used as an initial step to identify pesticides most likely to leach to ground water:

Trigger Values Related to Persistence

1. Aerobic soil metabolism half-life of greater than two to three weeks.
2. Field dissipation half-life of greater than two to three weeks.
3. Photolysis half-life greater than one week.
4. Hydrolysis half-life greater than 60 days in sterile water.

Trigger Values Related to Mobility

1. K_{oc} usually less than 300.
2. The pesticide is a weak to moderate acid which would not be attracted to most soil particles.
3. Water solubility greater than 30 parts per million (ppm).

THE GROUNDWATER UBIQUITY SCORE (GUS)

The Groundwater Ubiquity Source (GUS) is another risk estimation model that is useful for comparing the leaching potential of pesticides. The GUS model is more sophisticated than trigger values because it uses a formula that combines pesticide mobility and persistence parameters. To calculate the GUS, average values for only two pesticide parameters are needed: the soil degradation half-life, and the soil K_{oc}. Pesticides with a GUS greater than 2.8 are more likely to leach to ground water, while those with GUS values between 1.8 and 2.8 are somewhat less likely to leach. Pesticides with GUS values less than 1.8 are unlikely to leach to ground water. Dicamba salt (Banvel™, Clarity™) has a GUS value of 4.8.

THE PESTICIDE ROOT ZONE MODEL

The Pesticide Root Zone Model (PRZM) has been developed by Environmental Protection Agency (EPA) and provides site-specific leaching estimates. PRZM, like other pesticide soil fate and transport models, incorporates soil characteristics and hydrology, weather, irrigation, and crop management practices into complex mathematical formulas that estimate leaching potential. EPA uses PRZM (and similar models) to make multiple site comparisons of the leachability of a pesticide to older, reference pesticides with histories of use and extensive ground water monitoring. Models like PRZM also provide estimates of the concentration of a pesticide that will leach, but these estimates should be confirmed with actual field data. PRZM is available from the Environmental Protection Agency (EPA) as a downloadable computer program.

THE PESTICIDE ASSESSMENT TOOL FOR RATING INVESTIGATIONS OF TRANSPORT

The Pesticide Assessment Tool for Rating Investigations of Transport (PATRIOT) is a site-specific screening model. PATRIOT provides a quick estimation of the relative leaching potential of a pesticide at representative sites. The PATRIOT user must first select crops, geographical areas, and soil types of interest. PATRIOT automatically simulates weather, using historical records from stations with soils that closely resemble those selected for modeling; also it automatically incorporates appropriate irrigation schemes. PATRIOT is available from the Environmental Protection Agency (EPA) as a downloadable computer program.

RAVE: RELATIVE AQUIFER VULNERABILITY EVALUATION

RAVE is a numeric scoring system that helps individuals evaluate pesticide selection for on-site ground water contamination potential. RAVE is used solely by the state of Montana in assessing pesticide risks to groundwater. Nine major factors in a particular area determine the relative vulnerability of groundwater to pesticide contamination and includes:

1. Depth to groundwater. A 10-25 foot distance to groundwater ranks as a 12.
2. Distance to surface water. A 100-500 foot distance ranks as a 3.
3. Topographic Position. Rolling foothills rank as a 5.
4. Soil texture. Sandy soils ranks as a 15.
5. Irrigation practices. Non-irrigated ranks as a 2.
6. Percent organic matter. Greater than 3% organic matter ranks as a 2.
7. Pesticide application frequency. Greater than one time per year ranks as a 5.
8. Pesticide application methods. Foliar applied ranks as a 2.
9. Pesticide leaching index. 2,4-D ranks as high or 20 points.

RAVE scores of 30 are of low concern while 100 is a RAVE score of high concern.

The example above tallies to a total RAVE score of 66 that ranks just above moderate concern.

MANAGEMENT PRACTICES

The methods used to apply pesticides are another factor determining leaching potential. Injection or incorporation into the soil, as in the case of nematicides and soil-applied herbicides, makes these pesticides most readily available for leaching.

As indicated, the great complexity of soils, environmental conditions, chemical pesticides, and pesticide-soil-water interactions make it impossible for scientists to determine the fate of a pesticide once it has entered the environment. However, based on research, experience and scientific deduction, reliable conclusions can be drawn that will help managers make wise decisions about what pesticides to use in certain situations and the possibilities of risks to the groundwater environment.

Preventive Measures

Identify the target pest and understand its life cycle. Use pesticides only when necessary and only in amounts that will adequately control the pest. Pesticides that are applied less frequently and in low concentrations are less likely to leach into the groundwater. When possible, select those pesticides that are less toxic and less persistent.

Identify the vulnerability of the soil.

Well-drained or sandy soils, low in organic matter, have a high potential for groundwater contamination.

Consider the location of the pesticide application in relation to surface water, groundwater and well sites.

Keep pesticides away from water sources, including wells. Maintain a buffer to all water sources. Never mix and load uphill from a well site. Movement of pesticide residues associated with runoff into streams and rivers can also ultimately contribute to groundwater contamination under certain conditions.

Become familiar with pesticides that may leach.

Pesticides with a high potential for leaching are more likely to contaminate groundwater. Check the pesticide label for warnings about potential to leach to groundwater. Pesticides that are relatively stable, highly water soluble, and not adsorbed on soil particles have the greatest potential to leach through the soil.

Consider the vulnerability of the area.

Determine the relative susceptibility of the soil to leaching and depth of the water table. Sinkholes, ground squirrel burrows and large soil fractures can be especially troublesome as they allow surface water to quickly reach groundwater with little natural soil filtering.

Follow the directions on the pesticide label.

Many pesticide labels contain use instructions or precautions to avoid groundwater contamination. If you do not follow the label directions, you risk contaminating the groundwater. Always read pesticide labels carefully.

Apply the pesticide at the appropriate time.

Fewer applications are required if they are carefully timed relative to stages in the pest's life cycle. Information on proper timing of pesticides is available from the label, research documents or from the manufacturer.

Measure the pesticide properly and carefully.

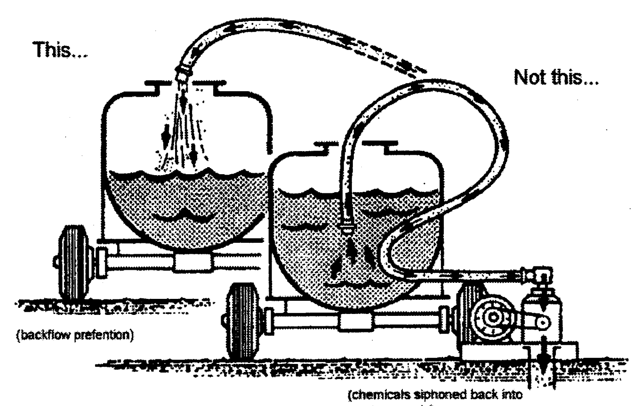
Avoid the temptation to use more pesticide than the label directs. It only increases the cost of pest control, the resistance of pests to chemical controls, and the risk of groundwater contamination.

Calibrate and maintain equipment properly.

Calibrate application equipment often. Check equipment regularly for leaks. Small leaks under pressure can produce fine droplets contributing to drift.

Avoid spills and back-siphoning.

Avoid spills, especially near wells or other water sources. Prevent back-siphoning of pesticide-contaminated water into the water source by keeping the end of the fill hose above the water level in the spray tank or install a backflow device (such as an air gap or check valve) on the filling pipe to prevent backflow problems.



Direct the application to the target site.

Avoid over-spraying and limit drift in sensitive areas to reduce the risk of surface and groundwater contamination.

Leave buffer zones or strips around sensitive areas.

When mixing, applying, storing, or disposing of pesticides (including cleanup) consider the location of sensitive areas. These include; sinkholes, fish hatcheries, domestic wells, groundwater recharge areas, springs, streams, ponds, wetlands, and other surface water. Establishing thick vegetation, such as turf or pasture grasses, or leaving an untreated border are two ways to provide a buffer zone between a pesticide-use or handling site and a sensitive area. The following minimum widths are recommended for protective buffer strips or zones. (BLM Manual H-9011-1).

Aerial Spraying------------------------	100 feet
Vehicle Spraying----------------------	25 feet
Hand Application ---------------------	10 feet

If a pesticide label also stipulates a buffer strip or zone, then use the width that offers the greatest buffer zone protection. For example, if you are vehicle spraying and the label mandates a buffer strip of 50 feet, then you are to use the label-mandated buffer zone of 50 feet instead of 25 feet as dictated by BLM policy. Conversely, if the label indicates a 15-foot buffer strip, use a 25-foot buffer as per BLM policy. You can always increase buffer widths for added insurance.

Dispose of pesticides properly.

Triple rinse or pressure rinse pesticide containers and dispose of rinse water to a site listed on the pesticide label. Follow the label for proper disposal of leftover pesticide so it does not cause groundwater problems. Good planning is the best insurance against pesticide disposal problems. Buy and mix only the amounts you need. Never dispose of pesticides or pesticide containers near a water source, in sinkholes, in abandoned wells, or where there is a shallow water table.

Store pesticides safely.

Store pesticides in their original containers in a cool, well-ventilated, secured and protected location away from pumps and water sources.

Maintain records of pesticide use.

Maintain records of all pesticides applied. Make sure that you follow the proper format for Pesticide Application Reports (PAR). See Chapter 11.

Be wary of rainfall or irrigation after pesticide applications.

Because pesticides frequently move with water through the soil profile, rainfall or irrigation can introduce recently applied pesticides into ground water. On the other hand, some moisture may be necessary to activate certain herbicides.

Consider weather and runoff.

To avoid pesticide movement with runoff, do not apply pesticides prior to a heavy or sustained rain and do not use excessive amount of water. This is especially critical for clay soils that are subject to rapid runoff.

Use Integrated Pest Management (IPM).

Integrated Pest Management (IPM) is a recommended alternative to purely chemical pest control. IPM integrates available pest control techniques in an economically and ecologically sound manner. IPM uses scientifically sound strategies, such as economic thresholds and pest monitoring, to determine the proper time for pesticide applications.

PESTICIDES AND WILDLIFE

While there are benefits from pesticides, there are also some risks to their use. Pesticide poisonings of people, livestock, and wildlife can occur when proper care is not exercised. Pesticide applicators must be very careful to avoid these risks. Pesticide effects on wildlife may be lethal, sublethal, habitat related, or there may be no effect at all. In general, the risk a pesticide poses to wildlife is related to the pesticide type, its toxicity, the proximity of the application to wildlife habitat, the dose, application rate, number of applications, the persistence of the pesticide in the environment, and its ability to concentrate in the wildlife food chain. These factors interact with food habits and behavior of individual wildlife species to produce a response.

PESTICIDE TYPE

In general, insecticides are more toxic to fish and wildlife than herbicides or fungicides. However, some herbicides may harm wildlife by damaging their habitat.

Many of the insecticides currently used are either the organophosphate (OP)/carbamate type or synthetic pyrethroid compounds. These insecticides work by interfering with the central nervous system of insects and animals. The toxicity of the various organophosphate and carbamate insecticides ranges from slightly toxic products to products that are highly toxic. While the more toxic products are generally classified as **restricted use pesticides (RUP)** that require applicators to be certified, not all highly toxic pesticides are classified as restricted-use.

Synthetic pyrethroid insecticides are considered low to medium in toxicity, and in most situations, mammals and birds can quickly detoxify and excrete them. However, fish and aquatic invertebrates cannot quickly detoxify or excrete synthetic pyrethroids, so they are highly susceptible to poisoning by these products. In general, herbicides and fungicides are low to moderately toxic to wildlife. Particular herbicides can have a large impact on the plant life making up the wildlife habitat.

DIRECT EFFECTS

Wildlife can be exposed to pesticides directly by consuming contaminated food or water, breathing pesticides, or by skin absorption. The type and magnitude of the effect depends on two factors: the pesticide toxicity and the amount of pesticide to which they were exposed.

The lethal and sublethal effects of pesticides on wildlife and fish may occur from one exposure over a short time period (**acute**) or they may result from exposures to small amounts over a longer time period (**chronic**). If exposure causes the animal's death, it is referred to as a lethal effect. Young birds that eat insecticide-treated insects are at great risk of suffering lethal pesticide exposure effects. Sublethal insecticide effects occur when damage to the central nervous system causes an animal to behave in an unusual manner that may affect the animal's ability to survive or reproduce. Other typical sublethal responses in birds exposed to pesticides include the inability to sing properly, establish a breeding territory, or attract a mate. Adults may be unable to care for themselves or their young properly, resulting in death to the nestlings or increased chance of predation.

INDIRECT EFFECTS

Wildlife in general, and birds in particular, may also experience lethal or sublethal effects without being directly exposed to a pesticide. This typically occurs when a pesticide application destroys or disrupts food sources such as insects. Insects supply the protein necessary for growing birds and studies indicate that the growth of young birds can be stunted in areas where insecticides have been used heavily. Fish that feed on aquatic insects and animals may also show stunted growth in areas of heavy insecticide use because their primary food sources are killed. Inadequate diets also can affect fish reproduction and survival. Herbicides can reduce the amount of cover and make the habitat less suitable for nesting.

AQUATIC ENVIRONMENTS

Aquatic toxicology is the study of the effects of environmental contaminants on aquatic organisms, such as the effect of pesticides on fish. Because not all animals of a species die at the same dose (some are more tolerant than others), a standard toxicity dose measurement, called a **Lethal Concentration 50 (LC_{50}),** is used to measure toxicity in aquatic environments. This is the concentration of a pesticide that kills 50% of a test population of animals within a set period of time, usually 24 to 96 hours.

Hazard Ratings	
Toxicity	**LC_{50}(mg/l)**
Minimal	>100
Slight	10 – 100
Moderate	1 – 10
High	0.1 - 1.0
Extreme	0.01 - 0.1
Super	< 0.01

Hazard ratings range from minimal to super. Suppose the 24-hour LC_{50} of the insecticide gumethrin to rainbow trout is <u>less than</u> 0.1 but <u>greater than</u> 0.01 ppm.

If one-half of the trout exposed to 0.05 ppm died within 24 hours, this would be mean that gumethrin is extremely toxic to trout.

Exposure of fish and other aquatic animals to a pesticide depends on its biological availability (bioavailablility), bioconcentration, biomagnification, and persistence in the environment.

Bioavailability refers to the amount of pesticide in the environment that is available to fish and wildlife. Some pesticides will breakdown rapidly after application. Some bind tightly to soil particles suspended in the water column or to stream bottoms, thereby reducing their availability. Some are quickly diluted in water or rapidly volatize into the air and are less available to aquatic life.

Bioconcentration is the accumulation of pesticides in animal tissue at levels greater than those in the water or soil to which they were applied. Some fish may concentrate certain "accumulative" pesticides in their body tissues and organs (especially fats) at levels 10 million times greater than in the water.

Biomagnification is the accumulation of pesticides at each successive level of the food chain. Pesticides present in water may be absorbed by plants that are in turn eaten by insects and minnows. Unless the pesticide is detoxified, these animals also become contaminated. At each step in the food chain the concentration of pesticide increases. When sport fish such as bass or trout repeatedly consume contaminated animals, they bioconcentrate high levels in their body fat. Fish can pass these poisons on to humans.

Chapter 3
PESTICIDE SAFETY

Terms To Know

Allergic effects------- Harmful effects, such as skin rash or asthma, that some people develop in reaction to pesticides that do not cause the same reaction in most other people.
Aromatics ------------ Solvents containing benzene or compounds derived from benzene.
Carcinogen ----------- A substance that causes cancer in animal tissue.
Chronic toxicity ----- The toxicity of a material determined beyond 24 hours and usually after several weeks of exposure.
Contamination ------ The presence of an unwanted pesticides in plants or animals; or their by-products in soil; water; air; structure; etc.
Dermal toxicity ----- The property of a pesticide to poison an animal or human when absorbed through the skin.
Diluent --------------- Added at the time of application to dilute the formulation. Usually water.
EC_{50} ------------------- The concentration (ppm or ppb) of the toxicant in the environment (usually water) that produces a designated effect in 50 percent of the test organisms exposed.
Emulsifiable concentrate (EC) --Concentrated pesticide formulation containing organic solvent and emulsifier to facilitate emulsification with water.
Emulsifier ----------- Substances used to stabilize suspensions of one liquid in another; oil in water.
EPA------------------- The Environmental Protection Agency, the federal agency responsible for pesticide rules and regulations, and all pesticide registrations.
Inhalation ------------ Exposure of test animals either to vapor or dust for a predetermined time.
LC_{50} ------------------- The lethal concentration in ppm or ppb in the environment (usually water) that kills 50 percent of the exposed test organisms.
LD_{50} ------------------- The lethal dose of a toxicant required to kill 50 % of a test population expressed as milligrams of toxicant per kilogram of body weight (mg/kg).
mg/kg------------------ (milligrams per kilogram) - Used to designate the amount of toxicant required per kilogram of body weight of test organism necessary to kill 50 percent of test animals.
MSHA ---------------- Mine Safety and Health Administration.
Mutagen ------------- Substance causing genes in an organism to mutate or change.
National Pesticide Telecommunications Network – 1-800-858-7378
Necrosis --------------- Death of tissue, plant or animal.
NIOSH ---------------- National Institute for Occupational Safety and Health.
Oncogenic ----------- The property to produce tumors (not necessarily cancerous) in tissues.
Oral toxicity --------- Toxicity of a compound when given by mouth. Usually expressed as LD_{50}.
Pesticide -------------- An economic poison used for controlling, preventing, destroying, repelling, or mitigating any pest. Includes fungicides, herbicides, insecticides, nematicides, rodenticides, etc.
Phytotoxic ------------ Injurious to plants.
Poison ---------------- Any chemical or agent that can cause illness or death when eaten, absorbed through the skin, or inhaled by humans or animals.
ppb-------------------- Parts per billion is the number of parts of toxicant per billion parts of the substance in question.
ppm ------------------- Parts per million. The number of parts of toxicant in a million parts of the substance in question. They may include residues in soil, water, or whole animals.

Personal Protective Equipment (PPE)--Clothing to be worn in pesticide-treated fields under certain conditions as required by the pesticide label.
Reentry intervals (REI)--Waiting period before personnel can enter a sprayed area without PPE. Required by law to prevent poisoning of unprotected persons.
Rinsate ---------------- Water that is used to rinse spray tanks during cleaning. Rinsate can be used as diluent as long as it is applied to a labeled site.
Signal word ---------- A required word that appears on every pesticide label to denote the relative toxicity of the product.
Teratogenic ---------- Substance that causes physical birth defects in the offspring following exposure of the pregnant female.
Tolerance ------------ Amount of pesticide residue permitted by federal regulation to remain on or in a crop. Expressed as parts per million (ppm).
Toxic ----------------- Poisonous to living organisms.

Pesticides are designed to kill or repel harmful living organisms – pests! Since human beings are living organisms, pesticides may also harm or kill people! With some pesticides, it only takes a few drops in the mouth or on the skin to cause damage. Others are less toxic, but prolonged exposure can also cause harm. Fortunately, the harmful effects of pesticides can be lessened by an understanding of basic pesticide toxicology.

Hazard is the potential for injury that you may face while handling a pesticide. While toxicity is a measure of a pesticide's ability to cause harm, many people mistakenly use the term toxicity and hazard interchangeably. Gasoline is extremely toxic but is used by millions of people since exposure to the chemical is made safe by efficient and safe pumps. Aspirin, on the other hand, is not very toxic but where there is an open bottle then the chance of exposure is high, especially to children. In this example the toxicity is low, but the potential exposure is high and, therefore, so is the hazard. The dose makes the poison!

ACUTE EFFECTS

Exposure to a single dose of a pesticide is known as an acute exposure. Acute effects are symptoms that occur within minutes or hours after exposure, and may be measured as acute dermal toxicity, acute oral toxicity, and acute inhalation toxicity.

To understand just how toxic some chemicals are, it helps to know how acute toxicity is measured. A range of pesticide doses is applied to the skin (dermal) or fed (oral) to test animals. The amount of chemical required to kill 50% of the test population is known as the **LD_{50}** (**L**ethal **D**ose to 50%) and can be expressed as an oral LD_{50} or dermal LD_{50}.

LD_{50}'s are expressed as the ratio of the weight of a chemical (in milligrams) to the weight of an animal (in kilograms). One milligram per kilogram (mg/kg) is also equal to 1 part per million (ppm). As a comparison, 1 ppm is equivalent to 1 penny in $10,000. **The lower the LD_{50}, the more acutely toxic the pesticide.** Therefore, a pesticide with an oral LD_{50} of 500 would be much less toxic than a pesticide with an LD_{50} of 5. The following formula illustrates this concept:

$$\text{Ounces of pesticide likely to cause death (oral)} = LD_{50} \times 0.0016 \times \frac{\text{Body weight (lbs.)}}{100}$$

*There are 60 drops in a teaspoon and one teaspoon is 0.33 ounces

For instance, if the LD_{50} of a pesticide is 8500, a 170 pound person would need to ingest 23 ounces of the pesticide to cause death. This is about 1½ pints. Conversely, if the LD_{50} is 5, only 0.0136 ounces or 5 drops* ingested would cause death to the same person.

The LD_{50} is limited because it refers to a single-exposure situation and cannot be used to determine toxicity from several exposures to the same substance, long-term exposures, or from a mixed exposure where an individual is exposed to more than one substance. Note that LD_{50} only measures one effect -- death. It does not indicate what dose may lead to less serious toxic effects.

LD 50s of Commonly Used Pesticides
(Lower number = higher toxicity)

Common Name	Brand Name	LD_{50}	Type of Pesticide
Aldicarb	Temik	0.79	Insecticide
Methyl Parathion	Penncap	3	Insecticide
Azinphos-methyl	Guthion	11	Insecticide
Bifenthrin	Capture	54	Insecticide
Paraquat	Gramoxone	150	Herbicide
2,4-D ester	Many	375	Herbicide
Dicamba	Banvel	1,040	Herbicide
2,4-D amine	Many	1,100	Herbicide
Clopyralid	Curtail	4,300	Herbicide
Glyphosate	Roundup	4,300	Herbicide
Picloram	Tordon	8,200	Herbicide
Metsulfuron	Ally, Escort	>5,000	Herbicide

LC_{50}'s are expressed as a ratio of the amount of chemical to the total volume of water or air. The ratio is commonly expressed as parts per million (ppm) when a gas or vapor, or in micrograms per liter (ug/L) when a dust or mist is present. LC means lethal concentration.

SIGNAL WORDS

- **Danger-Poison**
- **Danger**
- **Warning**
- **Caution**

SIGNAL WORDS are required on a pesticide label to indicate the relative toxicity of the pesticide. These **signal words** are assigned on the basis of the highest measured toxicity, be it oral, dermal, or inhalation. Since the toxicity category and signal words are generally based on the **total formulation**, certain products may have the same active ingredient but may bear different signal words in different formulations.

ASSIGNMENT OF SIGNAL WORDS BASED ON LD_{50}, SKIN AND EYE EFFECTS			
Route of Exposure	Signal Words		
	Danger or Danger Poison	Warning	Caution
Oral LD_{50}	0 - 50 mg/kg	50- 500 mg/kg	500 - 5,000 mg/kg
Approximate Oral LD for 150 lbs person	A few drops to one teaspoon	1 teaspoon to one ounce	1 ounce to 1 pint or 1 pound
Inhalation LC_{50} Dust or mist (ug/l) Gas or vapor (ppm)	0 - 0.2 ug/liter (0-2,000 ppm)	0.2 - 2 ug/liter (2,000-20,000 ppm)	2 - 20 ug/liter (> 20,000 ppm)
Dermal LD_{50}	0-200 mg/kg	200-2,000 mg/kg	2,000-20,000 mg/kg
Skin Effects	Corrosive	Severe irritation	Moderate irritation
Eye Effects	Corrosive, not reversible within 7 days	Reversible with 7 days; irritation persisting for 7 days	Irritation reversible within 7 days

CHRONIC EFFECTS

Chronic effects are the harmful effects produced by long-term, low-level exposure to pesticides. The pesticide label may not tell you of any chronic effects that a pesticide might cause but it will tell you how to avoid exposures that might lead to chronic effects. The pesticide's Material Safety Data Sheet (MSDS) may also make note of chronic effects but it must be noted that MSDS information pertains only to persons exposed to pesticides in an occupational setting. While situations resulting in acute exposure (a single large exposure) do occur, they are nearly **always** the result of an accident or careless handling. On the other hand, persons may be routinely exposed to small amounts of pesticides while mixing, loading, and applying pesticides or by working in fields after pesticides have been applied.

Chronic Toxicity Measures

While LD_{50} measures acute toxicity, there is no standard measure for chronic toxicity. How the chronic toxicity of chemicals is studied depends upon the adverse effect being studied. Chronic adverse affects may include:

- Carcinogenesis - means the production of malignant tumors
- Teratogenesis – means the production of birth defects
- Mutagenesis – means a substance that may cause a genetic change
- Reproductive toxicity – means the effects on fertility or reproductive rates

Chronic Toxicity Testing

Chronic toxicity testing is both lengthy and expensive. EPA and regulatory agencies in other countries require an extensive battery of tests to identify and evaluate the chronic effects of pesticides. These studies, which may last up to two years, utilize several species of animals to evaluate toxicity from multiple exposures or continuous long-term exposure.

SYSTEMIC EFFECTS

A systemic effect is the delayed illness or injury to a bodily system such as the circulatory system, nervous system and kidneys or liver. Some systemic effects may result from acute exposure but are most commonly associated with the chronic effects of pesticides and include:

- Blood disorders (hemotoxic effects), anemia or an inability to clot.
- Nerve/brain disorders (neurotoxic effects), paralysis, excitation, trembling, or blindness.
- Skin disorders, such as rash, irritation, and ulceration.
- Lung and respiratory disorders, such as emphysema and asthma.
- Liver and kidney disorders, such as jaundice and kidney failure.

ALLERGIC EFFECTS

Not all people develop harmful effects when exposed to pesticides. It usually takes more than one exposure for a person's body to develop a response that results in an allergic reaction to a substance. This process is known as sensitization.

Once a person's body is sensitized to a substance, an allergic reaction may occur and includes:

- Systemic effects, such as asthma or even shock.
- Skin irritation, such as rash blisters, or open sores.
- Eye, nose and throat irritation, such as itchy, watery eyes; sneezing and tightness in the throat.

There is no way to predict who will be allergic to any given pesticide. Unlike acute and chronic effects, allergic effects are not so much properties of the pesticide, but of the people who use them. A pesticide's toxicity does not affect the likelihood of an allergic response. People who are allergic to many things may be more likely to be allergic to some pesticide products.

ROUTES OF EXPOSURE

HOW PESTICIDES ENTER THE BODY

While many pesticides can damage the skin and eyes, the most harmful effects usually occur when pesticides enter the body, usually by four main routes:

1. **Dermal exposures** occur when pesticides get on the skin and are absorbed by the body. Dermal exposures account for about 90% of the exposure pesticide users receive from pesticides. The amount of pesticide that is absorbed depends not only on the chemical itself, but also on the product's formulation, the area of your body that is exposed and the condition of the exposed skin. In general, oil-based pesticides, such as emulsifiable concentrates (EC), are absorbed more quickly. Water-based formulations are absorbed more readily than dry materials unless the dry materials are mixed with water. Different areas of the body absorb pesticides at varying rates with the genital area tending to be the most absorptive. The scalp,

ear canal, and forehead are also highly absorptive. Also, pesticides enter the body more readily through scrapes and cuts than through unbroken skin. Hot, sweaty skin also absorbs pesticides faster than cool, dry skin.

2. **Oral exposure** occurs when a pesticide is ingested or swallowed. The most common form of oral exposure occurs when a pesticide is transferred to unlabeled bottles or food containers. Oral exposure may also occur because of an accident, but is more likely to occur as the result of carelessness, such as blowing out a plugged nozzle with your mouth, and smoking or eating without washing your hands after using a pesticide. The seriousness of the exposure depends upon the oral toxicity of the material and the amount swallowed. See the formula on page 41.

3. **Inhalation exposure** is when you breathe in pesticide vapors or dusts. This type of exposure is particularly hazardous because the lungs can rapidly absorb pesticide vapors and fine dusts. Inhalation hazards are high when you handle dusts or powders or when you apply pesticides in a closed environment.

4. **Eyes** are particularly absorbent. Some pesticides can cause irreversible damage to your eyes. Never wear contacts when handling pesticides, especially soft contact lenses. Always wear eye protection when mixing as this is the time when pesticides are more concentrated.

PESTICIDE POISONING & FIRST AID

The severity of pesticide poisoning depends on exposure and subsequent rapid response to the situation. Generally, if a pesticide poisoning occurs, the acute signs and symptoms will be noticeable during the first 12 hours after exposure. Early recognition may save a life.

TYPES OF INJURIES

If someone does suffer ill effects from an accidental exposure to pesticides, their symptoms will probably fall into three general categories: heightened sensitivity, acute illness, or chronic illness.

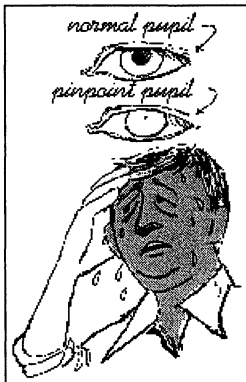
Heightened sensitivity is an allergic reaction on an area of skin. Over time, a pesticide handler may develop an allergy to a chemical they have worked with for several years. A rash may develop on any area of skin that contacts the chemical. Another type of sensitivity is called photosensitivity. In this case, pesticide residues left on the skin react with sunlight to form rash-like areas.

Acute injury appears shortly after the exposure and is a common type of pesticide injury. Acute injuries are the immediate or near-immediate effects of accidental swallowing, skin contamination, or breathing toxic fumes. A skin contamination, that is ignored or not dealt with in time, may cause a skin rash in the exposed area. Often, sores or boils may appear shortly after a pesticide has come in contact with the skin.

The less common form of injury due to pesticide poisoning is **chronic** or long-term injury. This type of injury may require weeks, months, or even years after the initial exposure to the pesticide to develop symptoms. Chronic illnesses from pesticides may result in tumors or various cancers.

However, over time, frequent minimal exposures to a pesticide can build up in the body and cause an acute reaction, e.g., an attack on the nervous system or lung failure.

Signs and symptoms of pesticide poisoning will vary with the pesticide, the exposure and the individual. Also, the **symptoms of pesticide poisoning may be confused with the symptoms of food poisoning, asthma, flu and heat-induced injuries**. So be aware that your symptoms may or may not be the result pesticide exposure. If you have been working with pesticides within the last 12-24 hours and you experience any of the following signs or symptoms, see a physician immediately.



Mild Symptoms: Headache, fatigue, loss of appetite, dizziness, weakness, nervousness, nausea, perspiration, diarrhea, loss of weight, thirst, moodiness, and irritation of skin, eye, nose and throat.

Moderate Symptoms: Nausea, trembling, muscular incoordination, excessive salivation, blurred vision, constricted throat or chest, labored breathing, flushed or yellow skin, abdominal cramps, vomiting, diarrhea, mental confusion, perspiration, rapid pulse and cough.

Severe Symptoms: Vomiting, loss of reflexes, inability to breathe, muscle twitching, constricted pupils, convulsions, unconsciousness, thirst, fever and increased respiration rate.

FIRST AID

Prevention is the best first aid! Always have a plan of action ahead of time in the event that an accident occurs. First aid procedures should be practiced so that they become second nature.

In the event of pesticide poisoning, **first remove the victim** from the contaminated area. Send for medical attention and then perform basic first-aid procedures. The basic life saving steps are:

- **A.** Establish an open **Airway.** Remove debris if possible.
- **B.** Ensure **Breathing.** Keep the airway clear but do not contaminate yourself.
- **C.** Stop bleeding to support **Circulation.** Perform CPR if necessary.
- **D.** Prevent further **Disability.** Continue to remove from pesticide-contaminated area. If pesticide is in the eyes, flush with water. If pesticides are on clothing, remove and wash skin with soap.

In general, medical attention should be obtained if any feeling of discomfort or illness or unusual appearance occurs. Remain alert to symptoms of pesticide poisoning because the symptoms may be delayed up to 12-24 hours after exposure.

IF A PESTICIDE IS SWALLOWED

Swallowing a pesticide is a serious situation. The decision you must make is whether or not to induce vomiting. Read the label and get immediate medical attention.

- If pesticide is still in the mouth, wash it out with plenty of water.
- Quickly, but accurately, read the first aid section of the pesticide label. Some pesticides should be diluted with water or milk. Some chemicals should never be diluted.

- If vomiting is to be induced, position victim so that they do not choke on or inhale matter ejected during vomiting. Ipecac syrup can be used to induce vomiting, but if it is not available, use a blunt instrument such as a spoon handle and touch the back of the victim's throat. Do not use salt water to induce vomiting or attempt to give liquids.
- Do not induce vomiting if the victim is unconscious because the victim could choke.
- First aid for some chemicals includes giving activated charcoal mixed with water after vomiting. Activated charcoal adsorbs many poisons and is available without a prescription. Do not give activated charcoal and ipecac syrup together as the charcoal adsorbs the syrup.
- Keep the victim calm and take them to the hospital. Also take the product label and any Material Safety Data Sheets relating to the swallowed pesticide.

IF A PESTICIDE IS INHALED

An inhaled pesticide presents a different problem but is just as serious. Breathing a pesticide can hurry the effects of poisoning--quick action is a must.

- Get the victim to fresh air but do not jeopardize your own safety. Use PPE as necessary.
- Calm the victim, and have them lie down.
- An inhaled pesticide can cause convulsions so protect the victim's head if convulsions occur.
- Keep the victim's air passage clear.
- Remove any foreign object or matter from the victim's mouth.
- If the victim stops breathing, begin artificial respiration. If you work with pesticides, learn cardio pulmonary resuscitation (CPR).

IF A PESTICIDE GETS ON THE SKIN

The hands and forearms account for most skin exposures and are usually caused by splashes or spills that occur while mixing the chemicals. If a chemical gets on your skin:

- Immediately remove all saturated clothing.
- Wash the exposed area with generous amounts of water and soap.
- Use a brush and soap to remove residues from under your fingernails.
- If your hair is contaminated, shampoo well.
- Put on fresh, clean clothes.
- See a physician depending upon the severity of exposure.

Even if you are not accidentally exposed, follow the above steps anytime you handle pesticides. And follow the same steps before going home. Do not expose your family to the pesticides you have used during the day.

IF A PESTICIDE GETS IN THE EYES

If you splash any chemical into your eyes, immediately wash with plenty of cool, clean water and wash at least 15 minutes to help prevent eye damage. Some chemicals can permanently damage the eyes in less than two minutes! Set up an eyewash station or keep an eyewash bottle in your first aid kit. Do not wash out the eyes with any water containing drugs, because this could aggravate the situation. Seek medical attention immediately.

AT HOSPITAL OR DOCTOR'S OFFICE

Remember to present the pesticide label to medical staff. The label contains specific instructions for doctors to use in treating pesticide poisoning emergencies. **The label is the probably the most important piece of information a physician can have.**

PREVENTION

Prevention is the key to protecting yourself and other workers from pesticide injuries. **You should <u>always</u> be concerned about personal safety when handling, mixing and applying <u>all pesticides</u> regardless of the pesticides toxicity.**

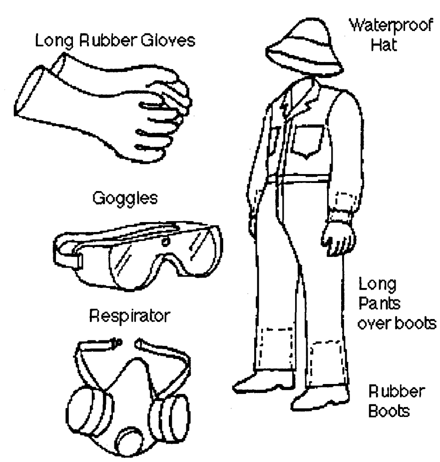
In addition to a well-stocked first aid kit, your first aid kit should also include:

- Eyewash bottle and a basic first aid kit
- Plenty of clean water
- Syrup of ipecac
- Activated charcoal powder
- Soap
- Disposable towels and plastic bags
- Clean change of clothes

All pesticides have the potential to cause bodily harm. But when used according to the label, they pose no special hazard. Always read the label and follow all instructions when using any chemical. **Always read and heed pesticide label, even the small print!**

PERSONAL PROTECTIVE EQUIPMENT (PPE)

Remember! The skin, eyes, lungs, and mouth are the pathways that a pesticide can enter your body. You need to protect these four routes of exposure.



PROTECT THE SKIN

The skin is extremely sensitive to the effects of pesticides and most pesticide-related accidents are **dermal** exposures. Skin exposures may also lead to more serious poisonings. Over time, enough toxic chemical can be absorbed by the skin to cause damage to the nervous and respiratory systems. This type of poisoning often goes undetected until another exposure, even a relatively small one, brings on more serious effects such as lung failure.

Gloves. Most skin exposures can be avoided by wearing extra-long, **<u>unlined</u>** nitrile or neoprene gloves. <u>DO NOT USE</u> cotton, canvas, and leather gloves because that are easily penetrated by chemical materials. Chemically-resistant gloves are made of such rubbers as natural, butyl, chloroprene, nitrile, and fluorocarbon (Viton) or of various plastics such as polyvinyl chloride (PVC), and polyethylene. These materials can be blended or laminated for better performance.

For added protection, make sure the gloves reach almost to the elbow and make sure your gloves fit properly.

> **Unlined gloves (no cloth lining) and as described, must be worn anytime that pesticides are handled either during the mixing or loading operations or during the actual application! (BLM Manual H-9011-1)**

Sleeves and pant legs need to be worn outside of the glove or boot. This prevents spills from running onto your arms or legs. In some instances you may want to tuck your shirtsleeves **inside** the glove such as when you are changing nozzles or working on the boom. Again, this will prevent the pesticide from running onto your shirtsleeve and into your arms. Discard leaky gloves and **never wear leather** or **lined gloves!** These types of gloves will absorb pesticides and concentrate them next to your skin. For the same reason, never wear leather or lined boots.

Coveralls. Cover as much of your skin as possible. Always wear clean, long pants and long sleeved shirts that are free of holes and tears. Cotton woven materials, such as heavy denim, offer adequate protection from dry formulations and certain liquid pesticides in limited exposure situations. Starched or treated clothing will add more protection from pesticides. If a spraying operation will result in heavy spray or mist, a waterproof suit should be worn. It is always best to use chemical-resistant materials when using liquid pesticides and when performing tasks such as mixing and loading.

Often coveralls are made of Tyvek, a non-woven fabric made of olefin fibers. This material is lightweight, water repellent, fairly strong, and tear resistant. It is flammable, so do not use near heat, flame, or sparks. Tyvek is manufactured in several types for different protective purposes. Uncoated Tyvek (often a single use material) is suitable for handling granules or powdered formulations and diluted or less toxic pesticides. Polyethylene-coated Tyvek repels water-based chemicals and has better chemical resistance than uncoated Tyvek. It should not be used with chlorinated hydrocarbons or organophosphates.

Coveralls are also available in two-piece styles. Common materials used in two-piece coveralls are Nitrile and PVC coated fabrics that resist water based chemicals and GoreTex, which is widely used as rain gear. For maximum protection, coveralls with a hood provide added safety for the head, neck, and ears. Elasticized sleeves, wrists, and ankles along with bound or sealed seams also increase protection.

Aprons. Aprons offer protection from spills and splashes of concentrates during mixing and loading. Aprons are always worn over regular work clothes or coveralls and should cover the area from the knees to the chest. Disposable apron materials are similar to coverall materials.

Footwear. Unlined, chemical-resistant footwear is essential and is a sensible practice for all pesticide use. Common boot materials are PVC, natural rubber, latex, neoprene, butyl, and nitrile. DO NOT wear leather or canvas footwear! (BLM Manual H-9011-1)

Head. Liquid-proof, washable plastic hard hats must be worn during pesticide mixing and application (BLM Manual H-9011-1). Use a plastic headband and liner as these items can be washed. Hats with leather or fabric headbands should not be worn.

PROTECT THE EYES

The eyes are an extremely sensitive and fragile area of the human body. If you do not wash out your eyes immediately after an accidental chemical exposure, eyesight can be permanently lost within two minutes.

Goggles or a face shield must be worn when mixing or pouring a pesticide (BLM Manual H-9011-1)

A pair of indirectly vented goggles will provide adequate eye protection. If foggy lenses are a concern, a full-face shield will cover exposed facial area. Anti-scratch lenses are usually more desirable. In severe exposure situations, a face shield may be worn over goggles. Safety glasses with side shields and brow guards are acceptable in many work situations. Do not use eye protection fitted with headbands that can absorb pesticides.

Keep an eye-washing station set up or keep a personal eyewash bottle in close proximity to flush out the eyes in case some chemical splashed into them. **Also keep in mind that eye protection may be required during application.** Read the pesticide label and adhere to organizational policies.

Never wear contact lenses when handling pesticides. Ever!!!

PROTECT THE LUNGS AND MOUTH

Whenever there is a risk of inhaling or ingesting vapors, fumes, or dust, a prudent applicator will wear a respirator with a particle cartridge or canister designated for pesticides. Remember! Lungs are much more absorbent than skin. Most pesticide labels list the type of respirator that you need to wear.

Specific respirator information for BLM personnel will be included in this manual as it becomes available.

MINIMUM PPE REQUIREMENTS FOR BLM PERSONNEL

The following are minimum Personal Protective Equipment requirements for BLM personnel

Minimum PPE Requirements For BLM Personnel				
	Aerial contract (Admin)	**Loading**	**Mixing**	**Application**
Coveralls	Required	Required	Required	Required
Gloves		Required	Required	Required
Goggles			Required	Required
Boots			Required	Required
Headgear			Required	Required

DECONTAMINATION

The Worker Protection Standard (released in July 1993 by the Environmental Protection Agency) makes provisions for a decontamination site to be established for those who handle or work with pesticides at places involved in the production of agricultural or other plants. In reality, this requirement should be practiced by <u>all</u> pesticide applicators. Supplies that must be included at the site should include; water for routine washing and emergency flushing, soap or heavy duty liquid detergent, single use towels, clean change of clothes, and plastic lined container for placing soiled clothing and equipment.

CLEANING PPE

Always wear chemical-resistant gloves when handling soiled PPE. All PPE should be thoroughly cleaned with warm water and detergent after each use. Washing gloves and boots before taking them off helps prevent contamination. Read and follow instructions from the PPE manufacturer unless the pesticide label requires other cleaning requirements. If no specific instructions are given, wash thoroughly in detergent and hot water; air dry and place in well-ventilated place. Some plastic or rubber items that are not made flat, such as gloves, footwear, and coveralls, must be **washed twice**--once to clean the outside surfaces and secondly, after turning the item inside out. Rigid items (as hats or helmets) should be washed by hand. Use hot water and heavy duty detergent. Hang items to dry, if possible. Hang for 24 hours in a well-ventilated area, preferably outside. Store separately from other clothing or unused PPE and away from area where pesticides are handled.

Follow manufacturer recommendations for cleaning respirators. Otherwise disassemble your respirator and wash the plastic and silicone parts with warm water, detergent, and a soft brush. Rinse. Replace respirator cartridges according to the manufacturer's recommendations or when breathing becomes difficult, whichever is sooner.

TAKE PRECAUTIONS TO AVOID ADDED RISKS

- Do not smoke, eat, drink, or use the toilet without first decontaminating. It is most ideal to limit pesticide use to a period of four-hours or less. Even low toxicity pesticides pose greater risk when you are exposed to them for a prolonged amount of time .
- Do not wear leather boots, other leather goods or fabric shoes, unless worn inside other boots and washed after each use.
- Do not wear baseball style caps when handling or using pesticides.
- Facial hairs can inhibit the fit of some respirators.
- Do not wear contact lenses when handling pesticides.
- Always keep an extra change of clothing on hand.

LAUNDERING PESTICIDE CONTAMINATED CLOTHING AND EQUIPMENT

The improper handling and cleaning of pesticide soiled PPE poses a great risk of exposure. The following suggestions provide protective precautions in handling such items.

- ✓ If clothing or other PPE has been saturated with undiluted pesticides with signal words DANGER or WARNING on the label, do not reuse the clothing/PPE. Dispose of it immediately by placing it in a plastic bag and taking it to an approved disposal site. Do not attempt to burn or place with other garbage.
- ✓ All clothing worn while handling or applying pesticides is considered as pesticide-soiled.
- ✓ Keep contaminated clothing separate from other non-contaminated laundry items.
- ✓ **Never launder pesticide contaminated clothing at home. (BLM Manual H 9011-1)**
- ✓ Use chemical resistant gloves when handling all pesticide soiled clothing/PPE.
- ✓ Before entering an occupied dwelling, discard pesticide-contaminated clothing.
- ✓ Dispose of any contaminated leather apparel. Pesticides can't be removed from these items.
- ✓ Pre-rinse other garments twice in a pail of hot water. Use as subsequent spray diluent or spray onto a labeled site. Expose the garments to sunlight first.
- ✓ If the clothing can be laundered, inform the person doing the wash about the pesticide-contaminated clothes and tell them whether the pesticide was in a liquid or powder form.

Here are eight ways to minimize pesticide exposure when laundering pesticide-contaminated clothes.

1. Separate pesticide-soiled clothes from other non-contaminated items (wear gloves).
2. Launder as soon as possible after soiling; daily is best.
3. Launder only a few items at a time.
4. Launder with HOT water.
5. Launder using the longest wash cycle. Launder at least twice.
6. Use heavy-duty liquid detergent. For granular or powder-type pesticide use a PHOSPHATE powder detergent. (If unavailable, use a heavy-duty liquid).
7. Clean the washer afterwards by running two complete empty cycles with hot water and detergent.
8. Line dry garments if possible. This prevents contamination of the dryer if the pesticide hasn't been completely removed in the wash.

CAN LAUNDERING ADDITIVES HELP?

Starch, yes. Cotton or cotton-blend fabrics may be starched to help prevent pesticides from reaching the skin. Starch traps pesticide so that both the starch and pesticide wash away in the next laundry. Starch must be reapplied after each wash. Heavy starching of the lower pant legs helps form a pesticide-barrier. Ammonia and bleach have NOT been shown to assist in removing pesticide residues. **Never use bleach and ammonia in the same wash load; toxic fumes result.** Studies show that fabric softeners neither help nor hinder residue removal in cotton fabrics. Solvent-based aerosol sprays assist removal of oil-based pesticide formulations in cottons. To tell if pre-wash sprays contain a solvent, read the caution label. It should say something like, "Caution: Contains petroleum solvents." Salt helps remove paraquat, but not other pesticides. Add 1 cup of table salt to your wash load with regular detergent.

STORING PESTICIDES SAFELY

You are responsible for the safe storage, transport and disposal of pesticide in your possession. Do all you can to prevent problems and be prepared for emergencies.

Many pesticide handlers use buildings or areas within existing buildings for pesticide storage. Some storage sites are temporary and on the job site. Regardless, if large amounts of pesticides will be stored, you may need to build a special pesticide storage facility. A well-maintained pesticide storage site needs to protect people, animals and the environment from accidental exposure and contamination. A well-designed storage area will also prevent damage to pesticides from temperature extremes, excess moisture, protect from theft, vandalism, unauthorized use, and reduces the likelihood of liability.

Secure the site -- Keep out unauthorized people. Whether it is a temporary or permanent facility, it is an important function of the storage site to keep pesticides under lock and properly secured. Post signs on doors and windows to alert people that pesticides are stored there. Post "No Smoking" warnings as well.

Prevent water damage -- Water from burst pipes, spills, overflows, excess rain or irrigation, or flooding streams can damage pesticide containers and pesticides. If the storage site is not protected from the weather or if it tends to be damp, place metal, cardboard, and paper containers in sturdy plastic bags or cans for protection. Large metal containers, which may rust when damp, often can be placed on pallets within the storage site.

Control the temperature -- Choose a cool, well-ventilated room or building that is insulated or temperature-controlled to prevent freezing or overheating. The pesticide labeling may tell you at what temperature the product should be stored. Temperature extremes can destroy the potency of some pesticides.

Provide adequate lighting -- Pesticide handlers using the facility must be able to see well enough to read pesticide container labeling, notice whether containers are leaking, corroding, or otherwise disintegrating, and clean up spills or leaks completely.

Use nonporous materials -- The floor of the storage site should be made of sealed cement, glazed ceramic tile, no-wax sheet flooring, or another easily cleaned material. Carpeting, wood, soil, and other absorbent floors are difficult or impossible to decontaminate in case of a leak or spill. For ease of cleanup, shelving and pallets should be made of nonabsorbent materials such as plastic or metal. If wood or fiberboard materials are used, they should be coated or covered with plastic, polyurethane or epoxy paint.

Prevent runoff -- Inspect the storage site to determine the likely path of pesticides in case of spills, leaks, drainage of equipment wash water, and heavy pesticide runoff from firefighting or floods.

Provide clean water -- Each storage site must have an immediate supply of clean water. Potable running water is ideal. If running water is not practical, use a large, sealable container with clean water stored away from the chemicals but in close proximity. Change the water at least weekly to ensure that it remains safe for use on skin and eyes.

Prevent contamination -- Store only pesticides, pesticide containers, and pesticide equipment (other than personal protective equipment) in the facility. Spill cleanup kits, personal protective equipment (PPE) necessary for emergencies and clean water can be stored at the site but not in it! Store this equipment so that it can be accessed readily if needed. Do not keep food, drinks, tobacco, feed, medical supplies, veterinary supplies, medications, seeds, or clothing at the site. These items can be contaminated by vapors, dusts, or by spills and cause accidental exposure to people or animals.

Keep labels legible -- Store pesticide containers with the label in plain sight. Costly errors can result if the wrong pesticide is chosen by mistake. Labels should always be legible. They may be damaged or destroyed by exposure to moisture, dripping pesticide, diluents, or dirt. You can use transparent tape or a coating of lacquer or polyurethane to protect the label. If the label is destroyed or damaged, request a replacement from the pesticide dealer or the pesticide formulator immediately.

Keep containers closed -- Keep pesticide containers securely closed whenever they are being stored. Tightly closed containers help protect against spills, cross-contamination, evaporation of pesticides and dust, dirt, and other contaminants from getting into the pesticide, causing it to be unusable.

Use original containers -- Store pesticides in their original containers. Never put pesticides in containers that might cause children and other people to mistake them for food or drink. As an applicator, YOU are legally responsible for someone who is injured by pesticides that YOU have placed in unlabeled or unsuitable containers.

Watch for damage -- Inspect containers regularly for tears, splits, breaks, leaks, rust, or corrosion. When a container is damaged, put on appropriate personal protective equipment and take immediate action. If the damaged container is an aerosol can or fumigant tank that contains pesticides under pressure, use special care to avoid accidentally releasing the pesticide into the air.

When a container is damaged -- Use the pesticide immediately at a site and rate allowed by the label, or transfer the pesticide into another pesticide container that originally held the same pesticide and has the same label still intact. Chemical manufacturers may also be able to provide new unused containers. If possible, remove the label from the damaged container and use it on the new container. Otherwise, temporarily mark the new container with the name and EPA registration number of the pesticide, and get a copy of the label from the pesticide dealer or formulator (whose telephone number is usually on the label) as soon as possible.

Store volatile products separately -- Volatile pesticides should be stored apart from other types of pesticides and other chemicals. A separate room is ideal. Vapors from opened pesticide containers can move into other nearby pesticides and chemicals and make them useless. The labeling of volatile herbicides usually will direct you to store them separately from seeds, fertilizers, and other types of pesticides.

Isolate waste products -- If you have pesticides and pesticide containers that are being held for disposal, store them in a special section of the storage site. Accidental use of pesticides meant for disposal can be costly. Clearly mark containers that have been triple rinsed or cleaned by an equivalent method because they are more easily disposed of than un-rinsed containers.

Know your inventory -- Keep an up-to-date inventory of stored pesticides. Each time a pesticide is added to or removed from the storage site, update the inventory. The list will help you track your stock and will be essential in a fire or flood emergency. The inventory list also will aid in insurance settlements and in estimating future pesticide needs.

Do not store unnecessarily large quantities of pesticides for a long time. Buy only as much as you will need for a year. Pests, pesticides, or pesticide registrations may change by the following year making the pesticides useless. Some pesticides have a relatively short shelf life and cannot be carried over from year-to-year.

Consider shelf life -- Mark each pesticide container with the date of purchase before it is stored. Use older materials first. If the product has a shelf life listed in the labeling, the purchase date will indicate whether it is still usable. Excessive clumping, poor suspension, layering, or abnormal coloration may indicate that the pesticide has broken down. However, sometimes pesticide deterioration from age or poor storage conditions becomes obvious only after application. Poor pest control or damage to the treated surface can occur. If you have doubts about the shelf life of a pesticide, call the dealer or manufacturer for advice.

PREVENT PESTICIDE FIRES

Some pesticides are highly flammable while others are not. The labeling of pesticides that require extra precautions will contain a warning statement in either the Physical/Chemical Hazards section or the Storage and Disposal section. Pesticides that contain oils or petroleum-based solvents are most likely to contain these warning statements. Some dry products also present fire and explosion hazards.

Store combustible pesticides away from open flames and other heat sources. Do not store glass containers in sunlight where they can focus the heat rays and possibly explode or ignite. Install fire detection systems in large storage sites, and equip each storage site with a working fire extinguisher approved for all types of fires, including chemical fires.

If you store highly toxic pesticides or large amounts of any pesticide, develop a fire plan and inform your local fire department, hospital, public health officials, and police of the location of your pesticide storage building. Tell fire department officials what types of pesticides are regularly stored at the site, give them a floor plan, and work with them to develop an emergency response procedure.

TRANSPORT PESTICIDES SAFELY

When transporting pesticides, the following precautions should be taken:

- Carry pesticides in the cargo compartment and never in the passenger compartment. Steel beds are the best since they can be more easily cleaned if a spill should occur.

- Never carry pesticides near passengers, pets, fertilizers, seed, food, feed, or where contamination will result should a spill occur.

- All containers should be tightly closed and have legible labels.

- Secure containers so they will not roll or slide.

- Protect all containers from moisture and temperature extremes.

- Never leave a vehicle unattended when the pesticides are unsecured. The legal responsibility for the injury of curious children and careless or mischievous “adults” is yours.

- After transportation, all pesticide containers should be inspected for damage and leaks. The vehicle should also be inspected for contamination.

- Minimize travel adjacent to streams and sensitive areas with loaded pesticide sprayers. Careful route planning is a must.

- **All valves capable of draining tanks must be locked when the sprayer is unattended (BLM Manual H-901-1).** Also consider locks for the tank openings to prevent vandalism.

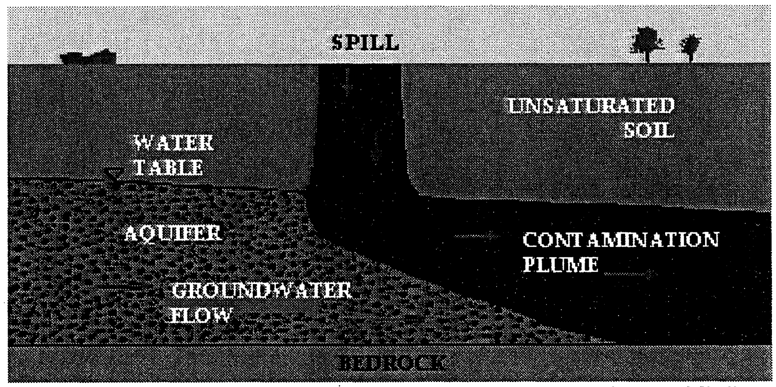
APPLICATION

The following guidelines pertain to safety precautions to be taken during the actual application. It is important that sufficient planning precedes the application so that contract specifications or instructions to applicators are clear.

- Read and understand the labels of the pesticides you are using.
- Keep equipment in good mechanical condition. Repair leaks immediately.
- Calibrate equipment on a regular basis, especially prior to project initiation.
- Wear appropriate clothing and PPE as required. Wash work clothing daily. Bathe and change to clean clothes when not on duty. **Cleanup is mandatory after each day’s work**.
- Wash hands with soap and water after contact with chemicals, and before smoking or handling food. Do not eat, drink, smoke or touch direct skin when applying pesticides.
- Do not work into direct spray drift.
- Avoid downwind areas that have been sprayed. Work upwind.
- When working in tall weeds, always go to the farthest point and work away from the area you are treating. Never work through areas you have already sprayed.

SPILLS

The most hazardous activities involving pesticides are mixing and loading of concentrated pesticides. Use no more than the amount called for to prevent injury to exposed plants or animals and to prevent illegal residues. Do not combine spilled pesticides unless the combination is listed on the label or if you have consulted an authority. Remember to wear all protective clothing indicated on the pesticide label during the entire cleaning process.



Source: "Variables and Technical Relationships Involved in the Contamination of Shallow Groundwaters by Agricultural Chemicals", William F. McTernan

The following procedures are recommended for cleaning up small spills:

1. Do everything possible to immediately stop the leak or contain the spill. If the material is a liquid, use a shovel for other equipment to construct a dam to prevent it from spreading.

2. Isolate the contaminated area. Keep people away from the spill.

3. Soak up the spill. Spread an absorbent material such as vermiculite, fine sand, or sawdust over the entire spill.

4. Collect the material for disposal. Sweep or shovel the contaminated absorbent material into a heavy-duty plastic bag.

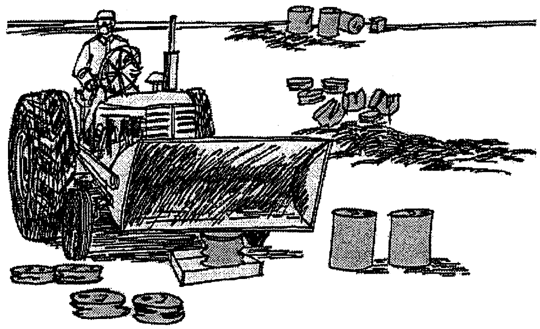
5. Decontaminate the area. For floors, work a decontamination agent (usually hydrated lime or a high pH detergent) into the spill area with a coarse broom. Add fresh absorbent material to soak up the now contaminated cleaning solution. Sweep or shovel the contaminated material into a heavy-duty plastic bag. Repeat this procedure several times to ensure thorough decontamination. For soils, shovel the top 2 to 3 inches of soil into a heavy-duty plastic bag. Next, cover the area with at least 2 inches of lime. Finally, cover the lime with clean topsoil. Minor spills can sometimes be cleaned up by immediately applying activated charcoal to the contaminated surface.

6. Clean up contaminated vehicles and equipment. Use of diluted liquid bleach or detergent to clean metal surfaces. Porous materials and equipment such as brooms, leather gloves, and sponges cannot be decontaminated effectively and must be disposed of.

7. Dispose of contaminated materials. This also includes contaminated absorbent materials, soil, and porous equipment. Most materials can be disposed of in a licensed sanitary landfill, but some contaminated materials are considered hazardous waste and require special handling.

For major spills, or spills that may contaminate water, follow the first three steps under the directions for cleaning up minor spills. Then call the CHEMTREC telephone number (800) 424-9300. A qualified person will answer and direct you regarding what procedures to follow and whom to notify.

If necessary, the area coordinator will dispatch a pesticide safety team to the site. Spills may also require notification steps to other authorities. If a state or federal highway is the site of a spill, notify the highway patrol and the state highway department. If food is contaminated, notify state or federal food and drug authorities and city, county, or state health officials. If water is contaminated, notify public health authorities; regional, state, or federal water quality or water pollution authorities; and the state fish and game agency.



DISPOSAL

"Empty" pesticide containers are never truly empty. There will always be small amounts of pesticide even after they have been rinsed out properly. Never toss them into streams, ponds, fields, or vacant buildings. Always be able to account for every pesticide container you used for the job. Never give them to children to play with or allow uninformed persons to have them for any use. Dispose of all your pesticide containers carefully and properly.

As soon as they are emptied, containers with liquid pesticides should be triple-rinsed.

1. Allow the pesticide to drain from the container into the spray tank for at least 30 seconds.
2. Fill the container one-quarter full with the proper diluent (usually water).
3. Replace the closure or plug the opening of the container.
4. Rotate the container, making sure to rinse all surfaces.
5. Remove closure and drain container into spray tank.
6. Allow 30 seconds for rinsate to drain.
7. Repeat this procedure two more times.
8. Puncture the top and bottom of the container to prevent reuse. Crush flat.
9. Deposit the container in a licensed sanitary landfill.

Measuring containers should also be rinsed and the rinsewater used as future diluent. Rinse them at least three times with the same liquid that the tank is being filled with. Replace container caps and close bags. Return them to the pesticide storage area. All containers must be accounted for and properly stored or disposed. Otherwise, they too may end up in a water source or may poison other people or animals.

Chapter 4
PESTICIDE LABELS

The pesticide registration process requires extensive testing for potential adverse health and environmental effects for every pesticide. The process of registering a pesticide often takes several years and can costs millions of dollars. Pesticide labels are developed to inform applicators about safe and proper use of the product, warn about potential risks and recommend methods to avoid risks. In general, by following the directions on the pesticide label, you will:

1. Obtain practical pest control,
2. Use the pesticide safely and correctly,
3. Store the pesticide in a safe manner.

The pesticide label should be read, understood and followed before the pesticide is purchased, mixed, applied, stored, or disposed of. Anyone possessing, handling, or applying a pesticide is responsible and can be held liable for any damage, loss, or unintended consequences that the pesticide may cause. The pesticide label is the main method of communication between a pesticide manufacturer and pesticide users. The information that is printed on or attached to a pesticide container is called the **label**. **Labeling** includes the label plus all other information provided by the manufacturer about the product and includes brochures, leaflets, and other information that may accompany the product. The pesticide label provides valuable information about the proper handling, use, potential risks a pesticide may pose, and instructions on how to minimize or avoid those risks. Every pesticide applicator has the responsibility to read and follow the label information so no harm will result from misuse or mishandling of the pesticide. Pesticides handled in a careless manner can endanger the health of the applicator, other people, animals, plants, or the environment.

Before you consider using a pesticide, you should consider the following:

- What are the target pests and will the pesticide give adequate control?
- What is the lowest pest population density that causes economic damage? This is known as the **economic injury level**, a term often used with integrated pest management to describe the point where the benefits derived from control measures exceeds the cost of control. The concept is that you do not apply a pesticide at the first sign of a pest, but wait until the pest population reaches a level <u>before</u> it can cause economic damage. You then apply the pesticide at the right time to catch the most number of pests instead of multiple pesticide applications to kill a few pests at one time. You then limit the number of pesticide applications that you make overall.
- Are there alternative methods of pest control available?
- Can the pesticide be applied safely and legally? Do you know the areas where the pesticide can and cannot be applied?
- What are the necessary application and safety equipment?
- How much pesticide is needed for the application? You should buy only what you need.
- What are the restrictions for use of the pesticide?
- Could pesticides pose problems for children, pets, non-target plants, insect and animals in the area?

You should always compare different pesticide labels, because several different products may control the same pest. A comparison of the labels and product prices will help you select a product that controls the pest and is also less toxic or less expensive.

Parts of the Label

The main federal regulation that pertains to pesticide labels is the Federal Insecticide Fungicide and Rodenticide Act (FIFRA). FIFRA mandates that specific information appear on a pesticide label. Pesticide users have the legal responsibility to read, understand and follow the label directions.

Pesticide labels will contain the following sections:

1. **Classification.** All uses of pesticides are classified on the basis of hazards, the intended use, and the pesticides effect upon the environment. Pesticide use is classified either for "**general-use**" or "**restricted-use**". General-use pesticides are less likely to harm the user or the environment when used according to the label. They generally contain a low percentage of toxic chemicals. On the other hand, restricted-use pesticides (RUP) have a greater potential to harm the environment or the applicator when not used as directed. However, not all highly toxic pesticides are classified as RUPs. Training and certification is required for an applicator to purchase, apply or supervise the application of a "restricted use" pesticide (RUP).

2. **Product or brand name.** Each manufacturer has a brand name for each product and different brand names from different manufacturers may pertain to the same pesticide active ingredient (a.i). For example: Company X may produce a 2,4-D product called D-Lux where Company Y also produces a 2,4-D product called D-vine. Pesticide users must use caution in choosing pesticide product by brand name alone. The example label shows that SNAFU is the brand name where snorzalone and triclopyrazine are the common names of the active ingredients and *2,4 Phrenetic-acetic acid* and *2,5,6-pyrmidic acid* are the chemical names.

3. **Type of pesticide.** The label must indicate what type of pesticide the product is or what types of pests it will control. Example: insecticide, herbicide, fungicide.

4. **Ingredient statement.** Each pesticide label must include the active and inert ingredients in the product. The list is written to show the active ingredient and the amount of each ingredient listed. The ingredient statement must list the official chemical names and/or common names for the active ingredient. Inert ingredients need not be named, but the label must show what percent of the total contents they comprise. Check the active ingredients when comparing pesticides, as different brands of pesticides may contain the same active ingredient. By purchasing pesticides according to the common or chemical name, you will be sure you are getting the right active ingredient no matter what the brand name or formulation. When comparing different products with the same active ingredient, be sure to compare the percentage of active ingredient in each product. Often products will contain the same active ingredient, but in different concentrations. Two pesticide products with the same active ingredient and same rate, but with differing concentrations, may show some difference in the amount of control that is achieved.

5. **Net contents.** The net contents statement on the front panel of the pesticide label will tell you how much product is in the container. The label may also state "This product contains 4 pounds of active ingredient per gallon." This is an important statement when figuring the proper pesticide rate based on the pounds of active ingredient (a.i.) per acre.

6. **EPA registration number.** The EPA registration number indicates that the pesticide has been registered by EPA and legally may be sold or applied according to label directions. The EPA registration is not a guarantee of safety in all situations. The EPA registration number usually has two numbers. The first number identifies the company and the second number identifies the product. **EPA establishment number.** The EPA establishment number identifies the establishment or facility where the pesticide was manufactured. The first number indicates the company and the second the location.

7. **Name and address of the manufacturer of the pesticide.** Very often there will be a toll-free number listed so that you can directly contact the manufacturer for more information regarding the pesticide.

8. **Keep out of reach of children.** This warning statement is required to be on **all** pesticide containers. **Signal words.** The signal word indicates the approximate toxicity of the pesticide product. Products with the skull and crossbones symbol and the signal words **DANGER-POISON** are highly toxic and may kill you if ingested, injure you if spilled on your skin or affect you with toxic fumes. Products that display only the signal word **DANGER** are corrosive and can cause irreversible eye damage or severe skin injury. Products that display the signal word **WARNING** are moderately toxic or can cause moderate eye or skin irritation. Products that display the signal word **CAUTION** are slightly toxic or may cause slight eye or skin irritation.

9. **Statement of practical treatment (First Aid).** The statement of practical treatment lists the first aid treatment that should be administered to someone accidentally exposed to the pesticide. There may also be a **Note to Physicians** to provide emergency medical personnel with poison treatment information, antidotes, and often provides an emergency phone number to contact for further information. An emergency telephone number may be listed.

10. **Precautionary statements.** Precautionary statements identify potential hazards and recommend ways that the risks can be minimized or avoided. Types of precautionary statements include "Hazards to Humans and Domestic Animals," "Environmental Hazards," and "Physical or Chemical Hazards."

    - *Hazards to Humans and Domestic Animals*. The signal word is listed, followed by statements indicating which routes of entry (mouth, skin, lungs, eyes) are most likely to be harmed and those body parts that must be particularly protected. The label will then provide specific actions that can prevent overexposure to the pesticide.
    - **Personal Protective Equipment** or **PPE** that is required to handle or apply the pesticide.
    - **User Safety recommendations** will also be noted.
    - *Environmental Hazards*. The environmental hazards section of the label warns of pesticide risks to wildlife, birds, fish, bees or to the environment and provides practical ways to avoid harm to organisms or the environment.

- *Physical or Chemical Hazards.* The physical or chemical hazards section of the label will tell you of any special fire, explosion, or chemical hazards the product may pose.

11. **Directions for use.** Directly under this heading is the statement, *"It is a violation of federal law to use this product in a manner inconsistent with its labeling."* It is illegal to use a pesticide in any way not permitted by the labeling. A pesticide may be used only on those pests or sites named in this section. You may not use higher dosages or more frequent applications than is allowed. You must follow all directions for use, safety, mixing, diluting, storage and disposal. You must wear the personal protective equipment that is listed on the label.

THE USE DIRECTIONS AND INSTRUCTIONS ARE NOT RECOMMENDATIONS. THEY ARE REQUIREMENTS!

There are certain circumstances where you can use pesticides in ways not specifically mentioned in the labeling. Just make sure you are not in violation of any state or tribal laws.

- You can apply a pesticide at any dosage, concentration, or frequency **less than** that listed on the label.
- You can apply a pesticide against a pest not listed on the label as long as the application is to a **site** that is listed on the label. Suppose a weed that you want to control is not listed on the label of the herbicide you intend to use. Suppose the label does indicate that the herbicide may be used on rangelands. You would not be in violation of the labeling if you applied the pesticide to the weed on a rangeland site. You would be in violation of the labeling if you applied the product to the weed in a lawn. However; keep in mind that the pesticide manufacturer may not guarantee that their pesticide will be effective on any pest not listed on their label.
- You can mix two or more pesticides, if all of the dosages are at or **below** the recommended rates.
- You can use any method of application or equipment that is not prohibited by the labeling.
- You can mix pesticides together, or mix pesticides with fertilizers, as long as the mixtures are not prohibited by the labeling. Conduct a compatibility test before you mix.

Penalties under FIFRA can be as much as $1000 for each offense. Correct application of a pesticide product is accomplished by following the instructions found in this section of the label. The Directions-for-use instructions will advise you of the **Agricultural Use Requirements**, **Storage and Disposal Instructions** and **General Use Instructions.**

12. **Agricultural Use Requirements.** In 1994, the EPA issued the Worker Protection Standard (WPS) to protect employees on farms and in forests, nurseries and greenhouses from exposure to both general and restricted-use agricultural pesticides. The WPS covers workers in areas treated with pesticides and employees who handle pesticides in the production of agricultural plants or commodities. The Worker Protection Standard is applicable when a WPS-labeled pesticide is used to produce an agricultural commodity.

    If you are using a pesticide with labeling that refers to the Worker Protection Standard, you must comply with the standard as noted on the label. Otherwise, you may be in violation of Federal law, since it is illegal to use a pesticide in a manner inconsistent with its labeling.

Some pesticide uses are not covered by the WPS, even when the Agricultural Use Requirements section is on the labeling. For example, if the pesticide labeling bears an Agricultural Use Requirements section, but the product can also be applied to rights-of-way, the rights-of-way use is not covered by the WPS.

The WPS does **NOT** apply to pesticides applied:

- on pastures, rangelands or livestock.
- for control of vertebrate pests such as rodents, ground squirrels, etc.
- on the harvested portions of agricultural plants or harvested timber.
- for mosquito abatement or similar government-sponsored wide-area public pest control programs.
- plants grown for other than commercial or research purposes, which may include plants in habitations, home fruit and vegetable gardens, and home greenhouses.
- on plants that are in ornamental gardens, parks, golf courses, and public or private lawns and grounds, and that are intended only for decorative or environmental benefits, (Sod farms are covered by the WPS).
- on plants in golf courses (except those areas set-aside for plant production), or right-of-way areas.
- in a manner not directly related to the production of agricultural plants, including the control of vegetation along rights-of-way and in other non-crop areas, and structural pest control, such as wood preservation.
- for research uses of unregistered pesticides.

This section will also state the amount of time that must pass before any workers are allowed to re-enter treated areas. This is known as the Restricted Entry Interval or **REI**. Also noted may be other intervals between pesticide application and harvest of food crops.

A **Non-agricultural Use Statement** may appear with instructions for those applicators exempt from the Worker Protection Standard.

13. **Storage and Disposal.** All pesticide labels contain general instructions for the appropriate storage and disposal of the pesticide and its container.

14. **General Use Instructions.** This section states the pests that the manufacturer claims the product will control. The crop, animal, or site the product is intended to protect. When, where, and how the product should be applied. The proper equipment to be used. The correct dosage and mixing directions. The compatibility with other often-used products, and the minimum time between the applications. Mixing instructions may also be noted here.

Restricted Use Pesticide #1

Due to Corrosive Effects on Skin and Eyes. For retail sale to, and use only be Certified Applicators or persons under the direct supervision of a Certified Applicator, and only for those uses covered by the Certified Applicator's Certification

Agro Petro Chem™

#2

SNAFU

#3

Rangeland Herbicide

For the control of Perennial Weeds in Rangeland and Pastures.

ACTIVE INGREDIENTS: #4

Snorzalone: 2,4-Phrenetic-acetic Acid, Butoxyethyl Ester.............................35%
Triclopyrazine: 2,5,6-pyrmidic acid Butoxyethyl Ester..............................15%
INERT INGREDIENTS..................................50%
TOTAL..100%

Acid Equivalents: #5
Snorzalone – 2 lb./gal.
Triclopyrazine – 1 lb./gal.

NET CONTENTS: 2 ½ gallons

EPA REG NO. 43567-23-45672 #6
EPA EST. NO. 34567-MT-01

Agro Petro Chem™ -
Box 666
Yada Yada Yada, NY 50000 #7

KEEP OUT OF REACH OF CHILDREN #8

DANGER/PELIGRO

SEE BELOW STATEMENTS FOR ADDITIONAL PRECAUTIONARY STATEMENTS AND FIRST AID

Statement of Practical Treatment - First Aid

In case of contact: Flush skin or eyes with plenty of water for at least 15 minutes. Get medical attention if irritation persists.
If swallowed: Do not induce vomiting. Call a p #9 or poison control
For emergency Assistance Call (800) 330-XXXX

PRECAUTIONARY STATEMENTS #10

HAZARDS TO HUMANS AND DOMESTIC ANIMAL

DANGER/PELIGRO

CORROSIVE. Causes irreversible eye damage. May be fatal if swallowed or absorbed through the skin. Do not get in eyes, on skin or on clothing.
Remove saturated clothing as soon as possible and shower. Avoid inhaling mists.

Prolonged exposure may cause allergic reactions in some individuals.

Personal Protective Equipment (PPE)

Applicators and other handlers must wear:

- Long sleeved shirt and long pants
- Chemically resistant gloves such as nitrile rubber or neoprene or viton
- Protective eyewear #10
- Shoes plus socks

Follow manufacturer's instructions for cleaning/maintaining PPE. If no instructions are available, use detergent and hot water. Keep and wash separately from other laundry.

User Safety Recommendations

Users should:

- Wash hand before eating, drinking, chewing gum, using tobacco or using the toilet.
- Remove clothing immediately if saturated with pesticide. Wash thoroughly and put on clean clothing.
- Remove PPE immediately after using this product. Wash outside of gloves before removing. Show and change into clean clothing

Environmental Hazards

This product is toxic to fish. Drift or runoff may adversely affect fish and non-target plants. Do not apply directly to water, to areas where surface water is present. Do not contaminate water when disposing of equipment washwaters.

DIRECTIONS FOR USE

It is a violation of Federal law to use th #11 t in a manner inconsistent with its labeling. pply this product in a way that will contact workers or other persons either directly or through drift.

This product may not be applied to forage that is to be cut and sold for commercial purposes.

Mixing and Loading: Most cases of groundwater contamination involving phrenetic herbicides such as 2,4-P have been associated with mixing/loading and disposal sites. Caution should be exercised when handling 2,4-P pesticides at such sites to prevent contamination of groundwater supplies. Contain all spills by making a soil dam where practical. Placement of the mixing/loading equipment on an impervious pad to contain spills will help prevent groundwater contamination.

Use in Liquid Nitrogen Fertilizer: SNAFU may be combined with liquid nitrogen fertilizer suitable for foliar application. Test for mixing compatibility before mixing in spray tank. A compatibility aid may be needed in some situations. **Compatibility is best with straight liquid nitrogen fertilizer solutions.**

#12

AGRICULTURAL USE REQUIREMENTS

Use this product only in accordance with its labeling and with the Worker Protection Standard. It contains requirements for training, decontamination, notification, and emergency assistance. It also contains specific instructions and exceptions pertaining to the statements on this label about personal protective equipment, notification of worker, and restricted-entry intervals. Do not enter or allow worker entry into treated areas during restricted entry interval (REI) of 48 hours after application. PPE required for early entry to treated areas is: coveralls, chemical resistant gloves and shoes plus socks.

NON-AGRICULTURAL USE REQUIREMENTS

The requirements in this box apply to uses of this product that are NOT within the scope of the Worker Protection Standard for Agricultural Pesticides (40 CFR Part 170). The WPS applies when this product is used to produce agricultural plants on farms, forests, nurseries, or greenhouses.

Entry Restrictions for Non-WPS Uses: For applications on rangeland, permanent grass pastures, and non-cropland. Do not enter or allow worker entry into treated areas until sprays have dried, unless applicator and other handler PPE is worn.

STORAGE AND DISPOSAL

#13

Do not contaminate water, food or feed by storage or disposal.

Storage: Store above 10°F or agitate before use.

Pesticide Disposal: Pesticide wastes are toxic. Improper disposal of excess pesticide, spray mixture, or rinsate is a violation of Federal law and may contaminate groundwater. If these wastes cannot be disposed of by use according to label instructions, contact your State Pesticide or Environmental Control Agency, or the Hazardous Waste representative at the nearest EPA Regional Office for guidance.

Plastic Container Disposal: Do not reuse container. Triple rinse (or equivalent). Puncture and dispose of in a sanitary landfill, or by incineration, or, if allowed by state and local authorities, by burning. If burned, stay out of smoke. Consult federal, state, or local disposal authorities for approved alternative procedures.

Do not store spray mixture. Application during very cold weather (near freezing) is not advisable.

Note: Do not use spray equipment for other applications to land planted, or to be planted to susceptible crops or desirable plants, **unless** it has been determined that all phytotoxic herbicide residue has been removed by thorough cleaning of the equipment.

GENERAL INSTRUCTIONS

#14

General Information

For control of perennial broadleaf weeds in rangeland and pastures. No other uses are allowed. Apply as a broadcast spray or spot application.

Chemigation: Do not apply this product through any type of irrigation system.

Foliar sprays should be applied during warm weather when perennial weeds are actively growing. Application under drought conditions may provide less than desirable results. Use low spray pressures to minimize spray drift. **Apply SNAFU in a manner to avoid contacting nearby susceptible crops or other desirable plants and to avoid contaminating water intended for irrigation or domestic use. Read and follow all use precautions given on this label.**

With ground broadcast equipment, drift can be reduced by keeping the spray boom as low as possible; by applying no less than 20 gallons of spray per acre; by keeping the operating spray pressures at the lower end of the manufacturer's recommended pressures for the specific nozzle type used (low pressure nozzles are available from spray equipment manufacturers); and by spraying when the wind velocity is low.

Do not spray pastures containing desirable broadleaf forbs, especially legumes such as clover, unless injury or loss of such plants can be tolerated

Grazing or harvesting green forage:

1) Lactating dairy animals. Do not graze or harvest green forage from treated area for 14 days after treatment.

2) Other Livestock. If less than 25% of a grazed area is treated, there is no grazing restriction.

Mixing Directions

SNAFU in water forms an emulsion (not a solution), and separation may occur unless the spray mixture is agitated continuously.

Adding SNAFU. Fill the spray tank about half full with clean water. Then add the SNAFU and complete filling the tank with agitation running. Mix thoroughly and continue moderate agitation while spraying.

Approved Uses:

Note: For rangeland and pastures, the maximum application rate is 4 quarts per acre per application per growing season.

Us SNAFU at a rate of 2-4 quarts per acre. Use heavier rate if weed stands are dense.

bindweed, field	thistle, Canada
milkweed – suppression only	wormwood
spurge, leafy	

Warranty Disclaimer

Agro Petro Chem™ warrants that this product conforms to the chemical description on the label and is reasonably fit for the purposes stated on the label when used in strict accordance with the directions. It is impossible to eliminate all risks associated with use of this product.

Chapter 5
Material Safety Data Sheets

According to the Occupational Safety and Health Administration (OSHA), a chemical is hazardous if it is:

- Specifically listed as a toxic and hazardous substance in the Code of Federal Regulations (CFR);
- Assigned a threshold limit value (TLV) by the American Conference of Governmental Industrial Hygienists (ACGIH). A TLV is the maximum airborne concentration of a material to which most workers can be exposed daily during work without adverse health effects); or
- Determined to be cancer causing, corrosive, toxic, an irritant, a sensitizer, or to have damaging effects on specific body organs.

The OSHA Hazard Communication Standard requires that manufacturers or distributors of hazardous materials assess the physical and health hazards of their chemicals. This information is called a Material Safety Data Sheet (MSDS) and must be provided to the purchasers of such products. OSHA requires that MSDS be available for every chemical used in the workplace for employees to view during their work shift.

The purpose of the MSDS is to protect workers who handle pure forms or very high concentrations of a chemical for long periods of time. **MSDS's are not meant for the average consumer or average applicator**. An MSDS reflects the hazards of working with the material in an occupational fashion. For example, an MSDS for paint is not highly pertinent to someone who uses one can of paint once a year, but is extremely important to someone who does this in a confined space 40 hours a week.

The objective of an MSDS is to concisely inform workers about the hazards of materials they handle, so they can protect themselves and respond to an emergency situation such as a spill or accidental release.

To that end, an MSDS is divided into 16 distinct sections where pertinent information can be quickly reviewed:

Section 1 - Product & Company Information

This section list brand or trade name of the chemical as well as the name and address of the manufacturer and an emergency phone number where questions about toxicity and chemical hazards can be directed.

Section 2 - Composition/Information on Ingredients

Included in this section are **common and chemical names,** groups of chemicals with related physical and chemical properties, the chemical formula, and the **CAS Number** (number assigned to chemicals or materials by the Chemical Abstracts Service.

Section 3 – Hazards Information

This section identifies hazardous ingredients and exposure limits. Exposure limits are commonly expressed as:

- The **TLV** (Threshold Limit Value) is a recommended maximum average concentration over an eight-hour workday.
- The **PEL** (Permissible Exposure Limit) is amount of a substance in the air that any employee may be exposed to over an eight-hour work shift.
- The $\mathbf{LD_{50}}$ is the lethal dose concentration that kills 50% of the test animals used.
- Milligrams of substance per cubic meter of air (**mg/m^3**); a unit for measuring concentrations of dusts, gases or mists in air.
- Milligrams of substance per kilogram of body weight (**mg/kg**); used generally for solids or liquids taken in by mouth rather than inhaled substances.
- Parts per million (**ppm**); a unit for measuring the concentration of a gas or vapor in air, i.e. the number of parts (by volume) of a gas or vapor in a million parts of air. Also used at other times to indicate the amount of a liquid or solid.

Remember that this information is only for the individual ingredient, not for the entire mixture.

Section 4 – First Aid Measures

Based on the toxicity of the product, degree of exposure and route of contact (eye, skin, inhalation, ingestion, injection), emergency and first aid procedures are recommended in this section. Additional cautionary statements, i.e., **Note to Physician**, for first aid procedures, when necessary, will also appear here.

Section 5 – Fire Fighting Measures

This section should provide information on the fire hazards of a product and special precautions necessary to extinguish a fire. Key points to remember are:

- **Flash point:** This is the lowest temperature at which a liquid vaporizes to form a mixture with air that can be ignited by a spark. Liquids with flash points below 100°F are considered *flammable*, and liquids with flash points between 100 and 200°F are considered to be *combustible*. Flammable and combustible liquids require special handling and storage precautions.
- **Extinguishing media:** This section should specify what kind of fire extinguisher to use. There are four classifications of fires: *Class A* for paper and wood, *Class B* for more flammable materials such as liquids or greases, *Class C* for electrical fires, and *Class D* for fires involving metals or metal alloys.
- **Special firefighting procedures and unusual fire and explosion hazards:** For example, some chemicals (such as corrosives) must not be extinguished with water in case of fire.

Section 6 – Accidental Release Measures

Section 6 outlines the procedures to be followed in case of accidental release of the chemical, including methods to be used to clean up spills. Note that these measures are unlikely to be sufficiently detailed if the chemical is particularly hazardous, and local procedures should be drawn up to supplement what is given in the MSDS sheet.

Section 7 – Handling and Storage

This section contains information on proper equipment to use and precautions to follow if a spill or leak occurs. It should also describe safe waste disposal methods and precautions to be taken in handling and storing.

Section 8 – Exposure Controls/ Personal Protection

Section 8 provides information on regulatory standards for exposure; the maximum permitted concentration of the material in the environment to which workers are allowed to be exposed.

This section also includes general information about appropriate personal protective equipment (PPE) for handling this material. Many times, this section of the MSDS is written for large-scale use of the material. Appropriate personal protection may be determined by considering the amount of the material being used and the actual manipulations to be performed.

Section 9 – Physical and Chemical Properties

This section outlines the physical properties of the material. The information may be used to determine conditions for exposure. For example, one can determine whether or not a chemical will form a vapor (vapor pressure), whether this vapor will rise or fall (vapor density), and what the vapor should smell like (appearance and odor). The following information is usually included:

- **Boiling Point:** temperature at which liquid changes to vapor state.
- **Melting Point:** temperature at which a solid begins to change to liquid.
- **Vapor Pressure:** a measure of how volatile a substance is and how quickly it evaporates. For comparison, the vapor pressure of water (at 20° C) is 17.5 millimeters (mm) of mercury (Hg) in a mercury barometer. Vaseline (non-volatile) is close to 0 mm Hg, and diethyl ether (very volatile) is 440 mm Hg.
- **Vapor Density (air=1):** weight of a gas or vapor compared to weight of an equal volume of air. Density greater than 1 indicates it is heavier than air, less than 1 indicates it is lighter than air. Vapors heavier than air can flow along just above ground, where they may pose a fire or explosion hazard.
- **Specific Gravity (water=1):** ratio of volume weight of material to equal volume weight of water.
- **Solubility in Water:** percentage of material that will dissolve in water, usually at ambient temperature. Since humans are made mostly of water, water-soluble substances absorb and distribute more readily in the body.
- **Appearance/Odor:** color, physical state at room temperature, size of particles, consistency, odor, as compared to common substances. Odor threshold refers to the concentration required in the air before vapors are detected or recognized.
- **% Volatile by Volume:** Percentage of a liquid or solid, by volume, that evaporates at a temperature of 70°F.
- **Evaporation Rate:** usually expressed as a time ratio with ethyl ether = 1, unless otherwise specified.
- **Viscosity:** internal resistance to flow exhibited by a fluid.
- **Other Pertinent Physical Data:** information such as freezing point is given, as appropriate.

Section 10- Stability and Reactivity

This section includes information regarding the stability of the material and any special storage or use considerations and includes:

- **Stability:** "unstable" indicates that a chemical may decompose spontaneously under normal temperatures, pressures, and mechanical shocks. Rapid decomposition produces heat and may cause fire or explosion. Conditions to avoid are listed in this section.
- **Incompatibility:** certain chemicals, when mixed, may create hazardous conditions. Incompatible chemicals should not be stored together.
- **Hazardous Decomposition Products:** chemical substances that may be created when the chemical decomposes or burns.
- **Hazardous Polymerization:** rapid polymerization may produce enough heat to cause containers to explode. Conditions to avoid are listed in this section.

Section 11 – Toxicological Information

Section 11 lists relevant toxicology data like the LD_{50} and known results of chronic toxicity tests. Any LD_{50} for oral and dermal exposure less than 50 or 200 mg/kg body weight, respectively, would be considered highly toxic, requiring the utmost caution and maximum in protective safety equipment.

Section 12 – Ecological Information

Ecological information is not specifically required under the OSHA Hazard Communication Standard. You will normally find data that is useful in evaluating the environmental impact of the material if it is released to the environment (e.g. toxicity to fish, birds, plants and microorganisms). This information is intended mainly for environmental professionals and other company staff evaluating use, disposal or spill control.

Section 13 – Disposal Considerations

There are currently no specific OSHA requirements in this section, however you may find data such as RCRA (U.S. Resource Conservation and Recovery Act) classification, EPA (U.S. Environmental Protection Agency) waste number etc.

The MSDS does not usually contain all the steps and precautions necessary for adequate hazardous waste disposal. As well, the MSDS often does not give the federal or local regulations that must be followed. The appropriate authorities for your area should be contacted for this information.

Section 14 – Transport Information

This section of the MSDS is intended for those responsible for shipping the material. If there are special precautions necessary during shipment, they will be provided. For example, some products may be sensitive to shock or sensitive to high temperatures. The U.S. DOT (Department of Transportation) identification number may be provided if the product meets the DOT criteria. The supplier may include the U.S. DOT (Department of Transportation) classification for the product.

Section 15 – Regulatory Information

Information in this section is aimed primarily at regulatory compliance professionals. Useful references to applicable health, safety and environmental laws and regulations may be provided, along with information on the regulatory status of the product. For example, whether or not the product is considered to be hazardous as defined by the OSHA Hazard Communication Standard may be stated.

Section 16 – Other Information

The other information section is used to provide supplementary information that the writer of the data sheet considers important for the safe use of the material. Reference sources used in preparing the data sheet are sometimes listed. You can use this reference list to obtain additional information on the material.

Important Questions To Answer When Reading An MSDS

Identification

_____ Do you have the right MSDS for the material with which you are working or will be working?
_____ Do you have an up-to-date MSDS?
_____ Does the MSDS description of the material match the material you have?

Potential Hazards

_____ Can this material burn or explode?
_____ Is this material unstable? If so, under what conditions?
_____ Can this material react with other chemicals? If so, which ones?
_____ Can this material harm your health? Do you know the symptoms that may warn you of exposure?
_____ Have you discussed the health effects information with your doctor?
_____ Can this material cause harm to the environment?

Preventive Measures

_____ Does your work site need engineering controls?
_____ Does this material require special handling precautions?
_____ Do you need protective equipment?
_____ Do you need to be careful when mixing this material with any other chemicals?
_____ Does this material require special storage conditions?

Emergency Measures

_____ Do you know what to do in case of a fire or explosion?
_____ Do you know the first aid measures needed in case of an exposure?
_____ Do you know what to do in case of a spill or leak?
_____ Do you know where the emergency response equipment is and how to use it?

Conclusion

It is important to remember that an MSDS is not a complete source of health and safety information on its own. This is because MSDS's are usually written for many different work sites and, therefore, cannot be specific in the advice they offer They are, however, an essential starting point for developing a complete chemical health and safety program.

Chapter 6
PESTICIDE APPLICATION EQUIPMENT

Terms To Know

Abrasive ------------- The wearing away or grinding down of another object.
Agitation ----------- The process of stirring or mixing.
Band application---- A treatment applied to a linear strip usually on or along a crop row rather than applied continuously over the entire area (Broadcast).
Broadcast application - A treatment applied as a continuous sheet over an entire area.
Calibrate ------------ Measure and adjust the <u>amount of a pesticide mixture</u> that application equipment will release <u>per unit of area</u>. Usually expressed as Gallons Per Acre (GPA).
Carriers ------------ Added to concentrates by the manufacturer to give a formulation "body" and "surface" adequate for application. Carriers are often inert ingredients such as water or talc. This term is often confused with Diluent.
Concentrate--------- A pesticide having a high percentage of active ingredient; occasionally applied full-strength, but usually diluted before application.
Corrosion ----------- The process of being worn away gradually by chemical action.
Diluent--------------- Anything used to reduce the concentration of a pesticide formulation at the time of application.
Dilute pesticide------ A pesticide that is not concentrated.
Drift ------------------ Pesticide is carried off target as small droplets or vapor.
Emulsifiable concentrate (EC) ---- A pesticide formulation that usually contains a liquid active ingredient, one or more petroleum-based solvents, and an agent that allows the formulation to be mixed with water to form an emulsion.
Formulation -------- Pesticide product as sold, usually a mixture of active and inert ingredients.
Fumigant ------------ Pesticide that is a vapor or gas when applied and whose pesticidal action occurs in the gaseous state.
GPA ----------------- Gallons Per Acre. Application volume or sprayer delivery rate.
GPM ----------------- Gallons per minute. Usually used to express nozzle flow.
Hydraulic agitation- Stirring or mixing provided by the circulation of surplus spray material from the pump back to the tank.
Hydraulic ----------- Operated by the pressure created by forcing liquid through a narrow opening.
Mechanical agitation - Stirring or mixing done by rotating paddles/propellers in a sprayer tank.
Nontarget ----------- Any site or organism other than the site or pest to which the pesticide is being directed.
Personal protective equipment (PPE) - Devices and clothing worn to protect the human body from contact with pesticides or pesticide residues.
PSI-------------------- Pounds per square inch. Used to measure sprayer pressure.
PTO -- ------------ Power Take Off. A device that transmits engine power to an auxiliary device i.e. winches, pumps.
RPM --------------- Revolutions Per Minute.
Suspension --------- Undissolved particles mixed throughout a liquid.
Target--------------- The site or pest toward which control measures are being directed.
Volatile ------------- Evaporating rapidly; turning easily into a gas or vapor.

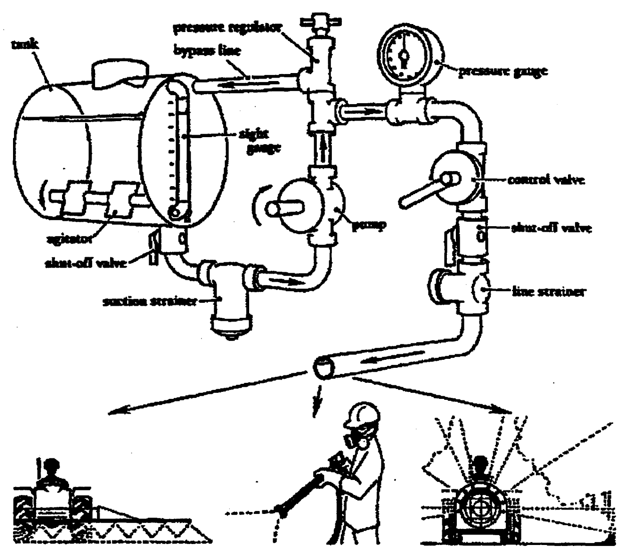
This chapter provides an overview of what you should know about choosing, using, and caring for most types of pesticide application equipment. To use any equipment safely and effectively, **study the manufacturer's directions carefully**.

Prior to using any pesticide always:

- **Wear** protective clothing and safety devices as recommended on the label.
- **Bathe** or shower after each use.
- **Read** the pesticide label-even if you've used the pesticide before.
- **Follow closely** the instructions on the label (and any other directions you have).
- **Be cautious** when you apply pesticides.
- **Know** your legal responsibility as a pesticide applicator. You may be liable for injury or damage resulting from pesticide misuse.

LIQUID PESTICIDE APPLICATION EQUIPMENT

Many pesticides used to control weeds and insects are applied with equipment that uses hydraulic (liquid) pressure or air to propel the pesticide droplets to the target. Backpack sprayers, tractor-mounted sprayers, pull-type sprayers, and pickup-mounted sprayers are available from numerous suppliers. Spray pressures range from near 0 to over 300 pounds per square inch (psi), and sprayer output can vary from less than 1 to over 100 gallons per acre (GPA). While some sprayers are simple in their design and function, most sprayers used for large-scale pesticide applications have the following basic components: (1) pump, (2) tank, (3) agitation system, (4) flow-control assembly, (5) pressure gauge, and (6) distribution system (booms, broadjets, nozzles, spray guns etc).



Types of Liquid Pesticide Application Equipment
Image from "Safe and Effective Use of Pesticides." UC Davis, 1999.

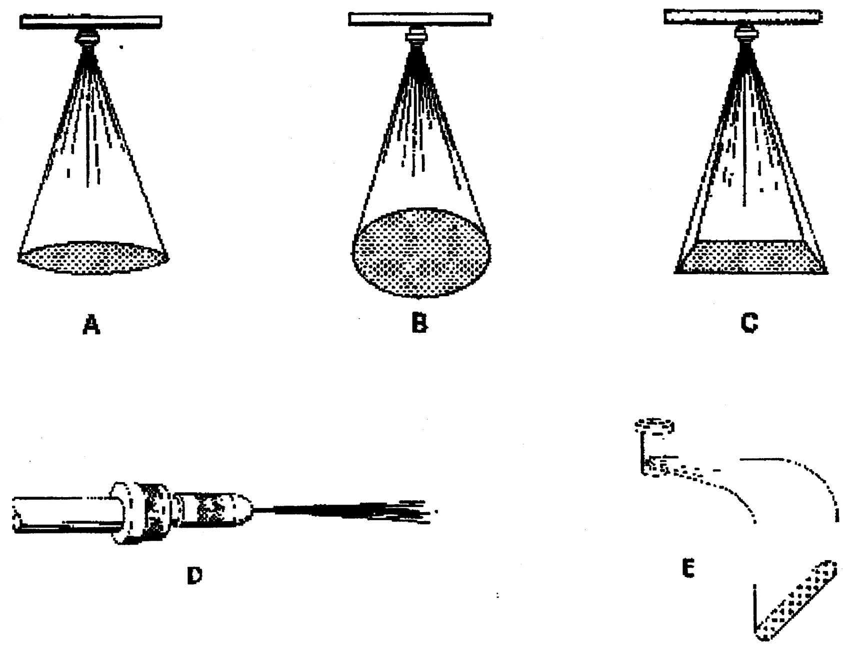
Backpack Sprayers

A backpack (a.k.a. handgun or knapsack) sprayer consists of a tank, a pump, and a spray wand with one or more nozzles. Backpack sprayers are well suited for:

1. Small acreages and spot spraying.
2. Hard-to-reach locations.
3. Spraying jobs where larger sprayer units (tractors, helicopters, etc.) are unavailable.

Sprayer tank capacities range from 2 to 5 gallons so a full 5-gallon tank would weigh over 40 pounds (water weighs 8.3 pounds/gallon).

For spot applications with backpack sprayers, hollow or solid-cone nozzles work well, but only even-flat-fan or flood-jet types should be used for single-nozzle **band** applications. They deliver a relatively even pattern and a constant application rate across the band.



Common types of nozzles for backpack sprayers: (A) tapered flat-fan nozzle -- makes a narrow, oval pattern with tapered edges; (B) solid-cone nozzle – used for spot treatment; (C) even-flat-fan nozzle -- makes a uniform pattern across its width, used for band or strip spraying; (D) adjustable nozzle common on hand-held sprayers – adjusts from solid stream to solid cone; (E) flood nozzle, also used for band or strip spraying a wide, uniform pattern.

Nozzles with low delivery rates (low GPM) are best for small sprayers since more area can be covered with less diluent. The angle of a nozzle's spray pattern and the height at which it is held from the ground determine the width of the spray pattern, known as the effective **swath width.**

Both piston and diaphragm pumps are available for backpack sprayers. Piston pumps are generally capable of developing higher pressures but the piston rings on these pumps wear and lose pressure after extensive use. Diaphragm pumps are mechanically simple but one must be sure the diaphragm material is resistant to chemicals or solvent in pesticides being used. Diesel oil, for example, may degrade some diaphragms.

Advantages:

- simple to operate.
- easy to clean and store.

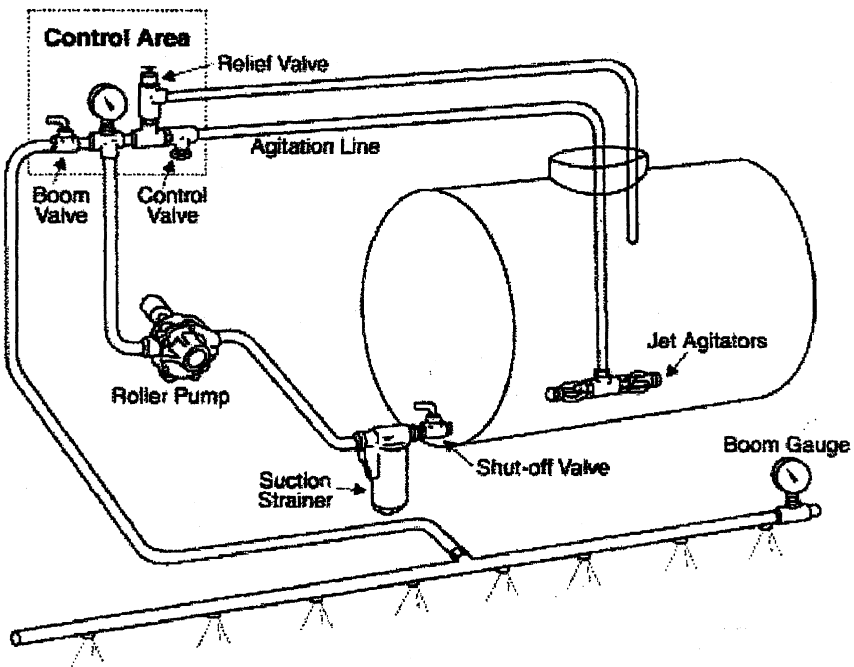
Limitations:

- applicator influences pressure and output rate.
- can be awkward and dangerous.
- difficult to maintain constant calibration.
- difficult keeping wettable powders (WP) suspended.

Power-Driven Sprayers (Low Pressure)

Power driven sprayers are designed to spray dilute liquid pesticides over large areas and deliver a low to moderate volume of spray (10 to 60 GPA) at working pressures ranging from 10 to 80 psi. These sprayers usually are mounted on tractors, trucks, or boats, but some are self-propelled. The point of delivery can be a boom, a single nozzle, or a spray handgun.

Typical Low Pressure Sprayer Setup
Image from "Standard Pesticide User's Guide," Prentice Hall, 1990.



Low-pressure sprayers are often equipped with sprayer booms ranging from 10 to 60 feet in length with multiple nozzles spaced according to manufacturer settings. Many nozzle arrangements are possible, and special-purpose booms are available.

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

Roller pumps and centrifugal pumps are most often used with low-pressure powered sprayers and provide outputs from 5 to more than 20 gallons per acre. Tank sizes range from less than 50 gallons to over 1,000 gallons. The spray material usually is hydraulically agitated, but mechanical agitation may be used.

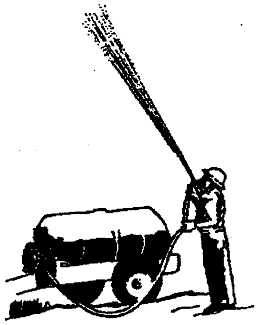
Advantages:

- medium to large tanks permit a relatively large area to be covered per fill, versatility.

Limitations:

- low pressure limits pesticide penetration and reach.

Large Power-Driven Sprayers (High Pressure)



These sprayers are used to spray through dense foliage, thick animal hair, to the tops of tall trees, and into other areas where high-pressure sprays are necessary for adequate penetration and reach. Since they are equipped to deliver large volumes of spray, usually 20 to 500 gallons per acre, large tanks are required. Since they operate under pressures ranging from 150 to 400 psi or more, piston pumps are used and provide outputs of up to 60 gallons or more per minute. All hoses, valves, nozzles, and other components must be designed for high-pressure applications. High-pressure sprayers are usually equipped with a hose and single handgun nozzle for use in spraying trees and animals. These sprayers also may be fitted with a boom for broadcast agricultural applications.

Advantages:
- provide good penetration and coverage of plant surfaces.
- usually well-built and long-lasting if well maintained.

Limitations:
- large amounts of water, power, and fuel needed.
- high pressure at nozzle tip may produce fine droplets that drift easily.
- leaks in plumbing and under high pressure may produce small droplets which contribute to drift.

Electrostatic sprayers

Electrostatic sprayer systems give the pesticide a positive electric charge as it leaves the nozzles. Plant leaves naturally have a negative charge, so the positively charged pesticide is attracted to the plants. The spray is directed horizontally through or above the crop (depending on the pesticide being applied).

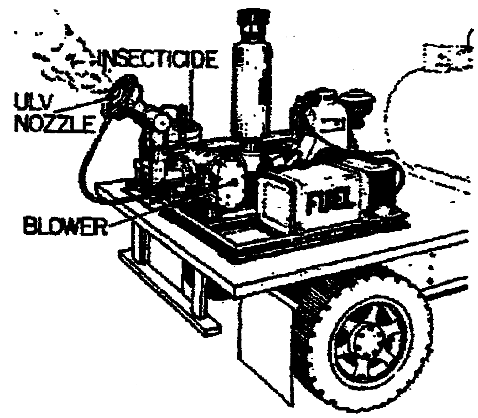
Aerosol Generators And Foggers

Aerosol generators and foggers convert special formulations into very small, fine droplets (aerosols). Single droplets cannot be seen, but large numbers of droplets are visible as a fog or mist. Aerosol generators and foggers are usually used to completely fill a space with a pesticidal fog. Some insects in the treated area are killed when they come in contact with the pesticide. Other insects are simply repelled by the mist but return quickly after it has settled. Thermal foggers, also called thermal generators, use heat to vaporize a special oil formulation of a pesticide. As the pesticide vapor is released into the cooler air, it condenses into very fine droplets, producing a fog.

Advantages:
- penetration in dense foliage.
- penetration of cracks and crevices.

Limitations:
- drifts easily from target area.
- no residual control.
- risk of explosion in enclosed areas.

Ultra-low-volume (ULV)



These sprayers apply a chemical concentrate without the use of water and any other diluents. Many ULV sprayers use a high-speed fan to breakup and transport the spray droplets.

Advantage of ULV sprayer:

- no water is needed, so less time and labor are involved.

Limitations:

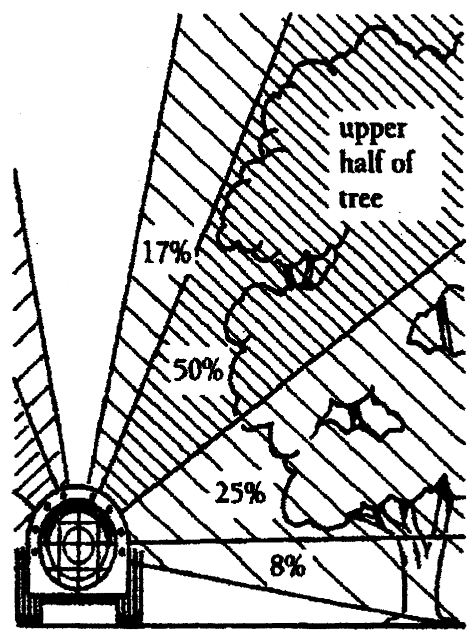
- drift hazards.
- coverage may not be thorough.
- high concentrates present safety hazards.
- use of concentrated pesticides may increase chance of dosage errors.
- few pesticides are labeled for ULV.

Airblast Sprayers

Airblast sprayers use air to propel the pesticide to the surface being treated and usually include the same components as low-pressure or high-pressure sprayers, plus a high-speed fan. Nozzles operating under low pressure deliver spray droplets directly into the high-speed airstream. The air blast shatters the drops of pesticide into fine droplets and transports them to the target. The air blast is directed to one or both sides as the sprayer moves forward.

An airblast sprayer may cover a swath up to 90 feet wide and reach trees up to 70 feet tall.

Orchard air blast sprayers may need to be adjusted to apply greater amounts of pesticides to some parts of the tree. This is done by using several different nozzle sizes or by using more nozzles in some locations. However, a general rule-of-thumb is to apply 50% to the upper half of the tree.



Airblast Sprayer
Image from "Safe and Effective Use of Pesticides." UC Davis, 1999.

Advantages:

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

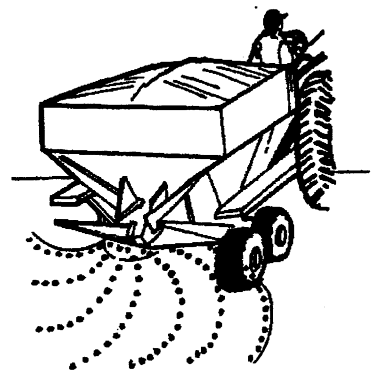
Limitations:

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

DRY PESTICIDE APPLICATION EQUIPMENT

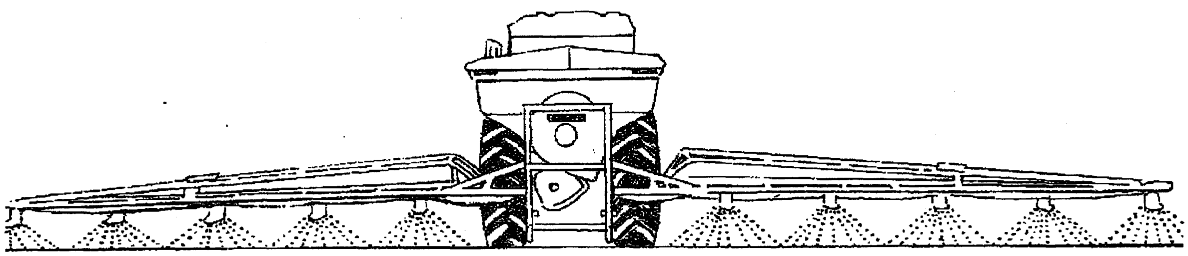
Granular Applicators

Granular applicators distribute granular pesticides by several different methods, including: forced air, spinning or whirling disks (fertilizer spreaders), multiple gravity-feed outlets (lawn spreaders, grain drills), soil injectors (furrow treatments), and ram-air (agricultural aircraft).



Granular applicators may be designed to apply the pesticides:

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



Pneumatic granular spreader.

Advantages of granular spreaders:

- simple in design.
- eliminates mixing -- no water needed.
- minimal drift hazard.
- low exposure hazard to applicator.

Limitations:

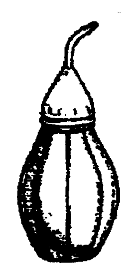
- limited use against some pests because granules will not adhere to most foliage.
- need to calibrate for each different granular formulation being used.
- spinning disk types may give poor lateral distribution, especially on side slopes.

Dusters

Dust applications are more common in greenhouses and other enclosed agricultural areas. Dusters are occasionally used in outdoor agricultural situations, but there is a high probability of drift.

Hand or Bulb Dusters

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



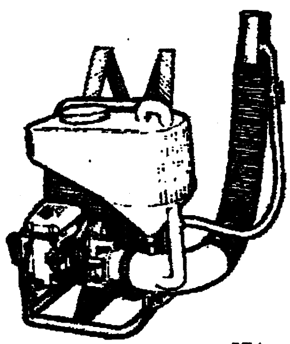
Bulb Duster

Advantages of hand dusters:

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

Limitations:

- dust may not stick to foliage.
- dust is difficult to direct.
- drift potential is high.



Power dusters

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

Advantages of power dusters:

- lightweight -- no water required.
- simple construction.
- easy to maintain.

Limitations:

- drift hazards.
- application may be less uniform than with sprays.
- dust may not stick to foliage.

Pesticide Sprayer Components

Tanks

The tank should be made of a corrosion-resistant material and include stainless steel, polyethylene, plastic, and fiberglass. Aluminum, galvanized or steel tanks should not be used with some pesticides as some chemicals react with these materials resulting in rust or corrosion inside the tank.

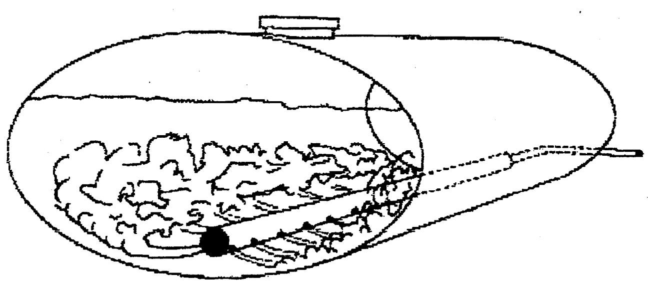
Keep tanks clean and free of rust, scale, dirt, and other contaminants that can damage the pump and nozzles. Debris can clog strainers and restrict flow of spray through the system. This can result in improper spray patterns and rates of application. An opening in the top large enough for internal inspection, cleaning, and service is a necessity.

Flush the tank with clean water after spraying is completed and then apply this water to a site that is listed on the pesticide label, but do not allow this rinsate to drain and puddle onto the ground. You can also collect the rinsate and use it for later applications of the same pesticide.

The volume of a pesticide/diluent mix to be used must be known in order to add the correct amount of pesticide to the tank. Spray tank volume and sprayer output in GPA must also be known to determine the size of the sprayed area (See Chapter 8 – Mixing Pesticides). Most new tanks have capacity marks on the side. If your tank is not translucent, it should have a sight gauge to indicate the fluid level. An in-line flowmeter is the best way to determine how much of a solution you have used.

Tank Agitation

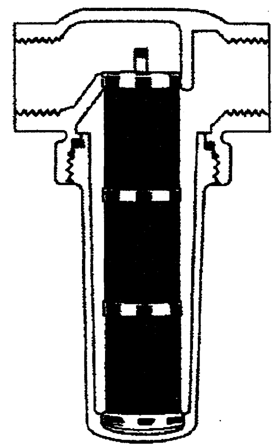
An agitator in the tank is needed to uniformly mix the spray material and keep chemicals in suspension. Liquid concentrations, soluble powders, and emulsifiable concentrates require little agitation whereas intense agitation is required to keep wettable powders (WP) and some dry flowables (DF) in suspension. For these types of formulations either a hydraulic or mechanical type of agitator is required. The hydraulic jet agitator should be positioned in the tank to provide agitation throughout the tank. A flow of 5 to 6 gallons per minute (GPM) for each 100 gallons tank capacity is usually adequate for an orifice jet agitator. Several types of venturi-type agitators are available that help stir the liquid with less flow. With these, the agitation flow from the pump can be reduced to 2 or 3 GPM per 100-gallon tank capacity. While most sprayers are installed with a jet agitator on the pressure regulator bypass line, this may not work in all situations as low pressure and intermittent liquid flow may produce poor results. The spray solution will only be agitated when the spray boom is shut off.



A mechanical agitator with a shaft and paddles will do an excellent job of maintaining a uniform mixture but is usually more costly than a jet agitator. Mechanical agitators must be operated by a separate drive, hydraulic motor or 12-volt electric motor. High speeds may also cause foaming of the spray solution.

Agitation should be started with the tank partly filled with the appropriate diluent and before pesticides are added to the tank. With wettable powders (WP) and dry flowables (DF), continue to agitate while filling the tank and during travel to the field. Do not allow these pesticide formulations to settle out of solution! They are extremely difficult to get back in suspension after they have settled out in the tank and in hoses.

Strainers



A plugged nozzle is one of the most frustrating problems that applicators experience with sprayers. Properly selected and positioned strainers and screens will do much to prevent nozzle plugging and reduce nozzle wear.

Three types of strainers are commonly used on pesticide sprayers:

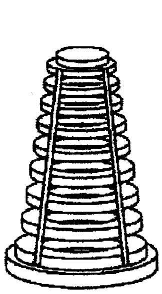
(1) tank-opening strainers (basket strainers).
(2) line strainers.
(3) nozzle screens.

Strainer numbers (e.g. 20-mesh, 50-mesh, or 100-mesh) indicate the number of openings per inch. Strainers with high numbers have smaller openings than strainers with low numbers.

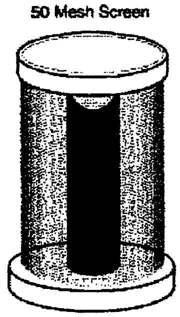
Coarse **basket strainers** set in the tank-opening prevent large debris from entering the tank as it is being filled. A **line strainer** is the most critical strainer of the sprayer. It usually has a screen size of 16- to 80-mesh. It is positioned between the tank and the pump, between the pump and the pressure regulator, or close to the boom, depending upon the type of pump being used.

Roller and other positive displacement pumps should have a line strainer (40 or 50-mesh) located between the tank and pump to remove material that would damage the pump. In contrast, the inlet of a centrifugal pump must not be restricted. A line strainer (usually 50-mesh) should be located on the pressure side of the pump to protect the nozzles. It is also helpful to install shut-off valves on either side of a strainer so as to minimize spillage when the strainer needs to be cleaned.

Slotted Strainer



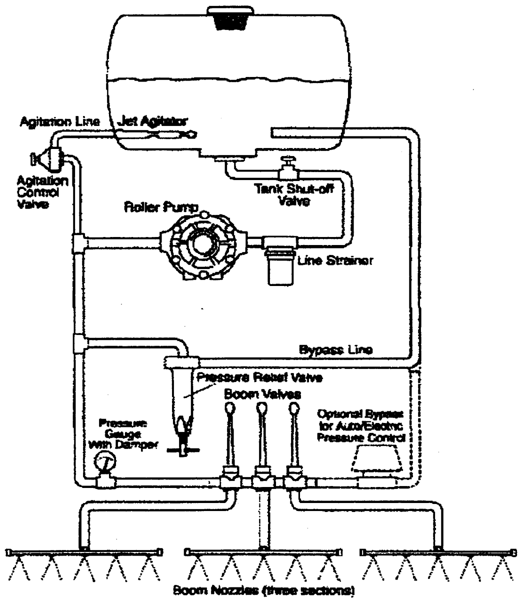
50 Mesh Screen



Nozzles are the third place where screens are usually located. Small-capacity nozzles must have screens to prevent plugging. Typically 50 to 100-mesh screens are used. There is little benefit in using a screen size smaller than the nozzle orifice itself. In general, 80 to 100-mesh strainers are recommended for most nozzles with flow rates below 0.2 GPM, and 50-mesh strainers for nozzles with flow rates between 0.2 and 1 GPM. The pesticide being used or nozzle specifications may dictate the strainer size to be used.

The Pump

Careful consideration must be made when selecting a pump. Rarely is there only one pump that can be used for all types of spraying operations. In order to select the right pump, you need to know about pump types, how the pump is to be driven, pump flow and pressure requirements for your specific spraying system and application.



Roller Pump Setup

Types of Pumps

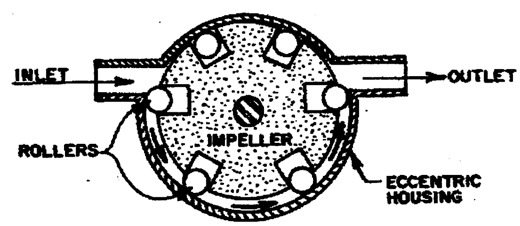
There are four main types of pumps used in pesticide applications:

(1) Roller,
(2) Centrifugal,
(3) Diaphragm,
(4) Piston.

In addition, pumps can be divided into two general categories: **positive displacement** and **non-positive displacement**. Roller, diaphragm and piston pumps are all positive displacement type pumps in that they are moving a set amount of liquid.

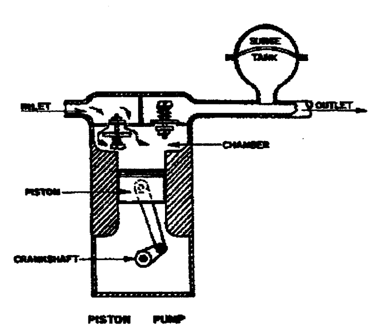
Roller Pumps (positive displacement) -Roller pumps are probably the most widely used pump.

From 4 to 8 polypropylene rollers revolve inside the pump housing to force the spray solution through the outlet to the nozzle. Roller pumps have a low initial cost and can be used for a variety of pesticide applications.



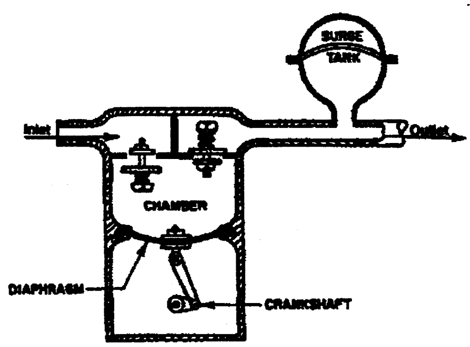
They can operate efficiently at PTO speeds of 540 and 1000 RPM and have a wide pressure range of up to 100 PSI and flow rates of 2 to 74 GPM. Roller pumps are self-priming and easily adapt to PTO or gas engine drives. Specific seal, roller and casting materials can usually be selected for compatibility with certain herbicides, pesticides, fungicides and fertilizers.

Piston Pumps (positive displacement)
Piston pumps are positive displacement pumps, where output is proportional to speed and independent of pressure. Piston pumps work well for wettable powders and other abrasive liquids. Lubrication of the pump is usually not a problem due to the use of sealed bearings and are available with either rubber or leather piston cups. This permits the pump to be used for water or petroleum based liquids and a wide range of chemicals.



While their cost is relatively high, piston pumps have a long life, which makes them economical for continuous use. Larger piston pumps have a capacity of 25 to 35 GPM and are used at pressures up to 600 PSI.

This high pressure is useful for high pressure cleaning, livestock spraying or crop insect and fungicide spraying. A piston pump requires a surge tank at the pump outlet to reduce the characteristic line pulsation.



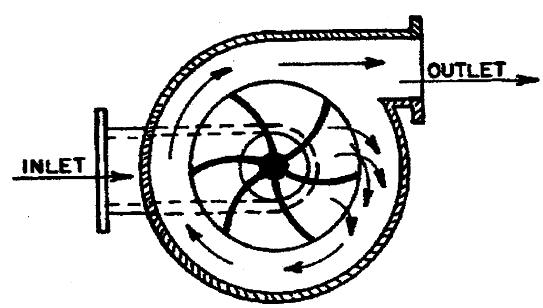
Diaphragm Pump

Diaphragm Pumps (positive displacement)

Diaphragm pumps can handle abrasive and corrosive chemicals at high pressures, operate efficiently at tractor PTO speeds of 540 RPM, permit a wide selection of flow rates and are capable of producing high pressures and high volume. Be sure the controls and all hoses are large enough to handle the high flow, and all hoses, nozzles and fittings must be capable of handling high pressures.

Centrifugal Pumps (non-positive displacement)

Non-positive displacement pumps are continuous flow and dependent upon high RPMs for high flow rates. Centrifugal pumps are the most popular type for low-pressure, high-volume sprayers. The spray solution enters through the center of a rotating impeller that's driven at speeds up to 6000 RPM. Spray solution is forced to the outer edge of the housing. This centrifugal force is what delivers the liquid to the nozzle. Traditionally thought of as low-to-medium pressure pumps (0-180 PSI), centrifugal pumps can deliver high flow rates (up to 190 GPM.) Because centrifugal pumps have minimum surfaces to wear and no valves, they are very durable, easy to maintain and well suited for pumping corrosive materials. Because centrifugal pumps operate at higher speeds, the PTO speed must be increased through a speedup gear drive, belt/pulley drive, or driven by a gas engine or high-speed hydraulic motor.



CENTRIFUGAL PUMP

Know Your Pumping Rate

Pesticide applications are measured in gallons-per-acre (GPA), whereas both pump flow and nozzle output is stated in gallons-per-minute (GPM). In order to properly choose a pump to apply a pesticide and also create suitable tank agitation, you will need to calculate the pump flow and the agitations requirements of your pumping system. The following formula will help:

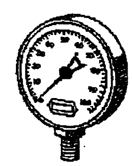
$$\text{Flow required for boom (GPM)} = \frac{\text{GPA x MPH x Boom Width (feet)}}{495}$$

Example 6-1. You have a 500-gallon sprayer that you want to apply at 30 GPA. Your field speed is 5 MPH and your sprayer's boom width is 60 feet.

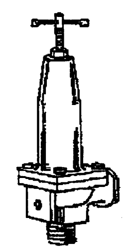
$$\text{18.18 GPM} = \frac{\text{30 GPA x 5 MPH x 60 ft.}}{495}$$

Refer to the section on **Tank Agitation** and you will see that you will need a pump that will deliver at least 18 GPM for boom flow and 25 GPM for agitation (5 gallons for each 100 gallons of tank). You will then need a pump that delivers 43 GPM.

Pressure



Pressure Gauge



Pressure Regulator

Accurate pressure adjustment and measurement are important since pressure is one factor that can be controlled. Pressure requirements are usually listed on the label or are provided by the nozzle manufacturer. Low pressures of 15 to 40 PSI may be sufficient for spraying most herbicides or fertilizer, but high pressures up to 400 PSI or more may be needed for spraying insecticides or fungicides. A pressure gauge should have a total range twice the maximum expected reading and the gauge should indicate spray pressure accurately and be placed near the nozzles.

Always remember that as pressure increases, the likelihood of pesticide drift also increases. In order to double the flow rate through nozzles, pressure must be increased four times. The following formula illustrates this concept:

$$\text{Resulting Pressure (psi)} = \text{Present Pressure (psi)} \times \left| \frac{\text{Desired GPA}}{\text{Present GPA}} \right|^2$$

Example 6-2. Current GPA = 20. Want 40 GPA. Present Pressure is 35 psi.

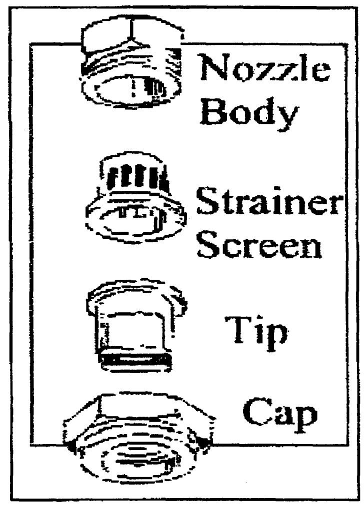
$$\text{Resulting psi} = \text{35 psi} \times \left| \frac{\text{40 GPA}}{\text{20 GPA}} \right|^2$$

$$\text{140 psi} = \text{35 psi} \times 4$$

Higher pressures not only increase the flow rate through the nozzles, but it also influences the droplet size and the rate of orifice wear. As pressure is increased, the number of small droplets is increased and the rate of orifice wear is also increased.

Nozzles

The term nozzle and nozzle tip are often used interchangeably but it is the nozzle body, screen, tip and cap that make up the nozzle.



Nozzle performance and nozzle setup are the keys to total system performance. It is the nozzle tip that primarily helps control the rate and uniformity of the spray application.

Factors to consider are:

(1) nozzle tip delivery in GPM.
(2) nozzle tip material.
(3) nozzle spacing and orientation on the boom.
(4) nozzle tip height above the target area.
(5) pressure at the nozzle tip.

Spray nozzles are designed to operate within a certain pressure range. Higher than recommended pressures increase the delivery rate, reduce or increase the droplet size, and may distort the spray pattern. This can result in excess spray drift or uneven coverage. Excessively low pressures reduce the spray delivery rate, and the spray material may not form a full spray pattern unless the nozzles are designed to operate at lower pressures. Always follow the pressure recommendations of nozzle manufacturers as explained in product catalogs.

Selecting Nozzle Tips and Strainers.

The efficiency and success of a spray program hinges on a tiny part that typically costs no more than $2 to $3 dollars each.

Nozzle tips (often called "spray tips") serve three functions:

1. A nozzle tip **regulates** the flow of liquid with the size of its orifice and pressure. As pressure increases, flow rate also increases.

2. **Atomization** of a liquid into droplets is caused by the tearing action of air. The nozzle tip spreads the liquid into a thin unstable sheet that breaks up into droplets as it exits the nozzle tip orifice. Each nozzle tip produces a range of droplet sizes from very small too large. Droplet size is measured in microns with one micron being one millionth of a meter. A human hair is about 100 microns and is considered to be a fine droplet. An increase in the pressure causes an increase in tearing action, thus the droplets become smaller. If the droplets are too small, drift will become a problem. If droplets are too large, they will not stick to the surface and will roll off. Droplet size is an important consideration when selecting nozzle tips.

3. Spread droplets in a specific pattern. When applying pesticides it is important to select the right nozzle tip **pattern** for the right situation. No one particular nozzle tip fits all applications. The type of nozzle tip that will work best depends upon: (1) the type of product you are applying. For example, soil applied pesticides need bigger droplets, (2) the droplet size for maximum coverage and drift control. Larger droplets reduce drift but smaller droplets increase plant coverage and reduce droplet bounce, and (3) desired sprayer output (gallons-per-acre or **GPA**).

   Read the pesticide label to determine if there is an optimum sprayer output for the product.

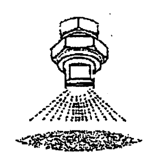
Nozzle Tip Spray Patterns

Nozzle tip spray patterns come in three basic angles (65°, 80° and 110°) and are of three basic types: solid stream, fan, and cone. Some special-purpose nozzle tips or devices produce special patterns. These include "raindrops," "flooding," and others that produce wide-angle fan such as broadjets and Boombuster™ nozzles.

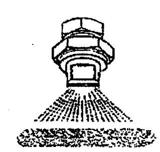
Solid stream nozzle tips are used in handgun sprayers to spray a distant or specific target such as livestock or tree pests. Solid stream nozzle tips may be attached to booms to apply pesticides in a narrow band or inject them into the soil.

Fan pattern nozzle tips - At least three types of nozzle tips have fan patterns. They are used mostly for uniform spray coverage of surfaces; for example, broadcast soil applications of herbicides or insecticides.

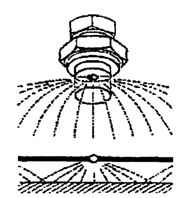
- The tapered flat fan nozzle tip makes a narrow oval pattern with tapered ends and is used for broadcast herbicide and insecticide spraying at 15 to 60 psi. The pattern is designed to be used on a boom and to be overlapped 30 to 50 percent for even distribution. Spacing on the boom, spray angle, and boom height determine proper overlap and should be carefully controlled. Generally, 80° tips are spaced at 20 inch intervals across the boom.



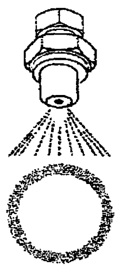
- The even flat fan nozzle tip makes a narrow oval pattern without the tapered ends. Spray delivery is uniform across its width. It is used for band spraying and for treating walls and other surfaces. It is not useful for broadcast applications. Boom height and nozzle spray angle determine the width of the band sprayed.



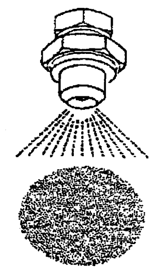
- Flooding (flat fan) nozzle tips deliver a wide-angle flat spray pattern that produce large spray droplets. If used for broadcast spraying, these nozzle tips should be overlapped to provide double coverage. They are often used for applying liquid fertilizers or fertilizer-pesticide mixtures or for directing herbicide sprays up under plant canopies.



Cone pattern nozzles - Hollow and solid cone patterns are used where penetration and coverage of plant foliage or other irregular targets are desired. They are most often used to apply fungicides and insecticides to foliage, although some types are used for broadcast soil applications of herbicides or fertilizers or combinations of the two.



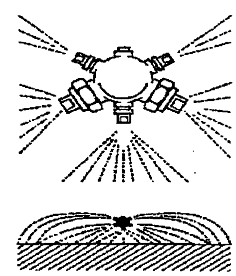
Core-insert cone nozzles produce either a solid or hollow cone spray pattern. They operate at moderate pressures and give a finely atomized spray. They should not be used for wettable powders because their small passages clog easily and they wear rapidly due to abrasion.



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

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

Cluster nozzles, broadjets and Boom Buster™ nozzles are essentially large flooding deflector nozzles that will spread spray droplets over a width swath from a single nozzle tip. Cluster nozzles are a combination of a center-discharge and two or more off-center-discharge fan nozzles. Coverage may be variable because the spray pattern is not uniform and spray droplets vary in size from very small to very large. Since no boom is required, these nozzles are particularly well suited for spraying hedgerows, fencerows, and other hard-to-reach locations where uniform coverage is not critical.



Nozzle Tip Material

Just as nozzles produce many different patterns, they are also made of many different materials. Some naturally wear better and last longer than others.

Brass nozzle tips resists corrosion from most pesticides but may be corroded by liquid fertilizers. They also wear quickly from abrasion due to the use of dry formulations and grit in the spray water. Excessively high sprayer pressure will also cause brass nozzle tips to wear. They are the cheapest nozzle tip and probably the best material for general use.

Plastic nozzle tips will not corrode, resists abrasion better than brass, but may swell when exposed to some solvents such as those in emusifiable concentrate (EC) formulations. Their useful life is about equal to that of brass nozzle tips.

Stainless steel nozzle tips, while expensive, offer good corrosion resistance, are suited for high pressures, and lasts longer than brass. Hardened stainless-steel nozzle tips resist abrasion from certain formulations like wettable powders and flowables.

Aluminum nozzle tips resists some corrosive materials but are easily corroded by some fertilizers, and their useful life is much shorter than brass.

Nozzle tips made of **tungsten carbide and ceramic** are highly resistant to abrasion and corrosion and are the best material for high pressures and wettable powders. They last much longer than brass.

It is important to note that the life of a nozzle tip is affected by factors other than the material from which it is manufactured. Is clean water used to mix chemicals or is water diluent drawn from a farm pond that may have a lot of silt in the water? What types of product are being sprayed? Wettable powders and liquid fertilizers are a few of the more abrasive products that increase nozzle wear. Operating at high pressures not only degrades nozzles faster, but also may contribute to drift.

Nozzle Tip Selection

In general, nozzle tip selection is based on nozzle output in gallons-per-minute (GPM), desired sprayer output in gallons-per-acre (GPA), field speed and angle of the spray pattern. Most manufacturers have a method of coding nozzle tips, and they print this code on the face of the nozzle tip. For example, a TP8008 nozzle is a tapered flat fan tip (TP) with an 80° spray angle (80) with a delivery rate of 0.80 gallons-per-minute (08) at 40 psi, the standard pressure upon which nozzles are rated. If you are trying to rate a nozzle tip at other pressures, then you will need to consult manufacturer tip charts. Remember! A lower volume tip (smaller tip number) will increase the number of smaller droplets being produced at the same pressure. An 8001 nozzle tip will increase the number of smaller droplets at 40 psi than an 8005 nozzles at the same pressure.

You can determine nozzle flow rate by using the following formula. This formula is based on a desired output in GPA, field speed, nozzle spacing in inches (or broadjet width in inches) and a constant.

$$\text{GPM (per nozzle)} = \frac{\text{GPA} \times \text{MPH} \times \text{W}}{5940}$$

GPM = gallons per minute per nozzle
GPA = Total sprayer output in gallons per acre
MPH = Miles per Hour (field speed)
W = Nozzle spacing in inches for boom sprayers.
= Sprayed width in inches for boomless nozzles
5940 = A constant.

Example: You want your sprayer to apply 32 gallons-per-acre (GPA) for maximum coverage. Nozzle spacing is 20 inches on your boom and you find you can spray your fields effectively at 7 miles-per-hour. How much do you need to collect from under each nozzle on your boom to achieve this sprayer output?

$$\text{GPM} = \frac{\text{GPA} \times \text{MPH} \times \text{W}}{5940} = \frac{32 \text{ gpa} \times 7 \text{ mph} \times 20''}{5940} = \frac{4480}{5940} = 0.754 \text{ or } 0.75 \text{ gpm}$$

You can now go to a supplier and request nozzles that apply 0.75 gallons-per-minute, or you can consult a tip chart to find the right nozzle. You can also verify that the nozzles on your boom are providing enough liquid to match your desired GPA. In this case, you may want to convert gallons-per-minute to ounces-per-minute. Since there are 128 ounces in one gallon, simply multiply 128 x GPM. In the above example, 128 multiplied by 0.75 equals 96. You will need to collect 96 ounces-per-minute from each nozzle on your boom to achieve 32 gallons-per-acre (GPA), provided you keep your field speed at 7 miles-per-hour.

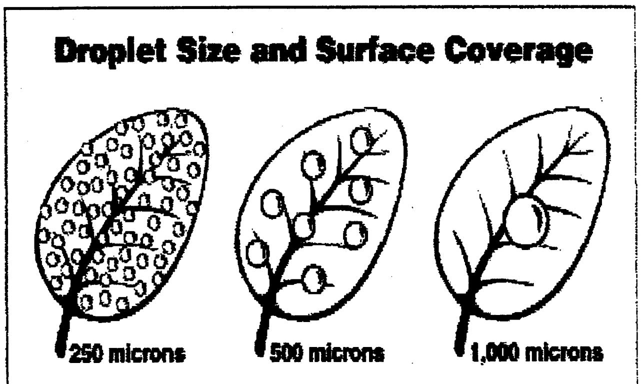
Nozzle Tip Wear

Worn nozzles tips have poor spray patterns and higher flow rates than new nozzle tips. Periodically, determine spray tip wear by comparing the flow rate of the used tip to the flow rate of a new one. Check the flow of each used tip by using an accurate graduated container and collecting liquid for a measured time. If the flow rate of the used tip is five to ten percent greater than a new one, it should be replaced.

Nozzles must be protected from grit and dirt by adequate screens and filters. Finely machined edges that control spray pattern can be damaged by the grinding action of dirt and abrasive spray mixtures. Clogged tips should be cleaned with a soft bristled brush or a stream of water or air. Never use a metal object. Use extreme care with soft tip materials such as plastic and brass. Remember!! **NEVER** put a dirty, clogged nozzle tip to your mouth to blow it out.

Nozzle Droplet Size

Droplet size is measured in microns with one micron being one millionth of a meter. A human hair is about 100 microns and considered to be a fine droplet. An increase in the pressure causes an increase in tearing action, thus the droplets become smaller. If the droplets are too small, drift will become a problem and droplets may evaporate before they reach the target. If droplets are too large they will not stick to the surface and will roll or bounce off. Droplet size is an important consideration when selecting nozzles. Most nozzle manufacturers give droplet size information in their catalogs.

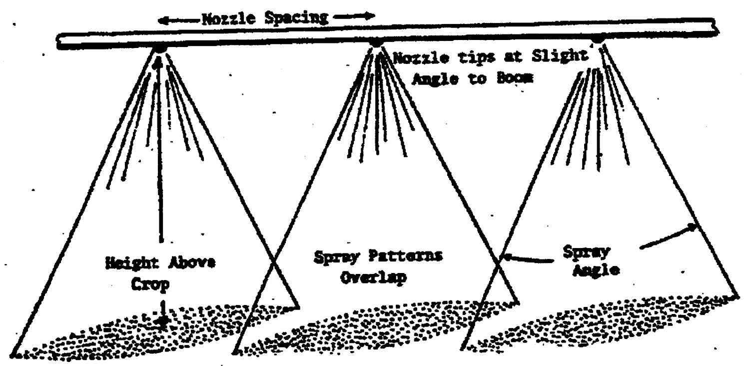


While it seems logical to select nozzle tips that produce large droplets all the time, this can result in spray droplets impacting the leaf surface with so much force that they actually bounce and shatter. Choose nozzle tips based on the target pest and the type of application to be used. Refer to the following chart for guidelines.

Pesticides	Droplet Description	Desired Droplet Size (microns)
Insecticides	Very Fine	< 119
Fungicides	Fine	119 - 216
Herbicides: Pre- and Post emergent	Medium	217 - 353
	Coarse	354 - 464
Soil application of Herbicides	Very Coarse	> 464

Nozzle Placement

Good pest control is dependent upon a uniform broadcast application of pesticides. With multiple nozzle booms, nozzles must be evenly spaced across the boom. Spacing is dependent upon the spray angle produced by the nozzle tip.



Section of a field boom showing proper alignment of taped flat fan nozzle to provide spray overlap

For example, tapered flat fan nozzle tips that produce an 80° spray angle are commonly spaced twenty inches apart. The reason for the spacing is to allow the edges of the spray patterns to overlap thus producing a fairly uniform pattern. Nozzles are also offset across the boom by 10° so that the spray patterns do not collide. As the sprayer moves forward, an even swath is created.

Sprayer Plumbing

A sprayer will not function properly without proper hoses and controls to connect the tank, pump and nozzles as they are the key components of the spraying system.

Select hoses and fittings to handle the chemicals at the selected operating pressure and quantity. Peak pressures, higher than average operating pressures, are often encountered when the spray boom is shut off. Choose components on the basis of composition, construction, and size.

Hoses must be flexible, durable, and resistant to sunlight, oil, chemicals, and general abuse such as twisting and vibration. Two widely used materials that are chemically resistant are ethylene vinyl acetate (EVA) and ethylene propylene dione monomer (EPDM).

Suction hoses (between tank and pump) should be airtight, non-collapsible, as short as possible, and as large as the pump intake. A collapsed suction hose can restrict flow and "starve" a pump, causing decreased flow and damage to the pump. If you cannot maintain spray pressure, check the suction line to be sure that flow is not restricted.

Guide for determining hose size.

Pump Output (gals/min.)	Suction Hose	Discharge Hose
	(inside diameter in inches)	
Under 12 GPM	3/4	5/8
12-25 GPM	1	3/4
25-50 GPM	1 1/4	1
50-100 GPM	1 1/2	1 1/4

Other lines, especially those between the pressure gauge and the nozzles, should be as straight as possible, with a minimum of restrictions and fittings. A high but not excessive fluid velocity should be maintained throughout the system. Lines that are too large reduce the fluid velocity so much that some pesticides, such as dry flowables or wettable powders, may settle out, clog the system, and reduce the amount of pesticide being applied. If the lines are too small, an excessive pressure drop will occur. Since some chemicals will react with plastic materials, check sprayer and chemical manufacturers literature for compatibility.

SPRAYER CLEAN OUT

Attempt to clean the sprayer after each days use and especially when you switch products and always wear appropriate protective clothing when cleaning any piece of application equipment. Flush with clean water inside and out to prevent corrosion and accumulation of chemicals. When finished for the season or when changing chemicals, thoroughly clean the sprayer with a cleaning agent. Be careful to avoid contaminating water supplies and avoid injury to plants or animals when washing. Apply the rinsate to a labeled site or use it in subsequent spray operations.

These steps are suggested:

1. Wash the inside of the tank and partially fill it with water. Flush this water through the nozzles. When the tank is empty repeat these steps for two complete rinses.
2. Remove the nozzle tips and screens. Clean them in a strong detergent solution or kerosene using a soft brush.
3. Fill the tank a third time, this time adding a cleaning agent. Refer to the following table for information on the type and amount of cleaning agent.

Pesticide	In 2.5 gallons of water add:	Instructions
Insecticides (1) and/or fungicides.	1 Tbsp. powder detergent (2)	Agitate, flush, and rinse.
Hormone herbicides, salt or amine formulations (2,4-D, Dicamba, MCPA, etc) (3)	1/2 cup household ammonia	Thoroughly agitate, flush small amount through system, and let remainder stand in sprayer overnight. Flush and rinse.
	Or 1/4 lb. trisodium phosphate	Same as above except let stand for at least 2 hours.
	Or 2 Tbsp. fine activated charcoal and 1-2 oz. powder detergent (2)	Agitate, operate sprayer for 2 minutes, let remainder stand for 10 minutes, then flush through sprayer. Rinse.
Hormone herbicides, ester formulations (2,4-D,brush killers, MCPQA, etc.) (1)	4 oz. washing soda (sal soda) + 1-1/2 cup kerosene + 1 Tbsp. powder detergent (2)	Rinse inside of tank and flush small amount through system. Let stand at least 2 hours. Flush and rinse.
Other herbicides (atrazine, simazine,alachlor, etc.)	1 Tbsp. powder detergent (2)	Rinse with clean water before and after using sudsy solution.

1) Organophosphate and carbamate insecticides may be detoxified by adding household ammonia to the cleaning solution (1/2 cup per 2.5 gallons).

(2) Liquid detergent may be substituted for powder detergent; mix at a rate to make a sudsy solution.

(3) Caution: Only a trace of 2,4-D herbicide can damage sensitive broadleaf plants. It may be risky to use an insecticide or fungicide on broadleaf plants in a sprayer that has been used to apply 2,4-D.

SECURITY OF EQUIPMENT

To prevent theft and malicious damage to pesticide equipment, consider the following:

1. Install security mechanisms on the spray tank's fill opening and at other locations that enter and exit the tank.
2. Always park spray equipment with empty tanks.
3. If possible, park spray application equipment at fenced-in, secured locations or where equipment can be easily monitored.
4. If possible, cover pesticide application equipment with tarps. This will help prevent impulsive vandalism.
5. Inform local law enforcement of your presence and locations of where you will be parking your equipment.
6. As appropriate, use alarm and security systems.

Chapter 7
CALIBRATION OF PESTICIDE APPLICATION EQUIPMENT

Terms to know

Application Rate---- Amount of liquid or dry material applied over a given area. Also known as **delivery rate**, **sprayer output** or **volume applied**. For liquid sprayers, it is measured in gallons on a per acre basis (Gallons Per Acre or **GPA**). For granular applicators, the delivery rate is usually expressed in pounds per acre.

Diluent -------------- Anything used reduce the concentration of a pesticide formulation at the time of application.

Field Speed ----------- Also known as travel speed. The speed at which the pesticide application will take place.

GPA-------------------- Gallons Per Acre. Describes sprayer output, spray volume or application rate.

GPM------------------ Gallons Per Minute. Usually describes **nozzle or pump output.**

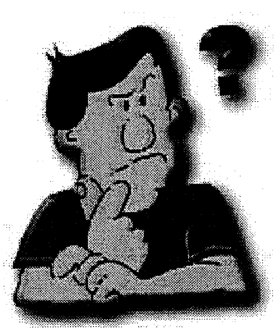
MPH------------------ Miles Per Hour.

Pesticide Rate-------- Also known as **product rate,** simply **rate or labeled rate**. The amount of undiluted pesticide required by a label to control a targeted pest. Example: the herbicide 2,4-D is often applied at a rate of 1 quart per acre to control certain weed species.

PSI ------------------- Pounds per Square Inch.

RPM ------------------ Revolutions Per Minute.

Swath Width--------- Width of the spray pattern as it appears over the target area.



Calibration is a series of steps that determines the output or application rate of pesticide application equipment under controlled conditions. Liquid sprayer output (a.k.a. delivery or application rate) is usually expressed as gallons applied per acre (**GPA**) while dry pesticide equipment is calibrated to deliver pounds of dry pesticide formulation per acre. When calibrating liquid sprayers water is normally used while the calibration of dry pesticides usually entails the use of the actual pesticide formulation. For calibration of all liquid pesticide equipment there is a set of controlled conditions to include:

1. Consistent field speed.
2. Consistent sprayer pressure in pound per square inch (psi).
3. Consistent and uniform nozzle delivery rate expressed in gallons per minute (GPM).

Unlike weather, the application rate or output of the equipment is the factor that is completely under the applicator's control. By adjusting any of the above conditions, the applicator can vary a sprayer's output in GPA. There are some cases where a lower GPA is desired as more acres can be covered. There are other cases where higher GPA's are desired. Higher GPA gives more coverage when spraying weeds.

So the challenge for any pesticide applicator is to:

1. **Determine the proper application rate** or sprayer output, usually in Gallons Per Acre (GPA). Some, if not most, pesticide labels will indicate a preferred application rate. For example: "Apply this product in no less than 20 gallons of water per acre (20 GPA)."
2. **Determine how to apply a small amount of pesticide concentrate to a large area.** This can be anywhere from one quart or even ounces applied over one or more acres.
3. **Determine how much pesticide is added with a diluent in** the tank to spray a given area at the proper product rate.

A label will most likely call for a certain amount of pesticide to be applied per acre. In order to physically apply a small amount of pesticide over a large area, the pesticide concentrate is usually diluted with a larger volume of diluent. In most cases this is usually water. On a per-acre basis, it is easier to apply one quart of a pesticide in water to make a 20-gallon mix than it is to apply the 1-quart alone.

To spray pesticides in a cost effective manner, there must be consistency between calibration and actual application. If you calibrate your sprayer at a certain speed or pressure, then make sure you use the same speed and pressure when you apply the pesticide.

SPRAYER PREPARATION PRIOR TO CALIBRATION

- Thoroughly clean all nozzles, screens and filters. This ensures uniform application.
- Make sure nozzles are all made of the same material. Some materials like brass will wear faster than stainless steel.
- Make sure the nozzle tips have uniform spray patterns and replace nozzles that do not. Be sure all nozzles have the same volume of delivery (nozzle output). While maintaining a constant sprayer pressure, collect and measure the amount of water each nozzle tip discharges in a certain amount of time. Find the average nozzle output across the boom and replace any nozzle tip that has a flow rate greater or less than five percent deviation from the average. See ***Boom Sprayers With Multiple Nozzles*** *– page 97*.
- Select an operating or field speed appropriate for the conditions of your equipment. When spraying, be sure to maintain the same field speed you used when calibrating.
- Select an operating pressure. Make sure that nozzles are open and adjust them to the desired setting (PSI) while the pump is operating normally.

THE FUNDAMENTALS OF SPRAYER CALIBRATION

The Calibration Test Strip Method

There are many special formulas for making the appropriate calibration calculations. While most of them are easy to use, most people cannot remember formulas or they are not familiar with basic calibration concepts. Also, formulas usually apply only to one method of application. A formula that works for liquid application may not work for granular methods. The calibration test strip method presented here is the fundamental concept behind calibrating almost any piece of pesticide application equipment and requires that the applicator remember only two basic pieces of information:

1. There are 43,560 ft^2 in one acre, and
2. How to work a ratio problem using simple multiplication and division.

Step 1: Establish a test strip. A test strip is a given area that can be any size but is usually established according to equipment setup. For boom, broadjet and granular application equipment, the test strip **area** is the effective swath width in feet times a known distance in feet (area = length x width). For hand sprayers, the test area is established based on the capability of the equipment to spray a test area without stopping to pump the sprayer.

Example 7-1: A liquid sprayer's swath width is 40 feet. The test strip distance is 200 feet long. The area of the test strip in feet is 8,000 ft^2 (40 x 200).

Example 7-2: A granular spreader applies a 10-foot swath at a certain setting. The test strip distance is 50 feet. The area of the test strip in feet is 500 ft^2 (10 x 50).

Example 7-3: A 2-gallon hand sprayers needs to be calibrated. A test strip of 15 feet by 15 feet is established. The test strip area is 225 ft^2 (15 x 15).

Step 2: Measure the amount of liquid applied to the test strip. Collect liquid from the sprayer for the same amount of time it takes to travel the test strip at field speed. Or, you can refill the tank back to a set mark to determine how much liquid is applied to the test strip. Remember, in most cases, water is used for calibration of liquid sprayers.

Example 7-4: A broadjet sprayer has an effective swath width of 35 feet. The test strip distance is set at 100 feet. It takes 14 seconds to drive the test strip at field speed. The sprayer is stopped and for 14 seconds, three gallons of liquid is collected from the one broadjet nozzle at the prescribed sprayer pressure.

Step 3: Set up a simple ratio. Establish the test strip data on the left side of the equation sign and the desired outcome on the right side. The number of gallons, or pounds, applied in the test strip is to the test strip square footage, as the desired gallons, or pounds, is to 43,560 ft^2 per acre.

--HAVE-- TEST STRIP		--DESIRED-- Volume Per Acre
$\frac{\text{Test strip gallons or pounds}}{\text{Test strip area (ft}^2\text{)}}$	=	$\frac{\text{Desired Volume}}{43{,}560 \text{ ft}^2}$

To solve, simply cross-multipy:

$$\frac{\text{Test strip gallons or pounds}}{\text{Test strip area (ft}^2\text{)}} \times \frac{\text{Desired Volume Per Acre}}{43{,}560 \text{ ft}^2}$$

$$\frac{\text{TEST STRIP GALLONS OR POUNDS X } 43{,}560 \text{ FT}^2}{\text{TEST STRIP AREA (FT}^2\text{)}} = \text{DESIRED VOLUME PER ACRE}$$

Example 7-5: A hand sprayer that is attached to a 500-gallon sprayer needs to be calibrated. A 66-foot by 66-foot calibration strip is established. The strip was sprayed with water for a total of 2 minutes. Spray was then collected in a 10-gallon container for another 2 minutes at the same pressure. A total of 7 gallons was collected.

$$\frac{7 \text{ gallons}}{4{,}356 \text{ ft}^2} = \frac{\text{Desired Volume (GPA)}}{43{,}560 \text{ ft}^2}$$

$$\frac{7 \text{ gallons x } 43{,}560 \text{ ft}^2}{4{,}356 \text{ ft}^2} = \text{Desired GPA}$$

$$\frac{304920}{4{,}356} = 70 \text{ GPA}$$

Example 7-6: A 2-gallon hand sprayers needs to be calibrated. A test strip of 15 feet by 15 feet is established. It takes 45 seconds to spray the test strip. A total of ½ gallon (0.50) is collected after spraying water for 45 seconds into a 5-gallon bucket.

$$\frac{0.5 \text{ gallons}}{225 \text{ ft}^2} = \frac{\text{Desired GPA}}{43{,}560 \text{ ft}^2}$$

$$\frac{0.5 \text{ gallons x } 43{,}560 \text{ ft}^2}{225 \text{ ft}^2} = \text{Desired GPA}$$

$$\frac{21780}{225} = 96.8 \text{ or } 97 \text{ GPA}$$

SPECIFIC EQUIPMENT CONSIDERATIONS

Backpack & Hand Held Sprayers

The procedure for calibrating a hand-held or backpack sprayer is the same as noted under the ***Fundamentals of Sprayer Calibration***; however, the accurate calibration of this type of equipment is more difficult because operator speed and sprayer pressure are difficult to keep constant. Always strive to keep both pressure and spraying technique consistent between calibration and actual application.

Self-Propelled Pesticide Application Equipment

Measuring Ground Speed – Using a test course to find your speed under field conditions

Avoid measuring field speed with a speedometer. When wheels slip in mud or loose dirt, or when tires wear down and get smaller, you can be traveling up to 30% slower than your speedometer reads. This in turn can cause you to apply 30% excess pesticide. Ideally, you should have a speed sensor or some other device to accurately determine and maintain a constant field speed both when calibrating and when actually applying a pesticide. In lieu of a speed sensor, either refer to a speed chart found in most equipment catalogs, or conduct the following steps to verify field speed in Miles Per Hour (MPH).

🗋 **Note: For the calibration strip method, actual MPH is not used directly for calibration purposes. It is only used to verify and maintain a constant field speed.**

1. Choose a test course distance on terrain that is typical of the surface and soil conditions of the area to be sprayed. A course length of 200 feet is common.

2. Fill the spray tank one-half full with clean water.

3. If using booms, extend them at this time.

4. Test to determine which gear and RPM will allow the sprayer to maintain the desired pressure on the nozzles while maintaining a constant, desired field speed. Most pesticide applicators operate within a 3 to 5 MPH field speed but always follow label instructions and the policies of your organization. Drive the sprayer through the test course three times. Start far enough away from the course to reach the desired speed before passing the first marker. Record the time of each run in seconds. Take the average of the three test runs.

5. Calculate the MPH based on the fact that 88 feet is covered in one minute at one MPH.

$$\text{MPH} = \frac{\text{Test Distance x 60 (seconds in 1 minute)}}{\text{Average Time (sec.) x 88 (feet in 1 minute at 1 MPH)}}$$

6. **Example 7-7**: You have set up your 200-foot distance, made three test runs, and logged the following times:

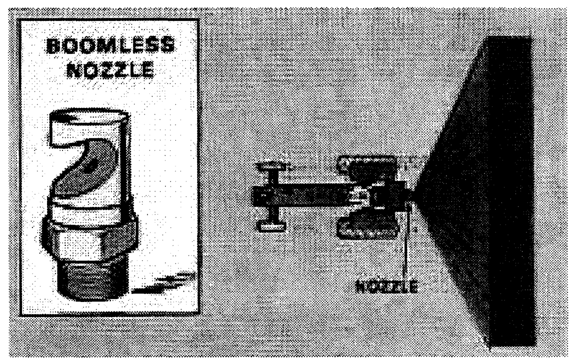
- Time 1 = 31.5 seconds
- Time 2 = 30.3 seconds
- Time 3 = 29.2 seconds

The average time is 30.3 seconds.
(31.5 + 30.3 + 29.2) ÷ 3 = 30.3 seconds
Now till in the average time to determine the actual MPH

$$\text{MPH} = \frac{200 \text{ ft. x } 60}{30.3 \text{ sec. x } 88} = 4.5 \text{ MPH}$$

Broadjet Sprayers

Broadjet or boomless sprayers enable a wide swath to be sprayed without using a series of nozzles across a boom. Swath widths vary with different brands of nozzles and can range from 10 feet on up. Calibration of these sprayers is easy, as there are generally only one or two nozzles. Refer to the ***Fundamentals of Sprayer Calibration.***



Example 7-8: A Boom Buster™ Model 437 spray nozzle covers 30 feet of swath. The test strip distance is 200 feet long. The area of the test strip in feet is 6,000 ft^2 (30 x 200). It takes 34 seconds to drive the test strip at field speed. A total of 10.4 gallons was collected from the nozzle for 34 seconds per nozzle.

$$\frac{10.4 \text{ gallons}}{6{,}000 \text{ ft}^2} = \frac{\text{Desired Volume (GPA)}}{43{,}560 \text{ ft}^2}$$

$$\text{Desired GPA} = \frac{10.4 \text{ gallons x } 43{,}560 \text{ ft}^2}{6{,}000 \text{ ft}^2}$$

$$75.5 \text{ GPA} = \frac{453024}{6{,}000}$$

Efficient Use Of Your Calculator

Using a set of calculator key strokes can simply the use of the calibration strip method formula.:

Test strip gallonage X 43,560 ft^2 ÷ Swath Width (ft.) ÷ Test Length (ft.)

Or;

Test strip gallonage X 43,560 ft^2 ÷ Test strip area (ft^2)

Or;

Test strip gallonage ÷ Test strip area in acres

Example 7-9: A Boom Buster™ Model 437 spray nozzle covers 30 feet of swath and delivers 10.4 gallons of water per test strip. The test strip distance is 200 feet long

$$10.4 \text{ gallons} \times 43{,}560 \text{ ft}^2 \div 30 \text{ feet} \div 200 \text{ feet} = 75.5 \text{ GPA}$$

or;

$$10.4 \text{ gallons} \div 0.1378 \text{ acres} = 75.5 \text{ GPA}$$

Boom Sprayers With Multiple Nozzles

The calibration of multi-nozzle boom sprayers is complicated by the fact that you want a fairly uniform output across the boom. If any one nozzle is providing more or less liquid, then the pattern of the pesticide application may be affected.

Checking Nozzle Output

The flow from some nozzles may be more or less than others. This will create an uneven swath pattern. To overcome this, collect from under each nozzle for a standard amount of time. You can use one minute or you can save a step and use the time it takes to travel the test strip. Then take the average flow of all the nozzles. If the flow of any nozzle varies by more than five percent on either side of the average, then those nozzles should be cleaned or replaced. This is a 10 % error across the average. Refer to your organization's guidelines for the acceptable error rate.

It is easy to find five percent First find a 10% error by simply taking the average and move the decimal place one space to the left. Now divide that number in half to find a five percent error. For example, suppose an average nozzle output is 60 ounces per minute. Moving the decimal one place to the left is 6 ounces or 10% of 60 ounces. Half of 6 ounces is 3 ounces or 5% of 60 ounces. So the "low" side of 60 is 57 ounces while the high side of 60 is 63 ounces for a five percent error on either side of the average. This is 10% across the average and any nozzle delivering between 57 and 63 ounces per minute falls with the acceptable 10% error range across the average. Any nozzle delivering outside of this range either needs to be cleaned or replaced

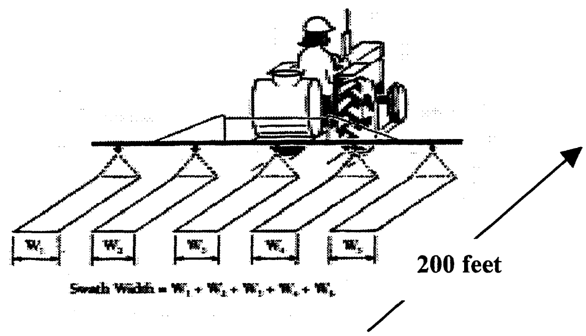
Example 7-10: Suppose there are six nozzles on a boom and you collected from under each nozzle for 35 seconds, the time it takes you to travel 200 feet.

Nozzle # ⇒	**1**	**2**	**3**	**4**	**5**	**6**
Ounces	40	40	41	39	38	42

The average output of the nozzles is 240 ounces ÷ 6 nozzles = 40 ounces. Ten percent is four ounces.
A five percent error for 40 ounces is two ounces. Half of four ounces is two ounces.
The error range is 38 and 42 ounces.
All nozzles fall within the acceptable 10% across the average

Band Applications

The swath width from banded applications is determined by adding the widths of the individual bands. Effective swath width does not include the unsprayed area between the bands.



Example 7-11: A five-row band sprayer is set with the rows 30 inches apart. A 15-inch band is sprayed over each row. The test strip distance is 200 feet. It is important to note that since this is a band application, the effective swath width will be the width of each band (in feet) times the number of rows that are being sprayed. The row spacing only tells us how far apart are the bands and is not used in this calculation. We will also need to convert the 15-inch band into feet, 15 inches divided by 12 inches per foot is 1.25 feet in each band. There are five bands so there are five treated strips, each strip being 1.25 feet in width. Therefore, 5 x 1.25 is 6.25 feet. The area of the test strip is 6.25 feet x 200 feet or 1,250 ft^2.

A total of 0.75 gallons is collected from the five nozzles for the same amount of time it took to drive the test strip.

$$\frac{0.75 \text{ gallons}}{1{,}250 \text{ ft}^2} = \frac{\text{Gallons}}{43{,}560 \text{ ft}^2}$$

$$\text{Desired Gallons} = \frac{0.75 \text{ gallons} \times 43{,}560 \text{ ft}^2}{1{,}250 \text{ ft}^2}$$

$$26.13 \text{ or } 26 \text{ GPA} = \frac{32670}{1{,}250}$$

Dry Pesticide Application (Pellets and Granular Formulations)

The techniques for calibrating dry pesticide application equipment are similar in many ways to calibrating liquid spray equipment. The differences being that (1) dry application equipment must be calibrated for each different dry formulation pesticide used; and (2) unlike liquid sprayers where water is most commonly used for calibration, granular equipment must be calibrated with the actual pesticide formulation. Always wear the label-prescribed Personal Protective Equipment (PPE) when calibrating dry pesticide application equipment.

Before calibrating a granular applicator, remove rust and corrosion on the feeder plates, agitator, and other working parts. Check nuts, bolts and other connections for tightness. Check feeder tubes and spreaders for obstructions, kinks, or corrosion that could interfere with delivery. Repair, clean and lubricate equipment as needed.

Factors affecting the delivery rates of granular applicators include size of the feeder gate opening, field speed, speed of the hopper agitator, nature and size of the granules, roughness of the ground, and relative humidity. Granules vary enough in density, size, and flow characteristics so that equipment must be calibrated for each granular pesticide formulation used. The variability among granular formulations makes it inadvisable to mix different granular formulations in a single application.

Step 1: Establish a test strip. The area used for calibration of granular application equipment will depend on the type of equipment used. Try to avoid areas that you intend to treat. If this is not possible, try either placing a bag or catch pan under the openings or use a tarp or plastic to catch the granules or pellets. Then sweep up and measure the amount of product applied.

Step 2: Measure the output. Collect and weigh the amount of chemical spread over the known area. The application rate will be the weight of the material collected for the area covered.

Step 3: Establish a ratio. This procedure will be the same as for liquid spray equipment except that the measurement will be in pounds of dry ingredient per acre.

Example 7-12: A 10G granular formulation needs to be applied in a broadcast application at a rate of 30 pounds per acre. A 20-foot by 20-foot plastic sheet is placed on the ground. At the desired field speed the equipment is operated across the plastic. It is determined that the granular applicator applies a 10-foot swath. Granules are swept up from the plastic and weighed. At total of 0.184 pounds is collected.

Step 1: Test area is 200 ft^2 (10 ft. x 20 ft.)

Step 2: A total of 0.184 pounds of 10G is applied to the test area

$$\frac{0.184 \text{ pounds}}{200 \text{ ft}^2} = \frac{\text{Desired Volume (Pounds)}}{43{,}560 \text{ ft}^2}$$

$$\text{Desired Pounds} = \frac{0.184 \text{ pounds} \times 43{,}560 \text{ ft}^2}{200 \text{ ft}^2}$$

$$\text{40 Pounds of 10G Per Acre} = \frac{8015.04}{200}$$

Note: The above equipment is calibrated to apply 40 pounds per acre and not the desired 30 pounds per acre. In this case the operator needs to adjust the equipment settings or increase the field speed.

ADJUSTING OUTPUT

You may have calibrated your sprayer only to find that its GPA is either too high or too low. Pesticide labels can be very specific as to what is required to improve pesticide performance, pesticide uptake and for drift prevention. On the other hand, the lower the GPA, the more acres you can treat with a given volume.

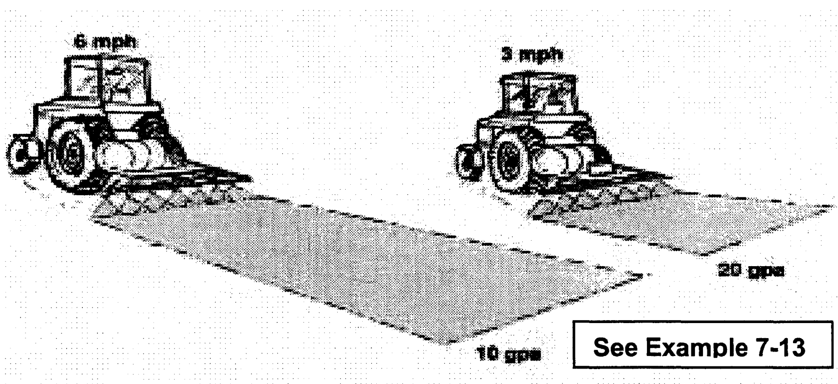
In order to affect output, there are three things to consider:

1. Adjusting speed is the **simplest** way to adjust output or volume.
2. Changing nozzles is the most **effective** and **best** way to adjust output or volume.
3. Adjusting pressure is used to make **minor** changes in output or volume. **Remember it takes four times the pressure to double output!**

Speed

Large changes in output (GPA) can be made by adjusting the travel speed of the pesticide application equipment.

As you slow down, you apply more. As you speed up, you apply less. If you are applying 20 GPA at 3 MPH and you double your speed to 6 MPH, you will apply half as much (10 GPA).



See Example 7-13

Changing the travel speed eliminates the need for altering the concentration of chemical in the spray tank. However, there are limits to the amount of speed change you can make. Operating application equipment too fast is a common error and will result in poor coverage. Operating it too slow results in runoff, waste and an increase in application time. While speed is not the most effective way to adjust output, if you need to adjust speed, use the following formula:

$$\text{Desired MPH} = \frac{\text{Current GPA x Present MPH}}{\text{Desired GPA}}$$

Example 7-13: Your sprayer is calibrated to apply 20 GPA at 3 MPH. You want to apply a particular pesticide at 10 GPA.

$$\text{6 MPH} = \frac{\text{20 GPA x 3 MPH}}{\text{10 GPA}}$$

Nozzles

The **most effective** and **preferred** method of adjusting sprayer output is to install nozzle tips of a different size. Larger nozzle tips (larger nozzle tip openings or orifices) increase volume, while smaller ones reduce the output and volume. The changing of nozzle tips usually alters the pressure of the system requiring an adjustment of the pressure regulator. Be aware that changes in nozzle tip size will also affect droplet size and spray pattern. Low-volume nozzle tips will generally increase the number of small droplets, thereby increasing the chance of drift. And above all, whenever you change nozzle tips, recalibrate the sprayer and refigure the new output. Never rely upon nozzle tip specifications alone.

Pressure

In order to double output using pressure, you will need to increase pressure fourfold. See page 82. For example if a sprayers output is 1 gallon per minute at 10 pounds per square inch (PSI), you will need to increase the pressure to 40 PSI to achieve 2 gallons per minute. Increasing pressure can lead to drift problems, the increased incidences of equipment failure, improper coverage or improper placement of the pesticides. It is best to use pressure to fine tune a sprayers output and use speed or different nozzles for major adjustments.

Chapter 8
MIXING PESTICIDES

Terms to Know

Catch Basin --------- Simply a container within a container. A measuring container may be placed inside of a pan or basin to catch any spillage.

Diluent ---------------- Anything used reduce the concentration of a pesticide formulation before it is applied.

Dose, Dosage --------- Same as rate. The amount of pesticide applied per unit of plant, animal, or surface.

Rate ----------------- Also known as **Product Rate** or **Labeled Rate**. A measured quantity of a concentrated pesticide used to control a targeted pest. Usually noted on the pesticide label as a given quantity per acre, per 1000 ft^2, etc.

You should also have a working knowledge of basic weights and measures.

Table of Weights and Measures				
HAVE	**→ ÷ by ← X by**	**WANT**	**WHY**	**EXAMPLES**
Pints	8	Gallons	8 pints = 1 gallon	2 gallons X 8 = 16 pints
Quarts	4	Gallons	4 quarts = 1 gallon	0.75 gallons X 4 = 3 quarts
Fluid ounces	128	Gallons	128 ounces = 1 fluid gallon	0.5 gallons X 128 = 64 fl. ounces
Fluid ounces	32	Quarts	32 fluid ounces =1 quart	3 qt X 32 = 96 fl. ounces.
Fluid ounces	16	Pints	16 fluid ounces = 1 pint	2 pints X 16 = 32 fl. ounces.
Tablespoons	2	Fluid Ounce	1 tablespoon = 0.5 fluid oz.	2 fl. ounces X 2 = 4 tablespoons
Teaspoons	3	Tablespoons	3 teaspoons = 1 tablespoon	2 tablespoons X 3 = 6 teaspoons
Drops	60	Teaspoons	60 drops = 1 teaspoon	2 tablespoons X 60 = 120 drops
Square Feet	43,560	Acres	43,560ft^2 = 1 acre	0.10 acre X 43,560 ft^2 = 4,356 ft^2
Dry ounces	16	Dry Pounds	16 dry oz. = 1 dry pound	3 lbs. (dry) X 16 = 48 oz. (dry)

CALCULATIONS FOR MIXING PESTICIDES

When preparing to apply pesticides, it is most important to mix the correct amount of a concentrated pesticide with a diluent to achieve the proper rate to control the targeted pest. The big question is always "How much pesticide do I add to the tank?"

HOW MUCH PESTICIDE TO ADD TO THE TANK

The accurate application of pesticides is dependent upon two major factors.

1. The area, usually acres, covered with a given volume of liquid in the spray tank and sprayer application rate (output) in Gallons Per Acre <u>**(GPA).**</u>
2. The proper product <u>**rate**</u> as determined from the pesticide label - 1 pint/acre, 1 quart/acre, etc.

Step 1: Determine Area Treated. You first need to know how much area you can treat with a given volume.

Mixing Formula 1

$$\frac{\textbf{Volume to be used (Gallons or pounds.)}}{\textbf{Output (GPA or pounds per acre)}} = \textbf{Acres treated}$$

Example 8-1: Your sprayer is calibrated to 25 GPA and you are going to use a full 500-gallon tank.

$$\frac{500 \text{ gallons}}{25 \text{ GPA}} = 20 \text{ acres}$$

Example 8-2: Your sprayer is calibrated to 25 GPA and you are going 250 gallons of a 500-gallon tank.

$$\frac{250 \text{ gallons}}{25 \text{ GPA}} = 10 \text{ acres}$$

Example 8-3: Your 2 gallon backpack sprayer is calibrated at 35 GPA and you plan on using a full 2-gallon tank.

$$\frac{2 \text{ gallons}}{35 \text{ GPA}} = 0.057 \text{ acres or } 2483 \text{ ft}^2 \ (43{,}560 \text{ ft}^2 \text{ per acre x } 0.057)$$

Commit this formula to memory. It is useful for many other calculations besides mixing. For instance, you can also use this formula for planning purposes. For example: if you had a 20-acre pasture to spray and your sprayer was calibrated at 25 GPA, then you would need a total of 500 gallons of a pesticide/diluent mix. Simply back-multiply.

Mixing Formula 2

$$\uparrow \frac{500 \text{ gallons}}{25 \text{ GPA}} \leftarrow \text{x} \quad = \quad 20 \text{ acres}$$

Or suppose you are filling out your application records. One requirement is that you fill out the area sprayed, usually in acres. This formula will help! For example, suppose your sprayer is calibrated at 25 GPA and you just sprayed 500 gallons of solution. By using the formula, you determine you have sprayed 20 acres.

Step 2: Factor in the Product Rate based on the pesticide label and the target pest.

Once you determine how many acres you can spray with a given volume, you then can determine how much pesticide you need to add to that given amount of volume in the spray tank.

Mixing Formula 3

ACRES TREATED X LABELED RATE = HOW MUCH YOU NEED TO ADD TO A GIVEN VOLUME IN THE TANK

Example 8- 4: A pesticide label calls for a rate of 1 pint/acre to applied for the control of perennial noxious weeds. The sprayer to be used is calibrated to apply 25 Gallons Per Acre (25 GPA). A 20-acre field is to be broadcast sprayed with 500 gallons of a pesticide and water mix. The amount of pesticide to be added to water to make this mix is 20 pints.

20 acres x 1 pint/acre = 20 pints

You will then be adding 20 pints to make up the 500-gallon mixture. There are 8 pints in a gallon so you will need to add 2 ½ gallons of pesticide to the tank. Fill the tank half-full with water, add the pesticide, surfactants, then top off with water to the 500-gallon mark.

Example 8-5: Suppose you have that a backpack that can treat 0.057 acres with 2 gallons of water (35 GPA). The label recommends a 1 pint per acre rate to control a particular pest. One pint equals 16 ounces so:

0.057 acres x 16 = 0.912 or 1 ounce of pesticide with water to make 2 gallons of mix.

It is helpful to note that 1 tablespoon is ½ ounces.

Also, commit the above formula to memory. It is also useful for other calculations such as recording the amount of undiluted pesticide that you use.

OTHER MIXING CONSIDERATIONS

CONVERTING FROM ACTIVE INGREDIENT TO FORMULATED PRODUCT

Remember that a pesticide formulation consists of two ingredients: active and inert. Both are noted on the pesticide label with liquid active ingredients (a.i.) usually expressed on a pound per gallon basis and dry active ingredients expressed as a percentage per pound. At some point you may be asked to either convert active ingredient into the amount of formulated product to use, or convert the formulated product to active ingredient (a.i.).

Mixing Formula 4

The basic formula is:

$$\frac{\text{Rate PER ACRE in a.i.}}{\text{Amount of a.i. per gallon (liquid formulation), or \% per pound (dry formulation)}} = \text{Amount to apply in terms of gallons or pounds of formulated product per acre}$$

How much of a liquid formulation will you per acre when the labeled rate is given in pounds of active ingredient (a.i.) per acre?

Example 8-6: A university bulletin recommends that you apply 3 lbs. per acre of the active ingredient (a.i.) found in Smashem EC™ insecticide. This insecticide contains 8 lbs. of a.i. per gallon of formulation.

$$\frac{\text{3 lbs a.i. per acre}}{\text{8 lbs a.i. per gallon}} = \text{0.375 Gallons}$$

The labeled rate for the formulated product will be 0.375 gallons or one and a half quarts.

Unless you have measuring containers graduated in gallons, you will need to convert this into a unit of measure compatible with your mixing gear. Since most containers are measured in ounces, you may need to convert **Gallons** to **Ounces**. Simply multiply the gallons times 128 (ounces in one gallon). With this example, you would add 48 ounces of **formulated product** per acre (0.375 gallons x 128).

Example 8-7: You have calibrated a 300-gallon sprayer. It can spray 7.5 acres per tank at 40 GPA. A recommendation indicates to apply ½ pound a.i. of schnozaline per acre to control spotted hollyworts. The label for schnozaline indicates that it contains 2 pounds of a.i. per gallon. How much schnozaline will you add to the tank to spray 7.5 acres?

Step 1: Determine acres that can be sprayed. 300 gallons ÷ 40 GPA = 7.5 acres
Step 2: Determine the formulated rate per acre. 0.50 lb a.i./acre ÷ 2 lb a.i./gallon = 0.25 gallon (1 quart) per acre
Step 3: Determine how much of the formulated product to add to the tank.
7.5 acres/tank x 1 quart per acre = 7.5 quarts which is also 1.875 **gallons**
(7.5 quarts ÷ 4 quarts/gallon)

CONVERTING FROM FORMULATED PRODUCT TO ACTIVE INGREDIENT

As with most calibration formulas, you can also back multiply to find the amount of active ingredient (a.i.) for a **TOTAL** amount of formulated product used. For example, you have applied a total 5 gallons of herbicide formulation that contains 2 pounds of active ingredient (a.i.) per gallon.

$$= \uparrow \quad \frac{\textbf{10 lbs a.i}}{\textbf{2 lbs a.i. per gallon}} \quad = \quad \textbf{5 Gallons}$$

$$\leftarrow \text{x} \text{ ---}$$

Mixing Formula 5

You have just applied 10 pounds of active ingredient.

The same formula also applies to dry formulations.

Mixing Formula 6

How much dry pesticide do you apply per acre when the rate is given as a percentage of active ingredient (a.i.)

$$\frac{\textbf{Rate Per Acre in a.i.}}{\textbf{\% a. i. per pound}} = \textbf{Amount formulated pounds to apply per acre}$$

Example 8-7: A recommended rate of 1 lbs. a.i. per acre of a 25% wettable powder (WP) is recommended. Remember to convert percentage to a decimal.

$$\frac{\textbf{1 lb a.i. per acre}}{\textbf{0.25 a. i. per pound}} = \textbf{4 pounds formulated product to apply per acre}$$

Think about! If the product us 25% active ingredient (one-quarter strength), then it would take four times the amount to equal a full strength concentration (100%).

SAFE MIXING OF PESTICIDES

As you know, the term pesticide is an "umbrella" term used to describe many products that are used to control or repel pests. These same chemicals used to control pests can also harm people, livestock, pets, fish, and wildlife. As a pesticide user, you have a legal responsibility to use pesticides according to the product label to reduce these risks.

YOU SHOULD ALWAYS BE CONCERNED ABOUT PERSONAL SAFETY WHEN APPLYING ALL PESTICIDES NO MATTER THE TOXICITY!

Since pesticide containers are open and most formulated pesticides are still concentrated during mixing, pesticide injuries are more likely to occur during this phase of pesticide application.

The first step towards safe mixing of pesticides is to always read the label of the pesticide you are using.

- The **Signal Word** and what it means.
- Statement of Practical Treatment (**First Aid**) and emergency telephone numbers.
- **Precautionary** Statements.
- Required **PPE** (Personal Protective Equipment).
- **General Use** Instructions – Mixing instructions, application instructions, use **rates**, labeled **sites.**
- Storage Information.

You should always be familiar with the pesticide formulations you are using. When mixing dry formulations, there is always a risk of inhaling the dry particles in the formulation. When handling liquid formulations, there is the risk of skin absorption. Keep in mind that emulsifiable concentrates (EC) contain solvents and may be more readily absorbed into the skin. These formulations are also skin irritants and can cause rashes and cracking of the skin thereby increasing absorption into the body.

Before you begin to mix, load and apply pesticides, and after you understand the label directions, make certain you have taken the following precautions:

1. Have detergent or soap and an adequate supply of water available.
2. Know the early symptoms of poisoning for the pesticide you are using.
3. Know the first aid procedures for the pesticide you are using and make certain that first aid materials and supplies are available.
4. Be certain that materials are available to handle spills.
5. Make certain that all equipment is functioning properly. Check over hoses, fittings, valves, and tanks on sprayer equipment for leaks or signs of failure. Set up an inspection list of sprayer equipment. A daily inspection is recommended.
6. Do not work alone. If you get into trouble, be sure help is available.
7. Have all the recommended protective clothing and equipment. Double-check that all respirators fit properly and have the correct canister or cartridge.
8. Never eat, drink, smoke, or go the bathroom while working with pesticides, without first washing your hands.

You are now ready to begin mixing and loading.

- Pesticide containers should be in a secure position when open.
- Make sure the proper personal protective equipment (PPE) is worn by all personnel involved.
- Only authorized pesticide handlers or supervisors should be in the mixing and loading area.
- Follow label directions; pay special attention to warnings and precautions.
- Work only in a well-ventilated, well-lighted area.
- If stirring is necessary, use a stir stick and never your hands.
- Use "**catch basins**" to contain any inadvertent splashes. A catch basin is simply a container within a container. For example, a measuring jar can be placed inside of a plastic tub. If the measuring jar happens to tip over, the spill is confined to the plastic tub.
- **Protect your eyes with splash-proof goggles**.

While this applicator is using a catch basin, what else can he do to reduce his exposure risk?

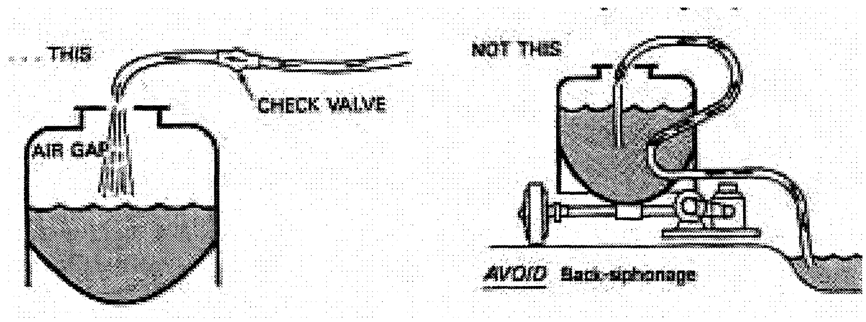
(Wear goggles. What else?)
(Headwear? Gloves and sleeves?)

- Mix and pour concentrated pesticides no higher than chest level. A spill or splash could be disastrous. Always remove clothing and wash yourself and your clothing thoroughly, immediately (within two minutes), if pesticides are spilled or splashed on you.
- Pour the pesticide into water, never water into the pesticide. Never pour pesticide directly into a spray tank. Always mix and dilute in a small container.
- When pouring, keep your head well above and to the side of the spray tank opening. This will limit pesticides from splashing in your face.
- Stand with your back to the wind so that any fumes or dusts are blown away from you.
- Consider the use of "nurse" tanks that always contain clean, fresh water that can be used for mixing and decontamination. These nurse tanks should **NEVER** be contaminated with pesticides.
- Mix and load on a concrete slab where spills can be contained; or use catch basins. Avoid mixing or loading near surface water or near a wellhead.
- Do not leave a pesticide tank unattended when filling. You should **NEVER** allow a spray tank to overflow. The cleanup could be an all-day, all-night task - costly and dangerous.

After the mixing-loading task has been completed, the responsibility continues:

- Securely close pesticide containers immediately after use. Return unused pesticide to its proper storage. Repair or replace torn labels. **NEVER** store excess pesticides in food or beverage containers.
- Clean up all spills, no matter how small the amount.
- Wash mixing and loading pails, measuring devices and stirring equipment or tools in strong detergent water, rinse in clear water, air-dry and store.
- Wash your personal protective equipment (PPE) in detergent, rinse and hang to air-dry.
- The wash and rinse water can best be disposed of by pouring it into the spray tank and apply over a site noted on the pesticide label. Do not overfill the spray tank; leave room for the rinse water.
- Remove your clothing and launder separately with heavy-duty liquid detergent and hot water. Use caution when using bleach as it could cause a dangerous chemical reaction with ammonia-based products. Line-dry the clothing where it is exposed to sunlight. Take a hot shower using detergent-type soap. Do not forget to wash your hair. Put on clean clothing.

Do not mix or transfer pesticides near a well or other water sources. When possible, mix in the field at various locations since small quantities of pesticide spilled over a period of time in one area may accumulate and cause a potential contamination.



If filling from a water system, leave an **air gap** between the hose and the tank or use a **back flow prevention** device. **Do not place the filler hose into the pesticide mixture**. These measures will prevent the pesticide from siphoning out of the tank if the water system allows draining.

Consider using a portable water supply tank (nurse tank). Not only will this allow mixing in the field, but it also may speed the time required to refill pesticide tanks.

RINSING APPLICATION EQUIPMENT AND PESTICIDE CONTAINERS

Rinse pesticide residues from application equipment before storage and before extensive repair. Rinse equipment at different locations in the field and over a labeled site to prevent puddling and concentration of pesticide residues

When handling pesticide containers of liquid products, triple or pressure rinse at the mixing site before disposal or recycling (see page 57). Do this as soon after emptying the container as possible. Add rinse water (rinsate) to the sprayer tank and apply it to a labeled site or use it to mix the next load.

HANDLING PESTICIDE SPILLS

The first step towards the prevention of pesticide spills is to evaluate your pesticide storage and transportation methods. Store pesticides in a locked storage area with an impervious floor, such as concrete, to help contain leaks or spills. If this is not possible, store your pesticides within other containers. Locate this area away from other activity and use only for pesticide storage. Locking the storage area will reduce the risk to children, as well as the potential for theft or misuse of the products.

Keep a current inventory of pesticides in storage and use the oldest products first. Not only will this help to keep products from degrading over time, but an inventory may be invaluable during an emergency situation such as managing a fire or cleaning up after a natural disaster.

Consider putting together a "spill response kit," and keep it handy. This kit should contain:

- duct or electrician's tape – for sealing cracks
- washer-headed screws – for sealing holes
- caulking or sealant – to temporarily patch containers and spray tanks
- absorbent materials (kitty litter, sawdust) – to absorb spilled material and also to divert spills away from sensitive area.

- extra hoses – for equipment repair
- hose clamps - for equipment repair
- plastic tarps or bags – bags to hold pesticide and contaminated materials during cleanup.
- shovel - to form a berm for containing spills and keeping pesticide from running into drainage areas.

Have several empty drums or others containers available in case a sprayer tank needs to be drained.

When a spill occurs, follow this procedure:

1. First, stop or sufficiently slow the leak to allow it to be contained. Never hose down a spill. This will only add to the problem.
2. Keep people away!
3. Mark the area to help determine how large an area is affected.
4. If the spill is not within a pesticide containment area (mixing/loading pad), contaminated soil generally will need to be removed and, depending upon quantity, stored for testing and later disposal.
5. For small spills, shoveling the contaminated material into heavy plastic bags may be sufficient. For large spills, a loader or backhoe may be needed to move contaminated dirt. Know where such equipment is readily available. The sooner the spill is cleaned up, the less soil may need to be removed. Current regulations will often allow the contaminated material to be disposed of by spreading it on a labeled site at no more than a labeled rate.

Chapter 9
PREVENTING PESTICIDE DRIFT

Pesticide drift is the movement of pesticide droplets, vapor, dust, or even pesticide-adsorbed soil out of a target area. The Environmental Protection Agency (EPA) further defines spray drift as:

> "The movement of a pesticide through air at the time of application or soon thereafter, to any site other than that intended for application (often referred to as off-target)."

There are two forms of drift: **physical** drift and **chemical** drift.

Physical spray drift is the movement of spray droplets outside the target site at the time of application and before deposition has occurred. Consider the following factors that contribute to physical drift:

- **Droplet size** – The primary cause of physical drift is small droplets that are highly mobile and susceptible to rapid evaporation. A small nozzle tip opening or orifice coupled with high spray pressure means more small droplets will be formed.
- **Spray Tip Height** – As the distance between the spray tip and target area increases, the greater the impact wind speed will have on drift.
- **Operating Speed** – Increased operating speeds causes a vortex to be created behind the sprayer. Small droplets can be trapped in this area.
- **Wind Speed** – While wind is not important in the formation of drift, it has the greatest impact on the movement of small droplets.
- **Air Temperature and Humidity** – Secondary causes of physical drift are associated with climatic conditions such as high air temperatures and low relative humidity. In temperatures over 77° F with low relative humidity, larger droplets tend to become smaller due to evaporation.
- **Pesticide Properties and Spray Output Volumes** – Before applying pesticides, always read the label for certain restrictions and recommended volumes. Always use high output volumes when practical.

A second form of drift is **chemical** or **vapor** drift and refers to the off-site movement of the active ingredient (a.i.) through the air after the droplets have deposited onto plant or soil surfaces. Vapor drift, also known as **volatilization** or **vaporization**, occurs when the energy of a liquid pesticide molecule exceeds the attractive forces of its neighboring molecules and **escapes as a gas**. This measurement of energy is known as **vapor pressure** and is the best indicator of a pesticide's potential to volatilize. The higher a pesticide's vapor pressure, the greater the tendency of the pesticide to volatilize.

Examples of vapor pressure as expressed in milli-Pascals (a standard for measuring pressure):

Triallate (Far-Go)	16 mPa @ 77° F	Volatile
Dicamba	4.5 mPa @ 77° F	Moderate to high volatility
Picloram	0.082 mPa @ 95° F	Low to moderate volatility
Glyphosate		Negligable

A good spray drift management program includes using common sense, good judgment, and a well-trained applicator. To prevent drift, follow these guidelines:

- Use as coarse a spray as permitted and still obtain good coverage and control. For most spray applications, the sprayer should be set up to deliver 200-micron size spray droplets or greater.

- Don't apply pesticides in windy or gusty conditions. Don't apply at wind speeds over 3 to 5 MPH for ground applications or 6 MPH for aerial applications. Read the label for specific instructions and adhere to established spray policies. (BLM Manual H-9011-1)

- Do not spray when wind is likely to cause excessive contamination to bodies of water or other sensitive areas. Read the label and adhere to established spray policies.

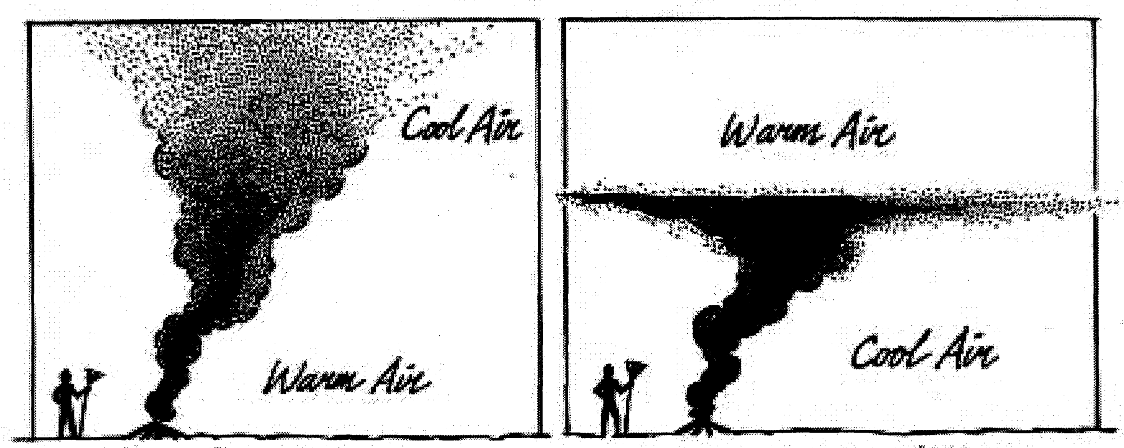
- Choose an application method and a formulation that is less likely to cause drift.

- Use drift control/drift reduction adjuvants. These materials are basically thickeners and are designed to minimize the formation of droplets smaller than 150 microns. They help produce a more consistent spray pattern and aid in deposition.

- Choose the formulation carefully. Water-based sprays volatilize more quickly than oil-based sprays, but oil-based sprays can drift farther because they are lighter, especially above 95° F.

- Apply pesticides early in the morning or late evening. Wind speed is the lowest and humidity is higher at these times. Avoid full daylight hours.

- Do not spray during temperature (air) inversions, a condition in which colder air next to the ground is trapped by a layer of warmer air above. Inversions may occur during the passage of a cold front or by high-pressure areas. During an inversion, pesticides released into the atmosphere's lowest layers are trapped and can move by the slightest wind.



Normal conditions— Smoke rises and disperses

Inversion condition— Smoke concentrates

- When possible, avoid spraying at temperatures above 90° to 95° F, ideally not over 85° F.

- **Know your surroundings!** Know the location of sensitive areas within a one-half mile radius and one mile downwind of sites on which pesticide applications are to be made. Follow label instructions regarding temperature, humidity, and proximity to sensitive locations.

- Determine wind direction and take this into account in determining application timing, equipment and whether or not to make an application. The wrong wind direction can cancel out everything else you have done to reduce drift.

- Do not apply pesticides near lakes, reservoirs, ponds, rivers, streams, marshes, etc. Add a drift retardant on fields near any water source! Read the label for specific instructions.

- Be sure you are getting the spray deposition pattern you think you are. Service and calibrate your equipment regularly.

- Check your system for leaks. Small leaks under pressure can produce very fine droplets.

- When using air blast sprayers in orchards make sure the machine is properly adjusted to direct the spray into the tree canopy. On most sprayers, one or more of the upper nozzles will not deliver spray to the tree and should be shut off. **Use only the nozzles that actually deliver spray to the tree**.

- In orchards or in shade tree plantings, and whenever possible, cut off the spray for missing trees in the row. Spray that does not enter the tree canopy is wasted and contributes significantly to drift problems.

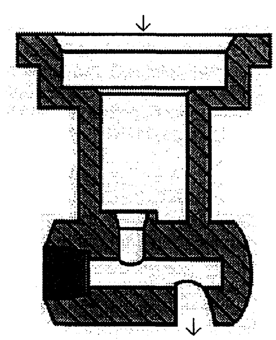
Low Drift nozzles

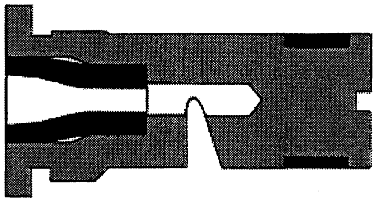
Almost all major nozzle manufacturers have their version of low-drift nozzles These nozzles are designed to create larger droplets at the same flow rate and operating pressures than comparable standard flat-fan nozzles.

Commonly Used Low Drift Nozzles

Pre-Orifice Flat Fan - A pre-orifice reduces the internal operating pressure of a standard tip, producing a coarser spray at standard pressures. The pressure gauge on the sprayer reads the external pressure, but the pressure drop in the nozzle body reduces the amount of fine droplets exiting the spray tip. Sizes range from 80015 to 8005 - also available in 110° angles.

Turbo TeeJet (Spraying Systems) - A unique flooding-type nozzle with a turbulence chamber produces a wide-angle (150°) spray. Sizes range from TT11001 to 11008. (Turbo TeeJet - 110° spray fan 0.1 GPM). A wide pressure range (15 to 90 psi) makes these nozzles very compatible with automatic rate controllers that use pressure to adjust flow rate in response to travel speed. Optimum pressure is 40 psi.



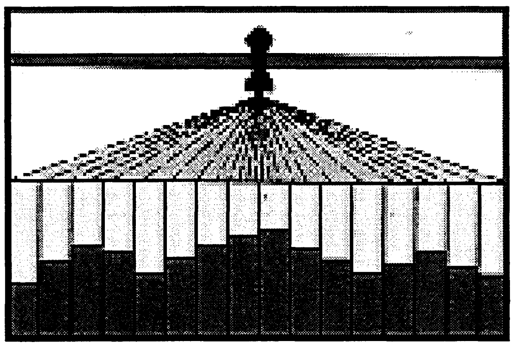


Turbo FloodJet Nozzle (Spraying Systems Co.)

Turbo Flood nozzles combines the precision and uniformity of flat spray nozzles with the clog-resistance and wide angle pattern of flooding nozzles. Turbo Flood Jet nozzles produce droplets that are 30 to 50% larger than those produced by standard flooding nozzle tips.

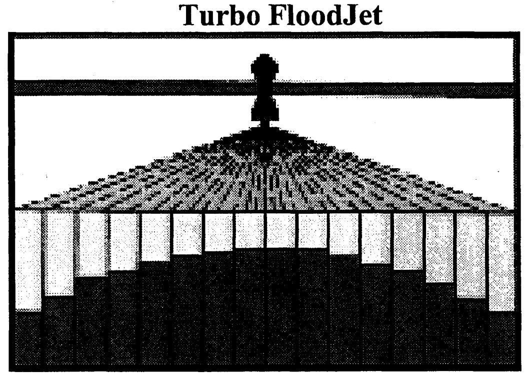
The major design difference between the new Turbo Flood nozzles and the conventional flood nozzles are a pre-orifice at the point of liquid entrance to the nozzle, and a turbulence chamber at the exit point. This results in more uniform droplet sizes and improvement in pattern uniformity. At common operating pressures. In addition to improvement in droplet size, Turbo Flood Jet tips provide a better spray pattern than conventional flood tips.

Conventional Flood



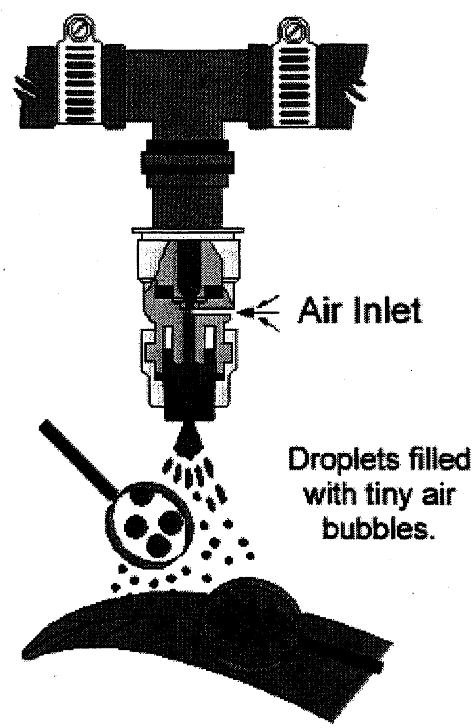
Spray pattern for boom TK-4, 30 psi, 30 inch spacing, 20 inch spray height

Turbo FloodJet



Spray pattern for boom TF-4, 30 psi, 30 inch spacing, 20 inch spray height

Venturi Nozzles - Most Venturi nozzles have the same basic design feature: two orifices, one to meter liquid flow, the other, somewhat larger, to form the pattern. In between these two orifices, a Venturi tube used to draw air into the nozzle body to mix with the liquid. This forms an air-amended spray. The resulting spray pattern is low pressure and can be described as a very coarse spray containing large, air-filled droplets and virtually no small, drift prone droplets. Venturi nozzles are also known as "Air Induction (A.I.) nozzles



Dramatic drift reductions have been observed with these tips and good spray coverage has generally been maintained. The reason is that the droplets are filled with air bubbles that break apart on leaf impact. This provides similar coverage to finer, conventional sprays.

Selection of Venturi Low Drift Nozzles

Pressure and Venturi Tips: Although most Venturi tips are rated at minimum pressures of 30 to 40 psi, most need to be operated at higher than normal pressures to give optimum performance over a range of conditions. Using lower than the recommended pressures may cause the pattern to collapse, and will reduce the activity of the air-induction mechanism.

Nozzle Size Selection: Since Venturi nozzles should be operated at higher pressures, you may need to choose a nozzle with a lower flow rate from the one you are currently using to maintain the correct water volume without increasing travel speeds. For example, if you currently use a conventional 02 size nozzle (0.20 GPM at 40 psi), a Venturi 015 tip* operated at 70 psi may provide the same flow rate and less drift. Check manufacturer specifications for recommended pressures, and calibrate your sprayer at the start of every season.

Boom Height: Although Venturi nozzles are sold as 110° fan angles, their spray patterns are closer to 80° that quickly become narrower at lower pressures. Watch patterns carefully, and place your boom at the height needed to achieve proper overlap.

Nozzle Plugging: Even with clean water and screens, nozzles will occasionally plug. A Venturi nozzle should present less plugging problems than conventional nozzles because the metering orifice is round, allowing larger particles to pass through. If plugging occurs, the nozzle will have to be taken apart for cleaning.

Adjuvants: Air bubble inclusion in droplets is a function of formulation and pressure. Air bubbles may not form without a surfactant or at lower pressures. Most post-emergent pesticides sold in the U.S. either have surfactants in the formulation, or call for them to be added. Low-drift adjuvants should not be used with Venturi tips, as the spray will not atomize properly. Always check your patterns after adding any adjuvant.

A Note About Low Drift Nozzles and Efficacy: Low drift nozzles, especially Venturi tips, are best known for their dramatic ability to reduce drift. But some pests are more difficult targets than others, particularly the difficult-to-wet weeds, such as lambsquarters, cleavers, wild oats, and green foxtail. These weeds generally require finer sprays to maintain effective coverage. When using Venturi nozzles on these weeds, make sure your pressure is high enough to achieve good coverage. Larger weeds and reduced product rates typically make chemical control more difficult, and these conditions may also reveal some performance differences between nozzles. Always check with a chemical representative to see if the manufacturer supports the use of low-drift nozzles with their products.

Chapter 10
LAWS AND REGULATIONS

THE RELATIONSHIP OF FEDERAL, STATE, AND LOCAL LAW

For most of the nation's history, laws regulating pollution and health have been local concerns that could usually be resolved through a lawsuit for nuisance or trespass. As large population concentrations and heavy industry appeared, local governments developed land use regulations to segregate residential areas from the noises and pollution of industrial and other commercial activity. With increased use of agricultural chemicals, agriculture and other areas of natural resource management have since undergone their own industrial revolution and consequent regulation. At first, pesticide regulation was largely for consumer protection. The laws focused upon the pesticide performing as promised. While, early federal regulation of pesticides was intended to prevent abuses in the nationwide distribution of pesticides, the discovery that the use of agricultural chemicals could cause adverse environmental and health effects led to an enormous expansion of federal laws and regulations.

In the "environmental decade" of the 1970s, several comprehensive federal laws were passed to address environmental problems. These laws are so broad and so complex that many facets of them are still far from full implementation or interpretation. To facilitate implementation and ease the burden on federal agencies, Congress allowed the EPA to approve state implementation and administration of the federal laws. Congress also encouraged states to pass legislation that meets or exceeds the demands of federal law.

State law fills the gaps and supplements federal law. State law also often duplicates federal law. In many instances, state law standards are stricter than federal standards. Consequently, compliance with state law often assures compliance with federal laws as well. However, when there is a conflict between state and federal law, federal law will always supercede state law as long there are inconsistencies between the two.

State law takes two forms: statutes and administrative rules. Statutes are passed by the state legislature and set out the basic goals of the legislature and the procedures it wants applied to accomplish these goals. Although statutes often provide fairly specific direction, many details are frequently too technical and minute for the legislation to address. To fill this void, the legislature will generally rely on administrative agencies to adopt rules within the narrow bounds of their directive from the legislature. These administrative rules have the force of law. For example, if the legislature decided there was a state interest in regulating the use of certain pesticides, it might pass a statute that broadly outlines pesticide uses or prohibitions, then leave it to an agency to make rules about when, by whom, and in what quantities the pesticide must be applied. In most instances, agencies also have the power to enforce these administrative rules through both criminal and civil penalties as well as through permitting or licensing regulations. Many states have gone forward with their own pollution control legislation, some of which is far more stringent than federal law.

The result has become a pyramid of federal, state, and local laws and regulations. Federal law often provides only a regulatory "floor" to which state and local governments add further requirements.

Because many state laws are patterned on federal law, an understanding of federal requirements enables users of pesticides to better understand state requirements.

FEDERAL LAWS

FEDERAL INSECTICIDE, FUNGICIDE AND RODENTICIDE ACT

The Federal Insecticide, Fungicide and Rodenticide Act, commonly known as FIFRA, was enacted in 1947 and replaced the Federal Insecticide Act of 1910. In 1970, federal responsibility for regulating pesticides under FIFRA was transferred from United States Department of Agriculture (USDA) to the newly formed U.S. Environmental Protection Agency (EPA). Through its Office of Pesticide Programs (OPP), the EPA uses the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) to manage and regulate pesticides. FIFRA is the premier law for pesticide regulation in the U.S.

Since its passage into law, FIFRA has been changed (amended) several times with the most important amendment being the Federal Environmental Pesticide Control Act (FEPCA) of 1972. This act shifted the emphasis of FIFRA from safeguarding the consumer against fraudulent pesticide products, to a role of protecting both public health and the environment.

Since FIFRA governs the licensing or registration of pesticide products, any product in the U.S. claiming pesticidal properties must be regulated under FIFRA. No pesticide may be marketed in the U.S. until the EPA reviews an application for registration, approves each use pattern, and assigns a product registration number.

In 1972, amendments to FIFRA gave the EPA principal authority to control pesticides, to register and inspect producing establishments, and to certify applicators using pesticide products designated as restricted-use pesticides (RUP). FIFRA was again amended in 1978 and gave states primacy with regard to enforcement of pesticide laws, provided that states have established an EPA-approved plan for such activities.

Registration - The distribution, sale, offering or holding for sale, shipment, delivery or receipt within any state of any pesticide which is not registered with the EPA is prohibited. The EPA can also cancel, suspend or deny registration for the uses of a pesticide if it is determined that the directed use of the pesticide poses a serious hazard to humans or the environment. The suspension of a pesticide registration, unlike cancellation, stops interstate shipments immediately, but can be initiated only when the product presents an imminent danger. The EPA Administrator may issue a "stop sale, use or removal" order when it appears that a pesticide violates the law or its registration has been suspended or finally canceled.

In 1996, the **Food Quality Protection Act (FQPA)** amended FIFRA to include: the establishment of a system for reviewing pesticide registrations and tolerances on a 15-year cycle, authorization for EPA to suspend pesticide registrations immediately under emergency conditions, and requirements that EPA develop criteria for reduced-risk pesticides and expedite their registration.

Classification of Pesticides - The 1972 amendments to FIFRA also required that all pesticides be classified as either general or restricted use.

A **General-Use Pesticide** is defined in FIFRA as one which will not generally cause unreasonable adverse effects on the environment when used in accordance with its labeling. Such pesticides normally are available to the public without a license.

Restricted-Use Pesticides (RUP) are defined as those that may generally cause unreasonable adverse effects on the environment, including injury to the applicator. Those pesticides placed in the restricted category may only be used by or under the supervision of certified applicators.

Additionally, it is Bureau of Land Management policy that all pesticides will be applied by certified applicators or under the direct supervision of a certified applicator (Appendix 1, BLM Handbook H-9011-1).

Classification of Pesticide Applicators - The 1972 amendments also established two classes of applicators, commercial and farm (private) as well as separate standards for each type of applicator.

A **farm (private) applicator** is defined in FIFRA as a certified applicator who uses or supervises the use of any restricted-use pesticide (RUP) for the purpose of producing any agricultural commodity on property owned or rented by the applicator or his/her employer.

A **commercial applicator** is defined in FIFRA as a certified who uses or supervises the use of any restricted-use pesticide (RUP) for any purpose or on property other than as provided by the definition of farm (private) applicator.

FIFRA Penalties - FIFRA provides for criminal and civil penalties to be assessed for violations of provisions of the Act. **Civil** penalties are assessed by the EPA on those applicators who unknowingly violate any portion of FIFRA. Any manufacturer, commercial applicator, dealer, or distributor may be fined up to $5,000 for each offense while farm (private) applicators or others not mentioned can be given a written warning and/or a fine of up to $500 for the first offense and up to $1,000 for subsequent offenses. Persons assessed a civil penalty must be given notice and be provided the opportunity for a hearing.

Criminal penalties are more serious violations of the law, are usually decided in the courts and apply to those applicators that knowingly violate the provisions of the FIFRA. Farm (private) applicators found guilty of misdemeanors under this portion of the law may be fined up to $1,000 or imprisoned for 30 days, or both. Commercial applicators may be fined up to $25,000 or one year in prison, or both. If the EPA Administrator is unable to collect the fine levied as a civil penalty, they may turn the case over to the U.S. Attorney General who can then take the case to the U.S. District Court.

Typical FIFRA violations include:

- Selling or giving a restricted-use pesticide (RUP) to a person not certified to purchase such products.
- Using a pesticide in a manner inconsistent with its labeling.
- Altering, defacing or detaching a pesticide label.
- Illegally storing or disposing of pesticides or containers other than as directed by regulations. Pesticides must be stored in their original containers.
- Failure to keep required records or to allow inspection, copying or sampling.

THE WORKER PROTECTION STANDARD (WPS)

FIFRA also gives the EPA the authority to develop regulations that are interpretations of the law and have the force of a law. In August 1992, EPA issued revised regulations (Title 40 CFR Part 170) governing the protection of employees on farms, forests, nurseries, and greenhouses from occupational exposures to agricultural pesticides. The Worker Protection Standard (WPS) covers both workers in areas treated with pesticides and employees who handle pesticides for use in these areas.

- **Agricultural workers** - those who perform tasks related to the cultivation and harvesting of plants on farms or in greenhouses, nurseries, or forests.

- **Pesticide handlers** - those who handle agricultural pesticides (mix, load, apply, clean or repair equipment, act as flaggers, etc.)

WPS regulations are intended to reduce the risk of pesticide poisonings and injuries among agricultural workers and agricultural pesticide handlers through appropriate exposure reduction measures. While there are exceptions to certain portions of the Worker Protection standard (Subpart B Section 170.102), label guidelines must still be followed. These exceptions include, but are not limited to:

- Farm owners and their immediate family.
- Wide-area public pest control programs sponsored by governmental entities.
- Livestock or other animals, or in or about animal premises.
- Plants grown for other than commercial or research purposes.
- Plants that are in ornamental gardens, parks, and public or private lawns and grounds that are intended only for aesthetic purposes or climatic modification.
- Pest control activities not directly related to the production of agricultural plants.
- For control of vertebrate pests.
- On the harvested portions of agricultural plants or on harvested timber.

The WPS uses three approaches to promote safe pesticide handling and application.

1. **Eliminating or Reducing Pesticide Exposure** – Under FIFRA, the EPA defines the ***Restricted Entry Interval,*** or ***REI***, as the time immediately following application of a pesticide when unprotected workers may not enter the treated area. Handlers and workers who enter a field before the REI is complete must wear the Personal Protective Equipment (PPE) as noted in the Agriculture Use Requirements on the pesticide label. When no reentry time is specified, treated areas can be reentered without protective clothing after the spray has dried or the dust has settled.

2. **Minimizing Damage if Exposure Occurs** – Employers must supply pesticide handlers and agricultural workers with an ample supply of water, soap and towels for routine washing. The employer must make transportation available to a medical care facility and provide information about the pesticides and nature of the exposure to the worker or handler.

3. **Informing Employees About Pesticide Hazards** - All agricultural workers must receive pesticide safety training and have access to a pesticide safety poster. Pesticide handlers must be informed about label safety information and a centrally located listing of recent pesticide treatments must be posted on the establishment.

Worker protection standards for both agricultural and non-agricultural entities appear on the label under Agricultural Use Requirements and Non-agricultural Use Requirements respectively. See Chapter 4 – Pesticide Labels.

FOOD, DRUG AND COSMETIC ACT OF 1938

Administered by the Food and Drug Administration (FDA), the Food Drug and Cosmetic Act (FFDCA) of 1938 has been amended several times in its history. FFDCA governs, among other things, pesticide residue levels in food or feed crops marketed in the U.S. Under the FFDCA, the EPA has the responsibility for setting tolerances, or maximum legal limits for pesticide residues on food commodities marketed in the U.S. The purpose of the tolerance program is to ensure that U.S. consumers are not exposed to unsafe food-pesticide residue levels. The Food and Drug Administration has the responsibility for enforcing tolerance levels set by EPA. This law:

- provides for monitoring of food crops for pesticide residues and enforces tolerances.
- provides for monitoring and enforcement of food additive tolerances and prosecutes violators.
- works jointly with EPA to register pesticides used on animals.
- provides for monitoring of pesticide residues in animals by the Meat Inspection Division of the U.S. Department of Agriculture.

In 1954, Congress passed the Miller Amendment to the FFDCA, which required tolerances to be set for all pesticides and further required any raw agricultural commodity to be condemned as adulterated if it contained a pesticide residue above the tolerance level established by the FDA. Another amendment in 1958, called the Food Additives Amendment, extended provisions of the Miller Amendment to cover food additives (i.e., chemicals remaining in or on food after processing). Thus, processed foods that contained pesticide residues exceeding established tolerance levels were considered adulterated and subject to seizure similar to raw agricultural commodities. Included in the Food Additives Amendment was the Delaney Clause that stated that no food additive (including pesticides) shall be considered safe if it is found to induce cancer when ingested by man or animal (a zero cancer risk or zero tolerance standard). A zero tolerance is defined as no detectable amounts of any pesticide remaining on or in any agricultural commodity when it is offered for shipment.

The Food Quality Protection Act (FQPA) signed into law August 3, 1996 revised the Delaney Clause so that it no longer affects pesticides. The FQPA instead instituted a general "safe" standard of a reasonable certainty of no harm to consumers.

OCCUPATIONAL SAFETY AND HEALTH ACT (OSHA) OF 1970

The Occupational, Safety and Health Act of 1970, administered by the Occupational Safety and Health Administration (OSHA) of the Department of Labor, requires any employer with eleven or more employees to keep records of all work-related deaths, injuries and illness, and to make periodic reports. Minor injuries needing only first aid treatment need not be recorded. Records must be made if the injury involved medical treatment, loss of consciousness, restriction of work or motion, or transfer to another job. The law also requires investigation of employee complaints that may be related to pesticide use, reentry or accidents.

HAZARD COMMUNICATION STANDARD (HCS)

This rule written and administered by OSHA, provides protection for employees exposed to hazardous chemicals such as pesticides. Under this rule, an employee is defined as a worker who may be exposed to hazardous chemicals under normal operating conditions or in foreseeable emergencies. Exposure is further defined as meaning that an employee is subjected to a hazardous chemical in the course of employment through any route of entry (inhalation, ingestion, skin contact or absorption), and includes potential (i.e. accidental or possible) exposure.

This law:

- requires employers to read the Standard and understand the provisions and responsibilities of an employer.
- requires a list of the hazardous chemicals in the work place be made.
- requires employers to obtain material safety data sheets (MSDS) for all hazardous substances on their list.
- requires all containers to be labeled.
- requires a written communication program be developed and implemented.
- requires that employee training be conducted based upon the chemical list, MSDS and labeling information.
- requires that employers create a hazard communication file, and make it available to any employee upon request in a reasonable period of time.

RESOURCE CONSERVATION AND RECOVERY ACT OF 1976

The Federal Resource Conservation and Recovery Act (RCRA) is administered by the EPA to manage all hazardous wastes. In general, private applicators (farmers) who properly dispose of pesticide wastes, excess pesticides, and triple rinsed empty containers on their own property are in general exempt from the requirements of this law. Others who <u>accumulate</u> 2.2 pounds of acute hazardous chemical per month or; 2200 pounds of waste containing a hazardous chemical, must register as a generator of hazardous waste and obtain an ID number from EPA and follow certain disposal requirements. Regulated waste includes unrinsed containers, excess pesticide and pesticide dilutions, rinse water, etc. which contain a listed chemical and cannot be properly used.

RCRA does allow that triple-rinsed used containers be disposed of in EPA approved sanitary landfills without an ID number or further regulation.

TRANSPORTATION SAFETY ACT OF 1974

The Transportation Safety Act of 1974 authorized the U.S. Department of Transportation (DOT) to declare, issue and enforce hazardous materials regulations for all modes of transportation. These regulations, contained in Title 49 of the Code of Federal Regulations (49 CFR), cover any safety aspect of transporting hazardous materials, including the packing, repacking, handling, describing, labeling, marking, placarding and routing of such materials. Many states have adopted these federal regulations and are enforcing them.

The materials included under this regulation are explosives, compressed gases, flammable liquids and solids, poisons and several other classifications of chemicals. Many pesticides are not defined by the DOT as hazardous although most of the hazard classes defined include pesticides.

The shipper who offers a hazardous material for transportation in commerce shall describe the hazardous material on the shipping paper as required by the regulations. The applicator or carrier may not transport a hazardous material unless accompanied by a shipping paper. However, in most cases pesticides do not need shipping papers unless the quantity of the material in one package equals or exceeds the "Reportable Quantity" (RQ) listed in the regulations. A pesticide would be considered a "hazardous substance" if its active ingredient (a.i.) is equal to or greater than the **reportable quantity (RQ)** per package. When transporting hazardous materials, the shipping paper must be within reach of the driver while in the seat belt. When the driver is away from the vehicle, the shipping paper must be on the driver's seat or in the pouch of the vehicle door.

SUPERFUND AMENDMENTS and REAUTHORIZATION ACT of 1986 (SARA TITLE III)

SARA Title III is a Federal Right-to-Know law that affects those that produce or store hazardous chemicals. Pesticide producers, distributors, retailers and some pesticide applicators are among those that must comply with this law. It is designed to inform communities regarding hazardous chemicals located in the vicinity and addresses the need for community emergency response plans in the event of an accident. Title III has many sections, however, there are sections that affect the pesticide applicator, applicator business, or dealers.

Section 302 - Emergency planning and notification describes when notification of the state and local officials is required. EPA has assigned a Threshold Planning Quantity (TPQ) for each active ingredient (not total weight of formulated product). When the product in storage is at or above the TPQ the State Emergency Response Commission (SERC) must be notified in writing. Each facility is also required to designate a coordinator to work with the Local Emergency Planning Committee (LEPC). The state will notify the LEPC that your operation is covered under SARA. This is a one-time notification.

Section 304- Emergency release reporting describes the safety measures when an accidental release (such as a spill) of any extremely hazardous substance occurs.

If all the following occur:

1. the pesticide was spilled.
2. the pesticide is covered under SARA Title III.
3. the spill quantity was greater than the Reportable Quantity (RQ).
4. and the spill created off-site exposure.

You must:

1. notify the State Emergency Response Commission (SERC).
2. notify the Local Emergency Planning Committee (LEPC).
3. report the release to the National Response Center (1-800-424-8802).

If a pesticide is applied according to the label, the use is exempt from emergency release reporting.

Section 311 - Material Safety Data Sheet (MSDS) reporting is required under SARA Title III. Employers are required to obtain and keep material safety data sheets and submit copies of each MSDS (or a listing of the MSDS that must be maintained) to their local fire department, the LEPC, and the SERC.

There is one exclusion for the Section 311 requirement. If a chemical is used solely for household, consumer, or agricultural purposes, then notification is not required.

Section 312 - This section states that facilities must submit an annual chemical inventory to their local fire department, LEPC, and SERC. This inventory must include all hazardous chemicals stored at the facility at or above 10,000 pounds and any extremely hazardous chemical stored at or above 500 pounds (or 55 gallons) or above the TPQ, whichever is less. Agricultural producers are exempt from this section.

THE ENDANGERED SPECIES ACT (ESA) OF 1973

The purpose of the Endangered Species Act (ESA) is to protect threatened and endangered species. An endangered species is a plant or animal that is in danger of extinction throughout all or a significant portion of its range. A threatened species is one likely to become endangered in the foreseeable future. Administered by the Fish and Wildlife Service (FWS) of the Department of the Interior, the ESA makes it illegal to kill, harm or collect endangered wildlife or fish or remove endangered plants from areas under federal jurisdiction. It also mandates that other federal agencies ensure that any action they carry out or authorize is not likely to jeopardize the continued existence of any endangered species, or to destroy or adversely modify its critical habitat. Before a spray program can be initiated on any Bureau of Land Management (BLM) lands, a survey of the area for threatened and endangered (T & E) species must be made. The BLM manual 6840 encompasses the BLM's policy for all endangered species.

The EPA is required to ensure that registered pesticide use is unlikely to jeopardize endangered species. Jeopardize means that the action "appreciably reduces the likelihood of survival of the species." To accomplish this, EPA estimates the maximum environmental concentration of each pesticide. If this estimated concentration appears to affect an endangered species, the pesticide is then referred to the FWS. When FWS finds that the uses may cause jeopardy to the endangered species, the agency will recommend alternatives and /or restrict the use of the pesticide within the habitat of the affected species.

EPA responds to the FWS jeopardy opinions by making changes to the pesticide label. The new label language may contain specific restrictions, or it may direct pesticide applicators to read an Endangered Species Bulletin, with directions for the use of the pesticide where endangered species may be affected.

Ultimately, protection of endangered species from pesticides will fall to the pesticide applicator. Preserving the biological diversity of our planet by protecting endangered species will contribute to the overall quality of life. Each plant or animal is part of a complex food chain; break one of the links and others are adversely affected. One disappearing plant can take with it up to thirty other species that depend on it, including insects, higher animals and even other plants.

ENDANGERED SPECIES PROTECTION PROGRAM (ESPP)

In addition to the Endangered Species Act, the EPA's Endangered Species Protection Program (ESPP) was initiated in 1988. This program relies on cooperation between the U.S. Fish and Wildlife Service, EPA regions, individual states and pesticide users. As part of this program, the EPA has created bulletins for individual counties within the United States that provide information on pesticide use limitations intended to minimize impacts to threatened and endangered species.

CLEAN WATER ACT

The Clean Water Act (CWA) is a 1977 amendment to the Federal Water Pollution Control Act of 1972, which set the basic structure for regulating **discharges of pollutants to waters** of the United States. This law gave EPA the authority to set effluent standards on an industry-by-industry basis (technology-based) and continued the requirements to set water quality standards for all contaminants in surface waters. The CWA makes it unlawful for any person to discharge any pollutant from a point source into navigable waters unless a National Pollutant Discharge Elimination System permit (NPDES) is obtained under the Act. The 1977 amendments focused on toxic pollutants. In 1987, the CWA was reauthorized and again focused on toxic substances, authorized citizen suit provisions, and funded sewage treatment plants under the Construction Grants Program.

In 2002, the 9th U.S. Circuit Court of Appeals ruled that under the CWA, the Forest Service needed to obtain a National Pollutant Discharge Elimination System permit for aerial application. The permit process can take several years and the ruling is currently under appeal (as of 1/3/03).

NATIONAL ENVIRONMENTAL POLICY ACT (NEPA) OF 1970

NEPA provides a longstanding umbrella for a renewed emphasis on pollution prevention in all federal activities. NEPA's purpose is to promote efforts that will prevent or eliminate damage to the environment. Section 101 of NEPA contains Congress' express recognition of the impact of human activity on the interrelations of all components of the natural environment and a declaration of the policy of the federal government to use all practicable means and measures necessary to create and maintain conditions under which humans and nature can exist in productive harmony. In order to carry out this environmental policy, Congress required all agencies of the federal government to act to preserve, protect, and enhance the environment.

Further, Section 102 of NEPA requires the federal agencies to document the consideration of environmental values in their decision-making in "detailed statements" known as Environmental Impact Statements (EIS).

OTHER REGULATIONS

Regulations governing agricultural aircraft operations are administered by the Federal Aviation Administration in the U.S. Department of Transportation. It issues commercial and private aircraft operator certificates for such operations under Title 14, Code of Federal Regulations, Part 137.

Pesticide regulation is very complex, merging science, public policy, and law. Since scientific knowledge constantly changes, as do the needs of society, the pesticide regulatory process is never at a standstill. EPA continuously updates pesticide decisions as knowledge increases and improves.

Chapter 11
REQUIRED FORMS

PESTICIDE USE PROPOSAL (PUP)

The Pesticide Use Proposal (PUP) must be completed and signed through all channels listed in the following instructions. Each state varies in the length of time that the PUP is valid, usually three to five years unless there is a change in the PUP. If a change is made then a new PUP must be completed and signed. If a pesticide is new or if a new situation occurs, it is then likely that the PUP will be valid for only one year. It has to be renewed before that pesticide treatment area can be treated again. Montana and the Dakotas have an electronic format that now must be completed and routed through proper channels.

Instructions for Pesticide Use Proposal Submissions

A pesticide use proposal (PUP) package contains the following:

1. A copy of the site-specific environmental assessment (EA) where each proposal was assessed.
2. Copies of labels of any chemicals and surfactants proposed for use.
3. Material Safety Data Sheets (MSDS) for any chemicals and surfactants proposed for use.
4. A properly and completely filled out proposal including any specific attachments.

The PUP is a Department of Interior form and its purpose is to enable the bureaus or agencies in the Department of the Interior to pass specific information about pesticide use on lands administered in those bureaus or agencies back to the Department. The form is designed to provide the Department with precise information on pests, chemicals, rates of application, locations of application, and how sensitive situations are handled. It is also designed to provide the site-specific information about chemical use on Bureau of Land Management (BLM) lands as required for Chemical EIS (Environmental Impact Statement) efforts. One proposal may not cover all the general weed problems in one Resource Area or District. A proposal that provides site-specific information is more likely to meet Department, Bureau, and State Office standards for pesticide use than a proposal that generalizes about weed situations and potential pesticide use.

The following are instructions on how to fill out each section of the PUP. The examples in this information concerning specific labels and products are examples only! Consult current labels for up-to-date information.

Proposal Number

The proposal number is one used to track each proposal. Typically, each office keeps a log. The office Pesticide Coordinator assigns a unique number based on year, state, office code, and the number of proposals issued in that office each year. This number needs to be written on both pages of the proposal. **The State Pesticide Coordinator will not approve a proposal without a current proposal number.**

EA Number

This number cites the number of the EA (Environmental Assessment) in which this pesticide application was specifically addressed. This number needs to be written on both pages of the proposal. **The State Pesticide Coordinator will not approve a proposal without an EA number listed in this section of the proposal.** The Colorado *Record of Decision for the Vegetation Treatment on BLM Lands in Thirteen Western States* requires site-specific analysis for all pesticide use. The BLM has ceased using Administrative Determination (AD) numbers. Now the Determination of NEPA Adequacy (DNA) is preferred.

Location

Refers to the specific site (township, range, section, and portion of a section where the application will take place.) More than one site is possible per PUP if the same chemical in the same amount is to be sprayed at each site. If several sites will be covered with one PUP, list the exact locations and the estimated acreage of each site to be sprayed on a separate page. Label the page with the proposal number and the reference number and attach the sheet to the PUP. In oil and gas fields, rather than listing the location of each pad, provide a location of the field and include a map. Estimate the number of acres to be sprayed in each field. Maps of the location(s) of each application are not necessary in other submitted proposals; however, they do provide a good framework for impact analysis, especially cumulative impact analysis across space.

Duration of Proposal

The State Pesticide Coordinator will approve proposals for up to five years. If more than one year's approval is desired, state the years in which the herbicide will be reapplied.

I. Pesticide Application (include mixtures and surfactants)

Mixtures of pesticides can be approved if at least one of the labels states that the mixture is compatible and if the mixture, or one of the chemicals in the mixture, is labeled to control the specific pest listed on the proposal.

Trade Name(s)

The trade name, also known as the brand name, is listed on the pesticide label. For example, tebuthiuron is the common name for the herbicide formulation Spike 20P which is commonly used for sagebrush control. "Spike" alone is not the trade name. The manufacturer also makes Spike 80W, Spike 5G, Spike 1G, Spike 40P, and Spike Brush Pellets. Provide the information for any surfactants requested as well as for any chemicals.

Common Name(s)

The front page of every label has a section that identifies the pesticide's active ingredient. On the Spike 20P label, tebuthiuron is the common name. It is followed by the chemical name N-[5-(1,1-dimethylethly)-1,3,4-thiadiazol-2-yl]-N,N'-dimethylurea. While chemical names are not a PUP requirement, common names are required for each PUP.

The Banvel label lists its active ingredient as "dimethylamine salt of dicamba." *The Record of Decision for the Vegetation Treatment of BLM Lands on Thirteen Western States* shortened the common name to "Dicamba." **Only those active ingredients listed in the Record of Decision as "Herbicides Approved For Use" can be approved by the State Pesticide Coordinator.**

EPA Registration Number

All pesticides are registered with the Environmental Protection Agency (EPA). The registration number is one of the best ways a specific product can be identified. All pesticide labels have an EPA registration number; it is typically listed on the front page of a label. As with most other information on pesticide labels, EPA registration numbers can change. If you are not using older stocks of a pesticide, include both the new number and state with the old number that you are using previously registered pesticide material, and include both the old and the most recent labels in your proposal package.

Manufacturer(s)

The manufacturer is the company that produces the pesticide. The manufacturer's name is always listed on the front panel of the pesticide label.

Formulation

The type of formulation is listed on the label. Emulisifible concentrates (EC), solutions (S), flowables (F), aerosols, invert emulsions, and fumigants are considered "liquid" formulations. "Dry" formulations include dusts (D), baits (B), granules (G), pellets (P), wettable powders (WP), soluble powders (SP), microencapsulation (M or ME), and water-dispersible granules (WDG).

Method of Application

There are numerous types of pesticide application equipment, including hand sprayers, small motorized sprayers, generators, foggers, fumigators, dusters, wiper applicators, etc. If you will be using a sprayer attached to a type of aircraft, please state you will be using aircraft. Certain pesticides sprayed by aircraft require Washington Office approval because of the increased potential drift problems.

Maximum Rate of Application

The maximum rate of application refers to the maximum amount of pesticide in measurable amounts (use unit on label) and inactive ingredients that a label states can be used for specific target pest species listed as a pest on the proposal. The maximum amount of active ingredient is a ratio calculation. When calculating the rates of application, do not round numbers up. Rounding up may result in stating a number on your proposal that exceeds the label or BLM maximum. Refer to the EIS in your area for maximums rates.

Use Unit on Label

Typically, labels have several different species lists with different rates of application. For example, if a proposal states you will be using Escort™ herbicide to control common mullein, the maximum rate of application is one-half ounce per acre. The Escort™ label also states that four ounces of product may be used to control Kudzu. But this information is irrelevant for this proposal, since the target species is common mullein. Another example: if the target species on a proposal to use Banvel™ is bull thistle, the maximum rate of application use unit on label on pasture, rangeland and non-cropland areas is three pints. Bull thistle, a biennial, is on the list of biennials that Banvel™ will control. The maximum amount of product that may be used for biennials on the label is three pints for those that are bolting.

Pounds of Active Ingredient Per Acre

Active ingredient (a.i.) is typically expressed as either pounds per acre (the labeled rate), pounds per gallon (liquid formulations) or as a percentage of active ingredient per pound of a dry formulation. Because of public concern over chemical use, there is a trend among the chemical companies to manufacture pesticides that require low rates in order to reduce releasing pesticides into the environment. In the ingredients section on a label of a liquid pesticide formulation, there is a statement about how many pounds per gallon of active ingredient may be found in that formulation. For example, the Banvel™ label states that this product contains four pounds per gallon of active ingredient. If the target species on the proposal to use Banvel™ is bull thistle, and the maximum rate of application use unit is three pints, then the maximum amount of active ingredient per acre is the amount of active ingredient contained in three pints of formulated Banvel™.

Using the table of weights and measures found on page 102, you can determine that three pints of Banvel™ is equivalent to 0.375 gallons of the formulated product (3 pints ÷ 8 pints per gallon). Then using the concepts found in Chapter 8, page 104 of this manual, this amounts to 1.5 pounds of the active ingredient dicamba.

$$\textbf{0.375 gallons of Banvel™} = \frac{\textbf{X pounds of dicamba}}{\textbf{4 pound dicamba per gallon}}$$

Then back multiply: 0.375 gallons times 4 pounds per gallon that equals 1.5 pounds of dicamba. Therefore, the maximum rate of application pounds of active ingredient per acre is 1.5 pounds **a.i.** for control of bull thistle. In other words, three pints of the Banvel™ formulation contains 1.5 pounds of the active ingredient dicamba.

For dry formulations, the active ingredient will usually be expressed as a percentage of active ingredient per pound of the product. The Spike 20P™ label does state that the product contains 0.2 pounds of active ingredient per pound, but the Escort™ label simply states that, by weight, the active ingredient makes up 60 percent of the product. If you propose to use one-half ounce per acre the maximum amount of active ingredient that may be applied per acre is 0.3 ounces. See Chapter 8, page 105.

$$\textbf{0.50 oz. Escort™} = \frac{\textbf{X pounds metsulfuron-methyl}}{\textbf{60 \% a.i. per pound (0.60)}}$$

0.50 oz. of formulated Escort™ x 0.60 a.i. per pound = 0.3 oz. of metsulfuron-methyl

Intended Rate of Application

Pesticide labels state a range of rates including the maximum amount of material that may be applied. Often, depending on soil type, organic matter, the amount of soil moisture present, air temperature and humidity at the time of application, it is more cost-effective and environmentally sound to use less than that maximum amount of a pesticides to control the pest. In this section, state the amount of pesticide you actually apply per acre. Table E2-3 of the BLM Environmental Impact Statement (EIS) lists the maximum rates allowed on BLM lands. **The intended rate of application may not exceed the rates listed in table E2-3.** End of the Year reports require reporting the amount of active ingredient that has been applied per acre.

II. Pest (List specific target pest(s) and reason for application.)

When deciding which herbicide to use, it is critical to identify the target pest(s) so that the most useful and cost-effective application may be chosen. **If target pests are not identified, the proposal will not be approved by the State Pesticide Coordinator.** Pesticides are rigorously tested and their labels list a number of species that the product is known to control. If the specific target pest(s) are not listed on the label, attach documentation from a recent scientific source stating that the product proposed is known to control the specific target species. For example, if you desire to control the target species of showy milkweed with Banvel™, you will note that the Banvel™ label lists several milkweeds, but not showy milkweed. *The 1993-94 Montana, Utah, Wyoming Weed Control Handbook* does list dicamba or Banvel with four pounds of active ingredient per gallon as a known treatment for showy milkweed. **Documentation must be attached for species not listed on the label, for approval of the proposal by the State Pesticide Coordinator. Documentation must also be supplied for mixtures, if the mixture is not listed on the label as one that controls the specific target pest(s).** The Western Society of Weed Science has published the *Weeds of the West* by Tom D. Whitson, Larry C. Burrill, Steven A. Dewey, David W. Cudney, B.E. Nelson, Richard D. Lee and Robert Parker that lists standardized common plant names. Chemical companies are also using the standardized names more often now when printing labels. Use the standardized common names of plant pest species <u>or</u> their scientific names in this section of the PUP. List the specific reason for this pesticide application.

III. Major Desired Plant Species Present

List the species that define the natural plant community at the site where the chemical is to be applied. If the natural plant community is not what the site is being managed for, also list the key management species, or state that you are managing for bare ground.

IV. Treatment Site

Describe the land uses in the treatment area, the stage of growth of the target pest species, the slope and soil type and other factors that relate to specific information found on the pesticide label.

Estimated Acres

Estimate the number of acres to be treated chemically at each specific site. (This will be included on an attached sheet when one pup covers more than one site.) The size of the acreage to be treated determines who the final authorizing official will be. **This section of the PUP must be completed for approval by the State Pesticide Coordinator.**

V. Sensitive Aspects and Precautions

Describe any sensitive areas, including wetlands and riparian areas, endangered, threatened, candidate and sensitive species habitat, and distance to the treatment site. List measures to be taken to avoid impact to any sensitive areas. **If an Administrative Determination is used and documented in the EA Number section of the proposal, this section of the PUP must be filled out before the State Pesticide Coordinator will approve the PUP.**

VI. Non-target Vegetation

Since pesticides are not selective at a species level, there will be some loss of species that are considered desirable. Describe the associated and cumulative impacts and mitigations associated with the loss of non-target vegetation on the site of the pesticide application. **If an Administrative Determination is used and documented in the EA Number section of the proposal, this section of the PUP must be filled out before the State Pesticide Coordinator will approve the PUP.**

VII. Integrated Pest Management

Vegetation Treatment on BLM Lands in 13 Western States must take an integrated vegetation management approach. The techniques proposed for use in an integrated management program include: Preventive actions, biological control, mechanical control such as prescribed burning, cultural control, such as changing grazing time, numbers, or type of grazing animal, manual practices, such as hand pulling or mowing, chemical control, and restoration practices. Vegetation management priorities: preventive, non-chemical, combination of preventative, non-chemical and chemical, then sole chemical use in that order. Because of these priorities, please document what is being done besides this chemical application to manage undesirable species in the project area. **If an Administrative Determination is used and documented in the EA Number section of the proposal, this section of the PUP must be filled out before the State Pesticide Coordinator will approve the PUP.**

Originators Signature

The originator is the person who first asks for approval to do a chemical treatment. It may be a Bureau employee, such as a range conservationist, who will apply the chemical in an allotment that they manage. Or it may be an employee, such as a realty specialist, who fills out the form for a utility company when weed control is part of the approval for a permit. It may also be someone from outside the Bureau, such as a county weed supervisor or oil and gas company representative. It is always best if someone within the BLM provides guidance to our customers as they supply information required by the BLM and the Department of Interior.

Originators Company

If the project is initiated by BLM employees, the originator's company is not applicable. In all other cases, state the company or firm who holds the BLM permit, such as Conoco, Moffat County, etc. This space is <u>not</u> intended to document an originator's contractor.

Certified Pesticide Applicators Signature

This is the signature of the person who will oversee the pesticide application on the ground. This person must be currently certified by the Bureau or must have a current state certification. There may be cases where a customer plans to contract out this pesticide application and does not know who the applicator will be at the time the proposal is submitted. A BLM Certified applicator may then sign and require that the customer to send a copy of the chosen applicators state certification to the BLM office's Pesticide\Weed coordinator. This must be done before the pesticide application takes place. The State Office Pesticide Coordinator keeps a list of currently certified BLM employees and **will not approve a proposal if the Certified Applicators signature is missing or if signed by someone whose certification has expired.**

BLM Office Pesticide\Weed Coordinator's Signature

This is the signature of the person in the District or Resource Area Office who has been assigned the duty of reviewing that office's proposals before they are forwarded to the State Office. This person should also keep a file of copies of State Certifications and is responsible for submitting Annual Pesticide Use Reports to the District Office.

Managers Approval

The Resource Area Manager or District Manager, or acting-manager must sign this proposal. **The State Pesticide Coordinator will not approve any proposal that does not have a manager's signature**.

State Pesticide Coordinator's Signature

This has been deleted from the Colorado form since the State Pesticide Coordinator has been delegated authority to sign as the acting Deputy State Director.

Deputy State Director's Approval

The Deputy State Director's acting will sign in this blank and check whether the PUP was approved as is, with modifications or is not approved. The original PUP and all labels and attachments will be returned to the Office requesting approval.

Washington Office Approval (IPM/Pesticide Specialist)

Deleted from the Colorado form since the Colorado Pesticide Coordinator signs for the Washington Office.

__(state)__ BLM PESTICIDE USE PROPOSAL
(6/4/2002)

PROPOSAL NUMBER

REFERENCE NUMBER

FIELD OFFICE ______________________ **COUNTY** ____________ **DATE**

LOCATION:

DURATION OF PROPOSAL:

I. PESTICIDE APPLICATION (including mixtures and surfactants):
TRADE NAME(s):

COMMON NAME(s):

EPA REGISTRATION NUMBER(s):

MANUFACTURER(s):

FORMULATION: Liquid ______\\ Granular _______\\

METHOD OF APPLICATION:

MAXIMUM RATE OF APPLICATION:

USE UNIT ON LABEL:

POUNDS ACTIVE INGREDIENT/ACRE:

INTENDED RATE OF APPLICATION:

APPLICATION DATE(S):

NUMBER OF APPLICATIONS:

II. PEST (List specific pest(s) and reason(s) for application):

III. MAJOR DESIRED PLANT SPECIES PRESENT:

IV. TREATMENT SITE: (Describe land type or use, size, stage of growth of target species, slope and soil type).

ESTIMATED ACRES ____________________**V. SENSITIVE ASPECTS AND PRECAUTIONS: (Describe sensitive areas [e.g., marsh, endangered, threatened, candidate and sensitive species habitat] and distance to treatment site. List measures taken to avoid impact to sensitive areas).**

VI. NON TARGET VEGETATION: (Describe the impacts, cumulative impacts, and mitigations to non target vegetation that will be lost as a result of this chemical application).

VII. INTEGRATED PEST MANAGEMENT: (Describe how this chemical application fits into your overall integrated pest management program for the treatment area.

Originator's Signature:
Date:___________________Telephone Number:
Originator's Company Name:
Certified Pesticide Applicator's Signature:
BLM Field Office Weed/Pesticide Coordinator's Signature:
BLM Field Manager's Approval:
Date:

____ **Date:**
BLM Certified State Pesticide Coordinator_or
WO Certified Weed Scientist or Specialist

_____ CONCUR OR APPROVED
_____ DO NOT CONCUR OR DISAPPROVED
_____ CONCUR OR APPROVED WITH MODIFICATIONS

PESTICIDE APPLICATION RECORD (PAR)

The Pesticide Application Record (PAR) must be completed by the lead applicator within 24 hours after the completion of the pesticide treatment. A daily record must be kept for the length of the treatment for each site.

The Field Office or Station must receive a legible copy of the PAR prior to any payment for treatment for anyone other that BLM treatment. BLM treatment must also complete this format and place the PAR in their files.

This record must be kept and maintained for 10 years at the field office or at the station level.

PESTICIDE USE REPORT (PUR)

The Pesticide Use Report (PUR) must be completed on the annual basis and sent to the State Office. The State Office then compiles all of this data and submits the compiled report to the Washington Office Senior Weed Management Specialist and IPM/Pesticide Specialist.

The Washington Office IPM/Pesticide Specialist will compile all of the states reports and submit it to EPA.

INTEGRATED WEED MANAGEMENT REPORT (IWMR)

The Integrated Weed Management Report (IWMR) must be completed on the annual basis and sent to the State Office. The State Office then compiles this data and submits the compiled report to the Washington Office Senior Weed Management Specialist and IPM/Pesticide Specialist. The Washington Office IPM/Pesticide Specialist will compile all of the states reports.

BUREAU OF LAND MANAGEMENT PESTICIDE APPLICATION RECORD (PAR) Form 3-3-94		
1.	a.	Project Name:
	b.	Operator:
	c.	Pesticide Use Proposal Number:
	d.	Reference Number:

2.	Name of Applicator of Employee(s) Applying the Pesticide:					
3.	Date(s) of Application: (MONTH, DAY, YEAR)			4.	Time Frame of Application:	
5.	Location of Application: T. R Sec. County					
6.	Type of Equipment Used:					
7.	Pesticide(s) Used:					
	a.	Company or Manufacturer's Name:				
	b.	Trade Name:				
	c.	Type of Formulation: Liquid or Granular				
8.	Rate of Application Used:					
	a.	Active Ingredient per Acre				
	b.	Volume of Formulation per Acre				
9	a.	Actual Area Treated:				
	b.	Total Project Area:				
10.	Primary Pest(s) Involved:					
11.	Stage of Pest Development:					
12.	Site Treated:					
		Native Vegetation		Seeded Vegetation		Other
13.	Weather Conditions					
	a.	Wind velocity:				
	b.	Wind Direction:				
	c.	Temperature:				
14.	Monitoring Record **(IF INSUFFICIENT SPACE-CONTINUE ON BACK):**					

* This record is required and must be completed except for monitoring within 24 hours after completion of application of pesticides. This record must be maintained for minimum of 10 years.

Appendix 1
Calibration Exercises

1. Convert: 0.51 gallons = _______ounces. See Page 102 (Table of Weights and Measures)

   ANSWER: 0.51 gallons x 128 ounces in one gallon = 65.28 or 65 ounces. Think about it! One-half gallon (0.5) is 64 ounces as there are 128 ounces per gallon.

2. Convert: 32 ounces = ______gallons. See Page 102 (Table of Weights and Measures)

   ANSWER: 32 ounces ÷ 128 ounces per gallon = 0.25 gallons. Think about it! 32 ounces is one quart!

3. Convert: 0.75 gallons = _______ounces. See Page 102 (Table of Weights and Measures)

   ANSWER: 0.75 gallons x 128 ounces = 96 ounces.

4. Convert: 0.10 acres = _________ square feet. See Page 102 (Table of Weights and Measures)

   ANSWER: 0.10 acres x 43,560 ft^2 per acre = 4,356 ft^2.

5. Convert: 12 pints = _______gallons. See Page 102 (Table of Weights and Measures)

   ANSWER: 12 pints ÷ 8 pints per gallon = 1.5 gallons

6. Convert: 28 quarts = ________gallons. See Page 102 (Table of Weights and Measures)

   ANSWER: 28 quarts ÷ 4 quarts per gallon = 7 gallons

7. If a sprayer delivers 30 GPA, how many acres can be sprayed with 120 gallons of a spray mixture? See Page 103 (Mixing Formula 1).

   ANSWER: 120 gallons ÷ 30 GPA = 4 acres

8. What is the area of a test strip if the swath width is 66 feet and the test strip distance is also 66 feet? See Page 102 (Table of Weights and Measures).

   ANSWER: 66 ft x 66 ft = 4,356 ft^2.

9. How many acres is an area of 4,356 square feet? See Page 102 (Table of Weights and Measures)

   ANSWER: 4,356 ÷ 43,560 = 0.10

10. Five (5) gallons of liquid covers a test strip that is 50 feet wide and 100 feet long. What is the GPA? Page 93 (Calibration Strip Method)

    ANSWER:

    $$\frac{\text{5 gallons per strip}}{\text{50 ft x 100 ft}} = \frac{?}{43{,}560} \quad \text{Cross multiply} \quad \frac{\text{5 gallons x 43,560}}{\text{50 ft x 100 ft}} = \text{GPA} \quad \frac{217800}{5000} = \text{43.56 or 44 GPA}$$

11. The output of a backpack sprayer is 0.454 gallons over an area of 18.5 feet by 18.5 feet. What is the sprayer's output in GPA? Page 93 (Calibration Strip Method)

    ANSWER:

    $$\frac{\text{0.454 gallons}}{\text{18.5 x 18.5 ft}} = \frac{?}{43{,}560} \quad \text{Cross multiply} \quad \frac{\text{0.454 gallons x 43,560}}{\text{18.5 ft x 18.5 ft}} = \text{GPA} \quad \frac{19776.24}{342.25} = \text{57.78 or 58 GPA}$$

12. A vehicle travels a 150-foot test strip in 20 seconds. What is the vehicles speed in MPH? See Page 95 (Measuring Ground Speed).

ANSWER:

$$\frac{150 \text{ feet} \times 60 \text{ (seconds in one minute)}}{20 \text{ seconds} \times 88 \text{ (feet in one minute at 1 MPH)}} = 5.12 \text{ or } 5 \text{ MPH}$$

13. What is the average of the following nozzle outputs? See Page 97 (Checking Nozzle Output).

Nozzle 1 - 48 ounces
Nozzle 2 - 43 ounces
Nozzle 3 - 50 ounces
Nozzle 4 - 51 ounces
Nozzle 5 - 48 ounces
Nozzle 6 - 45 ounces

ANSWER:

48 + 43 + 50 + 51 + 48 + 45 = 285 ÷ 6 = 47.5 ounces

14. The average nozzle output across a boom is 56 ounces. You want a 5% error range on EITHER side of the average. What is the error range across the average from low to high? See Page 97 (Measuring Nozzle Output).

ANSWER:

0.05 x 56 = 2.8 ounces   53.2 ounces ⟵ 56 ounces ⟶ 58.8 ounces.

15. If a five-row band sprayer applies 56 ounces over five, 15-inch bands for a test strip distance of 250 feet, what is the GPA of this band sprayer? See Page 98 (Band Applications).

ANSWER:

56 ounces ÷ 128 ounces per gallon = 0.4375 gallons of sprayer output. (page 102; Weights and Measures)
15 inch ÷ 12 inches per foot = 1.25 feet per band
1.25 feet x 5 bands = 6.25 feet per sprayed area (effective swath width)
6.25 feet wide x 250 feet long.

$$\frac{0.4375 \text{ gallons} \times 43{,}560}{6.25 \text{ ft} \times 250 \text{ ft}} = \frac{19057.5}{1562.50} = 12.19 \text{ or } 12 \text{ GPA}$$

16. A granular spreader applies 0.75 pounds of formulated material over an area that is 50 feet x 20 feet. How many pounds of this material per acre could this spreader apply? See Page 99 (Dry Pesticide Application).

ANSWER:

$$\frac{0.75 \text{ pounds} \times 43{,}560}{50 \text{ ft} \times 20 \text{ ft}} = \frac{32670}{1000}$$ = 32.67 pounds of <u>formulated</u> product per acre

17. Your sprayer is calibrated to apply 16 GPA at 10 MPH. To be within label instructions, you need a sprayer output of 20 GPA. What is your adjusted field speed to apply 20 GPA? See Page 100 (Adjusting Output – Speed).

ANSWER:

$$8 \text{ MPH} = \frac{16 \text{ GPA} \times 10 \text{ MPH}}{20 \text{ GPA}}$$

Think about it! You want to apply more GPA so you need to go slower.

18. How many gallons of a herbicide formulation is needed to spray 8 acres if the product rate is 3 pounds of active ingredient (a.i.) per acre. The formulation contains 5 pounds of active ingredient (a.i.) per gallon. See Page 104 (Mixing Formula 4) and Page 103 (Mixing Formula 3).

ANSWER:

First determine how many gallons of the formulated product that is needed.

$$\frac{\text{3 pounds a.i. per acre}}{\text{5 pounds a.i. per gallon}} = 0.6 \text{ gallons}$$

0.6 gallons x 8 acres = 4.8 gallons

19. How many acres can be sprayed with 250 gallons of solution and a sprayer that is calibrated to 35 GPA? See Page 103 (Mixing Formula 1).

ANSWER:

250 gallons ÷ 35 GPA = 7.14 acres

20. You plan to spray a 30-acre field in one pass. Your sprayer is calibrated to apply 35 GPA and has a 500-gallon tank capacity. At the given GPA, can you spray this entire field in one pass? See Page 103 (Mixing Formula 1 and Mixing Formula 2).

ANSWER:

30 acres x 35 GPA = 1050 gallons of solution needed...so NO, your tank is too small.
This a back multiplication of the formula to find acres treated

21. You want to apply a pesticide to a 16-acre field at a rate of 10 oz. of the formulated product per acre. How many pints of the pesticide will you add to the spray tank? Quarts? See Page 102 (Table of Weights and Measures) and Page 103 (Mixing Formula 3).

ANSWER:

16 acres x 10 oz = 160 ounces ÷ 16 ounces per pint = 10 pints
160 ounces ÷ 32 ounces per quart = 5 quarts; or 10 pints ÷ 2 pints per quart also equals 5 quarts

22. A 5-gallon backpack sprayer applies 120 ounces of liquid to a 30-foot by 30-foot test strip. You will be applying a pesticide at a product rate of 2 pints per acre. You plan on using a full 5-gallons. How much of the pesticide will you add to the backpack? See Page 102 (Table of Weights and Measures), Page 93 (Calibration Strip Method), Page 103 (Mixing Formula 1) and Page 103 (Mixing Formula 3).

ANSWER:

First figure out the GPA of the sprayer
120 ounces ÷ 128 ounces per gallon = 0.9375 gallons (Page 102; Weights and Measures)

$$\frac{(0.9375 \text{ gallons} \times 43{,}560)}{(30 \text{ ft} \times 30 \text{ ft})} = 45.375 \text{ GPA}$$ (Page 93; Calibration Strip Method)

Second, determine the acres that can be done (Page 103; Mixing Formula 1)
5 gallons ÷ 45.375 GPA = 0.110 acres

Third, determine how much to add to the tank when the rate is 2 pints (32 ounces) per acre). 0.110 x 32 ounces per acre = 3.52 ounces added in 5 gallons. (Page 103; Mixing Formula 3)

23. You have just applied 30 gallons of herbicide formulation that contains 3 pounds of active ingredient per gallon. How many total pounds of active ingredient did you use? See Page 105 (Mixing Formula 5)

ANSWER:

30 gallons of formulation x 3 pounds a.i. per gallon = 90 pounds of a.i. used. This is a back-multiplication of the formula for determining formulated product when given rate per acre in a.i. and a.i. per gallon.

24. You have just applied 800 pounds of a dry herbicide that is 35% active ingredient per pound of formulated product. How many pounds of active ingredient have you applied? See Page 105 (Mixing Formula 5 & 6)

ANSWER:

800 pounds of formulated product x 0.35 (35% a.i. per pound) = 280 pounds a.i. applied.

25. You are told to apply 0.35 pounds a.i. per acre of a herbicide that contains 4 pounds of active ingredient per gallon. How many gallons is this in formulated-product-per-acre? What is this in terms of ounces? Quarts? Pints? See Page 104 (Mixing Formula 4) and Page 102 (Table of Weights and Measures).

ANSWER:

- 0.35 a.i. per acre ÷ 4 pounds of a.i. per gallon = 0.0875 gallons of formulated-product-per-acre.
- 0.0875 gallons x 128 ounces per gallon = 11.2 or 11 ounces.
- 11.2 ounces ÷ 32 ounces per quart = 0.35 quarts ---also--- 0.0875 gallon x 4 quarts per gallon = 0.35 quarts
- 11.2 ounces ÷ 16 ounces per pint = 0.7 pints – also – 0.0875 gallons x 8 pints per gallon = 0.7 pints

26. You are told to apply 53.55 pounds a.i. per acre of a dry herbicide formulation that contains 63% active ingredient. What is this rate in terms of formulated product per acre? See Page 105 (Mixing Formula 6).

ANSWER:

53.55 pounds a.i. per acre ÷ 0.63 = 85 pounds of formulated product per acre. Think about it! If a product is only 63% strength, then it will take more of the formulated product to equal the amount of a.i. required!

27. You have applied a total of 850 pounds of a dry herbicide formulation that contains 35% active ingredient. What is this in terms of active ingredient? See Page 105 (Mixing Formula 6).

ANSWER:

850 pounds of formulated product x 0.35 = 297.5 pounds of a.i. NOTE: This problem utilizes the back-multiplication Mixing Formula 5 on Page 105. The only difference is that this is a dry formulation.

28. A pesticide contains 4.3 pounds of active ingredient per gallon. If this pesticide is mixed at the rate of one gallon per acre, how much active ingredient is being applied over 5 acres? See Page 104 (Mixing Formula 4) and Page 103 (Mixing Formula 3).

ANSWER:

4.3 pounds a.i. per gallon x 5 acres = 21.5 pounds a.i. over 5 acres.

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Glossary of Pesticide Terms

A

- **Abrasive** - Capable of wearing away or grinding down another object.
- **Absorption** - Process by which pesticides are taken into tissues, namely plants, by roots or foliage (stomata, cuticle, etc.).
- **Acaricide** (miticide)- An agent that destroys mites and ticks.
- **Active ingredient** (a.i. or AI) - Chemicals in a product that are responsible for the pesticidal effect.
- **Acute toxicity** - The toxicity of a material determined at the end of 24 hours; to cause injury or death from a single dose or short-term exposure.
- **Adjuvant** - An ingredient that improves the properties of a pesticide formulation. Includes wetting agents, spreaders, emulsifiers, dispersing agents, foam suppressants, penetrants, and correctives. Adsorption - Chemical and/or physical attraction of a substance to a surface.
- **Allergic effects** - Harmful effects, such as skin rash o r asthma, that some people develop in reaction to pesticides that do not cause the same reaction in most other people.
- **Antagonism** - Decreased activity arising from the effect of one chemical or another.
- **Aromatics** - Solvents containing benzene or compounds derived from benzene.

B

- **Back-siphoning** - The movement of liquid pesticide mixtu re back through the filling hose and into the water source.
- **Bactericide** - Any bacteria-killing chemical.
- **Band application** - Application to a continuous restricted band such as in or along a crop row, rather than over the entire field area.
- **Botanical pesticide** - A pesticide produced from naturally occurring chemicals found in some plants. Examples are nicotine, pyrethrum, strychnine, and rotenone.
- **Brand Name** - The name under which a pesticide is sold.
- **Broadcast application** - Application over an entire area rather than only on rows, beds, or middles.
- **Broad-spectrum insecticide** - Nonselective, having about the same toxicity to most insects.

C

- **Calibrate** - To determine the amount of pesticide that will be applied to the target area.
- **Carcinogen** - A substance that causes cancer in animal tissue.
- **Carrier** -The primary material used to allow a pesticid e to be dispersed effectively; for example, the talc in a dust formulation, the water mixed with a wettable powder before a spray application, or the air that disperses the pesticide in an air blast application.
- **Chemical name** - Scientific name of the active ingredient(s) found in the formulated product. The name is derived from the chemical structure of the active ingredient.
- **CHEMTREC** - A toll-free, long-distance, telephone service that provides 24-hour emergency pesticide information **(800-424-9300).**
- **Chronic toxicity** - The toxicity of a material determined beyond 24 hours and usually after several weeks of exposure.
- **Common pesticide name** - A common chemical name given to a pesticide by a recognized committee on pesticide nomenclature. Many pesticides are known by a

number of trade or brand names but have only one recognized common name. For example, the common name for Sevin insecticide is carbaryl.

- **Compatible** (Compatibility) - When two materials can be mixed together with neither affecting the action of the other.
- **Concentration** - Content of a pesticide in a liquid or dust; for example, pounds/gallon or percent by weight.
- **Contact herbicide**- Phytotoxin by contact with plant tissue rather than as a result of translocation.
- **Contamination** - The presence of an unwanted pesticide or other material in or on a plant, animal, or their by-products; soil; water; air; structure; etc.
- Cuticle - Outer covering of insects or plants.

D

- **Dermal toxicity** - Toxicity of a material as tested on the skin or lab animals. The property of a pesticide to poison an animal or human when absorbed through the skin.
- **Diluent** - Component of a dust or spray that dilutes the active ingredient. Usually water.
- **Dose, dosage** - Same as rate. The amount of toxicant given or applied per unit of plant, animal, or surface.
- **Drift, spray** - Movement of airborne spray droplets from the spray nozzle beyond the intended contact area.

E

- **EC50** - The median effective concentration (ppm or ppb) of the toxicant in the environment (usually water) that produces a designated effect in 50 percent of the test organisms exposed.
- **Emulsifiable concentrate** - Concentrated pesticide formulation containing organic solvent and emulsifier to facilitate emulsification with water.
- **Emulsifier** - Surface active substances used to stabilize suspensions of one liquid in another; for example, oil in water.
- **EPA** - The Environmental Protection Agency, the federal agency responsible for pesticide rules and regulations, and all pesticide registrations.
- **EPA Establishment Number**- A number assigned to each pesticide production plant by EPA. The number indicates the plant at which the pesticide product was produced and must appear on all labels of that product.
- **EPA Registration Number** - A number assigned to a pesticide product by EPA when the product is registered by the manufacturer or his designated agent. The number must appear on all labels for a particular product.

F

- **FIFRA** -The Federal Insecticide, Fungicide and Rodenticide Act of 1947.
- **Flowable** - A type of pesticide formulation in which a very finely ground solid particle is mixed in a liquid carrier.
- **Formulation** - Way in which basic pesticide is prepared for practical use. Includes preparation as wettable powder, granular, emulsifiable concentrate, etc.
- **Fumigant -** A volatile material that forms vapors that destroy insects, pathogens, and other pests.
- **Fungicide** - A chemical that kills fungi.

G

- **Gallonage** - Number of gallons of finished spray mix applied per acre, tree, hectare, square mile, or other unit.
- **GPA** – Gallons Per Acre
- **GPM** – Gallons Per Minute
- **General-use pesticide** - A pesticide that can be purchased and used by the general public without undue hazard to the applicator and environment as long as the instructions on the label are followed carefully. (See Restricted-use pesticide).

H

- **Hydrolysis** - Chemical process of (in this case) pesticide breakdown or decomposition involving a splitting of the molecule and addition of a water molecule.

I

- **Incompatible -** Two or more materials that cannot be mixed or used together.
- **Ingredient statement** - That portion of the label on a pesticide container that gives the name and amount of each active ingredient and the total amount of inert ingredients in the formulation.
- **Inhalation** – Exposure of test animals either to vapor or dust for a predetermined time.
- **Integrated pest management (IPM)** - A management system that uses all suitable techniques and methods in as compatible a manner as possible to maintain pest populations at levels below those causing economic injury.
- **Invert emulsion** - One in which the water is dispersed in oil rather than oil in water. Usually a thick mixture like salad dressing results.

L

- **Label** - All printed material attached to or part of the pesticide container.
- **Labeling** - Supplemental pesticide information that complements the information on the label but is not necessarily attached to or part of the container.
- **LC50 -** The median lethal concentration, the concentration that kills 50 percent of the test organisms, expressed as milligrams (mg) or cubic centimeters (cc, if liquid) per animal. It is also the concentration expressed as parts per million (ppm) or parts per billion (ppb) in the environment (usually water) that kills 50 percent of the test organisms exposed.
- **LD50** - A lethal dose for 50 percent of the test organisms. The dose of toxicant producing 50 percent mortality in a population. A value used in presenting mammalian toxicity, usually oral toxicity, expressed as milligrams of toxicant per kilogram of body weight (mg/kg).
- **Leaching** - The movement of a pesticide chemical or other substance downward through soil as a result of water movement.

M

- **mg/kg** (milligrams per kilogram) - Used to designate the amount of toxicant required per kilogram of body weight of test organism to produce a designated effect, usually the amount necessary to kill 50 percent of the test animals.
- **MSHA** - Mine Safety and Health Administration.
- **Montana Poison Control Center** – 1-800-525-5042
- **Mutagen** - Substance causing genes in an organism to mutate or change.

N

- **National Pesticide Telecommunications Network** – 1-800-858-7378
- **Necrosis** - Death of tissue, plant or animal.
- **Nematicide** - Chemical used to kill nematodes.
- **NIOSH** - National Institute for Occupational Safety and Health.

O

- **Oncogenic** - The property to produce tumors (not necessarily cancerous) in tissues. (See Carcinogenic.)
- **Oral toxicity** - Toxicity of a compound when given by mouth. Usually expressed as number of milligrams of chemical per kilogram of body weight of an animal when given orally in a single dose that kills 50 percent of the animals. The smaller the number, the greater the toxicity.
- **Organic matter** - Materials and debris that originated as living plants or animals.
- **Organochlorine insecticide** - One of the many chlorinated insecticides, e.g., DDT, dieldrin, chlordane, BHC, Lindane, etc.
- **Organophosphate** - Class of insecticides (also one or two herbicides and fungicides) derived from phosphoric acid esters.
- **Ovicide** - A chemical that destroys an organism's eggs.

P

- **Persistence** - The quality of an insecticide to persist as an effective residue due to its low volatility and chemical stability, e.g., certain organochlorine insecticides.
- **Pesticide** - An economic poison defined in most state and federal laws as any substance used for controlling, preventing, destroying, repelling, or mitigating any pest. Includes fungicides, herbicides, insecticides, nematicides, rodenticides, desiccants, defoliants, plant growth regulators, etc.
- **pH** - A measure of how acid or how caustic (basic) a substance is on a scale of 1-14. pH 1 indicates that a substance is very acid; pH 7 indicates that a substance is neutral; and pH 14 indicates that a substance is very caustic (basic).
- **Phytotoxic** - Injurious to plants.
- **Piscicide** - Chemicals used to kill fish.
- **Poison** - Any chemical or agent that can cause illness or death when eaten, absorbed through the skin, or inhaled by humans or animals.
- **Postemergence -** After emergence of the specified weed or crop.
- **Power Take Off -** The power-take-off (PTO) tractor connection is an auxiliary drive from the tractor engine and allows farmers to harness the power of a tractor engine to drive other farm machinery
- **ppb** - Parts per billion (parts in 10 x 9 parts) is the number of parts of toxicant per billion parts of the substance in question.
- **ppm** - Parts per million (parts in 10 x 6 parts) is the number of parts of toxicant per million parts of the substance in question. They may include residues in soil, water, or whole animals.
- **Preplanting treatment** - Made before the crop is planted.
- **Personal Protective Equipment (PPE)** - Clothing to be worn in pesticide-treated fields under certain conditions as required by the pesticide label.

R

- **Rate** - Refers to the amount of pesticide applied to a unit area. Usually expressed as a quantity per acre.

- **Reentry (intervals – REI))** - Waiting interval required by federal law between application of certain hazardous pesticides to crops and the entrance of workers into those crops without protective clothing.
- **Registered pesticides** - Pesticide products that have been approved by the Environmental Protection Agency for the uses listed on the label.
- **Residual** - Having a continued killing effect over a period of time.
- **Residue** - Trace of a pesticide and its metabolites remaining on and in a crop, soil, or water.
- **Restricted-use pesticide (RUP)** – Many pesticides designated by the EPA, that can be applied only by certified applicators, because of their inherent toxicity or potential hazard to the environment.
- **Rinsate -** Pesticide-containing water (or another liquid) that results from rinsing a pesticide container, pesticide equipment, or other pesticide-containing materials.
- **Rocky Mountain Poison Center** – 1-800-332-3073
- **Rodenticide** - Pesticide applied as a bait, dust, or fumigant to destroy or repel rodents and other animals, such as moles and rabbits.

S

- **Selective pesticide** - One that kills selected pests, but spares many or most of the other organisms, including beneficial species, either through different toxic action or the manner in which insecticide is used.
- **Signal word** - A required word that appears on every pesticide label to denote the relative toxicity of the product. The signal words are either Danger-Poison for highly toxic compounds, Warning for moderately toxic, or Caution for slightly toxic.
- **Slurry** – First mixing formulations such as wettable powders and flowables in a small quantity of diluent prior to addition to spray tank. Thin, watery mixture, such as liquid mud, cement, etc. Fungicides and some insecticides are applied to seeds as slurries to produce thick coating and reduce dustiness.
- **Soil application** - Application of pesticide made primarily to soil surface rather than to vegetation.
- **Soil persistence** - Length of time that a pesticide application on or in soil remains effective.
- **Solubility** - The amount of a substance that can be dissolved in a solvent, usually water.
- **Soluble powder** - A finely ground, solid material that will dissolve in water or some other liquid carrier. Spot treatment - Application to localized or restricted areas, as differentiated from overall, broadcast, or complete coverage.
- Solvent - Usually, a liquid in which other substances are dissolved. The most common solvent is water.
- **Solvent** - A liquid, such as water, kerosene, xylene, or alcohol, that will dissolve a pesticide (or other substance) to form a solution.
- **Spreader** - Ingredient added to spray mixture to improve contact between pesticide and plant surface.
- Sticker - Ingredient added to spray or dust to improve its adherence to plants.
- **Stomach poison** - A pesticide that must be eaten by an insect or other animal in order to kill or control the animal. Surfactant - Ingredient that aids or enhances the surface-modifying properties of a pesticide formulation (wetting agent, emulsifier, or spreader).
- **Suspension** - Finely divided solid particles dispersed in a liquid.
- **Systemic** - Compound that is absorbed and translocated throughout the plant or animal.

T

- **Tank mix** - Mixture of two or more pesticides in the spray tank at time of application. Such mixture must be cleared by EPA.
- **Teratogenic** - Substance that causes physical birth defects in the offspring following exposure of the pregnant female.
- **Tolerance** - Amount of pesticide residue permitted by federal regulation to remain on or in a crop. Expressed as parts per million (ppm).
- **Toxic** - Poisonous to living organisms. Toxin - A naturally occurring poison produced by plants, animals, or microorganisms; for example, the poison produced by the black widow spider, the venom produced by snakes, and the botulism toxin.
- **Trade name (trademark name, proprietary name, brand name)** - Name given a product by its manufacturer or formulator, distinguishing it as being produced or sold exclusively by that company.

U

- **Ultralow volume (ULV)** - Sprays that are applied at 0.5 gallon or less per acre or sprays applied as the undiluted formulation.

V

- **Vapor Density (Vapor Pressure)** - The density of the gas given off by a substance. It is usually compared with air, which has a vapor density set at 1. If the vapor is more dense than air (greater than 1), it will sink to the ground; if it is less dense than air (less than 1), it will rise.
- **Volatilize** - To vaporize.

W

- **Wettable powder** - Pesticide formulation of toxicant mixed with inert dust and a wetting agent that mixes readily with water and forms a short-term suspension (requires tank agitation).
- **Wetting agent** - Compound that causes spray solutions to contact plant surfaces more thoroughly.

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BUREAU OF LAND MANAGEMENT
PESTICIDE APPLICATOR
STUDY GUIDE

PLANT PEST MANAGEMENT

JANUARY 2004

Plant Pest Management

January 2004
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Preface

This manual provides basic information about the correct identification and management of insects, weeds and plant diseases.

Chemical trade names have been used for purposes of simplification, however, no endorsement of specific products is intended, nor is criticism implied of similar products or equipment that is not mentioned.

Introduction

Classification of Living Organisms

Why do many people use complicated, hard to pronounce names when speaking about familiar weeds and insects? Common names such as thistle and beetle, are successfully used in casual communication, and convey an immediate idea of what a particular weed or insect looks like. Scientists avoid using common names because these names are often not specific to a particular species. For example, the term "gopher" is commonly used to describe ground squirrels that are not "gophers" at all! ***Since the single most important step in controlling a pest is to identify the cause of the problem, misidentification wastes time and waste money through the use of inappropriate and ineffective remedies.***

In the 1750's scientist Carl Linnaeus suggested a method of naming things that could be used by scientists all over the world to uniquely describe an organism. He introduced binomial nomenclature, which means two names, both in Latin. For example, *Homo sapien* (humans) or *Centaurea maculosa* (spotted knapweed.) According to tradition, these names must be in Latin or at least "Latinized;" both are written in italics or underlined and the first name (genus) is always capitalized and the second name (species) is generally never capitalized.

The process of ordering organisms into groups is usually based on common characteristics and relationships. Most factors used in classification are structural but biochemical factors (DNA) are also being used.

It is important to know why certain pests are placed into groups based on certain features. For example, some insecticides only work on certain groups of insects. An insecticide that control insects with chewing mouthparts (grasshoppers) may not control insects with piercing or sucking mouthparts (aphids).

All the living things are divided into a series of sets and subsets depending on how closely they are related.

Kingdoms
All living things are first divided into 5 kingdoms - plants, animals, fungi, protozoa, and bacteria.

Phylum and Divisions
All organisms within a kingdom are then divided into groups based on common characteristics. The animal kingdom is subdivided into phyla (pl.), or phylum (s.), while most botanists divide the plant kingdom into divisions.

Class
Phyla (and divisions) are very broad classifications that are further broken down into smaller units called classes. The division of flowering plants contains two classes; the monocots and the dicots. Within the phylum Arthropoda, there is the class Insecta or insects. The class Arachnida contains the spiders, mites, ticks and scorpions.

Orders
Classes are further subdivided into Orders. While Orders are used in taxonomy, they are not always used in weed identification manuals.

Families
Orders are then divided into families. For example, within the order Lepidoptera (the butterflies) there are about 90 families. The order Coleoptera (beetles) contains the weevil family (Curculionidae). Many weeds are in the sunflower family (Compositae or Asteraceae).

Species or Scientific Name
The species name is composed of two Latin names: the **genus** (genera pl.) which describes a group of closely related or ecologically similar species, and a specific name (technically called a specific epithet) that further identifies the species.

Pests and Pest Management

A pest can be defined as any organism that causes economic or aesthetic damage to humans or their property. Examples include exotic weeds that displace native vegetation, deer mice (*Peromyscus maniculatus*) that carry the deadly hantavirus, and gypsy moths (*Lymantria dispar*) that defoliate oaks (*Quercus spp*). Pests can be classified as key pests, occasional pests or secondary pests.

Key Pests	Occasional Pests	Secondary Pests
Cause major damage on a regular basis. Example: An 80% infestation of leafy Spurge can reduce livestock carrying capacity by 100%. Grasshoppers consume up 25% of the available forage in the western United States annually.	Become intolerable on an irregular basis. Often as a result of climate environmental influences, or human activity. Example: Dry conditions can cause seed bugs to move from rangeland to areas of higher moisture like lawns, flower beds, swimming pools and houses.	Occur as a result of actions taken to control a key pest. Example: Cheatgrass establishment in areas that have been sprayed for spotted knapweed. Ticks and fleas that plague people after their natural hosts have been eliminated.

Pest management practices are often described according to the approaches used to deal with a pest problem. These approaches include:

Prevention – Prevention is action that is taken to thwart the occurrence of a significant pest problem. This approach may include either chemical or non-chemical methods. Planting weed- and disease-free seed and growing varieties of plants that resist diseases, insects or weeds is just one method of prevention. Other control options include using cultural methods to prevent weedy plants from seeding or choosing planting and harvesting times that minimize pest problems. Other prevention methods include exclusion which is the act of preventing pests from entering a target area. Exclusion includes the use of fences to prevent weed-seed-carrying wild or domestic animals from entering non-weed infested areas.

Suppression – Common pest control methods suppress pest populations but usually do not eliminate them. These methods reduce pest numbers below an economic injury threshold or to a tolerable level. Suppression sometimes lowers pest numbers so that natural enemies are able to maintain control. Suppression is the goal of most pesticide applications used to manage weeds, insects and diseases. Post emergence application of herbicides to reduce emerging weed populations is regarded as suppression. Spraying mature spotted knapweed plants with 2,4-D may not kill the mature plants but it will limit seed production and possibly kill younger more susceptible plants.

Eradication - When a pest problem must be totally eliminated from a designated area, the approach is termed eradication. If a new pest such as the Mediterranean fruit fly is detected in a fruit growing area, regulatory agencies may implement widespread actions to totally eliminate the pest problem before it becomes established to a point that it can no longer be eradicated. Over larger areas, eradication is a radical approach to a pest problem and can be very expensive and often has limited success. In general, eradication does not work towards the elimination of an established pest population that is spread over a large area.

Which pest control strategy you choose depends on the nature of the pest, the environment of the pest, and economic considerations. Combining prevention and suppression techniques usually enhances a pest management program. However, objectives might differ for the same pest in different situations. Eradication of spotted knapweed in most of western Montana is not feasible where eradication in parts of eastern Montana where the weed is not prevalent is justifiable.

Establishing A Pest Management Program

There are many ways to manage pests. Whenever possible, it is best to combine several methods into an integrated pest management program. Pest management practices include:

Biological Control - Biological control generally includes the manipulation of one biological organism to control another pest organism. Most insect pests are attacked by bacterial, fungal or viral pathogens. Specific weeds may be controlled by insects with specialized feeding habits.

When a non-native pest is found in a given area, it may be assumed that the biological organisms that regulated its population in its native environment are lacking. In such a situation, the **classical** approach of biological control is employed to (1) determine the pest's native home, (2) locate beneficial organisms that naturally control the pest organism in its native area, and (3) if feasible, import, multiply, release and establish the beneficial organisms in the problem area to facilitate biological regulation of the pest problem. If successful, the importation and establishment of the beneficial organisms will result in a long-term reduction of the pest problem and repeated releases of the beneficial organisms will not be required.

When existing or already-introduced beneficial biological organisms are mass-reared and released periodically to supplement the naturally occurring or classically-introduced biological agents, the approach is called **augmentation**. The mass-rearing rearing of yellow-winged knapweed rootmoth (*Agapeta zoegana)* and the knapweed root weevil (*Cyphocleonus achates)* in cages prior to release is an example of augmentative biological weed control.

Pest populations can also be maintained by a number of native, **naturally-occurring** predators, parasites and diseases. If such forces were not in effect, we would be overrun by pests. The balance of pest populations and their natural enemies can be significantly influenced by cultural practices and the use of chemicals. Populations of natural enemies can be enhanced by selective use of cultural practices or decimated by the indiscriminate use of pesticides. In some cases, pesticides have been developed that effectively control a pest population without having a significant effect on beneficial species.

Chemical - Pesticides are the most readily recognized method of pest management. The range of risks and benefits attributed to pesticides will remain a key issue of society. The use of pesticides will remain as a dominant method to be incorporated in future pest management programs.

Cultural & Mechanical - With the development of pesticides, the relative impact of various cultural and mechanical practices on pest populations has often been overlooked. As public interest in environmental issues expands, the impact of cultural and mechanical pest management practices is receiving greater attention. Crop rotation, tillage practices, barriers, traps, and other forms of environmental modifications all influence the incidence of pest problems.

Legal - Regulatory actions are often employed to prevent immigration of foreign pests or to prevent the dispersal of already established pests. Some governmental entities prohibit the movement of fill from weed infested gravel pits. Imported animals are often held in quarantine for a period of time to allow inspection for pests and diseases.

Integrated Pest Management (IPM)

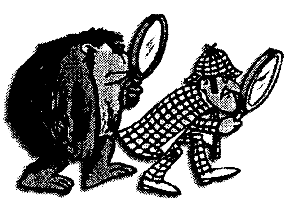
IPM is a pest control strategy that uses a combination of techniques to reduce pest populations to economically acceptable levels. IPM focuses on the long-term prevention or suppression of pest problems. IPM uses cultural, biological, physical, and mechanical methods in site-specific combinations. With IPM, pesticides are used only when careful field monitoring, based on economic threshold levels, indicates they are needed. Pesticides are then selected on the basis of their effectiveness and toxicity. The main aim of IPM is to control only the harmful pests without affecting beneficial and non-target organisms, human health and the environment.

The IPM Process

Integrated pest management offers the possibility of improving the efficacy of pest control programs while reducing some of the negative effects. Many successful IPM programs have reduced energy and pesticide usage. Consider the following factors when developing any IPM program.

1. Proper **pest identification** and **field scouting** are is the **first two most important steps** in an IPM program. Correct pest identification is critical to future success. Misidentification leads to mismanagement. When identifying a pest, it is important to know:
    - Correct pest identity.
    - Pest biology and life cycles. How the pest reproduces and multiplies.
    - The most susceptible stage in the life of a pest.
    - How the pest grows under specific conditions.
    - How the pest survives and lives.
    - How the pest spreads.
    - What are the effects of environmental factors on the pest?
    - In case of insects and disease, what are the damage symptoms?
    - What are the natural enemies?

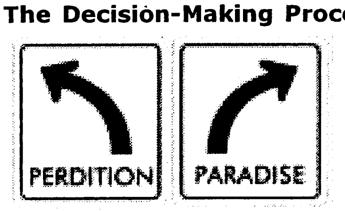
2. **Field Scouting** is systematic sampling of the pest populations and recording the pests.



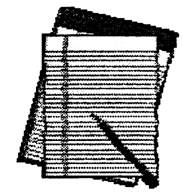
    - Weeds-- number per given area (density) and pattern in the field.
    - Insects--stage or size, symptoms and level of damage on the crop and symptoms and level of damage.
    - Disease--severity, symptoms and level of damage.

3. **IPM Tactics**. An IPM program revolves around prevention and control strategies. Prevention involves (1) encouraging natural enemies of the pest, (2) monitoring pest populations and other relevant factors, and (3) using resistant crops before pest numbers increase and cause economic damage. Control strategies may involve many control combinations.

4. **The Decision-Making Process**. Control action guidelines help decide whether management actions are needed to avoid losses from pest damage. Injury levels (sometimes called **economic** or **aesthetic injury levels**) establish the amount of pest damage that occurs from given pest densities. The **treatment or action threshold** indicates when management actions are needed to avoid losses. Guidelines for insect pests are generally numerical thresholds based on specific sampling techniques and are intended to reflect the population level that will cause economic damage if no action is taken. For example, the economic threshold for grasshoppers in rangeland is reached when there are 15 to 20 grasshoppers nymphs per square yard. Guidelines for other pests, including weeds and pathogens, are usually based on the vegetative history of the area, weather conditions and other observations. Defining an aesthetic injury level on which most people will agree is difficult and subjective. Defining economic thresholds for rangeland weeds is more difficult and may be based upon more practical experience and judgment than on refined mathematical models. In cropland, the economic threshold can be computed if you know (1) the cost of applying a pesticide, (2) labor and machinery costs, (3) future commodity prices of the crop, (4) the expected pest free yield, (5) the expected level of pest control and (6) the expected yield losses as determined by research.



5. **Keeping Detailed Field Records** is a must in IPM programs. Successful implementation of IPM tactics includes keeping records on the following:
    - Any relevant cropping or re-vegetation histories--variety, seeding date, fertilization (timing, rate and type), seed treatment (rate and type), tillage system (reduced or conventional)
    - Timing and date of any pest control methods, environmental conditions before, at, and after the treatment
    - Past, present and future re-vegetation plans
    - Pesticide use history
    - Results of the pest management practices
    - Any relative yield results.



6. **Evaluating your results.** A regular evaluation program will help to determine the success of pest management strategies. A critical evaluation will tell you what worked and what didn't. In addition, pest populations can also change which then calls for different strategies. It is important to note that a good evaluation is tied to good keeping good records. You should also develop a standard recordkeeping system to help you modify and continually fine-tune the IPM program. When evaluating an IPM program you must ask yourself:
    - Did IPM work?
    - What went wrong and what went right.
    - Was the pest properly identified?
    - Was the field sampling unbiased? What was the pest activity before and after implementation of IPM strategies.
    - What changes to the system would make it better? Consider all components of the IPM system including monitoring, action thresholds, and treatment options for overall effectiveness.
    - Was the choice of control based on sound judgment or outside pressure?

One of the Bureau of Land Management's (BLM) highest priorities is to promote ecosystem health. One of the greatest obstacles to achieving this goal is the rapid expansion of noxious weeds across public lands. Legally, a noxious weed is any plant designated by a Federal, State or county government as injurious to public health, agriculture, recreation, wildlife or property. A weed is a weed because it possesses certain definable characteristics that set it apart from other plant species. These characteristics include: (1) abundant seed production, (2) rapid population establishment, (3) seed dormancy, (4) long term survival of buried seeds, (5) adaptations for rapid spread, (6) presence of vegetative reproductive features, and (7) capacity to occupy sites disturbed by human activity.

Because of these features, weeds are better described as plants that are competitive, persistent and destructive. They interfere with human activities and as a result are undesirable.

Relatively few plants have the characteristics that make them true weeds. Of the total number of plants in the world (about 250,000 species) only 3% or 8000 are thought to behave as weeds. Of the 380 flowering plant families, 16 contain most of the most troublesome weeds.

Plant Families of Common Weeds

Plant Family	Representative weeds	General Identifying Characteristics
Amaranthaceae	Pigweeds	Prolific seed producers. Flowers in dense spikes. Spiny-like flowers
Asclepiadaceae	Milkweeds	Milky sap, covered with fine hairs
Asteraceae or Compositae	Thistles, knapweeds, hawkweeds, sagebrush, rush skeletonweed	Flowerhead with many small tube-like flowers clustered on a common base, with an outer row of strap-shaped flowers in some species.
Caryophyllaceae	Chickweeds	Round stem and leaves appear to be in whorls (circles) around the plant stem
Chenopodiaceae	Goosefoot, lambsquarter, kochia, Russian thistle, fourwing saltbush	Flowers are tiny and inconspicuous, but some species bear showy masses of fruits. Sometimes reddish coloration.
Convolvulaceae	Dodder, field bindweed	Trailing or climbing vines. Often have heart-shaped leaves and funnel-shaped

		flowers.
Cruciferae	Mustards, whitetop	Alernate leaves, and small four-part flower in white, yellow or purple
Cyperaceae	Nutsedges	Triangle-shaped solid stems
Euphorbiaceae	Spurges	Milky sap
Gramineae (Poaceae)	Grasses, cheatgrass, jointed goatgrass	Slender leaves with parallel veins
Leguminosae	Locoweeds, lupines	Compound leaves and flowers are typical pea blossom shape
Polygonaceae	Docks, knotweeds, wild buckwheat, smartweeds	Stem has a paper-like collar at the base of each leaf
Rosaceae	Cinquefoils, wild rose	Rose-like flowers, thorns
Scrophulariaceae	Toadflaxes, mullein	Snapdragon-like flowers; petals sometimes joined together, forming the shape of a bell.
Solanaceae	Nightshades, horsenettle, potatoes, tobacco, eggplant	Sometimes creeping. Five petals and 5 stamens in flower.
Umbelliferae	Poison hemlock, water hemlock, Queen Anne's Lace, wild carrot.	Flowers in umbrella-shaped clusters. Hollow stems. Fern-like leaves.

IPM and WEED MANAGEMENT

In recent decades there has been an increasing use of Integrated Pest Management (IPM) in weed control. One of the main motivations for using Integrated Weed Management (IWM) has been societal pressure to reduce or even eliminate the use of chemical methods of weed control, i.e. herbicides.

How is the concept of IPM applied in controlling weeds in pastures and rangelands? First, the land manager should carefully examine the area to determine whether or not the degree of weed infestation is serious enough to require human intervention. For example, a pasture does not need to be a monoculture, that is, completely one species. A monoculture crop, like wheat and barley, is dictated by the market demand. However, a pasture may actually be more productive with several species present. In addition, some weeds may be reasonably nutritious to livestock. As long as a weed is not eliminating the main forage crop and is not poisonous to livestock, it may be acceptable to tolerate a certain level of the weed. Finally, the land manager must balance the economic loss due to weeds against the cost of controlling the weeds – the economic threshold.

Applying the concept of economic threshold to a real world situation requires an understanding of weed ecology as well as the true economic value of the forage crop. In the case where a new, highly competitive weed (e.g. leafy spurge) invades a forage stand, the economic threshold is reached immediately. In other words, this weed must not be allowed to reproduce because once established it will be extremely expensive to control in future years. When dealing with weeds that are not aggressively spreading, are not poisonous, and are reasonably nutritious to livestock, a higher density of weeds may be tolerated before any control measure is implemented.

Insects are within the phylum Arthropoda meaning "jointed foot." Arthropods range in size from the king crab with its 12-foot armspan to microscopic insects and crustaceans. The Phylum Arthropoda also includes spiders, crayfish, millipedes and similar animals. The basic body plan of arthropods is fairly consistent. Arthropods have a stiff outer shell (exoskeleton, cuticle) composed largely of chitin, a natural carbohydrate polymer. It is the presence of this exoskeleton that differentiates the arthropods from all other phyla. The exoskeleton provides support and protection. In order to grow, arthropods must shed the exoskeleton or molt.

The various groups within the arthropods are distinguished from each other by the arrangement of their body parts. Insects are land animals with 3 pairs of jointed legs. The word "insect" comes from a Latin word which means "to cut into." This describes how the bodies of insects are divided into distinct regions: head, thorax and abdomen.

Insect Life Cycles

Understanding insect life cycles is important for management of pests. Many insects are easy to manage during one or two of their life stages. Pesticides may not be effective against insect eggs or adults, while the soft immature insect larvae or instars may be easily killed. Therefore it becomes important to recognize insect pests in immature stages of their life cycle. The series of changes through which an insect passes in its growth from egg to adult is called **metamorphosis**.

What differentiates between insect life cycles is the degree of metamorphosis the insect undergoes in its journey from an egg to an adult. All insect life cycles start with an egg, and end with an adult insect. The question that distinguishes the two different paths is really; is there or is there not a pupa?

Gradual, incomplete or simple metamorphosis

Insects in this group pass through three different stages of development before reaching maturity: egg, nymph, and adult. The nymphs resemble the adult in form, eat the same food, and live in the same environment. After feeding for a time, the young grows to a point where the skin (exoskeleton) cannot stretch further; the young sheds its skin (molts) and new skin is formed. The number of these developmental stages (called instars) varies with different insect species and, in some cases, may vary with the temperature, humidity, and food supply. The heaviest feeding generally occurs during the final two instars. The change of the body is gradual, and the wings become fully developed only in the adult stage. Examples are grasshoppers, cockroaches, boxelder bugs, lice, termites, aphids, and scales.

Complete metamorphosis

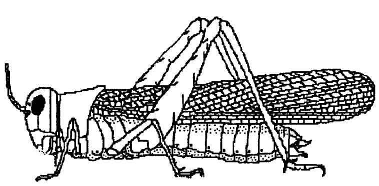
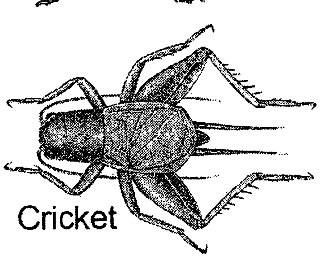
The insects with complete metamorphosis pass through four stages of development: egg, larva, pupa, and adult. The young are called larvae, caterpillars, maggots, or grubs and are entirely different from the adults. They usually live in different situations and in many cases feed on different foods than adults. Examples are the beetles, butterflies, flies, mosquitoes, fleas, bees, and ants. The army cutworm larvae cause serious damage in small grains while the adults, known as miller moths, are not considered destructive pests at all. Grizzly bears actually consume the adult miller moths in the absence of high quality forage during July and August.

Larvae hatch from the egg and grow larger, passing through one to several instar stages (called molting). Moth and butterfly larvae are called caterpillars and some beetle larvae are called grubs. Most fly larvae are called maggots. Caterpillars often have legs but maggots and weevil grubs are legless. Beetle larvae usually have three pairs of legs. The pupa is a resting stage during which the larva changes into an adult with legs, wings, antennae, and functional reproductive organs. Some insects form a cocoon during this stage.

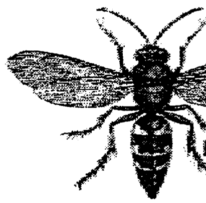
The mature (adult) stage is when the insect is capable of reproduction. Winged species develop their wings at maturity. In some species, mature insects do not feed, and in some species the adults do not feed on the same material as the immature forms.

Identifying The Major Orders of Economically Important Insects

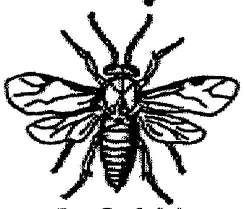
The class Insecta contains many economically significant orders (at least 29), seven of which will be discussed here.

Order Orthoptera – Grasshoppers, Crickets, Cockroaches and Cicadas	
  Cricket	**Adults:** Adults with two pairs of straight wings. The forewings are leathery with many netlike veins. The under wings are membranous and fan-shaped when expanded. The adults are often 1 inch long or longer, with appendages at the end of the abdomen called cerci. Hind legs of many species (with the exception of walking sticks and cockroaches) are enlarged for jumping. **Mouthparts:** Both adults and nymphs have chewing mouthparts and cause damage. **Larvae**: None. The adults and nymphs resemble each other. **Life cycle:** Gradual or simple metamorphosis. **Comments:** While there are a great number of grasshopper species, only about eight to 10 of these ever reach populations which could be considered economic. Some species, in fact, are beneficial. Species of the genus *Hesperotettix* also feed on undesirable forbs and shrubs and *Melanoplus packardii* feeds on thistles. In Great Plains rangelands, grasshopper densities tend to increase with drought and grazing intensities, and severe local outbreaks can occur every year. Major grasshopper outbreaks tend to occur during hot, dry weather cycles which lead to drastically reduced range vegetation and increased grasshopper numbers. The grasshoppers then compete with livestock and wildlife for the remaining vegetation.

Order Hymenoptera – Bees, Wasps, Hornets, Ants, Sawflies



Hornet



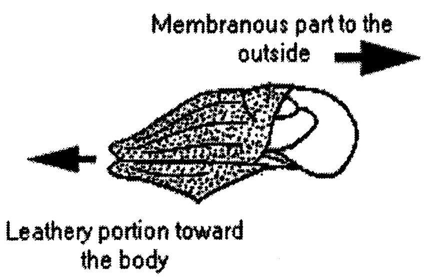
Sawfly Adult

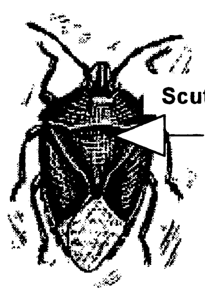
Adults: Adults have two pairs of membranous wings. Hind wings usually smaller than front wings, linked together by small hooks. Narrow junction (wasp waist) between thorax and abdomen - except in sawflies and horntails. Adult sawflies are wasp-like, except they have heavy bodies that are not constricted at the waist.
Mouthparts: Most have chewing mouthparts both as adults and as larvae - except in bees where the mouthparts form a proboscis for collecting nectar.
Larvae: The larvae lack legs, except for the sawfly larvae which resemble caterpillars. Sawfly larvae have legs on both their thorax and abdomen.
Life cycle: Complete metamorphosis.
Comments: This group also contains a large number of species. Many are important pollinators of agricultural crops, such as the honey bee, leafcutter bee, and alkali bee. Some are important predators or parasites and scavengers; some of the others may be injurious to crops.

Leafcutting bee adults are about 1/2 to 3/4 inch long and variable in color. They are noted for their long tongues, which allow them to pollinate crops such as alfalfa. The leafcutter bee gets it name from the fact that it cuts neat circles from the leaves of shrubs and trees. It uses these pieces of leaf to create a snug chamber for its larvae.

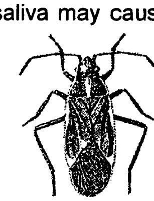
Ants also belong to the order Hymenoptera. Some common ants found in houses include carpenter ants, the pavement ant, the odorous house ant, and the southern fire ant. Ants tend to feed on other insects, and thus are beneficial predators.

Order Hemiptera – True Bugs (big-eyed bugs, plant bugs, assassin bugs)





Adults: Have two pairs of wings. The top pair are thickened or leathery at the base and membranous at the tips (hemi = half, ptera = wing). The under wings are membranous. True bugs have a triangular plate centrally located between the thorax and abdomen on the back called a **scutellum.** Many have glands that produce odors when the insects are threatened.
Mouthparts: Adults and nymphs both have piercing and sucking mouthparts, and both cause damage in plant-feeding species. Other species of true bugs are predators.
Larvae: None. The adults and nymphs resemble each other.
Life cycle: Gradual or simple metamorphosis.
Comments: Kissing bugs or cone-nose bugs are medically important true bugs that feed on blood. Normally found associated with pack rats, they may enter houses where they bite humans at night. The proteins in the saliva may cause allergic reactions in some individuals. Other true bugs that enter houses are often mistaken for kissing bugs, and alarm homeowners. Box elder bugs for example. Stink bugs are shield-shaped bugs about 1/2 inch to 1 inch long, so-named because they produce a variety of odors when captured. Some species are predaceous (feed on other insects) and others are plant feeders, so it is important to have them identified. Predatory true bugs include big-eyed bugs, minute pirate bugs, assassin bugs, ambush bugs and damsel bugs.



Boxelder bug

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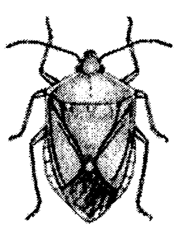
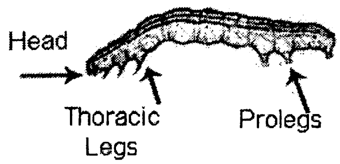
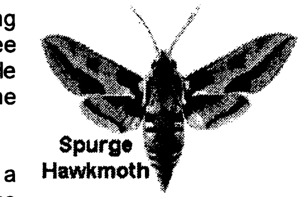


Order Lepidoptera – Butterflies, Moths



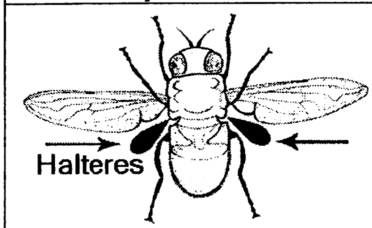
Lepidotera Larvae

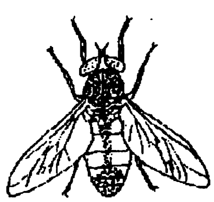
Adults: Adults are soft-bodied with four well-developed membranous wings covered with small scales.
Mouthparts: Adults have a coiled, sucking tube (proboscis) for feeding on nectar or no mouthparts at all.
Larvae: The larvae are called caterpillars. They are worm-like in shape and some are quite colorful. They have chewing mouthparts, and are voracious feeders. Larvae have three pairs of true legs on the thorax (thoracic legs) and a variable number of fleshy appendages called prolegs on the abdomen.



Life cycle: Complete metamorphosis
Comments: The spurge hawkmoth, *Hyles euphorbiae,* is a defoliator of leafy spurge, a noxious weed. Some moths commonly found in the West are cutworms, that feed on many crops. The cabbage looper is found on cole crops. The larva moves its rear end to meet its head as it crawls and loops foreword, giving it the name "looper."

Order Diptera – House Flies, Horseflies, Mosquitoes, Fruitflies, Midges and Gnats





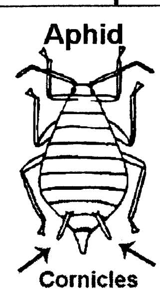
Horsefly

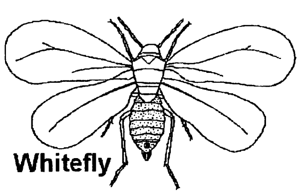
Adults: Adults have one pair of wings (di = 2, ptera = wings). Adult flies have one functional pair of wings and one small pair called halteres that are used for balance.
Mouthparts: Adults have sponging (house fly) or piercing (mosquito) mouthparts.
Larvae: Larvae may have mouth hooks or chewing mouthparts. Most larvae don't have legs, or a head capsule and commonly are called maggots.

Life cycle: Complete metamorphosis.
Comments: Fly larvae or "maggots" are generally found in manure, spilled feed, and other wet, decaying organic matter. Other medically important species, such as bot flies, are parasites of animals as larvae. The activities of some flies, like the horn fly, disrupt or annoy livestock to the extent that the animal stops feeding, causing economic losses for farmers.

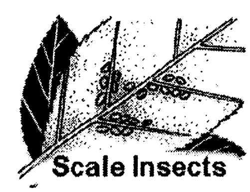
On the other hand, flies may be beneficial because they may be parasites of insect pests. For example, there is a fly that lays its eggs in gypsy moth larvae. The fly larvae feed within their host until they reach maturity, and pupate. The host is eventually killed. Many flies are excellent pollinators of flowering plants. *Urophora affinis,* a seedhead fly, was first released in the United States in 1971. as part of a program to control spotted and diffuse knapweed

Order Homoptera – Scales, Whiteflies, Mealybugs, Spittlebugs and Aphids



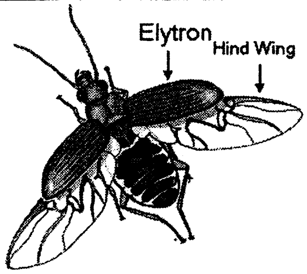


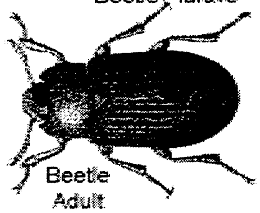
Adults: Soft-bodied insects. Some adult forms have wings, others do not. Aphids have small pear-shaped body, tip of abdomen has two short projections **(cornicles)**, some individuals have wings
Mouthparts: Sucking mouthparts.
Larvae: None. The adults and nymphs resemble each other.
Life cycle: Gradual or simple metamorphosis.

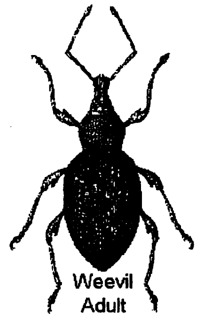


Comments: Many carry plant pathogens that are transmitted during feeding. Most species excrete a sugary residue called honeydew, which in turn leads to sooty molds. Scale insects are often hard to recognize because they do not look like insects at all. They are flattened, circular or ovoid bumps covered by a waxy or hardened scales. Most aren't serious pests, although they may cause unsightly blemishes. Because they suck plant juices, aphids cause chlorosis (a yellowing of the green tissue) or cause a plant to appear puckered. Whiteflies are not flies at all, but close relatives to scales and aphids. The immatures are flattened, scalelike forms that suck juices from the undersides of leaves. The adults are about 1/16 of an inch long and are covered with a white, waxy powder. Mealybugs are oval, flattened insects that cluster on the stems of a variety of houseplants, and also a few landscape plants. They are soft-bodied insects, often pinkish in color with a covering of white, powdery wax. They also suck plant juices, which may slow plant growth or cause wilting.

Order Coleoptera – Beetles and Weevils







Adults: One pair of hardened outer wings (forewings) called elytra, pl. (elytron, s.) that covers an inner pair of membranous wings. This gives them a "shell-like" appearance, and an (A few beetles are practically wingless, or lack the inner wings). Adult weevils cannot fly. Adults beetles have noticeable antennae. Adult weevils usually have antenna attached to snout.

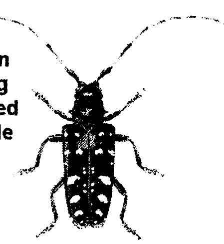
Mouthparts: Chewing mouthparts. Weevils have chewing mouthparts usually at the end of a long snout

Larvae: Sometimes called grubs. They have a hardened head capsule, and 3 pairs of legs on the thorax (thoracic legs). (Some weevil larvae lack legs). Note: lepidoptera larvae have 3 sets of thoracic legs and 3 to 5 sets of prolegs.

Life cycle: Complete metamorphosis

Comments: The order Coleoptera contains the most species of all the insect orders. Over 600,000 different species of beetles have been identified.

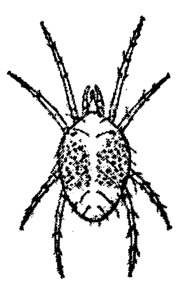
Asian Long Horned Beetle



A serious pests of hardwood trees, Asian long horned beetles are named for their long antennae as adults. Cereal leaf beetle is an economically important pest of small grains. Important beneficial species include the lady beetles, ground beetles, and tiger beetles. Lady beetles are about 1/4 inch long and are usually red or orange, generally with spots. Lady beetles are beneficial as larvae and adults, since they feed on aphids and other soft-bodied insect and mite pests. The *Apthona* species of flea beetles are a known biological control of leafy spurge, a noxious weed.

Weevils are the largest family of beetles. Weevil pests include the alfalfa weevil, the rice weevil in wheat and the clover leaf weevil of alfalfa. Beneficial weevils include the root boring weevil, *Cyphocleonus achates*, and the seedhead weevil, *Larinus minutus*, that are used for the biological control of spotted and diffuse knapweed.

MITES



Spiders, mites, ticks and scorpions are literally in a class all their own; class Arachnida. These organisms are not insects in the truest definition and most people still call them bugs

While insects have three body regions, arachnids have two body regions. Insects have three sets of legs (6 total); arachnids have four pairs of legs (8 total). Most insects are winged and have antennae; arachnids are wingless and have no antennae.

Mites are the most diverse and abundant of all arachnids, but because of their small size (usually less than a millimeter in length) we rarely see them. Many mites found on agricultural crops are major economic pests (spider mites in crops, varroa mites in honeybees) or useful biocontrol agents that attack other detrimental mites.

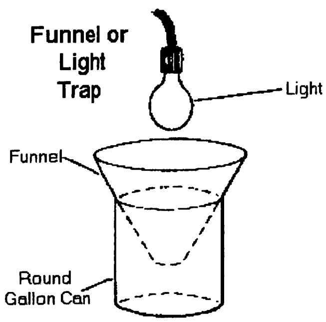
Insects and Integrated Pest Management

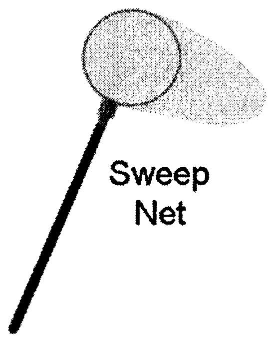
Establishing an IPM program to control insect pests requires an understanding of the growth habits of the plant and its cropping system, knowledge of the biology, behavior, life history and type of damage caused by potential pests, and information regarding the plant growth stage or environmental conditions under which pest damage is most likely to occur. Accurate pest identification is important.

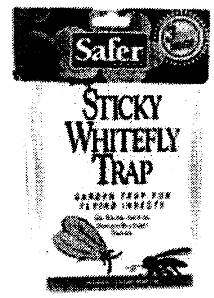
Most terrestrial ecosystems are inhabited by a diverse array of organisms including insects, spiders, mites and small animals. Most of these cause little or no damage and are generally considered non-pests. Others are beneficial and aid in the breakdown of organic matter, pollination of crops, or serve as natural enemies of pests.

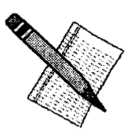
Of all the insects and mites, relatively few are actually plant-feeding pests. Because of the wide diversity of species present and the many similarities between pests and non-pests, it is important to be able to distinguish incidental and beneficial species from target pests. This is why it is important to know the basic identification characteristics of both plants and insects.

In a successful IPM program, pests are detected before they reach damaging levels. This can be accomplished through frequent inspections. When examining plants, look for natural enemies of pests, such as lady beetles, lacewings, spiders, or parasitic wasps that may be reducing pest populations. Insect monitoring aids include magnifiers, drop cloths, sweep nets, sticky traps, and light and pheromone traps.









Good record-keeping is essential to make maximum use of information obtained during plant inspections. Record the information in a quantitative fashion. For example, record the number of insects found per plant or leaf, rather than recording "many" or "few". After the growing season, review this information and plan to improve your pest management next year. You may detect certain patterns, such as more damage or pests on certain varieties or certain planting dates. Use this information next year to minimize pest problems. Good record-keeping allows you to know when to expect certain pest problems and plan to deal with them. Also, information from regular inspections will allow you to evaluate which control practices are effective and which need to be modified.

Insect Management Alternatives

IPM combines complementary strategies to effectively manage pest populations. Descriptions of many of these pest management strategies are described below.

Cultural Methods

Cultural methods involve manipulating the environment to make it less suitable for pest survival. Use of cultural measures requires a thorough understanding of the life history and habits of the pest. The most vulnerable stages in the pest's life history must be identified, with cultural practices altered to minimize attack by the pest, slow its rate of increase, or destroy it.

Selection of Plant Materials. Choose plant materials that are well adapted to local soil and environmental conditions. Planting insect resistant varieties is another valuable IPM tool. Many plants have been found to have some natural resistance to insect pests, although the degree of resistance may vary considerably from one species or cultivar to another.

Crop Rotation. Rotating the location of garden crops will not affect the incidence of foliar-feeding insects, but may reduce damage caused by soil-inhabiting pests such as wireworms, white grubs, beetles, corn rootworms, millipedes and some cutworms. Avoid planting root crops into areas recently infested with soil insects or into plots that were not cultivated or were in sod the previous year.

Sanitation. Many insect and mite pests seek shelter or attempt to overwinter in plant residues. Overwintering forms include eggs on dead leaves, adults in plant stems or under crop residues, and larvae or pupae in plant stems or in the soil. Removing dead branches or canes from trees and shrubs and raking and composting leaves, grasses and other plant debris helps eliminate many overwintering sites.

Cultivation. Keep crop areas weed-free. Many weeds serve as a reservoir for insects such as flea beetles, grasshoppers, leafminers and aphids which may later move to crops. Use fall and spring cultivation to incorporate compost or crop residues and expose soil-dwelling insects to natural enemies and the weather.

Variation in Time of Planting or Harvest. This strategy involves growing the crop when the pest is in a growth stage where it can do the least harm or planting the crop so that the most susceptible stage of crop occurs when the pest is least abundant.

Intercropping and Companion Planting. Intercropping refers to planting two or more crops in adjacent plots to slow the spread of pests and to provide habitat for natural enemies. This practice provides some isolation of pest infestations and can reduce the spread of damaging pest populations. Also, isolated pest infestations are generally easier to manage. Companion planting involves growing certain types of plants to protect neighboring crops by repelling or confusing insect pests. Scientific research in this area is limited, but when evaluated under controlled conditions, companion planting does not appear to consistently repel insects or provide other benefits.

Mulches. Exercise caution in the use of heavy mulches during the growing season. Thick mulches of plant material will encourage the development of potentially damaging pests such as white grubs, millipedes, sowbugs and cutworms. However, a light mulch of straw or shredded plant material will conserve moisture. Apply plant residues and compost in the fall and deeply till into the soil. Increasing the organic content of soils helps retain moisture and improve fertility.

Water and Fertilizer Management. Adequate fertilization and watering encourages healthy, vigorous plant growth. Although these practices do not prevent insect infestations, they tend to promote healthier growth and a more vigorous plant that is better able to tolerate pest damage.

Mechanical/Physical Methods

Mechanical/physical pest control methods include hand removal; use of screens, barriers, or trapping devices; freezing; crushing; and grinding. They are the oldest, and in some cases, the simplest of all insect control methods. These tactics differ from cultural control measures because they are directed against the pest itself rather than the pest's environment.

Hand Removal. Remove large or readily visible insects by hand and destroy, or dislodge pests into a can containing a small amount of water and detergent. The egg masses of many insects can be scraped off or smashed. Hand removal requires considerable time, however, and may not be feasible for heavy infestations or larger landscapes.

Exclusion Using Screens and Barriers. Cardboard or metal collars placed around transplants or container plants will reduce the risk of cutworm and millipede damage. Sticky bands placed around tree trunks will reduce infestations of spring cankerworm and elm leaf beetles.

Trapping. Various kinds of traps can be used to monitor insect abundance, and in some cases, help reduce pest numbers. Yellow sticky traps are highly attractive to whiteflies, aphids, thrips, leafhoppers and other small flying insects, and are used by some commercial greenhouses for insect control. In outdoor settings, traps placed near susceptible plants may capture some invading insects before they can damage the plant. Other trapping devices, used largely against fruit flies and caterpillars, use pheromones or attractive scents to lure flying adult stages to their sticky surfaces. They are better used as monitoring tools than control measures.

Biological Methods

This important IPM strategy uses beneficial organisms including predators, parasites or insect pathogens to reduce pest populations. It can be implemented by releasing beneficial organisms into the landscape or garden, or by modifying cultural, chemical and other control practices to conserve existing natural enemies.

Beneficial Insects and Mites. Natural populations of predators (e.g., lady beetles, lacewings, syrphid flies, praying mantis, wasps, and predaceous mites) and parasites (e.g., parasitoid wasps and tachinid flies) are valuable in reducing infestations of insect and mite pests. If these or other beneficial organisms are observed, take care to insure their survival. If pest suppression becomes necessary, select control measures which minimize injury to beneficial organisms, while still providing satisfactory control of the target pest. Remember that a low level of pest infestation may need to be tolerated to attract and maintain natural enemy populations.

Birds. Attract insect-eating birds and small mammals to areas by planting trees and shrubs that provide cover and furnish berries for food. Birds also can be encouraged by providing water or nesting sites. Remember, however, that some bird species are destructive to crops and may do more harm than good.

Disease-Causing Microorganisms. Disease-causing organisms or their products also can be used to suppress insect populations. Among the microorganisms known to attack insects are bacteria, fungi, viruses and protozoans. Generally, sustained warm and humid conditions favor the development and effectiveness of these organisms as pathogens. *Beauveria bassiana* is a fungus which causes a disease known as the white muscadine disease in insects. When spores of this fungus come in contact with the cuticle (skin) of susceptible insects, they germinate and grow directly through the cuticle to the inner body of their host.

Nematodes. Certain species of nematodes (microscopic worms) that only attack insects are available commercially. Because of their origin as soil organisms they are most suitable for use against soil insect pests (cutworms, white grubs, etc.). Nematodes are living organisms; extremes of temperature, moisture, or exposure to ultraviolet light can greatly decrease their survival. Survival is increased (and thus control is increased) if nematodes are applied to moist soil late in the day and irrigation is applied after nematode application. Maintaining adequate soil moisture after application also will improve nematode survival. Efficacy against different pest insects may vary widely with different nematode species and strains. New species and strains continue to be isolated from the soil.

Chemical Methods

Many important chemical control methods are available, including attractants, repellents, sterilants and growth regulators for pest suppression. Insecticides and acaricides (pesticide used to kill mites) are probably the most powerful tools available for insect and mite control. In many cases, they are the only practical method of reducing insect populations that have already reached threshold levels. Insecticides have rapid curative action in preventing pest damage and offer a wide range of properties, uses and application methods. They are relatively inexpensive, and may provide substantial financial or aesthetic benefits. Potential problems associated with insecticide use include:

- the development of pest resistance,
- outbreaks of secondary pests,
- adverse effects on non-target organisms including humans and beneficial insects,
- hazardous residues in our food supply, and
- ground water contamination.

Insecticides are classified according to their origin. Among the more common classes of insecticide are the inorganic compounds, plant-derived botanicals, microbial-based insecticides, petroleum oils, insecticidal soaps and the synthetic organic compounds. Included among the synthetic insecticides are the chlorinated hydrocarbons (Kelthane, lindane, methoxychlor), organophosphates (diazinon, Dursban, malathion), carbamates (Sevin) and synthetic pyrethroids (permethrin, resmethrin).

When insecticides are used in an IPM program, they should be carefully selected and their application timed with respect to the developmental stages of both target pest and crop. Proper selection and timing of pesticide applications are extremely important in obtaining the best possible control with the least effect on the environment. Always carefully measure pesticides and follow all label instructions.

Many compounds with insecticidal properties can be derived from natural products. Because these materials are not "man-made", many advocates of an "organic" approach find them acceptable for pest control. The following are some of the more commonly used non-synthetic materials. Most of these products have some level of toxicity to humans and can be highly destructive to beneficial insects.

Bacillus thuringiensis, commonly called "Bt", is marketed under a number of trade names including Dipel, MVP and Steward. When certain species of insects ingest the spores of this common soil-inhabiting bacterium, the action of a bacterial toxin on the digestive tract causes the insect to stop feeding, sicken and die within four to seven days. Until recently, control with this microbial insecticide has been limited to caterpillars of certain butterflies and moths, and to mosquito larvae, but strains of Bt are now available for control of some leaf-feeding beetles such as Colorado potato beetle and elm leaf beetle.

Pyrethrins. Pyrethrins are refined from natural pyrethrum, which is extracted from a species of chrysanthemum grown primarily in Kenya. Synthetic pyrethrins, called pyrethroids, are based on the chemical structure of natural pyrethrins, but are much more stable and do not break down as rapidly. Many formulations of pyrethrins have a synergist (such as piperonyl butoxide) added to increase their efficacy. Pyrethrins provide rapid knock-down, but residual activity is brief. They must be used often if insects persist. These chemicals are effective against many insect pests, especially soft-bodied forms, since they kill by absorption through the insect's skin. Pyrethrins generally are not effective against spider mites.

Rotenone. Rotenone is produced from the roots of two legumes, derris and cube, which grow in Asia and South America, respectively. The product is highly toxic to cold-blooded animals (especially fish), but only slightly toxic to most warm-blooded animals. Rotenone is the most effective and readily available of the non-synthetic insecticides and can be applied as a dust or a spray. Rotenone is effective against many insects, but not spider mites. The residual activity of this product is very short.

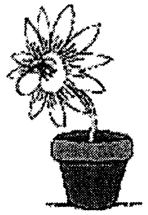
Nicotine Sulfate. This "natural" insecticide is derived from the tobacco plant and is highly toxic to humans and other warm-blooded animals. It is only suggested for commercial application.

Sulfur. Finely-ground sulfur can be applied as a dust or a spray. If sprays are preferred, be certain the formulation is intended as a foliar application. Sulfur is moderately effective for controlling spider mites and some fungal diseases. If the air temperature is 90°F or higher, it may cause a chemical "burn" on tender foliage.

Insecticidal Soaps. Certain commercially-produced detergent or soap formulations are effective in reducing populations of soft-bodied pests such as aphids, mites, leafhoppers, scale crawlers, plant bugs and thrips when used as sprays. Insecticidal soaps kill insects and mites by disrupting cell membranes, causing cells to burst. Insecticidal soaps can injure the leaves of certain plants.

Horticultural Oils. Horticultural oil sprays are highly refined petroleum oils used to control insects and mites on shade trees, shrubs, flowers and other foliage plants. Spray oils often are used as dormant treatments to control overwintering pests such as aphids, mites and scale insects. In many cases, they can also be used after leaves are present. Examples of insects controlled while plants are actively growing are scale crawlers, aphids, leafhoppers, sawfly larvae, mealybugs, caterpillars and some immature beetles. Under certain conditions, spray oils can cause plant damage, so care must be taken when using these products. Before using spray oils, consider refinement classification (dormant, summer, superior), dosage, growth stage of the plant, climatic conditions and the sensitivity of the plant species to be treated. Plants showing stress because of low moisture conditions should not be sprayed with a horticultural oil.

PLANT DISEASES

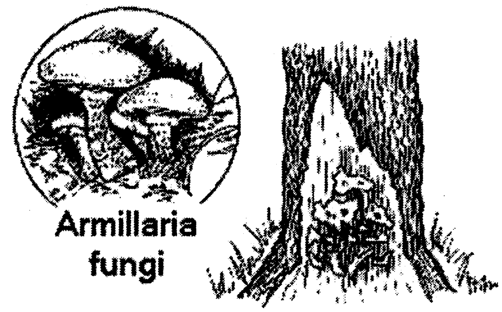


Plant pathogens are microorganisms that cause disease. Plant pathogens can be fungi, bacteria, viruses, mycoplasmas or nematodes. Parasitic plants such as dodder and mistletoe are considered plant diseases. Each pathogen has a different life cycle, which includes an infectious stage. A plant that is invaded by a pathogen is called a host. There are at least 50,000 diseases of crop plants and new diseases are discovered every year. Despite improved cultivars and disease control techniques, about 15% of the total U.S. crop production is lost annually to infectious diseases. Because disease-causing organisms (pathogens) multiply and mutate rapidly, damage from disease will never be eliminated. Because plant diseases reproduce rapidly and in great number, they quickly develop genetic resistance to chemical controls and have the ability to infect new plant hybrids.

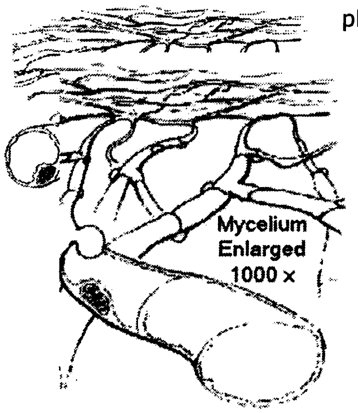
Types Of Pathogens

Fungi

Fungi are the most common plant pathogen. They are relatively simple organisms that lack chlorophyll and therefore cannot manufacture their own food through photosynthesis. Most fungi feed on decaying organic matter such as dead roots, leaves, and stems. They break down dead organic matter into useful minerals and other nutrients that are taken up by plant roots. Relatively few of the two hundred thousand species of fungi attack living plants, and then only when temperature and moisture conditions are favorable. Weakened or injured plants often lose much of their natural resistance to plant pathogenic fungi and exhibit more disease than when they are growing vigorously.



Armillaria fungi typically live on dead plant tissue in soil. However, they have the capability of causing a disease of roots and lower stem tissue on many species of woody plants including conifer and broadleaf trees throughout the temperate and tropical regions of the world. Typically, Armillaria fungi attack trees which may appear to be healthy but have been physiologically stressed by insect defoliation, competition with other trees, or climatic factors such as drought.



Plant pathogenic fungi penetrate into leaves, stems, and roots through wounds and natural openings or by forcing their way directly through the plant's protective epidermis. After growing for several days, weeks, or even years, most disease-causing fungi produce microscopic thread-like strands called **mycelium**. Individual mycelia invade plant tissues and give rise to spores or spore-producing bodies. Spores have many different shapes, colors, and sizes and are produced in a variety of ways. Some spores may appear as mold growth on the surface of buds, leaves, and shoots (as in the case of powdery and downy mildews, sooty molds, blights, and many rusts); others are borne in speck-sized, fungus-fruiting bodies embedded in diseased leaf tissue or in stems. Certain fungi may form decay resistant over-wintering, BB-sized structures called **sclerotia** that allow them to survive in the soil from season to season. With the exception of powdery mildews, fungi are more damaging to plants in damp humid areas or during wet weather than under dry conditions. Moisture is essential to the rapid reproduction and spread of practically all fungi and bacteria.

Bacteria

Bacteria are microscopic, one-celled organisms unable to make their own food. Bacteria reproduce by dividing every twenty to sixty minutes when food, temperature and moisture conditions are favorable. Most bacteria are beneficial to the environment because they feed on dead and decaying organic matter in or on the soil and break it down into useful nutrients for plants or other organisms. Only a few types of bacteria infect living plants and cause disease.

Plant pathogenic bacteria can only enter plants through wounds and small natural openings. Once inside the host plant, they multiply rapidly and may migrate throughout the plant. Chemicals or toxins produced by bacteria can kill cells, cause cells to grow abnormally, or break down tissues. Bacteria are transmitted by transporting diseased plant material by insects, birds, and other animals; and by splashing rains or wind-blown dust. The most common diseases caused by bacteria are angular leaf spots or blights, stalk rots, soft rots, and vascular wilts.

Fireblight is caused by the bacterium, *Erwinia amylovora*. It is a serious disease that affects new leaves, fruit, flowers, and stems of over 75 species of trees and shrubs in the rose family including: apple, crabapple, hawthorn, pyracantha, cotoneaster, spirea, flowering quince, and mountain-ash. Common entry points are through wounds, blossoms, and natural openings such as stomatas and nectaries. As the disease progresses, leaves and twigs take on a black shriveled appearance as if scorched by fire.

Viruses

Plant viruses are complex molecules of nucleic acids. Because viruses are nonliving, they cannot reproduce on their own. They rely on incorporating their nucleic acid into the nucleic acid of a plant cell to reproduce. When this happens the virus usually interferes with cell division, and normal growth is diverted into abnormal growth. The plant often expresses this as yellow to light- or dark-green mottling and stunting of the leaves, early leaf-fall, or loss of vigor. Virus diseases are frequently confused with nutrient deficiencies, pesticide or fertilizer injury, insect or mite activity, or other types of diseases.

Plant viruses have no way to infect a plant on their own and must rely on a vector for transmission to a plant. Transmission to healthy plants most often occurs by insect vectors, primarily aphids and leafhoppers. Some viruses are transmitted by infected seed, pollen, mites, and other animals.

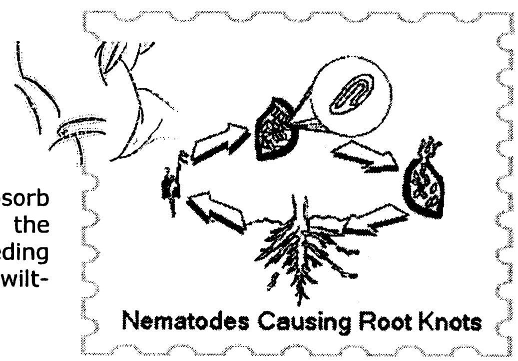
Viruses can overwinter in biennial and perennial crop and weed plants, in the bodies of insects, and in plant debris. Most plant viruses can infect a number of different plant species. Once infected, a plant usually remains infected for life. The most common virus-caused diseases are mosaics, mottles, and ringspots.

Mycoplasmas

A large number of "yellows" diseases are caused by bacteria-like organisms known as mycoplasmas. These peculiar organisms are saclike and pliable and vary greatly in size and shape. Mycoplasmas multiply by dividing in half or by budding. They are primarily transmitted by leafhopper insects.

Nematodes

Nematodes are very tiny (one-fiftieth to one tenth of an inch long), slender, somewhat transparent, round worms. Most nematode species are harmless, feeding on decaying organic matter and other soil organisms. Some species are beneficial because they feed on parasitic fungi, bacteria, insects, protozoa, and other soil pests. When nematodes infect roots, very high populations must be present to impair the ability of the roots to absorb water and nutrients. Nematodes can, however, greatly curtail the growth and vigor of all kinds of field crops. In addition, their feeding causes wounds that act as "open doors" to root-rotting and wilt-inducing fungi and bacteria and some viruses.



Nematodes Causing Root Knots

The Nature of Plant Disease

Infectious plant diseases are caused by a wide range of pathogens such as fungi, bacteria, nematodes, viruses, and mycoplasmalike organisms, or by parasitic plants such as dodder. These pathogens multiply within the host plant and can be transmitted from plant to plant. They may either invade the entire plant (systemic infection) or only affect certain plant parts (localized infection).

Noninfectious diseases are caused by abiotic (nonliving) agents. These agents cannot multiply within the host and cannot be transmitted from plant to plant. They are generally the result of unfavorable environmental or chemical conditions such as unfavorable temperatures, soil compaction, drought, or flooding, nutrient imbalances, air pollution, or chemical excesses and misapplication.

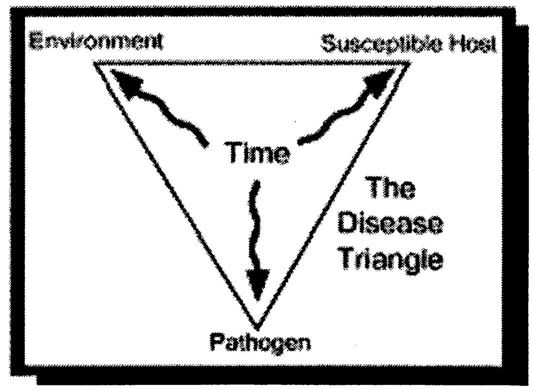
Most plants produce characteristic **symptoms** in response to infectious plant disease that greatly aid in diagnosing the cause of the disease. Symptoms are the plant's expression of disease. Some symptoms are easily seen such as wilts, lesions, yellowing, abnormal growth, mosaics, and root rots, whereas others, such as shriveled seed or reduced seed quality, may not be noticed until the crop is harvested.

Signs of infectious plant diseases are the evidence of the actual pathogen itself. Some signs of a pathogen are visible with an unaided eye, for example, mushrooms, exterior fungal mats (mycelium), large sclerotia, or fungal pustules. Others, such as, asexual spores (conidia), internal mycelium, perithecia, small sclerotia, bacterial ooze, or virus particles require the use of a hand lens or a microscope to be visible.

Plants affected by noninfectious diseases also produce characteristic symptoms. For instance, air pollution can cause leaf bronzing or scorching. However, no signs will be present because noninfectious disease is not caused by plant pathogens. This often makes diagnosis somewhat more difficult.

Observation of **field distribution** is also important for diagnosis. The most common distribution for field-crop disease is a random pattern. A disease distribution moving in from the edges of the field is often indicative of an insect-vectored disease. Another common pattern is disease associated with areas of high stress, such as low or compacted areas.

The Disease Triangle



Plant diseases are caused by many unique pathogens, plant host characteristics, cultural practices, weather and the environment. The disease cycle is circular, with neither a beginning nor an end. Once the disease cycle is understood, the mechanics of plant disease management become clearer.

Management of plant disease problems relies on several factors. The primary factor being an understanding of the "disease triangle."

Over time, plant diseases result from three interacting conditions:

1. A susceptible host;
2. An environment favorable for disease development;
3. A disease-causing agent (virulent pathogen)

Each of these components can be manipulated to help manage disease problems. If only a part of the triangle exists, disease will probably not occur. For example, planting resistant varieties or different species that are not susceptible to the attacking pathogen can eliminate a disease problem. First, even though the pathogen is present and the environmental conditions are favorable, infection does not happen because the host is not suitable. Second, healthy and vigorously growing plants are less susceptible to pathogen infection, so maintenance of plant health is important. And third, fungicides can be used to protect the host against pathogen infections

A comprehension of the disease triangle helps understand why most plants are not affected by the many thousands of diseases that exist.

Components of the Disease Triangle

Pathogens

Most pathogens are host-specific to a particular plant species, genus or family. For instance, white pine blister rust (*Cronartium ribicola*), affects only Western white pine and whitebark pine. Some diseases, such as the powdery mildews, produce similar symptoms on different plants. However, the fungi involved are usually host-specific. White pine blister rust does not affect species outside of the white (5-needle) pine group (similar symptoms on lodgepole or ponderosa pine may be caused by western gall rust).

Host

A susceptible host has a genetic makeup that permits the development of a particular disease. The genetic defense against a disease is called disease resistance. This resistance can be physical characteristics of the plant (fuzzy or waxy leaf surfaces), chemical characteristics (enzymes that kill pathogens and lack of enzymes) and growth patterns (ability to block off diseased tissue or outgrow damage).

Plants also may be disease-tolerant. Even though infected with a disease, they can grow and produce a good crop or maintain an acceptable appearance. The plant outgrows the disease and symptoms are not apparent or at a damaging level.

It is important to remember that plants labeled as disease-resistant are resistant only to a particular disease. They are not resistant to all diseases. Resistance does not mean immunity. Under extreme circumstances, resistant plants may be infected by the disease to which they have resistance.

For disease to occur, the host plant must be at a stage of development that allows it to be susceptible to infection. For example, damping-off (*Pythium spp.*) only affects seedlings. Botrytis is primarily a disease of buds, although it also can occur on flowers and leaves. Also, it is important that the pathogen be in a proper stage of its development to infect host plants.

Environment

Certain environmental conditions must exist for disease pathogens to cause infection. The specific conditions vary for different pathogens. High moisture and specific temperature ranges are necessary for many fungal diseases. These conditions must continue for a critical period of time while the pathogen is in contact with the host for infection to occur.

Moisture, temperature, wind, sunlight, nutrition and soil quality affect plant growth. If one of these factors is out of balance for the culture of a specific plant, that plant may have a greater tendency to become diseased. Moisture is critical to the spread of most plant diseases. Familiar diseases, such as black spot, fireblight and apple scab require moisture to spread to and infect new host plants. Constantly wet foliage from overhead irrigation is a condition that promotes disease development. Seedlings grown indoors in soggy, un-sterilized potting medium and pots are more prone to damping-off, a fungal disease.

Each disease pathogen has a specific temperature range for growth and activity. There are warm-weather and cool-weather diseases. Many powdery mildew diseases are late summer, warmer temperature diseases. Temperature affects how rapidly pathogens multiply. Soil temperature can also be critical for disease infection. Cool, wet soils promote fungal root diseases. Temperature extremes can cause stress in host plants, increasing susceptibility.

The combination of wind and sun affects how quickly plant surfaces dry. Faster drying generally reduces the opportunity for infection. Wind can spread pathogens from one area to another, even many miles. Wind and rain together can be a deadly combination. Windblown rain can spread spores from infected plant tissue, blowing these pathogens to new host plants. Sunlight is very important to plant health. Plants that do not receive the right amount of sunlight to meet their cultural requirements become stressed. This may make them more susceptible to infection.

Soil type and fertility can affect plant growth and also development of some pathogens. Light sandy soil, low in organic matter, favors growth of many types of nematodes. Damping-off disease increases in heavy, cold, waterlogged soils. Excessive nitrogen fertilization can increase susceptibility to pathogen attack. It causes formation of succulent tissue and delays maturity. This can contribute to certain patch diseases in pastures. On the other hand, nitrogen deficiency results in limited growth and plant stress which may cause greater disease susceptibility.

BUREAU OF LAND MANAGEMENT PESTICIDE APPLICATOR STUDY GUIDE

RIGHTS OF WAY

Revised JANUARY 2005

Right-of-Way Pest Management

Revised: January 2005

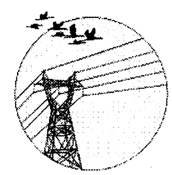
Reeves Petroff, Montana State University

Chemical trade names have been used for purposes of simplification, however, no endorsement of specific products is intended, nor is criticism implied of similar products or equipment that is not mentioned.

INTRODUCTION

Areas of land used for transportation, utilities and other services are known as rights-of-way and includes federal, state, county, and local highways; airports; railroads; telephone and electric transmission lines; transformer stations; drainage culverts, ditches and irrigation ditch banks.

Rights-of-way encompass many soil types, climates, vegetation complexes, land-use areas, and types of topography. Because rights-of-way are found in both densely populated urban areas and rural agricultural areas, controlling plants in rights-of-way requires a thorough understanding of pest management principles.



PEST MANAGEMENT OBJECTIVES FOR RIGHTS-OF-WAY

In a right-of-way, a pest may be any living organism that diminishes the safety, utility, attractiveness, or effectiveness of a right-of-way. Vegetation management in a right-of-way is desirable and necessary for:

- increased safety due to improved visibility on transportation rights-of-way,
- reduced fire hazard by encouraging less fire-prone plants,
- soil erosion control,
- assured continuity of utility services,
- promotion of public health and comfort,
- ornamental values enhanced by control of nuisance vegetation,
- control the spread of noxious weeds.

Levels of Vegetation Management in the Right-of-Way

Highways and railroads need complete vegetation control in the roadbed. The shoulder of the road or rail line is usually kept free of vegetation to allow drainage and prevent the spread of noxious weeds. The rest of the right-of-way may consist of grass or low-growing shrubs. The type of vegetation managed should be limited to plants that do not interfere with the movement of vehicles, the vision of their drivers or contribute to the spread of noxious weeds.

Electrical distribution lines are often surrounded by vegetation and continual efforts must be made to clear vegetation to eliminate power outages. Sometimes mature trees that pose a dangerous threat to electrical facilities must be completely removed.

Buried Utility and Gas pipelines are somewhat unique because the soil is disturbed when the line or pipe is laid. Without directed re-vegetation of these disturbed sites, the plant community may start out as a mix of weedy grass species. Other biennial and perennial weeds may move in and grow if conditions are right.

INTEGRATED PEST MANAGEMENT (IPM) IN RIGHTS-OF-WAY (ROW)

Problems associated with pesticide use led to the coordinated use of multiple tactics, an approach known as integrated pest management or IPM.

IPM is an approach that focuses on the long-term prevention or suppression of pest problems (weeds, insects and plant diseases) and uses cultural, biological, physical, and mechanical methods in site-specific combinations. The goal of right-of-way IPM is to manage pest populations in such a manner that the utility of the right-of-way is maintained and adverse side effects are minimized.

Because vegetation in rights-of-way is usually permanent and predominantly composed of perennial species, management practices are generally based on ecological rather than agronomic principles. The IPM practices relevant to rights-of-way include scouting, making site inventories and maps, using thresholds, and developing a unified program with few adverse side effects.

Scouting

Two important tools for IPM are correct pest identification and scouting. Scouting is the routine observation of the right-of-way to record pertinent information on desired and undesired species. Highways should be surveyed and inventoried for herbaceous vegetation and utility lines should be checked for brush problems.

Always attempt to correctly identify and record the prevalent species on a mile-by-mile basis. Make special note of noxious weed species that will require more intensive control measures and any significant differences in soil conditions (e.g., slope, texture, poorly drained areas). Record the approximate height of undesired vegetation. Indicate the presence of any "sensitive areas" (e.g., streams, home gardens, orchards, schools, high value or specialty crops) that will necessitate different management strategies.

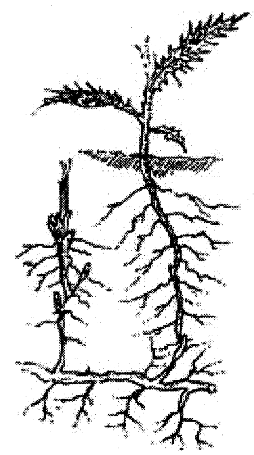
All of this information should be recorded and kept in notebooks, on topographical maps, on hand-drawn strip maps, or in computer-based mapping programs. Use the same method all year and save the information for several years to monitor the rate of vegetation growth (especially brush), the effectiveness of your management practices, the appearance of new species, and any other developments or changes.

Thresholds

Scouting information will help determine when you have reached the treatment threshold: the level of infestation at which control practices are justified. In commercial agricultural production systems, the threshold is based on economic criteria. In rights-of-way, non-economic criteria are used and are subject to great differences of interpretation. For example, some highway managers may decide that any vegetation around signposts and guardrails is undesirable (zero threshold) and routinely use total vegetation control in these areas. Other managers are willing to allow vegetation to grow in the sites and limit its growth to perhaps 2 feet or less by mowing. Their "threshold" is based on vegetation height, regardless of species and its density. Therefore, there may never be fixed thresholds for all right-of-way environments. The important point to remember is that some set of criteria is needed to make sound vegetation management decisions.

Management Techniques For Rights-of-way

Mechanical Management. One of the most widely used mechanical control options available for right-of-way vegetation management is mowing. The main drawback of this type of control is the frequency with which control efforts must be undertaken and the timing of mowing. Because the roots of mowed or cut vegetation remain largely intact, the vegetation eventually re-sprouts and grows again to an undesirable stage. If mowing is to be effective, annual and biennial plants that reproduce only by seed must be cut before viable seeds have been produced. The same is true of perennial broadleaf weeds that spread mainly by seeds. Some annual and biennial broadleaf plants are able to re-sprout after mowing so two to three clippings during the season may be necessary to prevent seed production. Noxious weeds should be mowed before they flower and during periods of low energy reserves in their roots, thereby reducing their ability to propagate. Since most perennials have specialized underground structures that serve for both reproduction and survival, destroying the top growth on a one-time basis will not kill the plant unless it is done in the seedling stage before underground survival structures have developed. Plants will simply produce new growth using food stored in the underground structures. Eliminating perennials by mowing can only be achieved if done many times for several seasons. Eventually the supply of stored food will be depleted to the point that re-growth is no longer possible. However, perennials such as Canada thistle normally have enough energy for re-growth stored in their roots to survive even intense mowing frequency. The most effective approach to controlling perennial weeds is to destroy the underground survival and reproductive structures. You can do this most effectively by combining mechanical practices with timely herbicide treatments in the fall.



Biological Management. The use of living organisms (insects, diseases, or animals) to control pest organisms is called biological control. Although popular and effective as a means of controlling agricultural, rangeland and aquatic pests, biological control of weeds in rights-of-way has limitations. Biological controls may not stop the spread of noxious weeds in rights-of-way where their effect often lags behind the development of the target vegetation. Moreover, confining the biological controls to the right-of-way is difficult to manage.

Cultural Management. Certain cultural management practices can be used to promote development of desired vegetation along a right-of-way. Such practices rely on controlled fire, fertilizers, lime, and mulches. For example, fertilization promotes the development of a dense stand of grass, which impedes weed development along a right-of-way; lime can alter the pH of soil, making a particular site unsuitable for certain weed species; mulches are useful for retarding weed development around landscaped areas.

Fire can also be used to remove established weeds, thereby eliminating competition for desired grasses and other vegetation that will emerge from the burned site. Extreme care must be used with this technique as smoke can obscure the right-of-way and fire may spread to other areas.

⚒ **Pesticides.** Terrain can make regular maintenance using mechanical methods impractical. Herbicides and plant growth regulators are often the only practical ways to control vegetation in rights-of-ways. In comparison to manual and mechanical weeding, herbicides are often more economical. However, factors such as proximity to sensitive vegetation, towns, ground- or surface water, type and condition of available application equipment, and local pesticide ordinances and restrictions must be considered when deciding if herbicides should be used. Sometimes the cheapest means of control may not be the appropriate choice. Nevertheless, the judicious use of the appropriate product, at the proper rate and time, when applied correctly, can be the right choice.

Right-of-way herbicide treatments can be applied by ground or air, depending on the situation. Ground applications may include: (1) foliar spray treatment, (2) soil-applied herbicides with dry and liquid formulations, and (3) the control of woody species.

(1) **Foliar herbicides** are often used for the control of herbaceous plants and small trees and shrubs. Brush can be defoliated with foliar herbicides to improve access for soil or trunk treatments, but foliar herbicides are normally not recommended for the larger brush species because the potential for drift is too great when tall species are sprayed. The applicator should operate the spray gun from the ground and with a hose of sufficient length to be able to treat from a position close to the plants.

Herbicides that are applied after the emergence of a crop or a weed are referred to as **postemergence.** Herbicides that are applied before the emergence of a crop or a weed are referred to as **preemergence.** They may be either **selective** or **nonselective** and either **contact** or **systemic**, depending upon the herbicide used. **Selective herbicides** kill some kinds of plants but have little or no effect on others. The use of selective herbicides allows the removal of unwanted weeds from desirable plant communities. 2,4-D is a selective herbicide that removes broadleaf weeds but will not injure grasses. **Nonselective herbicides** kill all vegetation. Examples are paraquat (Paraquat), bromacil (Hyvar), and glyphosate (Roundup, Accord).

Contact herbicides do not move readily in the plant and usually only kill the part of the plant they touch. Contact herbicides are most effective when applied to actively growing plants before flowering. They kill most annual weeds but do not provide any residual control; thus, a new flush of weeds may germinate from seed after an herbicide application. Contact herbicides also will burn off the top-growth of perennial weeds (e.g., Canada thistle), but these weeds will usually re-sprout from underground parts. Because contact herbicides fail to prevent later germination of annual weeds and only burn off the top-growth of perennials, they have limited importance in right-of-way situations.

Systemic herbicides are absorbed through plant top-growth or plant roots and interrupt critical physiological processes necessary for plant growth. They move into and throughout the plant as long as the plant is actively growing. They are of particular value in their ability to control established perennial weeds.

Foliar treatments are most effective when the herbicide is applied to actively growing foliage. Weeds growing during prolonged cool weather or under droughty conditions do not actively translocate herbicides and thus require a higher rate of application than do weeds that are actively growing. Ideal temperatures for applying most postemergence herbicides are between 60° and 85° F. At temperatures above 85° F, the risk of vapor drift from certain herbicides such as 2,4-D esters, dicamba, dichlorprop, or triclopyr is much greater.

The effectiveness of some foliar treatments will be reduced if rain falls shortly after application. The ester formulations of 2,4-D are absorbed in 1 to 2 hours, whereas 6 to 8 hours are required for adequate absorption of dicamba, glyphosate and 2,4-D amine formulations. Paraquat is absorbed within 30-60 minutes during warm, sunny weather.

Thorough wetting of the leaves and stems to the point of runoff is essential for some foliage treatments to be effective. The label may suggest that an adjuvant such as a surfactant, a crop oil, or a crop oil concentrate (COC) be added to the herbicide to improve its activity. These chemicals allow the herbicide to spread over more leaf surface so that more herbicide can be absorbed. Use of an adjuvant may be necessary for better absorption by foliage that is extremely waxy or hairy. Contact herbicides such as paraquat usually require the use of a surfactant to give satisfactory control. The activity of systemic herbicides, such as 2,4-D, is also increased when they are applied along with a surfactant, crop oil, or COC. Increased activity of selective herbicides may result in severe injury of desirable plants, so additives should not be added in all situations. Follow label guidelines.

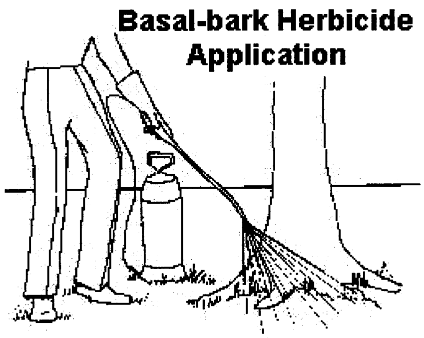
(2) **Soil applied herbicides.** Some herbicides move through the soil to the root zone, where they are absorbed. Others are absorbed by the shoots of emerging seedlings as the plant grows through the herbicide layer in the soil. Soil-applied herbicides are either selective or nonselective and range in residual activity from no residual to several months. Soil-applied herbicides can be formulated as liquids, granules, or pellets. Granules and pellets can be applied by hand shakers or by equipment such as rotary applicators, cyclone seeders, or other spinning-disk equipment. Even though granules drift less than do liquid sprays, their pattern of application from rotary applicators can be distorted by wind, resulting in an overdose in one area and under-application in another area. Refer to the Bureau of Land Management (BLM) Pesticide Applicator Handbook for information on calibrating granular spreaders.

Since most total vegetation control (TVC) compounds are applied close to the ground, it shouldn't be necessary to use high sprayer pressures. Instead, choose nozzle sizes large enough to apply large spray droplets in a course spray. Depending upon equipment, nozzle selection and label requirements, pressure should normally be maintained to under 40 pounds per square inch (psi) to limit drift.

In general, soil applications should not be made to frozen soil. However, some labels recommend that applications be made after the last hard frost in spring and before the first hard frost in autumn. A soil herbicide usually needs to be leached by rain into the soil where it can be absorbed by the plant root or shoot. It may take the herbicide several weeks to reach the roots of some deep-rooted plants. Injury symptoms will not appear until the plant has absorbed and translocated the herbicide. Symptoms from a late fall treatment may not be visible until the following spring.

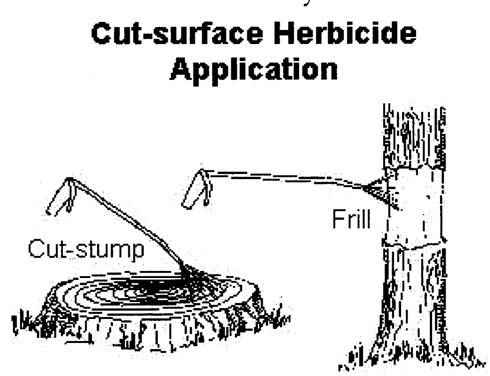
Do not apply soil herbicides in areas where they may leach into groundwater, or run off into water sources or cropping areas. Sandy soils have little adsorptive (binding) capacity, and may not hold the herbicide near the soil surface where most weed seeds germinate. Avoid making herbicide applications in areas where tree and shrub roots may extend. The recommended rates for soil-applied herbicides depend upon the weed species present, the soil texture (percent sand, silt, and clay) and the amount of soil organic matter.

(3) Woody plants are controlled by a number of different methods. **Individual Stem Applications** are used to apply herbicides directly onto or inside the stems of individual woody plants (trees or shrubs). Tree injectors, frill and squirt techniques, Hypo-Hatchets™ or similar devices, and cut stump treatments are used to deliver herbicides directly to the transport and growing tissues beneath the bark of woody plants. These treatments should not be applied to trees or shrubs where non-target plants of the same species or genera are nearby (generally within 10 to 20 feet). Trees and shrubs of the same species or genera may form root grafts or sprouts from the same rootstock. In these cases, the herbicide can be translocated from one tree to another, killing or injuring the non-target tree.



Basal-bark treatments can be used to control brush, and to control trees up to 5 inches in diameter. They are useful to selectively remove undesirable brush species from stands of desirable plants. Basal-bark treatments are made with oil-soluble herbicides in a carrier of diesel oil or kerosene. The spray is applied to the lower 18 inches of the stems, and should thoroughly drench the stem, crown, and all exposed roots. However, care must be taken during application because most vegetative ground cover will be injured by herbicide applied in a diesel oil carrier. Where only a limited number of trees are to be controlled, a 3- to 5-gallon knapsack sprayer works well for the application of a basal-bark spray. Basal-bark applications made during the dormant season do not result in brownout of foliage, which may make dormant treatments desirable. In addition, since vapors from basal-bark applications may drift out of the treatment area, undesirable brush in areas adjacent to susceptible plants can be treated during the dormant season to reduce injury potential.

Herbicide application to **cut surfaces** in the bark of trees is an effective method for controlling woody species. Cut-surface applications are recommended when plants have thick bark or when they have stems greater than 5 inches in diameter. Applications can be made effectively during any season except in the spring during heavy sap flow. The cut must be made rapidly with a sharp saw or pair of pruning shears. A chain saw should be used on larger trees. Then saturate the cut surface with herbicide as soon as possible after cutting. On large tree trunks, the cambium area next to the bark is the most vital area to wet. Do not wait more than several minutes to paint the stump. Woody plants have a wound response that quickly seals the cut surface and restricts the movement of herbicide into the roots. The best results are achieved by treating woody perennials that are not water stressed and are growing actively. Common herbicides used for cut stump treatments include 2,4-D amine, glyphosate, and triclopyr. Only the most concentrated herbicide formulations should be used for cut surface treatments.



Controlling Noxious Weeds

Noxious weeds such as Canada thistle, musk thistle, leafy spurge, spotted knapweed, and diffuse knapweed are often found in rights-of-way. These weeds can rarely be eliminated by mowing alone. Selective herbicides that control broadleaf plants with little or no effect on grasses are particularly useful in controlling these weeds. Frequently a spot application of the appropriate herbicide is all that is needed if the weed is present in small, localized areas. This minimizes the amount of herbicide needed (and thus the cost) and also greatly reduces any possible environmental damage because less chemical is used than if a broadcast application to the entire site were made.

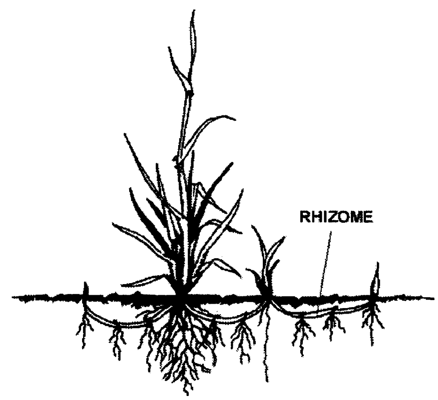
A complete program to control noxious weeds integrates mowing, herbicides and, if needed, the reestablishment of desired vegetation. For example, Canada thistle and leafy spurge infestations will be reduced significantly if patches of these weeds are mowed when they begin to flower, treated with a selective systemic herbicide 6 to 8 weeks later, and mowed again at the end of summer. Using this multiple-strategy approach for several seasons will result in a noticeable drop in population of these weeds.

Timing of Herbicide Applications In Rights-Of-Way

Life cycle and stage of development differences between species can affect herbicide performance. Weeds either are annuals, biennials, or perennials. Regardless of the life cycle, all weeds may start as seedlings. Since seedlings are young and succulent, less energy is required to kill plants at this stage than at any other. This is true whether the treatment is chemical or mechanical. Weeds in the vegetative stage may still be controlled, but not as easily as when they are seedlings. Once annual and biennial weeds reach the flowering stage, most of the plant's energy is devoted to producing seed. Chemical control in this stage is generally not effective or practical since the plants are approaching death or maturity.

Biennial plants, which develop from seed the first year and overwinter in the rosette stage, are generally controlled in fall or spring with 2,4-D or dicamba applied to the rosettes. Winter annuals, which germinate in the fall, become dormant, and then flower in the spring or early summer of the following year, are also controlled by fall or early spring treatments.

RHIZOMATUS PLANT

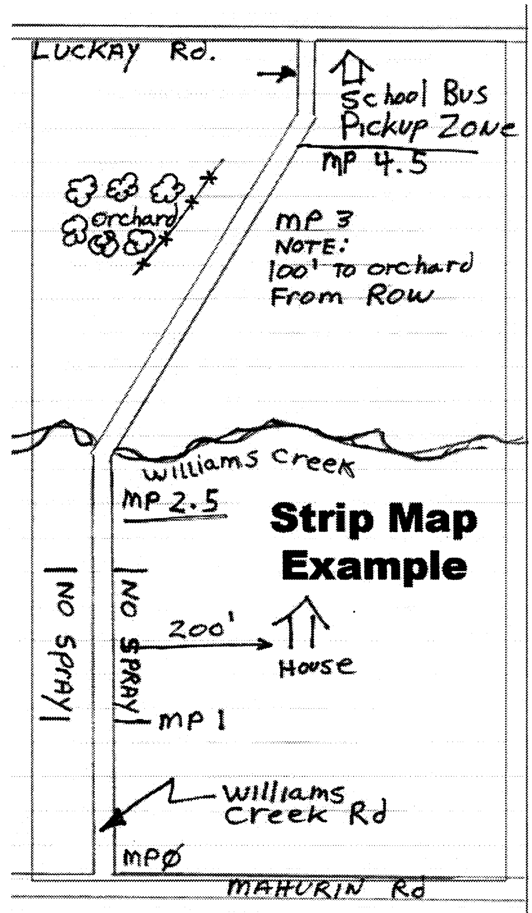


The most important source of infestation from perennial weeds is through their regenerative roots systems. The new shoots or leaves which emerge each year are connected to well-developed root and/or rhizome systems and are much less susceptible to total plant kill than are true seedlings. Perennial weeds will only be completely controlled if the underground portions of the plant are killed. The best results are obtained when treatments are made to herbaceous perennials in the true seedling stage, or in the bud or early flower stage. This produces the greatest drain on the underground food reserves. When perennials reach the full flower stage, control drops off. Treating the re-growth in the fall after mowing or clipping in the summer is normally effective. With a fall treatment, the target plant has to survive three successive stresses: herbicide effects; winter effects; and the effects of heavy nutrient demand caused by the rapid growth period in the spring. Thus, the chances of plant mortality are greatly increased.

Seedlings of brush species are very sensitive to herbicides throughout the year. However, it is usually a well established plant that is observed and must be controlled. Generally, foliar applications to brush are most effective in the late spring or early summer when the leaves are fully expanded and the plant is rapidly growing. The plant intercepts much of the herbicide and transports it both downward and upward within the plant. During dry, hot summer conditions, leaves produce thicker cuticles and waxy layers which reduce herbicide penetration, resulting in less effective control. By the fall of the year, the leaves are physiologically less active and will soon drop off. Therefore, foliar applications at this time would give poor brush control. (Krenite™ is an exception; this material should be applied to woody plants in late summer.)

Planning For Right-Of-Way Pest Management

An effective weed management program must be well-planned in advance. Experienced personnel develop an eye for interpreting what the environment shows in terms of vegetation changes. Areas of roadsides with annual weeds are either recently disturbed sites or are so nutritionally depleted they cannot support perennial groundcover. The presence of reed canary grass, cattails, swamp smartweed, and sedges reflects wet, poorly drained areas that may often have standing water. St. Johnswort, spotted knapweed, and hoary alyssum reflect sandy, well-drained soils. Foxtail barley or rabbit's foot clover along the pavement may indicate high salt levels in the soil. These and other responses to the environment can be useful clues too use in implementing a management program. For example, use of highly soluble soil sterilant herbicides around guardrails when spotted knapweed is present may endanger ground- and surface water sources if indeed the soil is very sandy. Further scouting may be necessary.



☑**Avoiding Sensitive Areas.** Always be aware of areas where off-target application may damage sensitive species. These **sensitive areas** include vegetables gardens, flowerbeds, ornamental shrubs, fruit gardens, home grounds, pastures, animal forage areas or shelterbelts. Just as you survey rights-of-way for weeds, you should also survey rights-of-way for sensitive areas and hazards. An easy way to note sensitive areas within a right-of-way is to develop strip maps of the areas to be managed. A strip map is a written or drawn description of hazards and sensitive areas in the rights-of-way to be treated. Strip maps can note no spray areas, stream crossings, irrigation ditches, and other hazards on the map. Milepost numbers or terrain features can be used to show where sensitive areas are located. Strips maps can be kept in a notebook and are a good way to convey information to applicators who are treating rights-of-way under your management.

☑**Equipment.** By adjusting boom and nozzle combinations, the same type of low pressure equipment used for other types of weed control can also be adapted for use in rights-of-way. .

☑**Calibration and Mixing.** Equipment should be calibrated prior to and at frequent intervals during the spraying operations. See the calibration section of the Bureau of Land Management (BLM) Pesticide Applicator Handbook and the calibration section of this manual instructions on how to calibrate equipment and mix for right-of-way vegetation management.

☑**Equipment for Broadleaf Spraying on Roadsides.** Application will vary according to the management demands of that particular right-of-way. A sprayer holding 100-200 gallons may be more than adequate in one situation, whereas, a 1000-gallon sprayer may be needed for efficient operation in another situation.

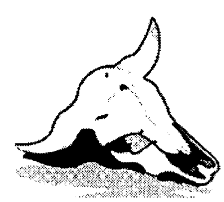
HAZARDS WITHIN THE RIGHT-OF-WAY

Injury to Desirable Plants. Selective herbicides can be chosen that will control the unwanted vegetation, but leave the desired ground cover. Potential drift may warrant switching from foliar application to either basal or cut-stump treatments, which are more selective and safe for desirable ornamentals.

Injury to Roots of Desirable Plants. The proper choice of herbicides will prevent root absorption by desirable ornamentals within the right-of-way. Glyphosate (Roundup™)and simazine (Princep™) are herbicides that can be carefully applied among established woody ornamentals. Imazapyr (Arsenal™) and tebuthiuron (Spike™) are soil active herbicides that should not be used around woody ornamentals. They will be absorbed by roots in the treated area and may move laterally to damage other ornamentals outside the treated area. Read the label and determine the potential problems with soil active herbicides being used.

Brownout. Plants that are sprayed with most herbicides turn brown and are unsightly. Along power line rights-of-way or along railroads this is a necessary part of vegetation management. In areas of high public visibility brownout becomes a serious public relations problem. Problem sites include major highways and urban and residential areas. Some growth regulator herbicides like 2,4-D are short-lived (short residual), and often require reapplication during a growing season. This adds to increased instances of brownout. The broadcast application of non-selective and contact herbicides also contributes to brownout.

Hazards to Pollinators. You should consider bees, other pollinators and wildlife when making pesticide applications. When using pesticides that are particularly harmful to pollinators, early morning or evening applications when pollinators are not active is recommended in the vicinity of apiaries. Read the label carefully for bee warning statements.



Hazards to Livestock. Due to the relatively low toxicity of the herbicides used on rights-of-way, it is unlikely that an animal grazing on treated plants would be injured. Where right-of-way applications may take place on land next to pastures or cropland, precautions should be taken to prevent overspray or drift from entering the pasture or from contaminating crops. Either of these situations could cause a residue to occur on pasture grass or crops that may later be used as livestock feed. These residues could, in turn, cause an illegal residue to occur in the milk and/or meat products from animals that graze on the pasture or eat the contaminated crops. In addition, there is danger of toxicity from poisonous plants that may become more attractive after treatment. For instance, spraying poison hemlock with salt-based herbicides will make the plant attractive to salt-seeking livestock. When the animals eat the hemlock they may not be affected by the herbicides but could possibly die from the toxic effects of the plant.

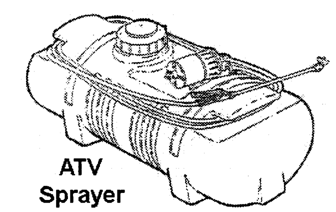
EQUIPMENT FOR RIGHT-OF-WAY APPLICATIONS

Pesticide application equipment used for right-of-way pesticide applications is not much different from equipment used for crop and rangeland spraying. In general, pesticide applications in rights-of-way include both high and low volume techniques. **High volume spraying** is normally done with truck-mounted equipment that delivers 60 to 400 gallons of solution per acre at high pressure through a hand-directed nozzle. This type of foliar spraying is fast and can deliver herbicide through dense brush. However, the risk of drift and unwanted effects on non-target plants is relatively high. This technique requires more planning and precautions than other ground application techniques.

Low volume spraying is normally done with hand-held equipment, such as backpack sprayers or low pressure ATVs or tractor-mounted sprayers that deliver 10 to 60 gallons per acre at relatively low pressure through a hand-held wand or spray gun. Low volume spraying also includes using boom sprayers and fixed height nozzles to apply herbicides to low-growing grasses and weeds with a great deal of control over the amount and distribution of herbicide. All types of low volume spraying are likely to cause fewer environmental problems compared to high volume/high pressure techniques.

Backpack and All Terrain Vehicle (ATV) Sprayers

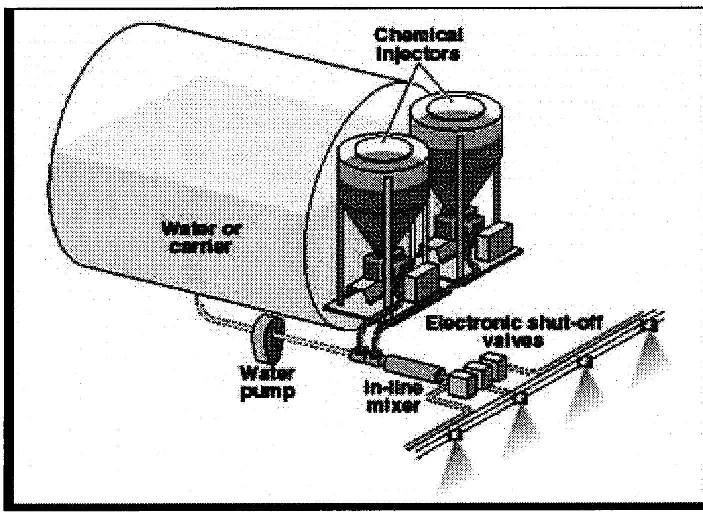
Small-capacity backpack and ATV sprayers are useful in many right-of-way areas and are well suited for treating individual plants, and for basal and cut surface applications. Tanks usually hold 3 to 5 gallons. The sprayers can be fitted with a single nozzle or with a boom with up to 3 nozzles. Some hand held and backpack sprayers are filled to about 3/4 of the tank capacity with liquid and then air is pumped into the remaining space. Initial pressure is 30 to 60 psi but drops continuously as the spray is applied unless a pressure regulator is used.



Calibration of hand-held equipment for application on an area basis is more difficult because operator speed and sprayer pressure are difficult to keep constant. Refer to the Bureau of Land Management (BLM) Pesticide Applicator Handbook for the basics of backpack sprayer calibration.

Direct Injection Sprayers

The rights-of-way application equipment of choice for managing roadside vegetation is the chemical injection sprayer. The basic principle of direct injection is that pesticide and water are kept in separate containers. When the sprayer is activated, a metered flow of pesticide is injected into the water stream, sometimes via a mixing chamber, at a point situated between the main water tank and the nozzles. Often a number of pesticide containers and pumps are fitted to allow the applicator to apply more than one product. A computer monitors and controls the herbicide mixing and application. Some units are designed so the volume of pesticide metered is determined by ground speed. Others are adjusted based on a constant travel speed. Any change in speed may cause over or under application. Injection sprayers are designed so that tank mixing and agitation are usually unnecessary. Because the tank contains only clean water, tank washout between sprays and disposal of any unused chemical mixture is eliminated. Injection can take place at various points on the sprayer, depending upon the design. When spraying is complete, the containers of concentrate can be removed to storage and with minimum cleanup the sprayer is ready for another use. A rinsing system may also be incorporated.



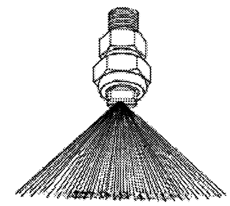
Injection equipment requires precise measuring equipment that is maintained in good condition. It is more difficult to measure a small amount of chemical on a continuous basis as compared to measuring one larger quantity and mixing it in the spray tank.

Nozzles

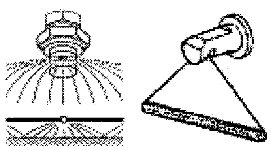
Nozzles control the volume of pesticide applied, the uniformity of application, the thoroughness of coverage, and the amount of drift. While many nozzle types are available, each one is designed for specific applications. **Regular flat-fan**, **flood**, and **cone nozzles** are preferred for weed control in rights-of-way.

Flat-fan nozzles produce a flat spray pattern and are widely used for broadcast spraying herbicides. Because the outer edges of this pattern receive less volume, adjacent spray patterns must overlap 30% to 50% depending on spray angle. Refer to the Bureau of Land Management (BLM) Pesticide Applicator Handbook for correct placement of flat-fan nozzles along a boom.

Flat Fan



The normal operating pressure for most flat-fan nozzles is 30 to 60 psi, but low-pressure flat-fan nozzles can operate at pressures from 15 to 20 psi. Lower pressures create larger droplets and reduce drift. Extended range (XR) nozzles maintain a uniform pattern over a wider pressure range than regular flat-fan nozzles. Drift reduction flat-fan nozzles are also available. Common angles of discharge are 65, 80, and 110 degrees. The angle of discharge and nozzle spacing determine the proper nozzle height for uniform application.

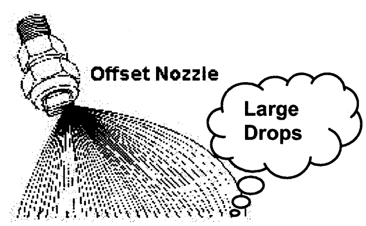


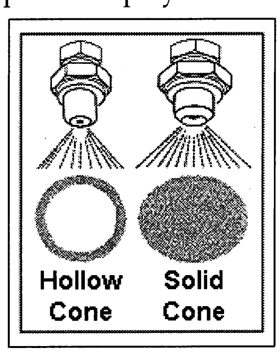
Flooding Nozzles

Flooding flat-fan nozzles produce a wide-angle pattern and function well when broadcasting herbicides. The flooding nozzle spacing on a boom should be 60 inches or less. Optimum operating pressures are generally 10 to 25 psi.

Pressure changes on flood flat-fan nozzles affect the angle and width of the spray pattern more than with regular flat-fan nozzles. The width of the spray pattern increases with pressure increase. Although the discharge can be directed horizontally backward for a uniform pattern or downward for minimum drift potential, the best compromise position is backward at 45 degrees with the soil surface.

Off-center, **flat-fan** nozzles are commonly used for right-of-way spraying of herbicides. These nozzles are ideal for negotiating signs, guard rails, and other obstacles. They produce a wide off-center spray pattern extending from one side of the nozzle. This allows the spraying of up to a 30-foot swath without the use of a boom. The coverage is relatively uniform when the nozzles are mounted at the proper height and operated within a pressure range of 15 to 40 psi. The spray from these nozzles, however, is more susceptible to drift than that from nozzles mounted on a spray boom. Off-center nozzles produce small droplets immediately under the nozzle, but deposit extremely large droplets at the outer edge of the swath.

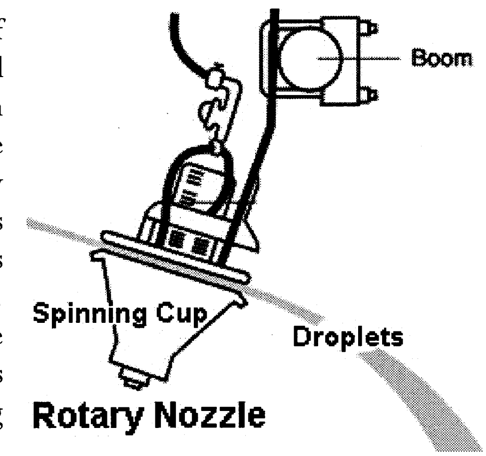




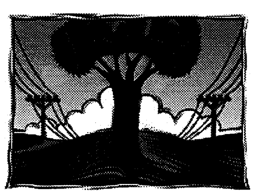
At pressures of 40 to 100 psi**, hollow-cone** nozzles produce many small droplets that penetrate plant canopies and cover both sides of the leaves more effectively than fan nozzles. They also can be used to spray the foliage of individual brush plants. Adjustable tip nozzles are commonly used on back-pack sprayers in rights-of-ways and they allow the operator to change the spray from a solid stream to a fine mist and are operated at relatively low pressures.

Full- or solid-cone nozzles are suitable for foliar sprays in many right-of-way sites. They give excellent coverage, produce few fine particles and are suitable for band or directed spraying around guardrails.

Directa-spray and Wobbler - Directa-spray, Radi-arc, and Wobbler nozzles produce very coarse spray droplets. The spray solution is discharged through a rotating (Directa-spray and Radi-arc) or oscillating (Wobbler) unit as a stream. When the stream hits the air, it is broken into large droplets. These nozzles are usually used to apply, 2,4-D and related products to brush.



Rotary Nozzles - The rotary nozzle uses centrifugal force instead of pressure to produce droplets. This process is known as controlled droplet application (CDA) and forms droplets of relatively uniform size. There are very few fine or mist-sized drops and very few large drops. Studies show that 80 percent are within a relatively narrow range. Liquid enters at the center of the spinning disc and is propelled outward to the teeth on the edge. When the droplet is heavy enough, centrifugal force throws it from the spinning disc. Droplet size can be controlled by varying the rotational speed of the disc. This allows the same unit to be used for insecticides, herbicides and fungicides. Flow rate, controlled by pressure and a metering orifice in the nozzle line, also has some influence on droplet size. Rotary nozzles with horizontal discs produce a hollow cone pattern. Some are mounted on extension arms perpendicular to the boom to eliminate obstructions which might interfere with the spray pattern. Experience has shown that a reduction in drift accompanies the uniform droplet size. However, the pattern is susceptible to distortion from wind, which may cause voids in the pattern, and canopy penetration is poor. Research tests show that in a 6 mph wind, the flat fan nozzle deposits up to 21 percent more material in the spray swath than a rotary nozzle.



Calibration For Right-Of-Way Applications

The purpose of calibration is to ensure that your equipment delivers the correct amount of pesticide uniformly over the target area. Unfortunately, calibration is the one step in pesticide application that is most often neglected and misunderstood. Unless your sprayer is new, it will contain a certain amount of pesticide residue in and on the various equipment components; therefore, personal protective equipment also is recommended. A pocket calculator may help facilitate calculations and minimize mathematical errors.

Pre-application Check

At the start of each season, lubricate and prepare the sprayer for operation. Add water to the sprayer tank and make practice applications to be sure that the pump, hoses, and nozzles are functioning and that there are no leaks.

Determine the nozzle output per minute and compare this to the manufacturer's specifications. Nozzles that apply 10% or more of the expected quantity indicate they are worn and should be replaced to assure that particle size and spray pattern are within acceptable ranges.

Application on a Per Acre Basis

In some cases it is appropriate to make broadcast applications to large areas of rights-of-way. Patches of leafy spurge or Canada thistle can be treated with fixed-boom or broadjet sprayers set up to deliver an exact gallonage of spray solution per acre (i.e. 30 GPA). This application method is also used to treat substations and other areas where total vegetation control is desired.

Calibrating a sprayer will ensure that the sprayer is delivering the intended volume of spray mixture to the target area. To attain this goal, you must determine each of the following:

1. How much spray mixture your sprayer applies per acre (Gallons Per Acre or GPA),
2. How many acres you can spray per volume of liquid in the tank,
3. The recommended rate of pesticide application (labeled rate), and
4. The amount of pesticide product to add to the spray tank .

Since broadjet and Boombuster™ nozzles are commonly used for right-of-way spraying, you should refer to calibration chapter in The Bureau of Land Management (BLM) Pesticide Applicator Handbook.

Ground Speed of the Sprayer

Provided the same throttle setting is used, as speed increases, the amount of spray applied per unit area decreases at an equivalent rate. For example, doubling the ground speed of a sprayer will reduce the amount of spray applied by one-half. To determine the new output after changing speed:

$$\textbf{New output} = \frac{\textbf{current output (GPA)} \times \textbf{old speed (MPH)}}{\textbf{new speed (MPH)}}$$

Example: Current sprayer output is 25 GPA. Current speed is 5 MPH. New speed is 7 MPH.

$$\frac{25\ \text{GPA} \times 5\ \text{MPH}}{7\ \text{MPH}} = \frac{125}{7} = 17.8 \text{ or } 18\ \text{GPA}$$

Some sprayers are equipped with control systems that maintain a constant application rate over a range of travel speeds provided the same gear setting is used. Pressure is automatically changed to vary the nozzle flow rate in proportion to changes in ground speed. Even so, do your calibration at a set ground speed. As you spray, you must keep the travel speed within certain limits to keep the nozzle pressure within the recommended range.

Nozzle Selection

Nozzles that deliver 0.25 to 0.75 gallons per minute at 20 to 30 psi are generally suggested. Choose a nozzle size that allows you to: (1) wet the foliage relatively quickly, (2) has few fine particles that will drift, and (3) few coarse droplets that will excessively wet the foliage beyond the runoff point.

Applicator Considerations

Sprayer pressure is seldom constant with hand-held equipment. This results in variable outputs per minute. However, experienced operators can maintain a relatively constant pressure. "Applicator style" is also important in making pesticide applications. Practice with water until you are able to achieve applications that wet the bark or foliage to, but not beyond, the point of runoff.

Calculation Examples

It is common for right-of-way pesticide recommendations to be expressed as a given volume of formulated product in a specified volume of water. Such recommendations are expressed as "volume/volume."

Example: volume/volume in water using percentage. A 2% solution of the formulated product Roundup is recommended to control Canada thistle. You have estimated that you will need 50 gallons of spray solution to treat patches of this weed. How much water and the formulated Roundup do you need?

Two percent of 50 gallons is 1.0 gallon (0.02 x 50 gallons = 1 gallon). To obtain the proper concentration, mix 1 gallon of Roundup in 49 gallons of water for a total of 50 gallons of spray solution.

When following label recommendations, it may be necessary to prepare a percent solution of the pesticide's active ingredient (a.i.) The active ingredient is mixed with water or other diluent to prepare a known concentration, regardless of sprayer's output in gallons per acre. These types of percent solutions are often mixed on a weight/weight basis (w/w), meaning pounds of active ingredient (a.i.) per pound of water. Percent solutions can be calculated for both liquid and dry formulations.

Percent Solutions – Liquid Active Ingredient (a.i.)

$$\frac{\text{Gallons} \times 8.34 \times \text{required percentage (decimal)}}{\text{pounds a.i. per gallon}} = \text{Gallons of formulation}$$

Example: You plan on using 150 gallons of water and glyphosate spray mixture. You are directed to apply a 1% solution of glyphosate (w/w basis) with a handheld spray gun. The formulation of glyphosate that you are to use contains 4.17 pounds of active ingredient per gallon.

$$\frac{150 \text{ gallons} \times 8.34 \times 0.01}{4.17 \text{ pounds a.i. per gallon}} = 3 \text{ gallons of formulation}$$

In this example, 150 gallons of liquid should contain 3 gallons of glyphosate formulation. The total volume of water combined with the glyphosate formulation should equal 150 gallons. You would therefore use 147 gallons of water and 3 gallons of the **formulated** glyphosate product.

Percent Solutions – Dry Active Ingredient (a.i.)

$$\frac{\text{Gallons} \times 8.34 \times \text{required percentage (decimal)}}{\text{percentage (decimal) a.i. per pound}} = \text{pounds formulation}$$

Example: in 100 gallons of water, you need to mix a 1% spray solution of a formulation that contains 75% active ingredient (a.i.) In other words, 1 pound of dry formulation would contain 0.75 pounds of pesticide active ingredient.

$$\frac{100 \text{ gallons} \times 8.34 \times 0.01}{0.75 \text{ a.i. per pound}} = 11.12 \text{ pounds of formulation}$$

You then add 11.12 pounds of the formulation to 100 gallons of water to achieve a 1% solution.

Parts-per-Million (ppm) Solutions

Some pesticides are mixed in parts-per-million concentrations, which are exactly the same as percent solutions For example, a 100 ppm solution is equal to a 0.01% percent solution (100÷1,000,000 = 0.01 or the decimal equivalent of 0.0001) The ppm designation represents the parts of active ingredient of pesticide per million parts of water.

As with calculating percent solutions, parts-per-million (ppm) can be calculated for both liquid and dry formulations.

Liquids

$$\frac{\text{ppm required x Gallons in tank x 8.34}}{\text{1,000,000 x lbs. a.i. in formulation}} = \text{gallons of formulation per given volume}$$

Example: A pesticide contains 5.4 pounds of a.i. in 1 gallon of formulation. You are directed to prepare a 100 ppm concentration of the active ingredient (a.i.) in a 500-gallon tank.

$$\frac{\text{100 ppm required x 500-gallons in tank x 8.34}}{\text{1,000,000 x 5.4 lbs. a.i. in formulation}} = \text{0.0772 gallons of formulation per 500 gallons}$$

0.0772 x 128 fluid ounces per gallon = 9.88 or 10 ounces of the formulation in 500 gallons to make a 100 ppm solution

Dry Formulations

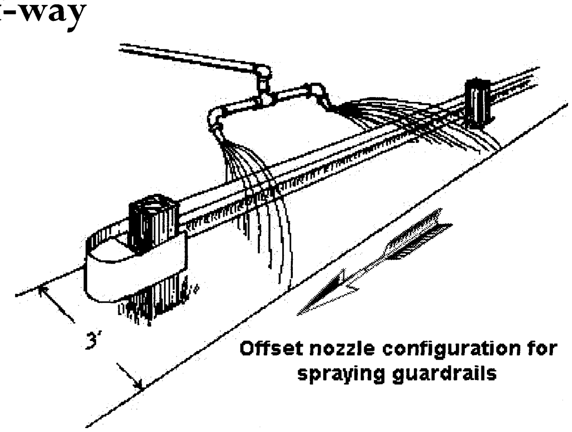
$$\frac{\text{ppm required x Gallons in tank x 8.34}}{\text{1,000,000 x \% a.i. in formulation}} = \text{pounds of formulation per given volume}$$

Example: You are given a recommendation requiring a 100 ppm concentration of the active ingredient (a.i.) oxytetracycline to be mixed in a 500 gallon tank to control fire blight on trees within a parking area. The formulation you have is a wettable powder containing 17% a.i.

$$\frac{\text{100 ppm required x 500-gallons in tank x 8.34}}{\text{1,000,000 x 0.17 a.i. in formulation}} = \text{2.45 pounds of formulation per 500 gallons}$$

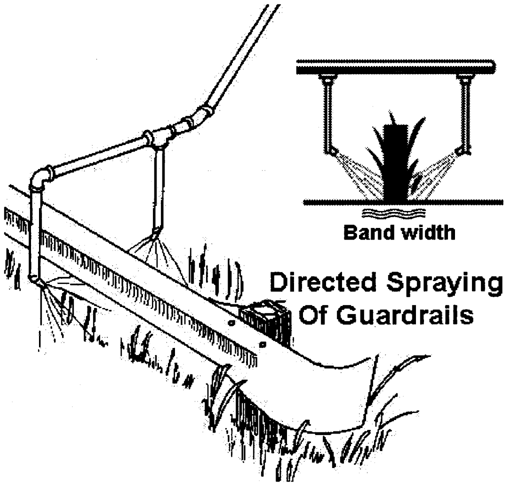
Guardrails and Band Spraying In Rights-of-way

Small off-center nozzles are effective devices for treating narrow strips under guardrails (generally about 3-feet wide). The nozzles are mounted about 15 inches above ground level on a fixed spray-bar and spaced approximately 18 inches apart in line with the direction of travel. They are adjusted so the front nozzle throws a pattern angled forward in the direction of travel, and the rear one throws a pattern angled back, as shown in the illustration above. This eliminates "shadowing" behind posts. The desired pattern width is obtained by adjusting the nozzle angles.



Offset nozzle configuration for spraying guardrails

Off-center nozzles can also be used to treat under guardrails without producing significant drift. This is done by using a single hand-held or truck-mounted spray bar fitted with two nozzles.



Band spraying is the application of a pesticide in single, parallel bands, leaving the area between bands free of the pesticide. The directed spraying is application of a pesticide to a specific area such as a plant canopy, a row or at the base of the plants. Normally used for crop spraying, band applications also are useful for spraying guardrails within the right-of-way. Calibrating a sprayer with two nozzles per "row" is similar to calibrating a band sprayer. With broadcast or band applications, GPA is equal to the output from one nozzle. When more than one nozzle is used per row, the combined amount collected from all nozzles directed at one row is equal to the GPA.

Example: You have set up two nozzles to apply a directed spray to a row (band) that is 30-inches wide. See the guardrail illustration above. You set up a test strip of 100 feet and drive at a speed to give good coverage. You do multiple speed tests and determine that it takes you 20 seconds to drive this strip. You collect 15 ounces from each nozzle for 20 seconds. What is the sprayer's output in GPA?

As explained in the Bureau of Land Management (BLM) Pesticide Applicator Handbook, the effective swath width will be the width of the band in feet (30 inches ÷ 12 in/foot = 2.5 feet). The test strip area is then 100 feet x 2.5 feet or 250 ft^2.

It is also important to remember that two nozzles are contributing to the total output so you need to multiply the single nozzle output by 2 and then convert to gallons (2 x 15 oz. per nozzle) ÷ 128 oz per gallon. This equals 0.234 gallons

$$\frac{\text{Test strip Gallons}}{\text{Test Strip Acres}} = \frac{\text{Gallons}}{\text{Acre}} \text{ Or GPA}$$

$$\frac{0.234 \text{ gallons}}{250 ft^2} = \frac{\text{Desired Volume (GPA)}}{43{,}560 \ ft^2}$$

$$\text{Desired GPA} = \frac{0.234 \text{ gal. x } 43{,}560 \ ft^2}{250 \ ft^2}$$

$$\text{40.7 or 41 GPA} = \frac{10{,}193}{250}$$

Public Relations and Right-of-Way Pest Management

The number of property owners along a right-of-way can be considerable. Vegetation control practices, if not restricted to areas within the right-of-way, can lead to public relations problems. Pesticide use is particularly controversial, even when there is full compliance with the pesticide label. Right-of-way operations are also highly visible to the public and because of this, may be unusually open to criticism. However, much of the potential criticism can be avoided if the applicator is considerate of public concerns, is knowledgeable and informative, and uses extra care in pesticide applications.

Right-of-way personnel must be aware of the objectives and operation of the vegetation management program and know how their work activities relate to the overall program. The what, why, how, where, and when should be politely explained to the public whenever and wherever the need or opportunity arises.

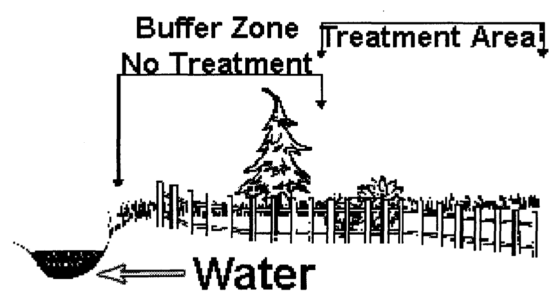
There may be a **difference in perception** between applicators and those who complain about their work. Applicators perceive that the plant brownout a verification that they have done their job properly while some property owners view it as a violation of the "green" space that they consider an extension of their own property. Property owners may realize that right-of-way maintenance does take place, but may have no understanding as to why it is necessary or how it is done. They are concerned about the visual impacts of the applicators' activities and about their personal safety.

Often problems of pesticide application are best resolved by improving operational practices. Most operational problems are within the control of the applicator; they are not unavoidable accidents. **Carelessness** can lead to repeated violations or misuses resulting in significant and visual off-target impacts. These misuses include careless mixing or transferring of pesticides with resulting spills; improper disposal of leftover spray mixture at the end of the day; contamination of surface water through drift, spills or improper disposal; and injury to off-target vegetation due to drift, volatility or lateral movement of pesticides.

It is possible to follow label instructions and still be careless. You are being careless:

- if you do not become familiar with the area to be sprayed prior to treatment,
- if you do not take all possible steps to avoid drift to include volatilization,
- if you do not use the proper pesticides or equipment for the job,
- if you do not regularly check application equipment to make sure it is in working properly,
- if you do not wear proper personal protective equipment (PPE).

You must practice a "good neighbor" policy with all adjacent land owners and residents. The goal is to prevent misunderstanding and confrontational situations. Review the herbicide use plan as it relates to adjacent areas that might be adversely affected by the herbicide application. Consider neighboring fields as well as the area you are treating. For example, many broadleaf crops are especially sensitive to dicamba, picloram, and 2,4-D. You should not use these herbicides adjacent to windbreaks, ornamental trees, shrubs, flowers, gardens or other areas where sensitive plants are growing.



Consider the presence of lakes, streams, or ponds in the vicinity of areas you wish to treat. Leave an untreated buffer zone adjacent to such sensitive areas to catch any runoff from the treated site. **As a BLM applicator, you are required to maintain at least a 25-foot buffer zone when applying pesticides by a vehicle and at least 10-feet when applying pesticides by hand.** For the greatest environmental safety and for maximum herbicide efficiency, keep the applied herbicide on the site you are treating.

SUMMARY

Use of pesticides to control weeds, brush and other pests in rights-of-way causes concern for some people. Typically, these concerns involve the products being used and whether or not they are safe. Many tests are required by law before a product can be marketed in this country. These tests include those on acute and chronic toxicity, carcinogenicity, reproductivity, impacts on wildlife (mammals, birds, fish and other aquatic animals) and tests on environmental fate, including the movement, persistence, dissipation and metabolism of the potential product in animals, plants and soil.

Many compounds do not make it through the screening process and are never marketed as pesticides. Those that do have undergone extensive review a review that will continue throughout the product's life. Detailed Material Safety Data Sheets (MSDS sheets) and concisely stated product labeling outline conditions of safe use established by extensive research and assist the applicator in performing operations safely.

Applicators on the job should:

Have available product information	Respond to public inquiries	Be professional
• sample label • MSDS sheet • literature	• get name, address and phone number • do not spray without landowner's permission • distribute literature • resolve complaints in a timely manner	• maintain equipment • dress properly; appear neat • be polite

Often, a landowner's questions concerning pesticide applications go unanswered or are not answered to their satisfaction. This generally results in a formal complaint and polarized viewpoints. Landowners feel the applicator is hiding "something" and the crew supervisor may view the questions as a nuisance. A simple solution to this problem is to know the answer to the landowner's question before it is asked. A quick, direct response to the public's concerns facilitates better communications and a more enjoyable working environment. Be prepared to respond to commonly asked questions such as these:

- What are herbicides and why are they used?
- Do herbicides affect birds?
- Is it safe to eat wild berries from areas that have been sprayed?
- What kinds of precautions are taken to make sure that pesticides don't get into groundwater supplies?
- Do herbicides and other pesticides pose any risk to me and my family?
- What happens if herbicides wash from the treated area into a pond how does it affect the fish?
- If my cattle graze on treated rights-of- way, will they be harmed?
- If a wild game grazed on a treated rights-of- way, is the meat safe to consume?

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BUREAU OF LAND MANAGEMENT
PESTICIDE APPLICATOR
STUDY GUIDE

FORESTRY

JANUARY 2004

Forest Pest Management

Prepared by Reeves Petroff
Montana Pesticide Education Program

This manual provides Bureau of Land Management (BLM) personnel with general information about the management of major insect, weed, diseases and vertebrate pests of forests and timberlands. Chemical trade names have been used for purposes of simplification, however, no endorsement of specific products is intended, nor is criticism implied of similar products or equipment that is not mentioned.

INTRODUCTION

An area may be considered as "forestland" if it is at least 1 acre in size and contains 10 percent tree cover. One-third of the U.S. — 747 million acres — is forestland. Two-thirds of these forestlands, or some 504 million acres, are classified as "timberlands." Timberlands are forests capable of growing 20 cubic feet of commercial wood per year. Commercial timberlands can be used for the repeated growing and harvesting of trees. Almost 72 percent of U.S. timberlands are located in the Eastern U.S. The Bureau of Land Management (BLM) oversees the management of 55 million acres of forests and woodlands on BLM-managed public lands in 12 Western states, including Alaska.

Most trees in the United States are referred to as either "hardwoods" or "softwoods." Hardwood trees are deciduous trees that, with a few exceptions, lose their leaves in the fall or winter. Softwood forest types, which represent 45 percent of U.S. timberland, are mostly conifers, or cone-bearing trees, such as pines, spruces, and firs.

The forest is a fragile environment. Management of it is a major concern to many people, including forest and wildlife managers, lumber companies, recreational-area managers, and homeowners. A healthy forest can vigorously renew itself. A healthy forest can recover from a wide range of disturbances, and retain its ecological resilience to meet the current and future needs of people for products, services and esthetic values.

FOREST PEST MANAGEMENT

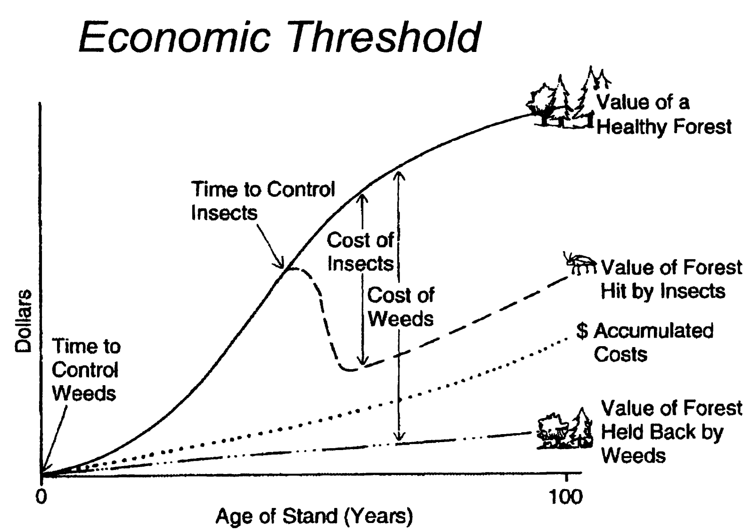
Forests are complex and varied ecosystems. In some cases, the pest damage may already be at such a stage that the best response is no response at all. Such a situation could occur where the terrain, undergrowth, or presence of a riparian or other sensitive areas would greatly limit treatment options. On the other hand, a pest infestation may be at such an early stage that an effective control program can be initiated based on correct pest identification and proper scouting for pests.

Managing tree pests effectively should be based on thorough consideration of ecological and economic factors. The pest, its biology, and the type of damage are some of the factors that determine which control strategies and methods, if any, should be used. Ultimately, pest management decisions represent a compromise between the value of the product, the extent of the pest damage, the relative effectiveness and cost of the control measures, and the impact on the environment.

The main emphasis of any pest management program is prevention, or at least keeping the pest damage to an allowable minimum. Monitoring for early signs of pest infestation and correctly identifying pest species can be the key elements of a successful forest pest management strategy.

The planned strategy of combining the best pest management methods is called Integrated Pest Management (IPM). The goal of forest IPM is to use all appropriate tools and tactics to prevent pest damage to forestlands without disrupting the environment. Information gathering and decision making are used to design and carry out a combination of measures for managing pest problems. Using a combination of prevention and control methods is the best approach to pest problems. The basic tools of any Integrated Pest Management (IPM) program include:

- Correct pest identification – Essential for selecting pest management options.
- Monitoring or scouting for the pest or pest symptoms – Also can provide information on daily or seasonal changes.
- Determining threshold levels – The level of pest infestation that justifies a particular treatment.
- Keeping good records – Helps monitor whether pests or natural enemy populations are increasing or decreasing. Also aids in forecasting pest outbreaks.
- Developing a management strategy or control action guidelines – Keeping good records will aid in this process.
- Evaluation of the management strategy – A critical step that helps determine what worked and what didn't.

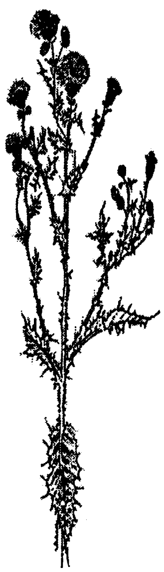


The decision to control a pest lies with the forest owner or manager. Proper decisions can be made only after the trees have been monitored for the level of pest activity, the injury potential has been evaluated, and a cost-benefit analysis has been made. By comparing the cost of applying controls to the projected market value of the stand at maturity, the pest population level at which it becomes economically beneficial to apply control measures can be determined. This population level is referred to as the **economic, treatment or action threshold** and indicates when management actions are needed to avoid losses. Generally, pesticide, especially insecticide, use in a forest is not justified because of the expense of the treatment, the low value of individual trees, and environmental considerations. However, with specialty forest crops such as Christmas trees, the economic thresholds may be different and the use of pesticides is more often justified.

FOREST PESTS

Forest pests belong to four groups: undesirable vegetation; insects (and other invertebrate pests); disease-causing organisms; and vertebrates.

◆ UNDESIRABLE VEGETATION



Reducing the competition from weeds is often the immediate goal of the forest pest manager. A pest manager might also consider the following objectives:

- Removing unwanted vegetation from planting sites to favor the planted trees.
- Releasing more desirable species from less desirable overtopping species.
- Thinning excess plants from a stand.
- Preventing disease movement through root grafts.
- Preventing invasion of herbaceous and/or woody vegetation into recreational areas and wildlife habitat.
- Controlling vegetation along forest roads and around buildings and facilities.
- Eliminating poisonous plants from recreational areas.
- Controlling production-limiting weeds in a seed orchard or tree nursery.
- Preventing and limiting the spread of noxious weeds.

Certain species of trees and shrubs are considered to be weeds or undesirable vegetation if they interfere with the development and growth of desirable tree species. For instance, conifer seedlings are often unable to compete effectively with grasses, shrubs, broadleaf weeds and other tree species during their establishment period.

After an area has been disturbed by logging or fire, grasses and broadleaf weeds are usually the first to appear. Although their dominance potential is usually short-lived, these plants can exploit site resources for many years if they become established ahead of shrubs, hardwood trees, or conifers. This is especially true of noxious weeds. Weeds often have special characteristics that pose problems in a forest environment. These characteristics include:

- ✔ Abundant seed production
- ✔ Rapid population establishment
- ✔ Seed dormancy
- ✔ Long term survival of buried seeds
- ✔ Adaptations for spread
- ✔ Presence of vegetative reproductive features
- ✔ Capacity to occupy sites disturbed by human activity

Some grasses can initiate active growth in the winter or early spring, when soil temperatures are relatively cold. The roots of downy brome (*Bromus tectorum*) and medusahead (*Taeniatherum caput-medusae*) are active at 36°F, while the roots of ponderosa pine require temperatures of 50°F to begin growth. As a consequence, young conifers such as ponderosa pine lag behind the more developed grasses as warmer weather arrives and soil moisture declines in the late spring into summer. This head start gives competing weeds a tremendous advantage, especially on drier sites.

Integrated Weed Control

Successful vegetation management plans incorporate the right package of practices into well planned programs that are executed on a timely basis. No single plan is best suited for each site, so careful analysis of each site is necessary. Routinely review the results obtained and modify the plans as needed to ensure satisfactory control.

Cultural Control

Cultural weed control is simply carrying out those practices that favor the desired tree species and make them more competitive with weeds. Examples include the following:

- Selecting and planting the best adapted species and varieties.
- Practice thorough site preparation.
- Plant vigorous, large, healthy seedlings.
- Plant seedlings at the appropriate spacing and replace those that die.
- Apply necessary insect, disease, and rodent control measures.

Mechanical Control

Many specialized machines and attachments are used in forest vegetation management, including brush rakes, angle blades, shearing blades, rolling brush cutters, and shredders. Large offset disks and integral plows are sometimes used. In addition, chain saws, axes, brush hooks, powered brush cutters, hatchets, and other hand tools can be used in weeding operations. On gentle slopes, mechanical means of site preparation and rehabilitation are generally sufficient to remove debris, control weeds, prepare seedbeds, reduce soil compaction caused by logging, and carry out minor land leveling operations. Mechanical thinning is sometimes practiced, especially in very dense stands where clearing in regularly spaced strips is desired and no selection of individual trees is necessary. Mechanical thinning is not acceptable for release when desired small trees are hidden by taller, brushy trees or where individual tree selection is desired.

Mechanical control is not suited to all sites. The major obstacles to the use of mechanical vegetation management are unsuitable terrain, the likelihood of soil erosion, and relatively high operating costs. Manual vegetation removal can be done in areas inaccessible to machines or to complement or replace the use of large equipment. Manual cutting is most effective when species to be cut are not too dense and do not resprout (coniforers). Many brush species resprout readily from the trunk or established roots, and this reduces the effectiveness of cutting. Manual cutting may not always be appropriate for site preparation or release, but it can be effectively combined with herbicide treatment of stumps to remove selected trees and prevent regrowth.

Chemical Control

Chemical control of weed species is normally practical only once or twice in the life of a forest stand. The benefits of herbicides applied during site preparation and release may be evident through the life of the stand if their use is supplemented by all the other principles of good forest management. Use of herbicides is only one step in a long-term production plan. Application of herbicides must be both necessary and compatible with all other phases of the plan. Once the weed species to be controlled have been identified, the correct herbicide, formulation, rate, water volume, method of application, and time of treatment must be determined. Before using any pesticide, read the entire label. Herbicides used to manage vegetation in a forest are applied either by broadcasting selective herbicides over an entire site or by directing herbicides onto undesirable vegetation using backpack sprayers or hose and spray gun combinations from larger skid-mounted sprayers.

Herbicide Characteristics

Herbicides are chemicals that affect the germination, growth, and behavior of plants. To choose the appropriate herbicide for a particular situation, you need to understand some basic herbicide characteristics.

Selectivity or Specificity

Herbicides are not equally effective on all types of vegetation. Selective herbicides are available that control grasses only, broadleaf plants only, or certain grasses and broadleaf plants. There are also non-selective herbicides that kill all vegetation that they come in contact with. Some herbicides are selective in Christmas tree plantations when applied during certain periods of the year, such as before the trees begin growing in the spring, after they have hardened off in the late summer, or when they are dormant.

Mode of Action

The overall manner in which a pesticide affects a weed at the tissue or cellular level is known as the herbicides mode of action. Therefore, herbicides affect plants in different ways. Some are absorbed through the foliage; others are applied to the soil and are absorbed though the root systems of actively growing plants. A few herbicides kill only the portion of the plant to which they are applied (contact herbicides). Other herbicides are applied to or incorporated in the soil to prevent the germination of weed and grass seeds.

Residual Nature

Herbicide effects vary, in part because of their residual characteristics. An herbicide is considered to have residual effect if it prevents the regrowth of vegetation for a period of time after application. This time period varies from a few months to more than a year. Several residual herbicides exert preemergent control by continuing to kill weeds as their seeds germinate. Application rate, soil texture (particularly clay content), soil organic matter content, soil moisture level and herbicide solubility affect an herbicides residual properties. Many herbicides that are absorbed through foliage have little or no residual effect (postemergent) in the soil. Those herbicides applied to the soil before weed growth usually have residual effect.

Formulation

Herbicides are available in several formulations:

- Solutions, which are completely soluble in water or other solvents.
- Emulsions, which are two unlike liquids mixed together.
- Wettable powders, which consist of finely divided solid particles that can be dispersed in a liquid.
- Granules, which contain crystals of the effective chemical bound together with an inert carrier.

Each formulation has advantages related to its manner of application and the targeted plants susceptibility to the formulation used. An herbicide mixture's effectiveness depends on the user's knowledge of the formulation characteristics. For example, soluble herbicides must be mixed with clean water because dirt may inactivate them. Combinations of emulsifiable compounds or wettable powders and water require spray tank agitation to maintain a uniform suspension. Failure to agitate may result in erratic application rates.

Factors Influencing Herbicide Effectiveness

To successfully control vegetation, the manager must understand the factors that influence herbicide effectiveness. These factors include:

Application Rate

The amount of herbicide required per acre to obtain effective control depends on several variables, including herbicide formulation, soil type, and targeted vegetation. Specific application rates for various conditions are listed on the herbicide label.

Equipment Calibration

Calibration is the process of measuring and adjusting the amount of pesticide that equipment will apply to a specific area. Proper calibration of equipment is required to obtain good results when using herbicides. Calibrate equipment at least once each year. Once equipment is calibrated, it is essential that the same ground speed, pump pressure, and nozzle size are maintained during actual application.

Application Method

For successful results, it is essential that coverage is uniform, regardless of method used for application. The equipment must be maintained and cleaned so that the herbicides will flow correctly. For herbicides that do not form true solutions, especially wettable powders, maintain agitation throughout the spray application. Failure to agitate can cause erratic application rates.

Targeted Vegetation

Because of differences in anatomy and physiology, some plants are more affected by herbicides than others. Annual weeds and grasses are easily controlled with preemergent products, while perennial grasses and weeds, particularly those with deep root systems, are more difficult to control chemically. Some plants, such as horsetails and sedges, are very difficult to control. Because of such differences, two or more herbicides are often combined in the spray tank. Read all pesticide labels to determine the compatibility of various herbicides before preparing tank mixes to avoid interactions that may make each compound less effective. There is also a danger that an improper tank mix could damage the plants you are trying to protect. Pesticide labels and dealers can provide information that outlines the compatibility of many herbicides.

Soil-site Characteristics

Soils with high clay or organic matter contents may require a heavier application rate of residual herbicide than coarse-textured sands or gravelly soils. If the amount of herbicide necessary for effective control on heavy soil is applied to a lighter textured soil, the herbicide may injure non-target plants. Further, residual herbicides persist longer on heavier soils because clay and organic particles adsorb more of the material.

Weather Conditions

Weather factors at the time of and following application can heavily influence herbicide effectiveness. Cool and cloudy weather following application of foliar herbicides may reduce their effectiveness. Lack of rain following soil application of herbicides may allow weeds to grow and germinate before the herbicide moves into the soil solution. Heavy rain, however, may leach the herbicide from the upper soil or wash it to low-lying areas. In both cases, the herbicide is less effective and may damage non-target plants. Weather conditions are one of the most common reasons why herbicide applications fail to control weeds.

Resistance To Herbicides

Weed resistance to herbicides has been a major problem in the agricultural areas of the United States. It is important to monitor the results of weed control applications carefully and follow guidelines to avoid weed resistance in a forest setting. Prevention is the best approach. Use the following practices to delay or prevent the development of herbicide resistance.

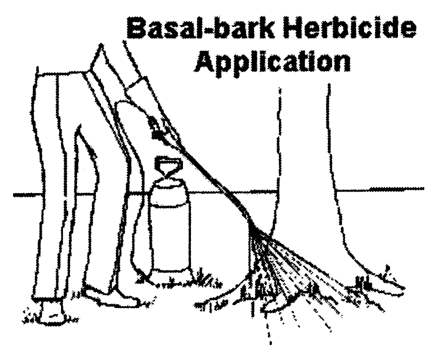
- Scout regularly and identify weeds present.
- Combine mechanical control practices such as cultivation with herbicide treatments.
- Rotate herbicides using herbicides with differing modes of action.
- Do apply more than two consecutive applications of herbicides with the same mode of action against the same weed unless other effective control practices are also included in the management system.
- Apply herbicides in tank-mixed, prepackaged, or sequential mixtures that include multiple modes of action. Combining herbicides with different modes of action and similar persistence in soil will help prevent herbicide resistance.

Evaluating the Results

After using any vegetation management practice, inspect the area to evaluate the results. Keep in mind the type and species of vegetation treated, the soil type, and weather conditions during and after application. Know the objectives of the control program when evaluating the results. In some cases, suppression of treated vegetation is sufficient; in others, selective control is desired. Initial herbicide activity and possible injury to adjacent desirable vegetation can usually be determined 2 to 4 weeks after application. The results of vegetation control treatments should be evaluated after about 2 months, at the end of the season, and then for several years. The effectiveness of brush and perennial weed control measures cannot be fully evaluated for at least 12 and sometimes 24 months after treatment. Evaluation must be an on-going activity. It allows you to make adjustments in rates, products, and timing of herbicide applications, and to plan any additional control measures that may be needed.

Controlling Trees and Woody Plants

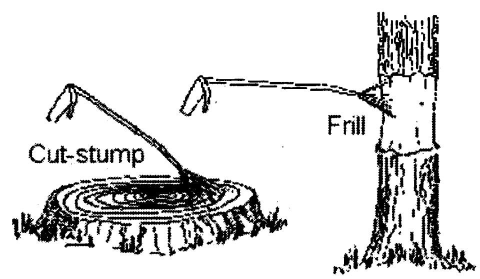
Controlling trees and woody plants are controlled by a number of different methods. Individual stem applications are used to apply herbicides directly onto or inside the stems of individual woody plants (trees or shrubs). Tree injectors, frill and squirt techniques, Hypo-Hatchets™ or similar devices, and cut stump treatments are used to deliver herbicides directly to the transport and growing tissues beneath the bark of woody plants. These treatments should not be applied to trees or shrubs where nontarget plants of the same species or genera are nearby (generally within 10 to 20 feet). Trees and shrubs of the same species or genera may form root grafts or sprouts from the same rootstock. In these cases, the herbicide can be translocated from one tree to another, killing or injuring the non-target tree.



Basal-bark treatments can be used to control brush, and to control trees up to 5 inches in diameter. They are useful to selectively remove undesirable brush species from stands of desirable plants. Basal-bark treatments are made with oil-soluble herbicides in a carrier of diesel oil or kerosene. The spray is applied to the lower 18 inches of the stems, and should thoroughly drench the stem, crown, and all exposed roots. However, care must be taken during application because most vegetative ground cover will be injured by herbicide applied in a diesel oil carrier. Where only a limited number of trees are to be controlled, a 3- to 5-gallon knapsack sprayer works well for the application of a basal-bark spray. Basal-bark applications made during the dormant season do not result in brownout of foliage, which may make dormant treatments desirable. In addition, since vapors from basal-bark applications may drift out of the treatment area, undesirable brush in areas adjacent to susceptible plants can be treated during the dormant season to reduce injury potential.

Herbicide application to **cut surfaces** in the bark of trees is an effective method for controlling woody species. Cut-surface applications are recommended when plants have thick bark or when they have stems greater than 5 inches in diameter. Applications can be made effectively during any season except in the spring during heavy sap flow. The cut must be made rapidly with a sharp saw or pair of pruning shears. A chain saw should be used on larger trees. Saturate the cut surface with herbicide as soon as possible after cutting. On large tree trunks, the cambium area next to the bark is the most vital area to wet. Do not wait more than several minutes to paint the stump. Woody plants have a wound response that quickly seals the cut surface and restricts the movement of herbicide into the roots. The best results are achieved by treating woody perennials that are not water stressed and are growing actively. Common herbicides used for cut stump treatments include 2,4-D amine, glyphosate, and triclopyr. Only the most concentrated herbicide formulations should be used for cut surface treatments.

Cut-surface Herbicide Application



◆ Insects

Insects are among the most successful of all organisms and are members of the largest group in the animal kingdom, the Arthopods. Less than one percent of the over one million insect species on the earth are considered pests. An even smaller percentage is considered forests insect pests. Insect pests of conifer trees are capable of limiting timber production; creating tree and fire hazards; reducing visual quality; affecting wildlife use; and degrading watershed properties.

Insects can be differentiated from the majority of other arthropods by many distinctive traits including: (1) three well-defined body regions; a head, a thorax, and an abdomen; (2) three pairs of legs in the adult stage; (3) one or two pairs of wings; (4) a single pair of segmented antennae on the head; and (5) an outer case or outer skeleton called an exoskeleton.

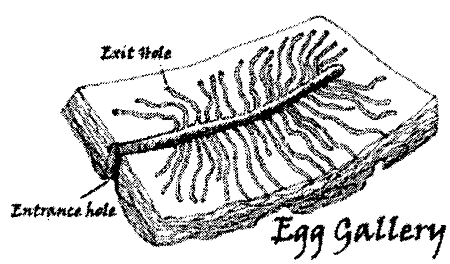
All species and every part of a tree—roots, trunk, branches, twigs, buds, leaves, needles, cones, and seeds—may be fed upon by insects. Insects may attack trees of any age. Stressed trees are often more susceptible to insect attack than healthy trees. Stunting, distortion, weakening, or death of a tree is frequently caused by some combination of adverse environmental factors and insect attack. It is important to realize that not all insects are pests; in fact, only a small percentage cause damage to trees. Most forest insects play important roles in forest ecosystems.

There are at least 1,000 insect pests common on conifer trees in Idaho and Montana alone. Of these, 45 diseases and 39 insects account for most of reported cases of damage. The major groups of insects affecting forest are:

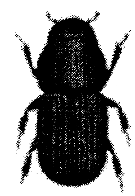
- bark beetles
- defoliators/foliage feeders
- branch and stem feeders
- cone and seed feeders

Bark Beetles

Bark beetles are small, cylindrical insects that attack and kill mature trees by boring through the bark and mining the phloem—the layer between the bark and wood of a tree. They chew out 'galleries' in which to lay their eggs. Within a few weeks the eggs hatch, but the beetle larvae remain in the tree until the following year, extending the network of galleries and eventually eating their way out. They emerge as beetles who then fly on to attack new trees. The combined action of the larval feeding and a fungus introduced by the beetle disrupts the translocation of water and nutrients within the tree, and typically results in tree death. The fungus carried by the adults penetrates the sapwood of the tree, creating a blue stain that degrades the appearance and value of the wood.



Healthy trees can often withstand light attacks by exuding pine sap or 'pitch' that expels invading beetles. The presence of whitish colored pitch tubes may indicate that the tree has repelled a beetle attack. Reddish brown pitch tubes on pine are an indication of attack.



The most important species of bark beetles are the mountain pine beetle, Douglas-fir beetle, the spruce beetle, and the fir-engraver beetle. Bark beetles play an important role in the natural life cycle of a forest. By attacking older or weakened trees, bark beetles help hasten the development of younger forests.

Mountain pine beetle, spruce beetle, Douglas-fir beetle, and the Western pine beetle are closely related and can be difficult to tell apart without a detailed knowledge of insect anatomy. However, the beetles can be distinguished by the trees they inhabit and the duration of their lifecycles.

- **Mountain Pine Beetle** (***Dendroctonus ponderosae***) - Attacks lodgepole pine, ponderosa pine and white pine trees from mid-July to mid- August. One-year life cycle.
- **Douglas-fir Beetle** (***Dendroctonus pseudotsugae***) - Attacks Douglas-fir trees from late April through May. One-year life cycle.
- **Spruce Beetle** (***Dendroctonus rufipennis)*** - Attacks Englemann spruce, white spruce and Sitka spruce trees from late April to early May. Two-year life cycle.
- **Western Pine Beetle** (***Dendroctonus brevicomis***) - Attacks ponderosa pine and has two generations per year. It is the smallest of the Dendroctonus bark beetles.

The fir-engraver beetle (*Scolytus ventralis)* attacks the true firs and occasionally attacks Douglas-fir, subalpine fir, mountain hemlock, and Engelmann spruce.

The best approach to general beetle management is preventative stand management. For example:

- Mountain pine beetle attack is related to tree vigor and maturity, and stands potentially at risk from this pest should be scheduled for harvest no later than about 80 years of age
- Mountain pine beetle occurs more frequently in pure pine stands than in mixed stands, so another preventative management strategy involves the cultivation of stands with a mixture of species
- Good slash disposal and logging can reduce the occurrence of Douglas-fir bark beetle

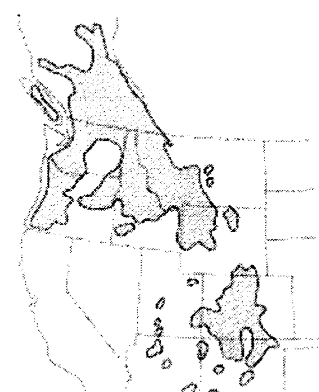
- Bark beetles often attack trees already weakened by other agents such as root rots or defoliating insects (e.g., Douglas-fir beetle often attacks mature Douglas-fir weakened by successive years of severe defoliation by Douglas-fir tussock moth); be on the lookout for potential problems.
- Insecticides can be used but their use is usually restricted to individual, high-value trees.

More specific control measures such as trap trees and logs are used to control spruce beetle and mountain pine beetle. Since spruce beetle are naturally attracted to wind-fallen timber, trees are sometimes felled into the shade and bucked into logs to attract these pests. For mountain pine beetle, live, standing trees are baited with attractants. Once the pests have become established in a trap log or trap tree it is destroyed.

Defoliators

Insects that feed on the leaves or needles of trees are known as defoliators. The larvae of these insects feed on the developing buds and new foliage of trees, causing height loss, deformity and reduced growth. After attack, the foliage is reduced, remaining damaged needles turn brown and wood growth slows down. Defoliation can weaken trees, making them susceptible to attack by other pests, and successive years of defoliation can kill trees outright. Defoliators include:

- Tent caterpillars – (*Malacosoma spp.*) – Most common tent caterpillar is probably the Western tent caterpillar (*Malacosoma californicum*). Usually feed on deciduous trees such as aspen and mountain mahogany. The newly emerged caterpillars move to crotches of branches and begin to produce a mass of dense silk.
- Gypsy moth, (*Lymantria dispar*) - Adult male moths are dark brown with black wavy lines across their forewings. Most easily identified by feather-like antennae. Adults do not feed and live only a about a week. Females are not capable of flight but 1st instar larvae emerge in late April or early May, suspend on a strand of silk and can be blown several miles on the wind. Preferred hosts include oaks, aspen, poplars, willow, apple, birch and mountain ash.
- Western spruce budworm – (*Choristoneura occidentalis*) - The most widely distributed and destructive forest defoliator in western North America. Larvae seek sheltered places under bark scales or in and among lichens on the tree bole or limbs. They spin silken tents called "hibernacula" in which they remain inactive through the winter. In early May to late June, larvae leave their hibernacula to search for food. They first mine or tunnel into year-old needles, closed buds, or newly developing vegetative or reproductive buds. Larvae usually leave traces of silken webbing and bits of excrement at the feeding site or entrance hole.



Distribution of spruce budworm

- Douglas fir tussock moth (*Orgyia pseudotsugata*) – Adult insects are charcoal-brown moths. Larvae initially feed on the underside of new needles, then switch to older needles and next year's buds. Attacks Douglas-fir, grand fir, subalpine fir; rarely pine, western hemlock, western larch, and Engelmann spruce

Managing the defoliating insects is keyed to early detection and appraisal of the problem (proper identification and scouting.) Common prevention measures include thinning to control stand density, and managing stands for a diversity of species and age classes. Defoliators are also vulnerable to parasites, diseases and extreme temperatures. In addition, insecticides can be used to control and kill defoliators. Other methods of control, such as growth regulators, which interfere with the insect's life cycle, or sex attractants that interfere with breeding can be used.

Cone-attacking Insects

Insect pests also attack tree cones, destroying the seeds of the next generation of forests. The cone-attacking insects include:

- Cone beetles (*Conophthorus* sp.) - Small shiny black beetle with bark beetle features. Adult is one of the injurious stages. Adults often burrow along axis of cone. Eleven species in Western North America. Attacks sugar pine, Western white pine and ponderosa pine.
- Douglas fir cone midge (*Contarinia oregonensis*) - Adult flies are small, only 3-4 mm long. Larvae are the injurious stage. After hatching from the egg, the larvae tunnel into the cone scale and form a gall. The gall fuses the developing ovule to the scale. Severe infestations will destroy all seeds in the cone. Attacks Douglas fir
- Douglas fir cone moth (*Barbara colfaxiana*) - The adult is a small moth (wingspan 15-20 mm) with greyish brown speckled forewings. Larvae begin feeding on scale tissue but as they mature, feed more on seeds. Attacks Douglas fir and true firs.
- Douglas fir seed chalcid (*Megastigmus spermotrophus*) - Females are amber colored wasp-like insects, about 4.0 mm long, with a long ovipositor which curves up over the abdomen. The larvae feed only on seed contents, each one destroying a single seed. Attacks Douglas fir.
- Fir coneworm (*Dioryctria abietivorella*) - Medium-sized greyish moth. Larvae feeds voraciously, tunneling indiscriminately through scales and seeds. Attacks Douglas-fir and true firs primarily, but will attack cones of many coniferous species.
- Spruce seed moth *(Cydia strobilella)* - Small dark grey moth with mottled forewings. Newly hatched larvae mine directly to a seed and commence feeding. Attack white, Engelmann, Sitka and black spruce.

Sucking Insects

Sucking insects feed on plant fluids below the surfaces of bark and leaves. Sucking insects usually attack in mass and reduce vigor as by killing shoots and leaves. Entire trees or stands may be killed. Sucking insects cause scaly, mealy or powdery masses on trucks, twigs and lower surfaces of leaves. Sucking insects include:

- Adelgids – aphid-like insects that form galls or abnormal growth of plant tissue.
- Aphids - Adult aphids may be either wingless or winged. Aphid feeds gregariously, sucking sap from old needles.
- Juniper scale. Female scale insects do not have wings and the head is not distinct from the rest of the body. Most of her life is spent at one spot feeding from plants through a long, thin tube she inserts into plant tissue. As she develops, she secretes a protective waxy or fuzzy covering. Male scale insects are very small, have one pair of delicate wings, live only a few days, and do not feed.
- Spruce spider mite. Mites are not true insects but belong to the Class Arachnida (spiders.) Spruce spider mites, can be found on many species of conifers with the most severe damage most often found on spruce and true firs.

Natural Controls

The term "natural control" implies that we are not directly involved in the regulation of insect numbers. The environment applies many pressures that usually keep insect populations from reaching damaging levels. Such environmental factors that limit the abundance or distribution of pest species include biotic (living) and abiotic (non-living) factors.

Biotic factors

- Insect-eating vertebrates such as rodents, skunks, and birds.
- Predaceous insects such as ladybird beetles, ground beetles, ants, and lacewings.
- Parasitic wasps and flies.
- Insect diseases caused by microorganisms such as viruses, bacteria, and fungi.

Abiotic factors

- Climatic factors, including heat, cold, and too much or too little moisture.
- Topographic barriers such as mountain ranges and bodies of water.
- Soil conditions, such as compaction, physical make-up, and moisture content.
- Disturbances such as wildfire.

Biological Controls

Biological controls use living organisms or their products to achieve pest control. The results are similar to biotic natural controls, but here the pest manager is directly involved in the application of the controls. The major groups of beneficial organisms involved are predaceous and parasitic insects and insect disease organisms. Methods include introduction of new natural enemies from the original home of a foreign pest species; rearing and releasing beneficial predator and ***parasitoid*** species; and conservation of natural enemy populations by providing food, overwintering habitat, alternative prey, or other resources for beneficial species, or by minimizing the use of broad-spectrum insecticides that would kill beneficial insects.

Insecticides

The application of insecticides in forest situations is limited because of the relatively high cost of application compared with the market value and long rotation age of trees. Insecticides are more commonly used for Christmas tree plantations because of the high value and the short rotation age of the crop.

Insecticides are used for many reasons to include the following:

1. Effects are immediate and predictable and offer a sense of gratification.
2. Can rapidly reduce damaging populations.
3. Can be used where needed.

However, chemical controls may have negative impacts on non-target organisms, including natural enemies, and may lead to contamination of soil or water.

Pest Resistance to Insecticides

The insects left alive after a pesticide application may be more tolerant to a pesticide, and, over time, the insect population can develop a genetic resistance to the pesticide. Insects can also develop cross-resistance. Cross-resistance occurs when an insect population has developed resistance to a certain pesticide then also develops resistance to other related or unrelated pesticide compounds to which it has never been exposed.

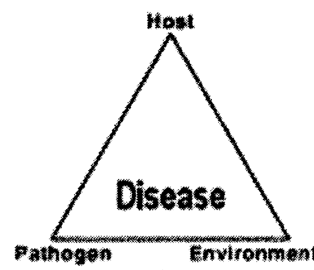
Resistance to insecticides can be prevented or postponed indefinitely by following label directions and these guidelines:

- Use integrated control strategies.
- Limit the use of pesticides as much as possible.
- Rotate different brands and classes of insecticides.

◆ Disease-causing Organisms

When a plant cannot function normally, it is diseased. The primary causes of disease in trees are pathogens and environmental factors. Trees have many disease pathogens: viruses, bacteria, fungi, nematodes, mycoplasma-like organisms, and parasitic higher plants. Fungal pathogens are the most prevalent. They cause seed rots, seedling damping-off, root rots, foliage diseases, cankers, vascular wilts, diebacks, galls and tumors, trunk rots, and decays of aging trees. Unfavorable weather and environmental factors such as temperature and moisture extremes, high winds, or ice can damage trees directly and predispose the trees to pest attack.

Three critical factors or conditions must exist for disease to occur — a susceptible host, a virulent pathogen, and the right mix of environmental conditions. The relationship of these factors is called the disease triangle. If only a part of the triangle exists, disease will not occur. Understanding the disease triangle helps us understand why most trees are not affected by the many thousands of diseases that exist.



Diseases are usually restricted to specific parts of the tree, and like insect pests are named by the part of the tree they attack, such as root rots, heart rots, leaf spots and stem cankers. They disrupt the normal growth functions of the tree causing specific injury, poor quality wood, reduced tree growth and sometimes death. Specific diseases can be encountered at almost all stages of a tree's development.

Most decay fungi are microscopic organisms that reproduce by spores. At certain stages in their life cycle some fungi produce large spore-producing 'fruiting bodies' which we recognize as mushrooms or conks. Diseased plants exhibit symptoms in reaction to the presence of the fungus. Trees infected with root rot develop yellowish needles. Those affected by rusts display red or brown spotting on their needles, and those with heart rot have internally decayed wood.

Disease problems are often harder to detect than insect problems, simply because the evidence of damage is not always easy to see. Even when it is, you still need to know what to look for. The following check list indicates the major disease categories and the tree species vulnerable to them.

Since fungi cause the greatest amount of damage to trees, they are the most common targets for control with pesticides (fungicides). Chemicals used to control fungi generally aren't effective on bacteria. Viruses aren't controlled directly by pesticides but are controlled by eliminating vectors and by cultural methods (non-chemical) that protect susceptible trees from infection. Pesticides have very limited use for forest disease problems.

Types of Disease Damage

Decay

Wood decay accounts for about half of all the forest losses to disease. It is a slow killer, working from the inner heartwood out toward the sapwood, that damages the tree's stability and leaves it vulnerable to wind blowdown. Decay is caused by various fungi that enter trees through scars and wounds. Though it is currently more of a problem in old growth stands than in second growth ones, it is nevertheless a potential threat to second growth forests. Some interior second growth spruce forests have particularly high levels of decay.

Root Rot

Root rots are diseases caused by fungi that spread from infected root systems to those of healthy trees. The potential for damage is great because of the difficulty of detection and the ease of spread. The worst of the rots can live in stumps for up to a century and survive even forest fires if the infected roots are insulated from the heat by the soil. In some cases the spread of root rot may be done without actual contact between the infected and the healthy root system—when fungi are spread by means of small, thread-like structures (mycelium) that stretch out through the soil from the infected roots.

Root diseases retard tree growth and can lead to susceptibility to wind blowdown. Young, second growth forests are particularly vulnerable to root disease and should be monitored carefully for signs of pockets of dead or dying trees. Root disease can also kill seedlings and pole-sized trees.

Fungal Blights

Blights are symptoms of a fungal and bacterial infections and are characterized by general and rapid killing of leaves, flowers and stems or trunks.

Needle cast, or needle blight (*Elytroderma deformans*), is the most important fungal disease of ponderosa pine in the Pacific Northwest. It also infects Jeffrey pine and rarely infects lodgepole pine. Symptoms of the disease include reddened, dead 1-year-old needles with green current season needles at the tip. The inner bark of infected branches contains numerous dark dead lesions. If severely infected, entire tree tops may be deformed, growth loss occurs, and occasionally, trees die or are predisposed to bark beetles and root diseases.

Juniper twig blight (*Phomopsis juniperovora*) and Cercospora Needle Blight (*Cercospora sequoiae* var. *juniperi)* are fungal diseases of Rocky Mountain juniper and Eastern red Cedar

Blights are often confused with winter injury or winter drought. However, winter injury is likely to affect almost all of the branches on one side of the shrub, especially if the shrub has a south or southwest exposure.

Stem Disease

Stem diseases such as rusts and cankers weaken the tree, damage wood and reduce growth. Rusts tend to attack young trees and are often identified by the presence of cankers on the branches and trunks of infected trees and dead or dying tops. The rust fungus enters through the tree's needles, and travels through the bark (often creating branch cankers) to the main stem where it forms cankers that girdle the tree.

Young plantations are especially vulnerable, and rusts pose a potential threat to the extensive lodgepole pine forests. Rusts generally require two hosts to complete their life cycle.

White pine blister rust (*Cronartium ribicola)* is a rust fungus that causes branch and stem canker disease of five-needle pines such as Western white pine, sugar pine, and whitebark pine. The life cycle of the fungus is complex and involves five different spore forms. It takes four to five years to complete. The fungus is an obligate parasite (its host must be alive for it to remain alive) and requires an alternate host in the genus Ribes, the gooseberries and currants. Infected pines exhibit yellow and red needle spots, spindle-shaped swellings, cankers with roughened bark, flagging of branches and tops and outright mortality, especially of sapling and pole-sized trees.

Dwarf Mistletoe

Classified as a disease-causing organism, dwarf mistletoes are parasitic flowering plants that attack Douglas-fir, lodgepole pine, coastal western hemlock and western larch. Dwarf mistletoe should not be confused with the leafy mistletoe that is used for holiday celebrations. Mistletoe spreads through a stand by ejecting its seeds at high speeds, and covering distances of up to 20 feet. The mistletoe attaches itself as a sticky seed to the tree, then sends roots through the bark and into the tree to tap water and nutrients.

The infection is recognizable by large swellings on tree stems or branches and by 'witches broom,' a dense tangle of branches. While it rarely kills the host tree (other than larch), it drastically reduces growth and leaves the tree vulnerable to attack by other disease or insects. In old growth stands it can substantially decrease the value of the tree, while in second growth, the effect is mainly a reduced rate of growth.

Foliage on young trees and cones on older trees also are disease targets. While foliar disease results mainly in cosmetic damage and is a problem for ornamental species and Christmas trees cone diseases can drastically reduce regeneration success. Spruce cone rust, which leads to malformation and premature opening of cones has had a serious effect on cone collection programs in the northern interior The impact of cone and seed diseases will increase with the move to second growth forests and extensive regeneration programs.

Disease Control in Forest Nurseries

Chemical control methods in nurseries rely primarily on treatment before the disease becomes established. This may be done by fumigating the soil to eradicate the pathogen or by protecting the plant with foliage, seed treatment, or root drench fungicide applications.

Soil fumigation. Fumigation is the application of solid or gaseous pesticides to the soil to control soil-borne pathogens. When small areas are to be fumigated, the most convenient method is through injection of the pesticide with a hand applicator or by placement of granules into the soil. Highly volatile fumigants often require the use of plastic sheeting to keep the fumigant in place. In this case, the pathogen may be eradicated from the site.

Seed treatment. Seed treatments are used in nurseries to control seed- and soil-borne fungal pathogens that cause seed rots, damping-off, and seedling root rots. Fungicides are applied as dusts, slurries, or pellets.

Soil drenches. A soil drench is the soaking or wetting of the soil with a solution or suspension of a pesticide sometimes saturating the soil itself. Soil drenches are used in forest nurseries to suppress soil-borne plant pathogens in seed and transplant beds. These treatments are most effective as preventive treatments.

Foliar applications. Protection of foliage with fungicide sprays is a common practice in nurseries. Foliage diseases frequently become epidemic under nursery conditions. Crop rotation, plowing to turn under crop refuse, and disease resistance, if available, can help control leaf spots and blights,

but, close spacing, overhead irrigation, and other factors contribute to frequent and severe foliar disease outbreaks unless treated. The high value of nursery crops justifies foliar treatments.
Effective treatment depends on the right selection of pesticides. Read the labels carefully. Timing and thoroughness of application also are important. Many fungicides are effective only when applied **before** infection occurs. This frequently requires application when stage of plant growth or weather conditions dictate it, rather than waiting for symptoms to begin to develop.

◆ Vertebrate Pests

In addition to the damage caused by insects and disease, the health and productivity of forestlands can be affected by animals and machines. Porcupines, bears, squirrels, deer, rabbits and a host of other animals cause damage mainly newly planted seedlings. Many innovative, but expensive techniques for discouraging wild grazing animals have been tried, including the use of repellents, enclosing individual seedlings in mesh protectors, selective hunting, and erecting scarecrows and electric fences. As a general rule, livestock movement should be controlled by the distribution of salt licks, or fencing, to keep them out of newly planted areas.

Mechanical damage usually occurs as a result of poor felling, skidding and road construction practices in which the main stems of standing trees are damaged. The bark is most vulnerable, and damage is the greatest, in spring during sap flow. In addition to the mechanical damage to the trees, damage to soil is a problem. Mechanical damage can leave trees vulnerable to attack by insects and diseases

Glossary

Bark Beetle - Any beetle which feeds exclusively in the cambial region of stems, or branches, and spends most of its life cycle there.
Blue Stain - Coloration of wood infected by fungi with blue, brown or black hypae; a group of lower fungi (Ascomycetes and Fungi Imperfecti) which cause blue stain.
Brood - All the offspring from eggs laid by one series of parents which mature at about the same time.
Bug - A species in the order Hemiptera-- the "True Bugs".
Canker - A definitive lesion on a stem, branch, or root; the cambium of which has been killed.
Chlorotic - Yellow appearance of normally green foliage caused by loss or lack of chlorophyll.
Cocoon - A covering spun or constructed by a larva as a protection to the pupa.
Decay - Wood decay: process or result of degradation of wood by fungi, bacteria, or yeasts.
Defoliator - An insect which feeds exclusively on foliage.
Egg Gallery - Usually referring to a tunnel or pathway in which an insect lives, feeds, or deposits eggs.
Elytra - The leathery front wings which serve as coverings to the membranous hind wings. Usually only referred to in the order of beetles.
Frass - Solid larval excrement.
Fruiting Body - Structure of a fungus which produces spores.
Fungus, plural = Fungi - Group of lower organisms lacking chlorophyll and dependent upon other organisms for source of nutrients.
Gall - Abnormal proliferation of plant tissue stimulated by insect or pathogen attack or abiotic influences.
Gallery - Usually referring to a tunnel or pathway in which an insect lives, feeds, or deposits eggs.
Generation - The development of insects from egg to adult; a brood.
Genus - An assemblage of species agreeing in some character or series of characters.
Gregarious - Living in societies or communities, but not social.
Grub - The larva of a beetle.

Host - Plant infected or infested by a pathogen or insect.
Infection - The process or result of a pathogen invading host tissue.
Instar - The period or stage between molts during larval development; first instar is the stage between the egg and the first molt.
Larva, plural Larvae - A young insect in an early stage of development; first instar is the stage between the egg and the first molt.
Lesion - Localized injury caused by a pathogen or insect.
Life Cycle - The time between hatching from the egg and the emergence of the adult from the pupal stage. Most insects have a 1-year life cycle.
Maggot - The larva of a fly.
Metamorphosis - The development of an insect as it goes through different stages from egg to adult. Varies between different groups but is basically of two types; simple and complete. In the simple form (grasshoppers), wings develop externally and there is no pupal stage. In the complete form (beetles) wings develop internally and there is a pupal stage.
Midge - Adults of a group of small 'flies' in the order Diptera.
Molt - The casting of skin between instars.
Mycelium - A mass of fungus hyphae. The vegetative portion of a fungus.
Nymph - An immature stage of an insect that does not have a pupal stage.
Overwinter - The act of passing the winter period--usually inactive-- of insect's life cycle.
Oviposition - The act of laying eggs, either singly or in batches.
Pathogen - An organism which causes disease in another organism.
Pheromone - A substance secreted to the outside of an insect's body that serves as a chemical signal between members of the same species. They are usually airborne and act as sex attractants, alarm systems, aggregators, or guides to food.
Phloem - Active, conductive tissue of the inner bark of trees or other woody plants.
Pitch Tube - A mixture of resin, boring dust, and frass on the bark of trees attacked by bark beetles.
Pupa, plural = Pupae - The resting inactive stage between larva and adult.
Puparium - A case formed by the hardening of the next to last larval skin, in which the pupa is formed (flies).
Pustule - Blisters of an infecting fungus which mature into fruiting structures.
Resinosus - Reaction of a tree to invasion by pathogens or insects or abiotic injury which results in flow of resin on outer bark or accumulation of resin within or under bark.
Sign – Physical presence of pathogen as seen on host plant.
Spore - Microscopic reproductive cell or cells. The principal way in which fungi reproduce.
Sporulate - Release spores.
Stage - Any definite period in the development of an insect; egg stage, larval stage, etc.
Symptom - An expression of disease or insect injury as abnormal growth or development of the tree.
Witches broom - An abnormal proliferation of branches or twigs on a single branch.
Woodborer - Usually referring to beetle species which feed and spend majority of life cycle within the wood of hosts--opposed to those which feed in cambial region or bark.

BUREAU OF LAND MANAGEMENT
PESTICIDE APPLICATOR
STUDY GUIDE

AQUATICS

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Aquatic Pest Control

IPM/Pesticide Certification Training Material

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PESTICIDE REGULATIONS FOR AQUATIC APPLICATIONS

The Environmental Protection Agency (EPA) conducts regulation of pesticides at the federal level under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).

EFFECTS OF PESTICIDE APPLICATIONS ON THE AQUATIC ENVIRONMENT

Many pesticides are designed to control pests in aquatic environments: herbicides for algae and vascular plants; insecticides for insects; and piscicides for fish control. When users apply these pesticides according to label instructions and follow the safety precautions stated on the label, pesticides pose little threat to the environment. Misapplication of pesticides to or near water can cause severe, adverse effects to nontarget organisms by acute toxicity, by modifying habits, and by altering oxygen levels or food quality and quantity.

Acute Effects

The acute toxicity of pesticides to aquatic organisms depends on many factors. One species may be more susceptible to the chemical than another. Therefore, the LD_{50} or any other measure of toxicity cannot be applied to different species. For example, trout are more susceptible than other fish species to copper sulfate applications used for algae control. Also, the response of a single species may vary depending on the sex, size, or age of the exposed individual. Chemical or physical differences in the water may affect an animal's response or the pesticidal action; copper sulfate decreases in pesticidal activity with increased water hardness.

Plants

Insecticides and piscicides are generally nontoxic to plants unless an adjuvant is added that is phytotoxic. Use herbicides carefully if desirable plants grow within the site, in drainage areas, or on nearby banks. For example, fluridone treated water may injure trees or shrubs growing in, or with roots exposed to, the water. Herbicides applied to or near water have the potential of moving off target with water movement. If water is used for irrigation, make sure no irrigation restrictions are stated on the label. Drift into nontarget areas may be another concern. Damage problems can also occur if you do not rinse spray tanks thoroughly between applications of different pesticides.

Fish

Acute toxicity of insecticides and herbicides to fish is usually small when you use the recommended dosages. However, evaluate each pesticide on an individual basis, depending on the treatment levels, species of fish, and chemical characteristics of the water. For, example, acrolein and xylem are highly toxic to shrimp, crabs, and fish at rates recommended for weed control. Temephos, a mosquito larvicide, has been shown toxicity to fish. Precautionary statements printed on both insecticide and herbicide labels warn of potential fish toxicity.

When considering the toxicity of pesticides to fish remember that the kind of chemical, species of fish, and nature of the water all play a role in the ultimate reaction of the fish to a toxicant. Fry, newly hatched fish, are the most vulnerable life stage. They are present in the spring when many aquatic herbicides are applied to young, actively growing weeds.

Piscicides are lethal to fish when used as directed. There is little selectivity. Fish restock intervals are stated on the label. Testing the water with a few fish before stocking is always recommended.

Invertebrates

Most herbicides and piscicides are not harmful to aquatic invertebrates (crabs, shrimp, insects) when used at recommended dosages, with the exception of the herbicides acrolein and xylene. Evaluate each pesticide on an individual basis and for each situation because toxicity does occur, the herbicide fluridone is toxic to crayfish. The high reproductive potential of most invertebrates allows population levels to return to normal relatively rapidly if some kill has occurred.

Insecticides you apply to water, generally larvicides, can reduce the population of other aquatic invertebrates. Adulticides applied on land may affect other terrestrial invertebrates. Use caution because these insecticides may be highly toxic to bees and other beneficial insects.

Other Animals and Humans

Precaution may be necessary to protect certain bird species from insecticide applications.

Some herbicides and piscicides used in aquatic resource management will be a potential hazard to people for a period of time. Treated water may be unsafe for swimming, for livestock watering, or for irrigation; and fish may be unfit for human consumption. Water treated with some herbicides, such as endothall, cannot be used for watering livestock, for irrigation, for domestic uses, or for crop spray diluents for set time periods that depend upon the concentration applied.

Indirect Effects

Pesticides affect aquatic life directly, but do not cause environmental harm when used properly. However, they may cause subtle changes and indirectly modify an aquatic ecosystem, both biologically and physically. Positive and negative indirect effects are just as important as acute effects in many cases.

Habitat Modifications

Aquatic plants provide cover, protection, attachment surfaces, and food for many aquatic animals. Bacteria, fungi, algae, diatoms, protozoans, insect larvae, thread and bristle worms, rotifers, and small crustaceans are the principle members of the community of organisms that live on and around larger plants. Plants contribute to and affect the chemical and physical nature of the aquatic ecosystem. Any reduction in quality and quality of aquatic plants affects the chemical and physical environment, and thus the animal community structure.

Weed management programs change the physical habitat. Dense mats of vegetation harbor larger numbers of small fish and their food organisms. Biologists have found that if too much cover is present, fish populations become unbalanced and stunted. A reduction in cover sometimes causes more of the smaller fish to become prey to the larger fish, benefiting both populations.

Most predatory game fish do not use areas of dense aquatic vegetation for spawning, and plant removal generally does not reduce their chances for survival.

Alteration in Oxygen Levels

Algae and flowering plants usually form the first link in aquatic food chains. Through photosynthesis, plants use the sun's energy to convert water and carbon dioxide to carbohydrates (food) and oxygen. Removal of aquatic plants or algae lowers the basic productivity (food and oxygen) of an aquatic ecosystem. Less energy is converted to food and less oxygen is available in the water.

Dead plants become organic matter (food) for microorganisms, such as algae and bacteria, and no longer produce oxygen. Microorganisms convert organic matter into simpler compounds or nutrients. An increase in dead plants increases microorganism populations. Since most bacteria require oxygen, this increase in microorganism activity may decrease the oxygen level below that necessary for the survival of higher organisms, including fish and invertebrates. Avoid causing low oxygen conditions by treating only a part of a weed infested area at a time, thereby giving fish an opportunity to move to untreated water. For example, late season applications of 2,4-D, an herbicide, may require treatment of portions of a body of water, leaving buffer lanes which can be treated when vegetation in the treated lanes has disintegrated. This reduces the total amount of plant matter decomposing at one time.

Carbon dioxide and other toxic by-products of plant and algae decomposition also build in the water and can be detrimental to other forms of life.

Changes in Food Quantity and Quality

Small invertebrates are important links in aquatic food chains. Typical aquatic invertebrates are worms, leaches, shrimp, scuds, water fleas, insect larvae, snails, and clams. Reductions in the number of invertebrates will reduce the food supply of organisms that feed on invertebrates. Temporary reductions in invertebrate populations replenish with time by migration of invertebrates into previously treated areas or by gradual repopulation by survivors.

Increased amounts of decaying plant material from an herbicide application may significantly increase invertebrate populations that feed on organic matter. This provides more food for fish and other higher organisms.

Fish populations may increase if rooted aquatic vegetation is removed. This is true when the nutrients released by decaying vegetation stimulate algae growth. Rooted aquatic vegetation tends to tie up nutrients and energy, and few animals use it as a source of food.

Fish can feed on a number of different food organisms but generally restrict their feeding to a preferred group. However, most fish will take whatever food is available in greatest quantities. Because fish adapt to varying conditions and are able to change foods within limits, they may not be adversely affected by a temporary alteration in the food chain. If the number of food organisms is reduced by the action of a pesticide when food is scarce, fish may exhibit reduced growth rates and fish populations may suffer.

Vertebrates (waterfowl, turtles, muskrats) that feed on aquatic plants or animals may be affected by changes in the aquatic supply, due to either quality or quantity.

Fish rapidly excrete most herbicides. Some herbicides may be found in fish; however, they are not accumulative. The concentrations found in the fish are not higher than the concentrations in the surrounding environment. These levels decline as soon as the fish is moved from the source of chemical. The pesticide label will state the minimum length of time required between pesticide application and fish harvest. This preharvest interval ensures fish are free of the chemical and fit for human consumption. Fish killed by the piscicide rotenone are not harmful to other forms of wildlife.

AQUATIC VEGETATION MANAGEMENT

Recreational, agricultural, industrial, and other uses place an increasing demand upon water resources.

Like land areas, water areas support a wide variety of plant life that varies within the different aquatic environments (streams, lakes, ponds, irrigational canals). Aquatic plants can be the dominant visible feature of some water areas. In other cases, they may occupy only water margins, grow out of sight beneath the water surface, or grow as minute organisms suspended in water.

The planned use for a body of water often determines the need for management or control of aquatic plants. A given body of water may be used for irrigation, fishing, boating, swimming, water skiing, and waterfowl hunting. Plant control may be required to meet the objectives of domestic, industrial, recreational, or agricultural water consumptions. Many aquatic plants may be pests in some situations and desirable plants in others, depending on:

- their abundance,
- the use of the waters which they inhabit, or
- personal values of people using or living near the water.

The desirability of aquatic plants depends on the point of view of the water user. Reservoir managers and swimmers want clean, clear water free of vascular plants, algae, and other organisms that detract from the usefulness of the water or pose human hazards. Waterfowl hunters want an abundance of aquatic plants that attract ducks and geese for food and cover. Anglers prefer to see lily pads, plant beds, and plankton that nurture fish and the organisms they feed upon, but only if they do not become widespread and spoil the fishing. Conservationists strive for suitable plant cover on watersheds and banks of streams, lakes, and ponds to control erosion and to protect water quality. Irrigators want clean, free-flowing water. It is clear the owners or managers of a body of water should know about aquatic plants so they can choose procedures to meet management objectives. The application of science to aquatic environment management offers the best solution for meeting the diverse interests of all water users.

Categories of Aquatic Weeds

The first step toward prevention or management of aquatic weeds is to correctly identify them. Most management methods are aimed at specific plants or groups of plants with similar growth habits. Aquatic weeds are usually separated into four broad categories based on their life form: algae, emersed, submersed, and floating vascular plants.

Algae

Algae are the simplest plants in structure and organization as well as the most primitive. They are the most common and most uniformly distributed of all aquatic plants. Algae are unicellular or simple aggregates of cells capable of carrying out all life processes without specialized tissue, such as leaves, roots, or stems. They vary from microscopic forms to long, stringy mats. Under conditions of high nitrogen and phosphorus levels and during hot, calm, sunny weather, algae multiply rapidly and may accumulate in large masses, called blooms. Algae reproduce by spores, cell division, and/or fragmentation. They can be divided into three groups.

Filamentous algae consist of long, stringy hair-like filaments that form mats or “pond scums” during summer. These can be seen without the aid of a microscope. Other algae may form a green, furlike coating on stones and other bottom objects. In early spring, they grow on the bottom and may rise to the surface during hot, calm, sunny weather.

Stonewort algae or muskgrass, because of their size, growth, and attachment to the pond bottom, may be mistaken for vascular plants. Examples are chara and nitella. Chara has a strong, musky odor, and is sometimes encrusted with calcium deposits, which give it a rough, gritty texture –

thus, the name stonewort. These plants consist of an erect central main stem, from which clusters of branches arise at various intervals. They can grow as tall as 2 or 3 feet, and can completely cover a pond or lake bottom.

Plankton algae are commonly single cells or small colonial groups. They are free-floating and green, blue-green, or brown. In large numbers, plankton algae may color the water brown, yellow, pea soup green, or even red during the warm seasons. When this occurs, the lake or pond is said to be "blooming". These blooms may indirectly provide food for fish, but they may also make water undesirable for swimming, fishing, or use as a domestic water supply. Each ounce of water in this condition contains millions of microscopic algae cells. Upon death, they may release foul odors and tastes into the water; some species release toxins capable of poisoning livestock. Complete chemical treatment after "water blooms" is not normally desirable or feasible. Treatments would be expensive and would be effective only for a few days. Serious oxygen depletion from sudden death of the bloom can cause fish kills.

Vascular Plants

Vascular plants are more complex in structure and organization. They have specialized tissues, such as roots, leaves, stems, and flowers. There are annuals, perennials, and woody plants; many flower and produce seed; others propagate asexually (tubers, winter buds, turions, fragments).

Emersed plants are rooted or anchored in the bottom soils with most of the leaf-stem tissue above the water surface and not falling or rising with changes in the water level. Most plants are perennial, having creeping rootstocks, or woody, and are found in shallow waters. The foliage is aerial. Examples are cattails, tules, yellow waterlilies, salt cedar, and purple loosestrife.

Submersed plants adapt to grow with all or most of their vegetative tissue below the water surface. They are usually rooted in the bottom soils. Examples are pondweeds, coontails, elodea, and milfoil.

Floating plants are either free-floating or anchored to the bottom and produce most of their leaf-stem surface tissue (thalli) at, or above the water surface. Leaves or thalli of floating plants rise or fall with the water level. Examples are duckweed, azolla, white waterlily, and water hyacinth.

Management and Control

Water Management

Wise management of water is necessary if control of aquatic vegetation is to be more than temporary. Management plans must begin with an evaluation of all uses of a given body of water. Work to balance the chemical, biological, and physical factors as much as possible to obtain maximum use of the water to benefit the greatest number of people.

Proper design and construction of ponds and ditches are important factors in preventive control of aquatic plants. Shallow water at pond and ditch margins provides an ideal habitat for emersed plants, such as cattails. Submersed plants can easily become established there, then spread into deeper waters. Steep banks with a 1:1 or 1:1.5 slope, until water depth is at least 3 feet, will help prevent establishment of many emergent and bank weeds. However, steep sides may create other problems. If small children frequent a pond, steep sides would definitely cause a safety hazard.

Remove fertile topsoil from the pond or reservoir basin before filling. If plans include a beach area for swimming and other recreational purposes, remove the fertile topsoil and replace it with sand. If possible, prevent waters heavily laden with silt and nutrients from entering an impoundment.

Construct ponds, lakes, canals, and ditches so they can be drained, if possible. The water levels in some large lakes and reservoirs may be lowered enough to expose plants in the shallow areas. Freezing or drying periods of several months may be necessary to control plants in some ponds and lakes. In most canals, it is not practical to interrupt water flow during the summer months when aquatic plants make their most rapid growth. The species of plants and the seasonal growing period will generally determine whether this method is practical or not. An overriding factor on lowering reservoirs or drying ponds will be the presence of a fish population and the need to maintain their spawning habitats.

Mechanical Control

Physical removal is effective for small quantities of plants near shorelines. The techniques consist of cutting, mowing, raking, digging, or pulling. In small ponds or lakes, emergent plants, such as sedges, cattails, and rushes, can be mowed, pulled by hand, or dug with a hoe.

Chaining may be practical in some instances, particularly in canals. Draglines are useful for deepening and cleaning canals and margins of lakes and ponds. Weed harvesters are used in lakes and some canals for cutting and collecting the cut plants.

Certain problems are associated with the previous methods. Pulling, cutting, or harvesting usually must be repeated several times to eliminate new growth as it appears. Single cutting treatments usually are not effective because most submersed and emergent vegetation is perennial, and the underground portion of the plants is unharmed by such a treatment. Attempts to dislodge submerged plants by cutting or dragging a chain or cable over the bottom are not effective unless the plant fragments are removed from the water. Actually, this practice may spread the infestation, because the plants can regenerate from plant fragments. Also, plant fragments and other debris dislodged by such devices plug irrigation sprinklers, pumps, etc. Mechanical control may be slower and more costly than other control methods.

Burning ditchbank weeds may increase the flow of water in a ditch and help to prevent seed from infesting new land. Sear green vegetation the first time, then thoroughly burn 7 to 10 days later. Control by burning is also temporary. Permits to burn may also be required prior to the action.

Biological Control

Biological control employs plant or animal agents to control or reduce growth of vegetation or to alter the habitat to favorably change the type of plant growth. People have tried using insects, mites, snails, pathogenic microorganisms, fish, ducks, geese, manatees, and competitive plants for biological control of aquatic weeds. Biological control is not new, but practical and safe means of controlling plants by these methods are extremely limited.

Muskrats may cut considerable quantities of plants, but in doing so they leave fragments that act as sources for plant propagation. Domestic waterfowl may feed on certain floating and submerged plants; however, the fertility resulting from their excrement may create excessive algae blooms that may be more undesirable than the original problem. Some exotic species of fish, such as the white amur or grass carp, are being promoted to control aquatic vegetation. Since the impact of these organisms on the aquatic ecosystems is not fully known, their release is prohibited in many states.

Chemical Control

Responsible use of aquatic herbicides requires careful consideration of many factors. The most important consideration is the use of the treated water. Contaminating domestic water supplies, or failure to observe the proper precautions in water-use restrictions may result in health hazards. Most waters are managed on a multiple-use concept. Gamefish, waterfowl, and aquatic mammals share use of a body of water with swimmers and boaters. Irrigation and domestic requirements also may be met by withdrawals from a lake, canal, or river.

Before selecting or using an herbicide in aquatic environments, consider four primary factors for a safe, effective, and legal application:

- characteristics of the environment: pest identification, population, and stage of plant growth present; types and numbers of desirable plants or animals present.
- water-use: human use, irrigation, livestock, fish production, etc.; destination and use of outflow; length of time water can be quarantined.
- characteristics of the water: temperature, turbidity, depth, inflow and outflow velocity, and quality.
- herbicide: labeled uses, restrictions, precautions, cost, and selectivity.

Most herbicides are applied in late spring or early summer when the plants are young and actively growing. Treatment at this time usually gives the best control with the least amount of chemical. Applications in late summer or early fall may require more chemical. Furthermore, access to normally dense aquatic vegetation is best in the spring or early summer before the plants reach the surface.

If possible, lower lake and pond water levels that have a high rate of inflow prior to treatment to ensure adequate contact time for the herbicide. Close the spillway and retain the treated water for at least the minimum period specified on the label before overflow. The amount of drawdown will vary according to the situation.

Vegetation management in static water. Sprayable formulations are almost always preferred for control of floating and emersed weeds. Surface water applications are made for floating and emersed weeds. These plants are killed by applying the spray mixture to the foliage from the air, ground, or boat. Both sprayable and granular formulations are used for submersed weed control.

Granular formulations are often used for control of algae or submersed plants. Because granules sink to the bottom, they perform about the same way as bottom soil treatments. Application rates for granular herbicides are based on either surface area or total water volume treatment.

Granular herbicides perform best when distributed evenly over the water surface of the area to be treated. They may be broadcast by hand or manual spreader over small areas. Special granule spreaders can be mounted on aircraft or boats for large-scale applications. Advantages of granular herbicides include:

- treatment is usually confined to the bottom where submersed plants are rooted;
- some formulations provide long contact time with plants (slow release granules); and
- chemicals can be formulated so they are nontoxic to fish.

Herbicide applications that are successful in smaller bodies of water often perform poorly in large impoundments. These impoundments often have more water movement caused by thermal currents or the wind. The following methods may improve plant control in these sites:

- use the maximum recommended application rates;
- treat relatively large water areas at one time;
- apply herbicides only during periods of minimal wind;
- use bottom treatment in deep water;
- use granular formulations when possible;
- select herbicides that plants absorb quickly.

Vegetation management in flowing water. Aquatic plants in flowing water are the most difficult to control. Because the water is moving from one location to another, herbicide use hazards are increased.

Herbicides are seldom used to control plants in natural streams, but use is more common in human engineered water distribution and drainage systems. Most of these carry irrigation water. Do not irrigate crops with treated water unless use is permitted by the pesticide label. Some systems also carry domestic, industrial, and recreational water. As the number of water uses increases, more restrictions and precautions are required.

Control methods for floating and emersed weeds are similar to methods on static water. But pay close attention to precautions, since the water is flowing and may impact the environment downstream.

Submersed plants and algae can be effectively controlled in flowing water only by continuously applying enough herbicide at a given spot to maintain the needed concentration for the required contact time. The greater the cross-section area and the depth of the stream and the greater the speed of flow, the larger the volume of water that must be treated. The larger volumes of water that must be treated make use of herbicides in flowing water costly; particularly when:

- the plant infestation covers only a small area, and,
- the herbicides are effective for only a short distance downstream.

Few herbicides are available for control of submersed plants in flowing water. Copper sulfate is available for algae control. It is toxic to trout and most other fish species. Xylene and acrolein are also used for weed control in irrigation systems. They are highly toxic to fish and other aquatic organisms.

Be certain that residues in the treated water and runoff water are at or below the level permitted for all subsequent uses.

Weed control methods used in limited flow waterways (flood drainage canals, sloughs, drains) are very similar to those used in static water. Consider the possible contamination of water used for other purposes when you plan the use of herbicides in limited flow water. In some areas, drainage water may flow directly onto cropland, may be used for irrigation, or may even enter a fishery or the drinking water supply.

Vegetation management on ditchbanks. Weeds on ditchbanks are a major obstacle in irrigation of crops and subsequent drainage. They reduce the flow of water and thus cause flooding, seepage, breaks in ditchbanks, increased evaporation and transpiration loss, decreased water delivery, and decreased drainage of water. They obstruct inspection and maintenance operations of the irrigation channels. Also, seeds and other propagules produced by weeds on ditchbanks can infest cropland.

Ditchbanks provide a variable plant habitat. A major reason is that soil moisture varies greatly within a short distance on an irrigation ditchbank. Emergent aquatic species are often found at the water line. Within a few feet of this area, up over the top of the bank, the soil may be very dry with drought tolerant species predominant.

Plant control methods will depend on which plants are to be controlled in relationship to the water level, intended use, and subsequent use of the water downstream. When spraying ditchbanks, keep the sprayer traveling upstream to avoid the possibility of concentrating any herbicide which may get in the water.

If there is any chance that the herbicide will mix with water when water levels rise, use only aquatic herbicide formulations.

Those herbicides are registered for the management of aquatic vegetation include the following:

Aquatic Herbicide Active Ingredient	Target Species	Comments
Copper sulfate	Algae	Contact herbicide and quickly kills sensitive algal species.
Copper chelates	Algae	Copper is held in an organic complex know as a chelate. Less corrosive to equipment than copper sulfate. Less toxic to fish than the copper sulfate.
2,4-D	Submerged and	Not all formulations have an aquatic registration..

	Emerged	Selective for broadleaves
Diquat	Submerged and Emerged	An approved nonionic surfactant is required with foliar applications. Tightly adsorbed to clay, which reduces activity in muddy water.
Endothall	Algae Submerged	Contact herbicide.
Fluridone	Submerged and Emerged	Moves within the treated plant. Slow acting herbicide, takes time for a complete kill.
Glyphosate	Emergent	Foliar applied, translocated herbicide. Non-selective.
Triclopyr	Emergent	Foliar applied, translocated herbicide. Selective herbicide – control broadleaves and woody species.
Imazapyr	Emergent	Foliar applied, translocated Non-selective

FISH MANAGEMENT

Programs to manage fish populations usually are initiated for one of two reasons: 1) to remove undesirable species, or 2) to attempt establishment of a desirable balance of game fish. The control techniques used include fishing regulations, mechanical control, biological control, chemical control, and various combinations of techniques.

Pestiferous Fish

The introduction of various fish species into new environments (for example, common carp) is an old practice. Quite frequently, introductions adversely impact the environment or the more desirable native species already present. Under such circumstances, plan to eliminate or control the undesirable, pestiferous, species.

Control is also desirable when one or more species overpopulate an aquatic environment. Such overpopulations may deplete the food supply or may interfere with the reproduction and survival of other species. Depletion of the food supply may lead to large numbers of small, stunted fish. Where predator (game) fish populations are not large enough to control forage fish populations (carp, bullheads, perch, suckers), or if forage fish are not harvested, they may reproduce to the point of being overpopulated. Control is essential to maintain a desirable population balance and to obtain optimum production.

Types of Control

Fishing Regulations

The goals of fishing regulations include limiting the total harvest of fish, protecting spawning fish, and distributing the total catch among more people. Techniques employed include size and creel limits, restricted seasons, and fishing gear restrictions. If predator (game) fish are harvested in excessive numbers or at too small a size, forage fish may overpopulate. Carefully planned and managed regulations on the size and numbers of game fish which can be harvested from a given body of water can maintain more and larger predators, thus providing a better balanced fish population and also better fishing.

Environmental Manipulation

Undesirable species and unbalanced populations can be removed from drainable ponds, lakes, and reservoirs by simply draining the body of water. Desirable species can be restocked in appropriate numbers and combinations after refilling the lake or body of water. Carp can sometimes be controlled by dropping water levels rapidly after the carp have spawned in shallow areas. A partial drawdown is sometimes used to force small forage fish to leave the protection of shallow, weedy areas, and thus, become vulnerable to predators. Removing vegetation without a drawdown sometimes produces a similar effect.

Mechanical Control

Mechanical methods are often effective in reducing the numbers of fish in overcrowded situations. Mechanical barriers may also be used to reduce the movement of undesirable species into new environments or to control normal migrations. Mechanical devices include seines, nets, and traps, as well as weirs and other barriers. Mechanical devices have the advantage of selectivity, since desirable species or size classes can be returned to the water, while undesirable fish can be removed.

Mechanical devices are seldom effective in completely eliminating undesirable species. Some individuals invariably escape mechanical devices, grow and reproduce, thereby maintaining their presence in the particular body of water. If complete eradication, rather than partial control is desired, draining or chemical toxicants will be more effective.

Chemical Control

Chemical control is used when other control strategies cannot be used to establish desirable balances of forage and game species. Undrainable ponds and lakes sometimes require the use of chemicals to kill all fish present before restocking with desired species or combinations of species. Chemicals may also be used to eliminate fish from isolated pockets, backwater areas, or inflowing streams where drainage is the principal control method. In some situations involving overpopulations of forage fish, it is possible to establish a desirable balance of fish by treating selected areas only.

Rotenone is the only piscicide currently registered for the control of fish populations. No chemical toxicant can be used if the fish are to be used for human consumption. Rotenone readily disperses both laterally and vertically and penetrates through thermoclines, layers in water dues to differences in temperature. Formulations of rotenone include liquids, spray powders, and dusts. Rotenone can be applied to impounded water or streams by air or ground applications, depending upon the label.

When liquid toxicants are used, dilute the chemicals sufficiently to assure complete and uniform coverage of the area. Various types of sprayers can be used. Powered toxicants are normally mixed with water to form a paste, which is placed in a cloth sack and towed behind a boat until even coverage is achieved. Backpack sprayers can be useful for liquids if the treatment area is remote or inaccessible by boat. In all cases, use only enough toxicant to kill the target species.

An overdose is not only inefficient and uneconomical, but may also lead to unforeseen side effects.

For proper application, calculate the area to be treated (volume of water). Volumes of water are usually calculated in acre-feet. Mix the toxicant completely throughout the body of water for a total kill.

When chemicals are used, lower the water level if at all possible. This reduces the volume of water to be treated and also decrease the possibility of an outflow of the toxicant into downstream areas. Any downstream fish kills are the legal responsibility of those who applied the chemical. As the water level recharges, the toxicant will be diluted. The combination of dilution and detoxification should make the toxicant harmless by the time the water level returns to normal.

When using a partial treatment, it is important to start the application at the point farthest from the shore and seal off the area to be treated with a curtain of fish toxicant. For example, if a cove is to be treated, seal off the mouth of the cove and then work toward shore. You will minimize the escape of fish into deeper, untreated water in this way.

Normal detoxification times vary from a week to a month, depending on different water factors (for example, alkalinity, temperature, turbidity). You can decrease detoxification periods by adding chlorine or potassium permanganate to the water. If outflow cannot be controlled, detoxification may be required.

Most piscicide labels have a restock interval intended to protect fish that will be planted into an environment where chemical control has been applied. For rotenone that period is 2 to 4 weeks, depending on how quickly rotenone degrades. To make sure restocking is safe, it is a good management practice to put a few fish in wire cages and place them in the water that is to be restocked. Leave them for 24 hours, and monitor survival. If all the fish survive, the aquatic site should be safe for restocking.

MOSQUITO CONTROL

Mosquitoes are an annoyance pest, and some species can transmit disease-causing pathogens. West Nile Virus is a virus transmitted from birds to people via a mosquito vector. Mosquito annoyance affects recreation activities and agriculture, both resulting in economic losses. Control measures are undertaken to reduce the pool of disease-infected mosquitoes and to reduce the annoyance suffered by the public. Essential to any mosquito control program is a thorough understanding of mosquito life cycles, their habitats, proper survey techniques, and effective control strategies.

Biology

Mosquitoes are distinguished from other closely related flies (midges and crane flies) by two main characteristics: 1) numerous scales on their bodies, wing veins, and wing edges, and 2) females have a distinct bloodsucking proboscis. Mosquitoes undergo complete metamorphosis, developing from eggs to larvae to pupae to adults. The first three stages are associated with water.

Adult males and females feed on plant juices and nectar for maintenance energy. Male mosquitoes do not require a blood meal. However, female require a sizable blood meal to produce viable eggs. They obtain blood from mammals, birds, reptiles, and other animals. Some mosquitoes are very particular as to the type of animal they will feed on and at what time of day. Females live longer than males and produce multiple broods.

Mosquitoes lay eggs either on or near water. Eggs that are laid on water hatch soon after the embryo is fully developed (3 to 4 days), but eggs of some species of *Aedes* that are laid near water will not hatch until the water level rises to them and embryo development is complete.

Larvae, “wrigglers”, must have water for development. Most have air tubes or siphons near their tail by which they acquire air from the water surface, but *Mansonia* species obtain air from plants beneath the water surface. Larvae feed on algae, bacteria, yeast, fungi, mold, and protozoans. They undergo four developmental molts (shedding of the larval skin) to increase their size prior to pupation. Larval development time largely depends upon food quantity and water temperature, and varies from 4 to 10 days. Almost any type of still water catchment will support larval development: saltwater or freshwater marshes, swamps, and margins of ponds or lakes. Larvae can develop in any contained water, such as potholes, ditches, old tires, cans, catch basins, and birdbaths, as long as the water is present long enough for development of the immature stages.

Pupae, “tumblers”, resemble a comma in shape with a pair of breathing tubes near their head. Pupae do not feed, but unlike most insect pupae, remain quite active. The pupal stage lasts around 3 days, depending upon air temperature. Adults split their pupal skins, emerge, rest on the water surface as their skins harden and their wings dry, and then fly away in pursuit of a mate.

Water and weather conditions affect mosquito activity and development. Adults tend to stay close to the ground in vegetation and dense shrubbery if the wind is blowing or if the humidity is low. Egg, larvae, and pupae develop faster under warmer water temperatures. Most species produce multiple generations in one year.

According to the American Mosquito Control Association, there are more than 2500 species of mosquitoes world-wide; about 200 of these species occur in the U.S. It is reported that, presently, there are 36 species occurring in the U.S. that have tested positive for West Nile Virus. The most common carrier is the Northern house mosquito (*Culex pipiens*). Other carriers include additional *Culex species* and species in the *Aedes* genus. Each of these groups has characteristics to distinguish it from the others. Different species of mosquitoes live in different habitats. Most control procedures are directed against the larval or adult stages. Applicators should be able to associate the more common pest species with their larval habitats, especially if control is targeted at the larval stage.

Common Mosquitoes and Their Habits

Group	Overwinter As	Egg Laid	Larval Habitat	Other Information
Aedes	eggs or larvae	singly on ground, or above water level in objects that can hold water	temporary & snow melt pools, irrigation & flood water, tree holes, and artificial containers	most common mosquitoes, larval position diagonal to water surface
Culex	adult females	rafts on water	still, stagnant, even polluted water in ponds, catch basins, cisterns, artificial containers, etc.	commonly found around cities & towns in association with humans, larval diagonal to water surface

Surveys

One of the most important elements of a successful mosquito control program is a good survey. Surveillance is the detection of mosquito problems, species identifications, counts, and location mapping. Surveys provide information for control decisions, such as when to control and what method to use for each situation. The success of control measures can also be determined from surveys.

Larval surveys. Larval surveys furnish data on sources and exact areas of mosquito producing habitat, the species present, and their abundance. Areas should be sampled and mapped. The frequency of surveys will depend upon the time of year. Usually a dipping ladle is used for collections, and then the larvae are identified and counted.

Adult surveys. Surveys of adults indicate the distribution and abundance of various mosquito species at any one time. Adults are generally monitored by three basic methods: landing counts (as they come to bite), light traps, or CO_2 traps. Other methods include traps baited with a bird or mammal, daytime mosquito resting stations, and vehicle-mounted net traps.

Landing counts rely upon exposed skin, such as a rolled up pant leg or shirt sleeve. Record the number of mosquitoes that bite during a period of time. If you need to identify the mosquito species for vector potential, capture the mosquito with a vial or aspirator and place it in a kill jar (jar containing a cotton swab with ethyl acetate) for later identification.

Most male and female mosquitoes are attracted to light. Set a light trap 6 feet from the ground in an open area near trees or shrubs. Some species are more readily attracted to CO_2. Strong winds, competing light, or smoke will reduce light trap effectiveness. Collect the mosquitoes daily and record the numbers and species collected.

Management and Control

Once the surveys are completed and the numbers or species are such that control is warranted, choose a control method that would be effective and safe. The term *abatement* is used in place of control for mosquito management, because it is unlikely that complete or long-term control will be accomplished. Abatement programs are designed to reduce the numbers of mosquitoes to an acceptable level. Mosquitoes can be controlled by a number of methods, such as water management, mechanical barriers, biological controls, and chemical controls. Abatement programs usually incorporate an integrated approach, using multiple control strategies dependent upon each situation.

Water Management

Water management is the most widely used and ecologically sound approach to mosquito control. This method involves many techniques designed to eliminate excess surface water or to manipulate water systems. Four basic principles are involved in water management:

- Eliminate mosquito breeding habitat: remove excess surface water within 5 days of accumulation; clean and replenish troughs, pools, ponds, and birdbaths; cover water sources.
- Prevent water accumulation: maintain drainage ditches and gutters; fill or grade pool-forming areas; eliminate temporary water containers.
- Increase the amount of standing water to create a suitable habitat for predacious fish, or construct means of access for these fish into and out of breeding sites.
- Increase the movement of water in the mosquito breeding area, thus creating stress conditions for the mosquito larvae and pupae; mosquito larvae cannot tolerate much mater movement.

Biological Control

A few organisms feed voraciously on mosquito larvae and pupae. A top-minnow, *Gambusia affins*, feeds on mosquito larvae. This mosquito fish is used in ponds and other permanent water impoundments. Refer to individual state regulations before consider the use mosquito fish.

Chemical Control

Larvicides. Mosquito larvicides are insecticides applied to water for control of larvae. Extreme care is essential when using insecticides to control mosquito larvae. A continuing survey is imperative so applications can be made before population growth exceeds a tolerable level. Make applications only to areas where mosquito larvae are present. Larvae generally live in pond or lake margins. Treat only infested areas. Sample shortly before conducting control measures to be sure larvae are still present.

Most larvicides work by toxic action or suffocation. Granules release toxicants and are extremely useful in very early spring or when spot treating areas with dense foliage. Oils act by either suffocation or lethal larval inhalation. Oils applied is small amounts are relatively safe to other organisms and can be used in sensitive areas, but phytotoxicity can result. Oil solutions consist of an active ingredient mixed with an oil base for more uniform applications. They do not evaporate quickly and are preferred when the applicator depends on drift for coverage. Emulsifiable concentrates are designed to be diluted in water; the droplets do not persist in air flow as long as oil formulations.

Growth inhibitors mimic an insect's own hormones, resulting in interference with normal development. They tend to be effective only at certain stages of immature development. Mosquito larvae exposed to growth inhibitors, at a sensitive period, never develop to the adult stage.

Bacillus thuringiensis var. *israelensis* (Bti) is a species of bacteria that is ingested by mosquito larvae. Its mode of action is the destruction of the midgut, resulting in larval death. It is available in pesticide formulations and can be applied using various application equipment. The mycelium and oospores of *Lagenidium giganteum,* a fungus, can be used as a larvicide.

Adulticides. Sometimes larval control cannot be used or is not effective and large populations of adults occur. For instance, if a small town, park, or camp is surrounded by many acres of breeding sites, usually larvicides are not an economical management approach. Sometimes an adult mosquito population, which has only been a nuisance, becomes a public health problem as a disease vector. Under these situations various adulticide applications may be necessary, but adult control is only short term because the source of the mosquito population is not controlled. Adults will return as soon as the larvae and pupae mature.

Two basic application methods used are space and residual treatments. Space treatments kill adults immediately, but only those present. They are applied as fogs, mists, or fine sprays, and they kill insects on contact. Residual insecticides may provide relief when applied to the stems, leaves, and trunks of trees or shrubs, or the walls of houses, where mosquitoes rest. Residual chemicals are contact poisons. They remain effective for several days, controlling insects that land on or crawl over treated surfaces.

Insecticides. Insecticide groups used for mosquito control include adulticides and larvicides. Examples of registered insecticides available include the following:

- Petroleum distillates which act by inhalation of toxic components through the insect respiratory system or by suffocation: oils and oil solutions – (larvicide).
- Botanicals are classified as contact toxins but do not exhibit lengthy residual activity: pyrethrum – (adulticide).
- Organophosphates inhibit cholinesterase, resulting in over-excitation of the nervous system: naled – (larvicide and adulticide), malathion – (larvicide and adulticide), temephos – (larvicide).
- Growth inhibitors disrupt normal development and maturation of immature insects: methoprene – (larvicide).
- Insect pathogens infect the pest, resulting in death: *Bacillus thuringiensis* var. *israelensis* – (larvicide) and *Lagenidium giganteum* – (larvicide).

AQUATIC APPLICATIONS

Knowledge of the potential effects of pesticides on humans, plants, fish, birds, insects, and other organisms in and around aquatic environments is essential for safe and effective aquatic pest control. Before selecting or using a pesticide, consider the entire aquatic environment – the life forms present, potential water usage, and the physical characteristics of the water. In addition, follow the label directions, paying attention to all precautions and restrictions. Use the best application method to ensure environmental safety.

- Biological characteristics
  - identify the problem species
  - identify other species present
  - determine pest population density and developmental stages
- Water-use considerations
  - human use, industrial, irrigation, potable, recreational, fish production, livestock, wildlife
  - length of time water can be quarantined
  - amount of and destination of outflow; can it be regulated?
- Physical aspects of the water
  - size of channel or pond to be treated
  - water depth and movement or velocity
  - water turbidity
  - water temperature
  - water quality

After you analyze all these factors carefully, choose the best control approach. If using a pesticide, consider labeling, safety, effectiveness, selectivity, residues, and cost. Correct application of pesticides to aquatic situations involves equipment selection and calibration, treatment type selection, calculation of appropriate water volumes or areas, and proper application and timing. Environmental hazards and potential health problems can result from misapplications.

Unlike terrestrial pesticides, which are applied to a stationary, two-dimensional area, some aquatic pesticides are applied to an area that has a third dimension, depth, and that usually has some degree of motion.

Application Equipment

Application equipment will vary depending on the sites where applications are to be made, the pests to be managed, and the pesticide formulation.

All liquid applications are usually made with sprayers, which come in a variety of sizes and types. To treat small areas, use a compressed air sprayer with a hand-operated pump, or a sprinkler may be all that is needed. For large areas, use a boat mounted pump and tank rig, an airplane or helicopter with a spray boom, or a ground-rig with a boom system or hand gun. If spraying for weed control, apply only under conditions that minimize the potential for drift. Foggers and ULV equipment are used frequently for insecticide applications.

Application of granules is usually much simpler, because the treatment is usually made on an area rather than a concentration basis. Applications are often made through cyclone spreaders or by hand (wearing protective clothing).

Compressed air sprayers. One of the most common sprayers for treating small areas is the 1-3 gallon compressed air sprayer. The air in the upper portion of the tank is put under pressure by a hand pump. The pressure created forces the spray through the nozzle.

Hydraulic sprayers. In hydraulic sprayers, the spray mixture is taken into the pump, put under pressure, and forced through a nozzle. In some sprayers, pressures of up to 600 psi may be reached. These range in size from backpack to boat-or truck-mounted models.

Mist blowers. Mist blowers work somewhat like hydraulic sprayers, but differ in that air carries the pesticide to the target. The tank mix is introduced into a stream of high speed air that carries the droplets to the target. The most commonly used units are backpack models.

ULV. ULV means "ultra low volume" and with these sprayers the pesticide concentrate is introduced into a swirl chamber, where shearing action of the air produces extremely fine droplets. Droplet size is relatively uniform and controllable. Units range in size from portable units to those mounted on aircraft.

Foggers. Foggers work by breaking up the liquid by mechanical or thermal (heat) means. Very fine droplets are produced, which are highly susceptible to wind and air currents.

Horn seeder. The horn seeder is comprised of a canvas bag with a tapered, telescoping wand or tube located at the front corner of the bag. It is slung over the shoulder. Granules are released as the operator's arm and wand move in a horizontal motion. Application rates can be adjusted by opening the base of the wand or by changing the speed at which the applicator walks.

Cyclone-type spreader. These are manually operated. Cyclone spreaders are cylinders with an adjustable slot in the base, through which granules fall onto a rotating disk. Granules are dispersed by centrifugal force. This disc is rotating by gears that are activated by turning a crank handle. The rate of dispersal may be altered by controlling the size of the slotted opening or by changing the forward speed of the applicator.

Blower-type spreaders. Power-assisted, blower-type granular applicators have feed tubes that meter the granules into the blast of an air blower. The speed of the air blast ranges from 75 to 150 mph. Spreaders range in size from backpack to truck-mounted. Similar blower-type spreaders are placed on helicopter delivery systems, since the air movement is too small for adequate dispersal of the granules. In fixed-wing aircraft, where the payload is greater, ram air-type spreaders are used that require only the air being driven back by the propeller.

Aircraft. Liquid spray or granular systems (for example, spray boom, spreaders, ULV), which can be mounted on either fixed-wing or rotary-wing aircraft, make applications to large or otherwise inaccessible areas quite easy.

Treatment Types and Calculations

Aquatic pesticides can be applied to four different zones in a body of water, depending on the location of the pest.

Surface/subsurface Treatment

Surface treatments simply treat the water at the surface to control only those weeds and insects at the water surface. You may also use subsurface application through injection hoses which a boat pulls through the water. Surface area measurements are the base for surface and subsurface applications. Applications can be made by air, ground, or by boat. These applications are usually made with boom sprayers. Surface and subsurface injection treatments are easier and more effective when you use large volumes of liquid carrier.

Surface area of odd shaped ponds or lakes sometimes can be cumbersome. Break the pond up into smaller units from which area measurements are more easily made. Generally, you should treat only one-fourth to one-third of the total water surface area with herbicide at a time. This helps protect fish by limiting vegetative decomposition than can cause a shortage of oxygen.

Surface Area Treatment Formulas

Rectangle:	Length x Width
Triangle:	1/2 Base x Height
Circle:	Radius^2 x 3.14

Total Water Volume Treatment

A whole body of water is sometimes treated for aquatic weed, fish, or insect control. When making total water volume treatments, you must calculate the volume of the water to be treated. The water volume unit most commonly used in pesticide labels is the acre-foot. Acre-feet of water = surface acres of water x average water depth in feet. If the pond to be treated is approximately 8.6 surface acres and the average depth is 2.4 feet, the pond would consist of 8.6 acres x 2.4 ft. = 20.6 acre-feet of water.

Some aquatic pesticide labels require the user to calculate the amount of pesticide necessary to establish a lethal concentration in a body of water. The pesticide concentration is sometimes expressed in “parts per million” (ppm). The concentration is measured in terms of the weight of the pesticide vs. the weight of the water.

If, for example, the required concentration for control of a specific pest is 2 ppm of the pesticide formulation, apply the product at a rate of 2 pounds of product to 1 million pounds of water in the area to be treated. An acre-foot of water weighs 2.7 million pounds. If you dissolve 2.7 pounds of the product in 1 acre-foot of water, there will be a concentration of 1ppm (by weight).

To determine the material needed to obtain a desired ppm concentration, use the following formula:

(2.7) x ppm wanted) x (acre-feet) = pounds of product required

For example: You want to treat a 5.6 acre pond having an average depth of 5 feet. The concentration required, as stated on the herbicide label, is 0.5 ppm.

First – Determine the acre-foot volume of the pond:

- 5.6 acres x 5 feet = 28 acre-feet

Second – Calculate, using the formula, how much product you need:

- (2.7) x (0.5 ppm desired) x (28 acre-feet) = 37.8 or 38 pounds of product.

Bottom Layer Treatment
Treating the deepest 1 to 3 feet of water is especially useful in deep lakes, where it is impractical and too costly to treat the entire volume of water. Such treatments are generally made by attaching several flexible hoses at 3 to 5 foot intervals on a rigid boom. Each nozzle is usually equipped with some type of nozzle at the end. They way be weighted to reach the depth desired. The length of hose and speed of the boat carrying the application equipment also affect the depth of application. For successful bottom treatments, applying the herbicide as a “blanket” in the lower 1 to 3 feet of water. Calculations for bottom treatments are similar to those for surface treatment, that is, amount product per bottom acre.

Canal or Ditch Water Treatment

Treating water flowing through an irrigation ditch depends upon water volume and its flow rate. Water volume is measured by the average width of the canal multiplied by the average depth of the canal. Water velocity is usually expressed as distance water moves per unit time, such as “feet per second” (fps) or “feet per minute” (fpm). Determine the flow rate of the canal or stream by multiplying the water volume by the water velocity:

Flow Rate = (average depth) x (average width) x (feet per sec. or feet per min.)

= cubic feet per second (cfs) or cubic feet per minute (cfm)

Labels generally state the application rates in ppm, either by volume (ppmv) or by weight (ppmw). Several additional calculations are necessary to determine ppm equivalent application rates:

► *First*, convert flow rates from cubic feet per second (cfs) to cubic feet per minute (cfm) by multiplying by 60 seconds

Example:

☞ 16.6 cfs x 60 sec per minute = 1,000 cfm

- ► *Second*, convert cubic feet of water per minute to volume (gallons) or weight (pounds) of water per minute, depending on whether the label is based on ppmv or ppmw, respectively.
    - ► One cubic foot of water is equal to 7.5 gallons

      Example:

      ☞ A flow rate of 1,000 cfm = 7,500 gallons
      (1,000 cfm x 7.5 gallons per cfm = 7,500 gallons)

    - ► One cubic foot of water is equal to 62.4 pounds

      Example:

      ☞ A flow rate of 1,000 cfm = 62,400 pounds
      (1,000 cfm x 62.4 pounds per cfm = 62,400 pounds)

- ► *Third*, convert the application rate in ppm to its decimal equivalent.

  Example:

    - ► Desired ppm concentration, as specified on the label, is 1500 ppm, therefore divide 1500 by 1,000,000.

      ☞ 1500/1,000,000 = 0.0015

- ► *Fourth*, multiply the decimal equivalent by the flow rate – gallons per minute or pounds per minute – to determine the amount of product needed.
    - ► Labeled product based on "volume":

      Example:

      ☞ 0.0015 x 7,500 gallons per min. = 11.25 gallons product

    - ► Labeled product based on "weight":

      Example:

      ☞ 0.0015 x 62,400 pounds per min. = 93.6 pounds product

Example #1: The label of a liquid formulation directs you to apply the product at a rate that will provide a product concentration of ppmv. The label also states that this concentration must be maintained for 15 minutes. Your application will be made to an irrigation canal that is 5 feet wide and 3 feet deep, on average, with a flow rate of 1 foot per second.

How many gallons of this herbicide must be applied per minute to achieve a concentration of 500 ppm, and how many gallons of the product will be needed to maintain the concentration for 15 minutes?

Steps to follow:

☞ Determine water flow rate:
5 feet wide x 3 feet deep x 1 foot per second rate = 15 cfs

☞ Convert to flow rate to cfm:

15 cfs x 60 seconds = 900 cfm

☞ Determine the flow rate in gallons per minute:
900 cfm x 7.5 gallons per cfm = 6,750 gallons of water per minute

☞ Determine the amount of herbicide needed to achieve the desired concentration (500 ppm – as stated on the label) in the canal that is flowing at the determined flow rate (6,750 gallons per minute).

First, convert the concentration rate (500 ppm – as stated on the label) to decimal equivalent:
500/1,000,000 = 0.0005

Second, multiply that value (0.0005) times the determined flow rate (6,750 gallons per minute).
0.0005 x 6,750 gallons = 3.375 gallons herbicide

☞ Since you know how much herbicide you will need to treat for one minute (3.375 gallons), determine the amount need to teat for the entire length of time by multiplying the amount needed for one minute (3.375 gallons herbicide) times the length of time stated (15 minutes).
3.375 x 15 minutes = 50.625 gallons herbicide need

Example #2: A concrete lined irrigation canal has an average flow rate of 150 cubic feet per second. The label of the herbicide directs the application should be at 5 ppmw for 1 hour.

How many pounds of herbicide will be needed per minute over the hour period?

☞ Determine flow rate per minute:
150 x 60 seconds per minute = 9,000 cfm

☞ Determine weight of water per minute:
9,000 cfm x 62.4 lbs. per cubic ft. = 561,600 pounds/minute

☞ Convert concentration, as stated on label, to decimal equivalent:
5 ppm/1,000,000 = 0.000005

☞ Multiply decimal equivalent times flow rate per minute (weight basis):
0.000005 x 561,600 pounds/min. = 2.8 pounds herbicide per min.

☞ Determine total amount of herbicide needed to complete the task:
2.8 pounds herbicide per min. x 60 minutes = 168 pounds herbicide need for the task

Pesticide treatments of flowing water can be very complex. The problems are often compounded by the fact that the quality and quantity of instructions on aquatic pesticide labels are quite variable. Some labels provide complicated but comprehensive instructions, while other labels off a minimum of instructions on application procedures. If you are not certain how to apply or how much to apply, please contact the chemical supplier for additional information.