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Real Property Operations and Maintenance

WEED CONTROL AND PLANT GROWTH REGULATION

This publication provides Department of Defense personnel with guidance and technical information on controlling weeds in noncropland, turf, ornamental plantings, and aquatic sites; and using plant growth regulators (PGR). It should be used by both appropriated and nonappropriated fund activities, including US Air Force Reserve and Air National Guard units and members. Weed control and plant growth regulation must be managed by well informed professional personnel.

Submit recommendations for changes through channels to: (a) Department of the Air Force—Air Force Engineering and Services Center (HQ AFESC/DEMM), Tyndall AFB FL 32403-6001; (b) Department of the Army—Director, Engineering and Housing Support Center (CEHSC-FN), Fort Belvoir VA 22060-5580; and Department of the Navy—Naval Facilities Engineering Command [Code 2042 (Natural Resources Branch) and Code 112B (Applied Biology Program)], 200 Stovall Street, Alexandria VA 22232.
Attachment 1 is a glossary of terms used in this publication.

The use of names of specific commercial products, commodities, or services in this publication does not imply endorsement by the military services.

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Chapter 1

GENERAL INFORMATION

Section A—Uses of Herbicides and Plant Growth Regulators

1-1. Beneficial Uses. Mechanical and manual methods once were the only effective means of controlling vegetation on military installations. Today, herbicides and plant growth regulators, together with improved management procedures, can be used to eliminate vegetation in areas such as industrial sites and storage yards; to control weeds along highways and railroads; to suppress woody plants in grasslands and utility rights-of-way; to eliminate weeds in ornamental plantings, turf, and aquatic sites; and to slow the growth of turf grasses and other vegetation. Under certain conditions, these chemicals can be used to reduce maintenance costs and to eliminate hazardous mechanical operations.

1-2. Limitations and Requirements:

a. Failure or poor control may result from selecting the wrong herbicide or plant growth regulator, improper mixing of chemicals, poor timing or method of treatment, and unsatisfactory conditions at the time of application. The conditions required for effective use; the potential for injury to desirable plants; and the hazards of the chemical to the operator, livestock, wildlife, and other nontarget organisms should be considered in choosing a herbicide or growth regulator.

b. The choice of a herbicide or growth regulator must include a study of the label. Rates and times of application, hazards, warnings, and cautions are stated on the label of each product.

It is required by law that the label be followed.

Cautions on all herbicide labels *must* be carefully observed:

c. Approval must be obtained from the major command (MAJCOM or MACOM) or engineering field division (EFD) pest management consultant before a herbicide can be used on a military installation. Such approval is included in the installation pest management plan required by DODD 4150.7 (DOD Pest Management Program). Early planning is important to allow time for approval so that treatments can be timely. Timing of application is often critical.

d. Where contamination of a drinking-water supply is possible, only those herbicides approved for use in potable water by the MAJCOM or EFD pest management consultant will be applied.

e. Restricted use herbicides, such as picloram and paraquat, can be applied only by, or under, the direct supervision of a certified applicator.

Section B—Biology of Plants

1-3. Annuals and Biennials. Plants are classified as annuals, biennials, or perennials, based on their life spans, and this is closely related to the ways they reproduce. All weeds pass through four stages of growth: seedling, vegetative, flowering, and maturity, and each class of weed (annual, biennial, and perennial) has a growth stage that is most susceptible to control. These aspects of plant biology dictate control strategies.

a. Annuals are plants that set seed and mature in one season. Seed is required for their initial establishment in temperate climates. Foxtail, crabgrass, common ragweed, wild buckwheat, and several mustards are examples. A variation of the true annual is the winter annual, which germinates in the fall, lives over winter, and matures early in the next season. Pennycress, common chickweed, corn cockle, downy bromegrass, and shepherd's purse are examples of winter annuals.

(1) Individual plants may produce thousands or, in some instances, hundreds of thousands of seeds that provide an enormous source of new plants. Many of these seeds remain alive for years. The high production of seed, the buildup of seeds in the soil, and the length of time the seeds remain viable in the soil are nature's way of ensuing that annual plants will be perpetuated. These properties of annuals make eradication almost impossible.

(2) The seedling stage of growth, at which time the plants are small, succulent, and actively growing, is the best time to apply herbicides to annuals. As the plant grows and passes through the other stages, control becomes more difficult. If the top growth is killed before seed is produced, the lifecycle of that plant is ended, since it cannot recover, but the reservoir of seeds

in the soil may produce new plants for many years.

b. Biennials require two growing seasons to complete their reproductive cycle. The first year's growth is purely vegetative, with top growth usually confined to a rosette of leaves. They are dormant during the winter and in the second season develop stalks with flowers and seeds. Because of this, they are easily confused with winter annuals. Because they reproduce only by seed, they can be treated like annuals. Burdock, evening primrose, common mullein, and wild carrot are examples of biennials.

1-4. Perennial Plants:

a. Perennials are plants that live more than 2 years. Many have several means of reproduction. In addition to reproducing by seed, they may reproduce vegetatively with the aid of storage organs in the form of stolons (prostrate aboveground stems), rhizomes (prostrate underground stems), bulbs, corms, and storage roots. Food is stored in these organs by the plant, and can be used when new growth occurs. New shoots may come from buds that live on these stored food reserves until the new plants become established. Unlike annuals, the top growth of many perennials may be killed, and still the plants can live and propagate by means of their belowground storage organs and dormant buds.

b. To control a perennial plant's vegetative reproduction, the plant's food reserves must be materially reduced, or its storage organs and buds must be destroyed. The food the plant stores is the excess manufactured by the green leaves and stems, over and above what is necessary for growth. Therefore, if photosynthesis can be prevented, the buildup of reserves will be curbed.

c. Cultural methods of control are designed to allow new growth to use up the plant's food reserves. New shoots draw on stored food for about 10 days after emerging. At this time the top growth is killed. This is repeated until the plant's food reserves are exhausted. The cultivation cycle usually takes 3 to 5 weeks, depending on the species and growing conditions, and the program often must be continued for at least two growing seasons.

d. Chemical control may also require repeated applications to deplete the plants supply of nutrients. While perennials do have a seedling stage, and control is easiest at this point, most are very inconspicuous, and accurate identification is difficult. Also, shoots that emerge from established roots are not seedlings and are more difficult to control. During their vegetative stage, perennials are not very susceptible to herbicides because they are drawing on their stored nutrients and not absorbing them from the surrounding environment. Control of perennials is best achieved during the bud and subsequent regrowth stage. As the plant is actively setting buds in order to reproduce, its food reserves are at their lowest levels, thus making it more susceptible to chemical control. Treatment at the early flowering stage is generally as effective as during the bud stage, but, when perennials reach full flowering, control levels decline drastically.

e. Quackgrass, Canada thistle, Johnsongrass, buttercup, and nutsedge are examples of perennials that are difficult to control. Some herbicides, however, are effective even on these hard-to-control perennials.

Section C—Characteristics of Herbicides and Plant Growth Regulators

1-5. Common and Trade Names. Common names and designations of herbicides and growth regulators used in this publication are those accepted or preferred by the Weed Science Society of America and the American National Standards Institute. Chemical names are those preferred by Chemical Abstracts Service of the American Chemical Society. Trademarks or trade names used by the herbicide industry are cited for information only, and do not constitute an endorsement over other products that may have been omitted. Because many users of this publication will be more familiar with trade names than common names, an alphabetical list of trade names with a cross listing of common names is given in attachment 2. Herbicides in other tables in this publication are alphabetized by common name.

1-6. Active Chemical Content and Formulations:

a. The containers of all commercial herbicides have labels that state the amount of active phytotoxic chemicals contained in the particular product. This is expressed in pounds per gallon for liquids and in percentage of active ingredient, acid equivalent, or phenol equivalent for granules and powders. Acid equivalent is commonly used to express the active chemical in herbicides derived from acids such as in dicamba; 2,4-D; glyphosate; and picloram. Phenol equivalent is used to express the active chemical in dinitrophenol derivatives.

b. Most herbicides are purchased as commercial formulations that can be (1) dissolved, emulsified, or suspended in a liquid carrier; (2) distributed dry as granular products or pellets by a spreader or by hand; or (3) injected into soil for vaporization and fumigation. Often an emulsifier, spreader, sticker, or other surfactant is added to facilitate dilution and adhering capacity to increase wetting by the diluted sprays.

c. Granules and pellets are prepared in several ways. Some herbicides are impregnated on granules of clay, vermiculite, or crop residues, such as ground corncobs. This is accomplished by spraying, dipping, or exposing the granules to the herbicide. Pellets and granules are also prepared by mixing a herbicide with finely ground clay or fertilizer salts and forming particles by extrusion or prilling.

d. Each herbicide, whether used in spray or granular form, is most effective if used by a certain application technique under specific climate and soil conditions. Recommendations prepared by weed research specialists in state agricultural experiment stations and by the individual manufacturers of herbicides outline these necessary conditions and techniques.

1-7. Modes of Action of Herbicides.

The actual mechanisms by which plants may be killed are so numerous, and plant functions are so intimately interconnected, that there can be no single theory on herbicidal action. The physiological responses of plants that may occur after a herbicide reaches a site of action include: changes in respiration, nutrient uptake, and carbohydrate utilization; disturbances in potassium metabolism; abnormal cell production; abnormal phosphatase activity; blockage of photosynthesis; reduction in vital leaf area; arrested cell division; and production of metabolites injurious to the cell.

a. Selective Versus Nonselective Herbicides. Selective herbicides kill certain plant species without seriously injuring other plants among which they are growing. Herbicides that selectively kill crabgrass or dandelions in a lawn are examples. The reasons that herbicides are selective in some combinations of weeds and desirable plants are known. The reasons they are selective in other situations are unknown.

(1) Selectivity is caused by the differing responses of plant species to a herbicide. There are various obstructions to herbicidal action along the critical path from the point of application to the arrival of the herbicide at its site of action in the plant. These obstructions differ among plant species and are part of the basis for selectivity. There are also varying plant responses at the sites of action that form a basis of selectivity. For instance, in some species the breakdown of the herbicide by the plant may keep pace with herbicide accumulation so that lethal concentrations are not reached, whereas in other species lethal concentrations are reached and kill the plant.

(2) Some of the barriers or obstructions that prevent a herbicide from killing plants differ among plant species and may be encountered at each of four steps in a critical path that a herbicide travels after leaving its container. The steps of the critical path are: (1) Achievement of herbicide surface contact with the plant or plant parts; (2) penetration or entry into the plant; (3) translocation to a site of toxic action; and (4) disruption of some vital function.

(3) Nonselective herbicides kill vegetation with little discrimination. A limited number of species, however, are physiologically resistant to the chemical, and some of these escape. Thus, there is no herbicide known that is completely nonselective. Some escapees are perennials that have part of their root systems below treated layers of soil; others are annuals and shallow-rooted perennials that reinfest the area after the chemical has leached below the surface layer.

b. Contact versus Translocated Herbicides. These are distinctly different in use and the types of weed that they will kill.

(1) Contact herbicides kill all tissues that are contacted by the spray. Whether the plant dies or recovers depends on whether it has a protected growing point. Also, many perennials have underground buds that are not contacted by the herbicide and that are capable of generating new plants.

(2) Translocated chemicals are absorbed by the leaves and stems, or by the roots, and move through the vascular system to the leaves, buds, and root tips. Translocated herbicides, when absorbed by the leaves and stems, commonly move in the plant's phloem (food-conducting tissue) with the food materials manufactured by the leaves and stems. When absorbed by the roots, they move in the xylem (water-conducting tissue). The growth-regulator type of translocated herbicide is a synthetic compound that

behaves like a plant hormone. It accumulates mostly in areas of rapidly dividing cells, upsetting the normal metabolism of the plant and causing death of the cells. Foliar applications of translocated herbicides are of great practical value because small amounts are effective and they can be applied in small volumes of water.

c. **Soil-Sterilant versus Preemergence Herbicides.** These both act through the soil but are used in different sites and situations.

(1) A soil-sterilant herbicide makes a soil incapable of supporting higher plant life; but it generally does not kill all life in the soil, such as fungi, bacteria, and other micro-organisms; nor does it kill ungerminated seeds. Its toxic effects may remain for only a short time or for years. Persistent residual toxicity depends on the nature of the chemical and its rate of decomposition or leaching, the colloidal and chemical properties of the soil, the relative tolerance among weed species, and the rate of application.

(2) Herbicides vary in their rate of disappearance from the soil because of differences in their volatility, susceptibility to decomposition by soil micro-organisms, sensitivity to sunlight, chemical reactions, and solubility. For example, some of the carbamates are volatile at moderately high temperatures and rapidly lose their toxic effect during the summer months. Certain soil micro-organisms effectively decompose herbicides such as 2,4-D in a short time. Amitrole is soluble in water and is readily leached.

(3) Some herbicides are readily adsorbed by mineral and organic colloids in the soil and are rendered unavailable, or only slowly available, for plant absorption. For example, diuron is adsorbed on clay colloid particles, making leaching difficult. Paraquat is completely inactivated by soil because its positively charged cations react with the negatively charged clay minerals to form complexes. The fertility and pH of a soil also influence the persistence and availability of certain chemicals.

1-8. Toxicity and Volatility:

a. Toxicity ratings are described in attachment 3, and the toxicities of herbicides and plant growth regulators are given in attachment 4. Those herbicides rated extremely toxic (low LD_{50}) must be handled with great care (while those rated as slightly toxic (high LD_{50}) require less special attention). The dermal toxicity rating is also given, and the same precautions are required.

b. The relative toxicity of chemicals is determined in small animal tests. Unfortunately, humans do not always react the same as small animals. It is always possible that a human will be poisoned by a smaller dose of a given chemical than results with animals would indicate, or vice versa. The extremely toxic herbicides included in this publication are acrolein and endothall, and the general-purpose fumigant, methyl bromide. They must be handled with particular care.

c. Volatility refers to the tendency of a liquid or solid to change to vapor. Vapors of some herbicides kill plants. This is an important consideration in purchasing herbicides such as 2,4-D or other phenoxy herbicides. When using volatile herbicides, the use must be aware of temperature as well as wind speed and direction. Volatility generally increases as temperature rises. When vapors from the herbicide are likely to injure adjacent crops or other plants, an amine salt or a low-volatile ester formulation should be used.

d. Esters of 2,4-D are classified as being of high or low volatility according to the degree of vaporization that occurs. In general, methyl, ethyl, isopropyl, butyl, and amyl esters are considered highly volatile and should not be used. The high molecular weight esters are low in volatility and include: butoxyethyl, butoxyethoxypropyl, ethoxyethoxypropyl, propylene glycol butyl ether, and isooctyl esters.

Section D—Hazards to Non-Target Organisms

1-9. General Information. Nearly all herbicides are potentially dangerous in one way or another, but they are not likely to cause injury if used properly and if recommended precautions are observed. Because several kinds of danger are associated with handling and applying herbicides, and possible injury is not limited to the operator, consider the potential effects on all of the following: operator and handler, livestock, desirable plants, fish and wildlife, water quality, and equipment.

1-10. Operator and Handler. The person who hauls, mixes, and applies the herbicidal spray, or spreads the dry product, could be poisoned from swallowing the herbicide, by skin absorption, or by inhalation. In each case, there is greater danger from the concentrated material than from the diluted spray solution or suspension. Be sure to read the label for each chemical used.

The use of safety equipment is mandatory when mixing and applying herbicides when indicated on the herbicide label.

a. If a concentrated spray is ingested, take immediate and appropriate action for the chemical, as indicated on the label. Notify the military hospital, and, if possible, immediately transport the victim to the hospital emergency room, accompanied by the herbicide label with antidote instructions.

b. Prevent absorption by the skin, and irritation of skin and eyes, by keeping exposure to a minimum. Some individuals are hypersensitive to certain chemicals, and have allergic reactions that are not possible to predict without skin tests. For most herbicides, washing the hands and face with soap and water after handling is sufficient protection. Prolonged contact is more dangerous than short exposures.

c. For the more readily absorbed chemicals and those that are irritating, wear clean clothing that covers the body. Wear long pants and long sleeves. Remove clothing that has become contaminated with the chemical. Use synthetic rubber gloves that are unlined. Where splashing may occur, wear goggles or a face shield and a rubber or plastic apron. If spray or dust is spilled on the skin, wash thoroughly with soap and water. If the herbicide contacts the eyes, flush the eyes with plain water and call the medical facility emergency room. An emergency shower and eye wash must be maintained in the shop area, and a portable eyewash should be carried in any vehicle used for pesticide work.

d. Purchase liquid concentrates and powders in containers that can be readily lifted by the operator in the field, or provide special pumping equipment for transferring chemicals to the sprayers. Packages of powders should be small enough so that it is unnecessary to remove the contents with a scoop. Never transfer chemicals to unmarked, unlabeled containers.

e. Do not inhale vapors, dusts, and spray mists. Using a respirator approved by MESA/NIOSH for the particular type of exposure is mandatory when label directions indicate the need. In the case of a severe exposure, move the victim into fresh air, administer artificial respiration if needed, and call the medical facility emergency room.

f. Some chemicals are flammable or support fire. Avoid ignition from sparks and contact with combustible materials.

g. Some herbicides are dyes that can stain unprotected skin and hair. Handle these with care.

1-11. Livestock and Domestic Animals. For most herbicides, the chief dangers of poisoning livestock come from consuming herbicide remnants that are in open containers or spilled on the ground or floor.

a. Herbicides are often used to improve pasture by controlling undesirable plants that provide poor forage. Desirable plant species will increase as competition from weeds decreases.

b. Herbicides such as 2,4-D and similar compounds may increase the palatability of plants not ordinarily eaten. If these are poisonous species, such as jimson weed, larkspur, hemlock, and cherry, the hazard of animal sickness and death may increase temporarily. The nitrite content of some plants can be increased enough to be toxic to livestock when sprayed with 2,4-D. Significantly increased nitrite content of plants, however, does not usually follow spraying. More commonly, unfertilized soils are so low in nitrogen content that nitrite poisoning is no hazard.

1-12. Desirable Plants. Certain precautions in the use of herbicides are necessary to prevent damage to nearby desirable plants. This damage may result from spray drift, washing, or leaching.

a. Drift hazards are greatest when herbicides are sprayed on foliage. These may be of the growth-regulating type such as 2,4-D, dicamba, and picloram; or of the contact type such as paraquat and petroleum oils. Danger is decreased with granular applications of nonvolatile herbicides. Spray drift occurs not only with volatile herbicides, i.e. high-volatile esters of 2,4-D, but also with sprays that are atomized into a mist by high pressure and a small nozzle opening. Controlling drift is discussed in paragraph 2-7.

b. Wash-off migration of herbicides can be an important hazard on slopes, bare ground, and pavements. The herbicide may be carried by surface runoff water to valuable plants down slope. Problems often occur when water runs across an area treated with soil sterilant herbicides onto lawns or ornamental beds or among trees. Do not drain or flush equipment where runoff to desirable plants may occur.

c. Leaching moves chemicals downward through the soil. If the herbicides are readily absorbed by roots, plants whose roots extend under the treated area are likely to be injured. Desirable trees growing adjacent to areas treated with soil sterilants, or near ponds treated with some aquatic herbicides, are often injured. Avoid treating such areas with soil sterilants. Do not drain or flush equipment where leaching to the roots of desirable plants can occur.

1-13. Fish and Wildlife. Applications of herbicides may have primary and secondary effects on wildlife.

a. Primary effects are from direct poisoning. There are a few herbicides, such as the dinitros, that can directly poison animals; and copper sulphate can poison fish and fish food organisms. A few herbicides are very toxic to fish; but some, such as 2,4-D, can be used safely to control aquatic weeds. In general, most injury results from excessive application rates and spillage.

b. Secondary effects of herbicides on wildlife include animal poisoning due to changes in palatability of poisonous plants, changes in the chemical composition of plants, and effects on organisms in the food chain. All herbicides have the potential of exerting major effects on wildlife habitat by changing the species in the plant community.

c. Indiscriminate spraying can destroy cover, but herbicides can also be useful in management. Openings in wooded areas, such as clearings for rights-of-way, can be beneficial to wildlife. Herbicides can be used to induce sprouting of browse species for deer. Herbicides used to eliminate or reduce weedy plants may allow the increase of other desirable plants, such as in the selective control of brush in rights-of-way, and lead to increases in feed or browse. The control of submersed weeds in ponds and streams can be beneficial to fish populations. Safe amounts of herbicides, expressed in parts of the chemical per million parts of water, vary widely with age, size, and species of fish. Aquatic biologists and natural resources managers should be consulted to determine appropriate uses and precautions. Management of fish and wildlife habitat is discussed in the tri-service Fish and Wildlife Manual (TM 5-633, AFM 126-4, NAVFAC MO 100.3).

d. When any proposed spraying program might endanger fish and wildlife, you should consult federal or state fish and wildlife agencies for advice. Be sure no state or federal endangered or threatened species will be affected. Also check on local water quality regulations regarding pesticide use.

1-14. Damage to Equipment. Thorough draining and cleaning of equipment with water and a detergent is sufficient protection against most herbicides. Some chemicals, however, corrode the metal parts of spraying equipment; and oils and solvents can injure rubber seals, gaskets, and lines. When corrosive chemicals are used, purchase equipment with noncorrosive metals or coat the metal parts of the equipment with protective paint, oil, or undercoating before use. Teflon and neoprene will resist oils and solvents.

Chapter 2

SELECTING, USING, STORING, AND DISPOSING OF HERBICIDES

Section A—Selecting Herbicides

2-1. Analyzing the Situation:

a. Chemical control of a mixed population of weeds and brush requires a herbicide or a mixture of herbicides to which the many species on a site are susceptible. Therefore, it is important to know the kinds of weeds that are present and the herbicides that will control them. Identifying the main species in the population is the first requirement.

b. The response of a plant to an application of a herbicide depends not only on the species but also on the age of the plant, the rate of application, and the soil and climatic environment in which the plant is grown. Seedlings are killed most easily—even seedlings of some resistant species are killed. Many plants become more tolerant to a herbicide as they grow older. Some perennials are most easily killed when in bloom. Woody plants may be more susceptible to one method of application than to another. A weed may be more susceptible to a herbicide if treated at the optimum time, with the optimum rate, and under the optimum environmental conditions, but may be more tolerant under conditions that are less favorable for control.

c. Selection of herbicide, in addition to controlling the weeds, must also fulfill other criteria. Is it cost effective? Does the herbicide kill all the vegetation, or does it selectively leave some types of plants in the area? Methods of application, modes of action of the herbicide, and effects on the ecology of the area are important considerations. What are the hazards of drift or runoff water from treated areas to nearby desirable plants or other biota?

2-2. Choosing a Formulation. Formulations make an important contribution to the efficacy of herbicides and to their ease of use in the field.

a. Emulsifiable concentrates and wettable powder formulations are readily dispersed in a water carrier, but require agitation during the spraying operation. Water-soluble salts, water-miscible liquids, and water-soluble powders normally do not require agitation. Granular materials are applied with granular pesticide spreading equipment, modified fertilizer spreaders, or by hand.

b. One of the most important properties of granular and pelletted herbicides is their physical selectivity. The particles tend to bounce off dry foliage and other plant parts to the soil or to settle to the bottom of ponds, lakes, and other bodies of water. This enhances the chemical selectivity of the herbicides when used on growing crops or on submersed aquatic weeds. Granules and sprays of many herbicides are equally effective on germinating weed seed in soil. However, when a herbicide is applied as a spray, it is often intercepted by foliage, and its effectiveness in killing germinating weed seeds in the soil is reduced. Granular herbicides frequently have been used because of the scarcity of clean water supplies for spraying in many areas and the need for extra labor and equipment for water hauling.

c. Granular herbicides are of special interest for ornamental plantings because their physical selectivity helps to broaden the use of a few effective herbicides to cover a relatively large number of plant species. That is, sprays of some herbicides would injure plant foliage whereas the herbicide in granular form does not. Therefore, they have been used rather extensively in horticultural plantings after clean cultivation. Granules also fill a specific need in transplanted ornamental crops where preemergence herbicide treatments cannot be used. As a matter of convenience, granular herbicides have also been used extensively in preplant soil-incorporated treatments and preemergence treatments of ornamental plantings.

d. Each herbicide, whether used in spray or granular form, is most effective if used by a certain application technique under specific climate and soil conditions. Recommendations prepared by weed research specialists in state agricultural experiment stations and by the individual manufacturers of herbicides outline these necessary conditions and techniques.

2-3. Comparing Costs. The carrier components contained in herbicide formulations, such as emulsifiers, solvents, and other adjuvants, often improve mixing, spraying, and weed-control results, but the cost of the herbicide largely depends on the amount of phytotoxic chemical that it contains.

a. One of the guides to use in comparing the costs of herbicides is the price per pound of active chemical. The costs shown in attachment 4 were the approximate retail prices per pound of active chemical when the publication was prepared, and may be useful in planning. Actual costs will probably be different.

b. Usually the concentrated commercial formulations are less costly to use than the more dilute concentrations. For example, 2,4-D formulations that contain 4 pounds of acid equivalent per gallon nearly always cost less per pound of active chemical than do formulations containing only 1 or 2 pounds of 2,4-D equivalent per gallon. However, herbicides to be broadcast dry in granules or pellets may require purchasing diluted concentrations such as 4, 10, or 20 percent to permit precise and uniform application.

c. Where a formulation contains a mixture of herbicides, the amount of each herbicide is given on the label and should be considered in determining the relative value of the mixture.

2-4. Effective Herbicides. Herbicides and plant growth regulators that may be useful on military installations are listed by common name in attachment 4 along with costs, commercial formulation, trade name, toxicities, modes of action, and other basic information needed for their use.

a. Common weedy plants are listed in attachment 5, along with herbicides that give fair to excellent control. Genus, species, and, in some instances, variety are given where response to herbicides is specific and information is available. There may be other effective herbicides that are not included.

b. Some herbicides are effective only when used as either preemergence, preplanting, or postemergence treatments. Others are effective as both preemergence and postemergence treatments. Some act only through the soil, and some only from foliage treatments. Usually the preemergence treatments are effective only on germinating seedling plants. Some other herbicides must have well developed plants at treatment time. It is critically important that herbicides be used according to the directions on the herbicide label.

Section B—Using Herbicides

2-5. A Systematic Approach. Many factors contribute to the success or failure of herbicide treatments.

a. Identify the weeds you want to control. If in doubt, obtain assistance from a weed specialist, the EFD or MAJCOM consultant, or other authoritative source.

b. Select the right herbicide to control these weeds without harm to nearby desirable plants. Before applying a herbicide on a military installation, make sure that the product has been approved by the MAJCOM or EFD pest management consultant and is included in the installation pest management plan.

c. Read the label on each container before using the contents. Heed all cautions and warnings, especially the antidote and protective equipment statement for each chemical used. Antidotes for each herbicide used should be printed and posted in mixing and office locations and in vehicles which transport or disperse chemicals.

d. Handle herbicides that are rated extremely toxic (low LD_{50}) with great care. Handle slightly toxic (high LD_{50}) herbicides carefully, also. This applies to both oral and dermal toxicities. Avoid skin contact with the chemicals.

e. Follow mixing and application directions. Do not mix more than will be needed. Do not apply more than is recommended.

f. Always store herbicides in original labeled containers. Neither chemical concentrates nor diluted sprays should be kept in unlabeled containers. Follow label instructions for disposing of empty pesticide containers.

g. Remember that weather conditions, the soil, and the growth stage of weeds affect the action of many herbicides. Hence, for best results, follow label directions on when and how to apply the materials.

h. Avoid any hazard of contaminating groundwater or other possible drinking water sources. Water-soluble herbicides are often more readily leached through soils, but all can be carried in runoff water to streams and other surface water.

i. When applying herbicides to control aquatic weeds, remember local and seasonal variations in water quality and chemistry affect both the response of aquatic weeds to herbicides and the chemical and physical stability of herbicides in water. Salinity and alkalinity of the water are among the more variable and important characteristics. Calcareous deposits on the surfaces of aquatic weeds greatly reduce their susceptibility to herbicides. Water pH influences the ionization state of many herbicides and the formation of salts and complexes that frequently are less reactive and less soluble in water.

2-6. Application Rates:

a. Application rates of herbicides are often given in minimum and maximum amounts, depending on the situation. This range is necessary to accommodate differences in the response of plant species, the stage of growth when treatment is made, the desired period of residual toxicity, the amount and distribution of rainfall, soil texture and composition, and other environmental conditions. Figure 2-1 shows situations when light and heavy application rates are needed.

Variable Factor	Lighter rates	Heavier rates
Herbaceous plants	Susceptible species	Tolerant species
	Annuals	Perennials
	Seedlings	Annuals and biennials in flower
	Perennials in bud	Established perennials-flower to maturity
	Shallow-rooted	Deep-rooted
Woody plants	Susceptible species	Tolerant species
	Foliage applications when plants are in full leaf	Foliage applications before and after full leaf
	Actively growing	Dormant
Residual toxicity of herbicide	Short period	Several years
	Arid regions	Humid regions
	Cool climate	Warm climate
Soil	Low in organic-matter content	High in organic-matter content
	Low in clay content	High in clay content
	Well drained	Poorly drained
Root-absorbed chemical	Bare soil	Heavy trash

Figure 2-1. Factors Influencing Herbicide Application Rates.

b. In some cases, rates are given in units of the chemical per 100 or 1,000 square feet, per square rod, or per acre. It is not necessary, however, to measure the area to be sprayed each time an application is made. Calibrate the sprayer to deliver the proper amount of chemical per unit area (see chapter 9).

2-7. Effects of Weather:

a. Effects of Wind:

(1) Wind causes improper distribution of herbicides and greatly increases the hazard of damage from drift to sensitive plants in nearby fields, gardens, or ornamental plantings (figure 2-2).

(2) Vapors of some herbicides, such as 2,4-D or other phenoxy herbicides, kill plants. When vapors from the herbicide are likely to injure adjacent crops or other plants, an amine salt, or a low-volatile ester formulation should be used.

b. Effects of Humidity. High or moderate humidity increases the effectiveness of most herbicide applications to foliage by reducing evaporative losses of spray and aiding the foliar absorption of herbicides. Low humidity reduces the effectiveness of herbicide sprays by increasing the rate of evaporation. The disadvantages of low humidity can be partly overcome by using oil and oil-water emulsions instead of water as spray diluents.

c. Effects of Temperature. Temperature affects the rate of chemical reactions in plants and animals and also evaporation rates of sprays.

(1) Moderate temperatures, ranging from 70 to 85°F (21 to 29°C), are favorable for spray applications of most herbicides. The carbamates, dinitro compounds, and high-volatile esters of phenoxy compounds volatilize rapidly at temperatures above 80°F (27°C). At temperatures above 90°F (36°C), even the low-volatile esters of 2,4-D and other phenoxy compounds become significantly volatile. In general, do not apply herbicidal sprays when the temperature is above 90°F.

- Use nozzles that apply a coarse spray. Get advise from agricultural engineers and weed-control specialists.
- Use low pressures—no more than 30 lb/in^2 for boom sprayers, 100 pounds for spray guns.
- Avoid spraying on windy days and do not spray with ground equipment or from airplanes when the wind velocity is sufficient to cause drift to sensitive areas. Usually, stop spraying when wind speed reaches 5 mi/h. Never spray above 10 mi/h. 2,4-D and similar herbicides should never be applied when wind of any velocity is blowing across the spray area toward nearby valuable sensitive plants.
- Do not spray when an air-temperature inversion exists. An inversion is characterized by little or no wind and by air temperatures that are lower near the ground than at higher levels. A continuous smoke-generating device on aircraft can be used to indicate the direction and velocity of air movement. Layering of the smoke may indicate a temperature inversion. When spraying large acreages, use the burning tire or other smoke generator to indicate the presence of inversions.
- Spray when a light wind is blowing away from susceptible crops and toward the area being sprayed.
- Where special drift hazards exist, either do not spray or use specialized spray equipment. One of the special drift control agents or formulations in properly designed and adjusted equipment can help reduce drift. Obtain professional advice before using these products.

Figure 2-2. Suggestions for Minimizing Drift Hazards.

(2) Water temperature has a strong influence on the effectiveness of aquatic herbicides. Poor herbicidal activity can be anticipated at temperatures of 60°F (16°C) or lower. Herbicides such as acrolein and xylene perform poorly at high water temperatures due to rapid losses by volatility.

d. Effects of Rainfall. Rainfall affects efficacy of herbicides in other ways than by affecting the plant's rate of growth.

(1) Rainfall immediately after postemergence foliar applications of herbicides may wash spray off of leaves of plants and reduce the effectiveness of water-soluble formulations such as salts of 2,4-D; glyphosate, dinitro, and amitrole compounds; and some other foliar herbicides. Effectiveness usually is not reduced if a moderate rain occurs 4 to 6 hours after postemergence application. Check the weather forecast before applying herbicides.

(2) The effectiveness of preemergence herbicide treatments may be increased by moderate rain occurring shortly after application. In low rainfall areas, sprinkler irrigation is often used with good results when the water is applied immediately after preemergence herbicide application. However, if heavy rains occur soon after preemergence treatments, the herbicide may wash off of treated areas or may leach below surface soil where weed seeds germinate; and weed control may be reduced or crop damage increased.

2-8. Counteracting Misapplications and Spills. If herbicides are overapplied, applied on the wrong plants, or spilled; or if residues persist; they usually can be detoxified with activated carbon such as Gro Safe or Aqua Nuchar A. Fast action is needed. Even 2,4-D injury can be prevented or reduced if the accident is treated immediately, before plant uptake. One hundred to 200 lb. of activated carbon are required to completely absorb 1 lb or active herbicide. Normal field rates are 100 to 400 lb of carbon per acre to detoxify residues. Apply either dry carbon alone, dry carbon mixed with soil, or carbon as a slurry at 1 to 2 lb/gal water. To detoxify residues in soil, thorough incorporation of the activated carbon into the soil is needed.

Section C—Storing Herbicides

2-9. Flash Points. Chemicals with low flash points (40°F or less) are dangerous in storage.

They should not be stored unless special precautions are taken (figure 2-3). Chemicals with flash points of less than 100°F are flammable and require special handling.

2-10. Temperature and Moisture:

a. Chemicals may crystallize out of solution at temperatures below 32°F. If this happens, warm the products to 40°F or higher and roll the drums or shake the containers. If the crystals return to solution, no harm has been done. Low-volatile esters of 2,4-D do not freeze if stored in unheated rooms.

b. Dusts and wettable powders cake when wet, and packages may deteriorate. They present no problem as long as they are kept clean and dry. Water-soluble solids also cake when wet and when subjected to great changes in temperatures. If packages are left open, hygroscopic chemicals become wet by absorbing water from moist air. Chemicals such as chlorates, borates, and ammonium sulfamate cake when they are wet.

c. Liquid formulations should be stored on pallets or duckboards to keep the metal containers from rusting. The containers should be tightly closed. Air vents punched in cans to facilitate pouring should be plugged. Even small amounts of water introduced into emulsion concentrates or oil solutions can make them gel and cause deterioration of the container.

2-11. Facilities and Procedures. Pesticides should be stored in a dry, well ventilated building which is separate from offices and laboratories and where fire protection is provided. Pesticides should be protected from freezing or overheating. All pesticides in storage *must* be labeled.

a. Where large quantities are stored, the entire storage facility should be secured by a fence, and doors and gates should be kept locked to prevent unauthorized entry.

b. Highly visible, waterproof identification signs on doors, gates, buildings, and fences to advise of the hazardous nature of contents, with telephone numbers and names for additional information, should be posted in areas where they will be visible.

c. Pesticides must be stored according to special storage requirements and compatibility properties as specified on the label, and separately from other products and materials in storage areas.

d. A current inventory of all pesticides in each storage unit must be posted in an inside location accessible and visible to program personnel. This inventory will include the name(s), listed in order of toxicity category with the appropriate signal words of each pesticide; the number and kind of containers; and the date each was received.

e. All quantities of highly toxic and experimental pesticides must be secured in a lockable storage unit with limited access.

f. Pesticides must be stored off the floor. Wooden pallets should be used.

g. Insecticides, herbicides, fumigicides, and plant growth regulators must all be stored so as to prevent cross-contamination. Liquid pesticides should be stored in such a manner that a spill or leak would not contaminate nonliquid pesticides. Fumes from volatile herbicides can cause contamination, so secure containers and adequate ventilation must be provided.

h. Pesticide containers should be stored with the labels plainly visible. If containers are not in good condition when received, the contents should be placed in a suitable container and properly relabeled.

i. Containers should be checked regularly for corrosion, leaks, and gas formation. If such is found, the contents should be transferred to a sound, suitable container and be properly labeled or disposed of.

j. Materials such as adsorptive clay, granulated activated charcoal, hydrated lime, and sodium hypochlorite should be kept on hand for emergency treatment or detoxification of spills or leaks. On discovering a spill or leak, isolate the contaminated area and keep out all unauthorized personnel. Allow no smoking in the area. Ventilate the area thoroughly. Immediately contact your safety and health manager so pesticide and container can be disposed of in an acceptable manner.

k. Adequate fresh water and soap or special solvents for decontamination of personnel and equipment should be available.

l. Additional guidance is in Armed Forces Pest Management Board Technical Information Memorandum 17, Pest Control Facilities.

- Store herbicides in a cool, dry place that is vented and where negative pressure is maintained.
- Store herbicides away from foods, fertilizers, feed, seed, and other types of pesticides.
- Make sure that the storage area is lockable and not accessible to children, unwary adults, or animals.
- Store herbicides only in the original, labeled containers.
- Rotate the stock. Use old product before new.
- Follow local regulations for stacking heights. Check with the local safety office and fire department.
- Record the lot numbers of herbicides in your inventory system. Every herbicide container has a lot number.
- Have emergency phone numbers available, including those for medical facility emergency room, environmental coordinator, bioenvironmental engineering official, and facility fire department.

Figure 2-3. Basic Precautions for Storing Herbicides.

Section D—Disposing of Herbicides

2-12. Waste Herbicides and Containers. Mix only the amount of herbicide that you will need for the job. Any that is left over should be used, if you have a valid requirement for it. Otherwise, it may have to be treated as a hazardous waste. Pesticide containers must be disposed of according to instructions on the label. Often this involves burning paper and cardboard containers in approved incinerators; burying polyethlene and other synthetic containers; or triple rinsing, puncturing, crushing, and burying metal containers in a Class I landfill.

2-13. Hazardous Waste Requirements. Be sure to comply with federal, state, local, or host nation hazardous waste regulations. Waste herbicides and containers that qualify as hazardous wastes must be disposed of according to those regulations. The label provides instructions. The Armed Forces Pest Management Board's Technical Information Memorandum 18, Pesticide Disposal Guidelines for Pest Control Shops, also provides guidance. If you have any questions, ask the MAJCOM or EFD pest management consultant.

Chapter 3

VEGETATION CONTROL IN SEMI-IMPROVED AND UNIMPROVED GROUNDS

Section A—Methods of Vegetation Control

3-1. Earth Forms and Structures. A number of earth forms and structures can contribute to the case and success of weed-control practices.

a. Embankments, fences, floodways, tank farms, road and utility rights-of-way, and similar areas should be designed, constructed, and managed in a manner to enhance efficient vegetation management. Ditchbanks should be shaped to provide uniform crowns and slopes, and a roadway should be maintained on each bank for efficient use of mowers and spraying machinery. Shaping ditches, grades, and backslopes along highways to avoid steep or irregular contours provides similar benefits.

b. Providing suitable livestock guards, instead of gates, greatly facilitates access to the area when using livestock grazing for weed control.

3-2. Land Management Practices:

a. Seeding areas such as magazines, ditchbanks, fence lines, and rights-of-way to low-growing grasses or other desirable plants usually provides sufficient competition to reduce the weed problem greatly. It will also increase the effectiveness and economy of grazing, mowing, or using selective herbicides for vegetation control. Maintaining desirable vegetation on these areas prevents or reduces wind and water erosion and provides habitat for wildlife. Establishing suitable stands of the desired competitive vegetation is much easier on recently constructed ditchbanks, road rights-of-way, and similar areas than on those already heavily infested with weeds. Frequently, weed growth can be eliminated by spraying with nonpersistent herbicides, such as paraquat and glyposate. Then a grass or other revegetation mixture can be seeded almost immediately and successfully established.

b. Controlled grazing by cattle, sheep, goats, and geese, where feasible, often provides effective and economical means of vegetation control on ditchbanks and floodways. Only a few biological agents other than livestock effectively control weeds. Examples are insects that control Scotchbroom, gorse, puncturevine, and St. Johnswort in uncultivated areas, and alligatorweed in aquatic sites. Also, wild ducks, Tilapia, and grass carp eat aquatic vegetation. Removing sources of excess nitrogen, which encourages the growth of aquatic plants, is another means of controlling aquatic weeds.

c. Repeated mowing tends to eliminate or reduce tall weed species, and encourages the dominance of more desirable low-growing vegetation. Mowing may need to be repeated three to eight time each growing season to maintain effective control of undesirable plants.

3-3. Recommended Herbicides:

a. Attachments 6, 7, 8, and 9 list herbicides that are recommended for semi-improved and unimproved grounds. Herbicides that kill all vegetation are listed in attachment 6; while attachment 7 contains those that work best on broadleaf weeds without killing the grasses. Attachment 8 contains those primarily controlling grasses. Herbicides for woody plants are given in attachment 9. Rates of treatment and instructions for use are abbreviated. More detailed information is included on labels and company brochures for each of the herbicides. Follow the instructions completely. The approximate retail prices given in the attachments may be useful in preliminary planning. Actual costs will be somewhat different.

b. The low-volatile esters of 2,4-D and other phenoxy herbicides must be used with caution near agricultural crops and improved grounds when drift or volatilization could damage ornamentals or desirable plants. The high-volatile esters should not be used in these situations. The amine salt formulations do not volatilize, but the sprays may drift. These also should be used with care.

Section B—Controlling All Vegetation

3-4. Problems With Bare Soil. These problems are not always fully appreciated.

a. Controlling all vegetation, and thus leaving the soil bare, has such great disadvantages that the method should be used very sparingly and only after fully considering potential consequences and alternatives. Bare soil erodes both by water movement and by wind. The loss of soil maybe accompanied by rill and gully erosion, and the dust problem from wind erosion may be considerable. Also, water erosion of soil often carries the herbicides with it and may severely injure or kill desirable grasses, woody plants, or other vegetation in downslope areas. Mowing existing vegetation may adequately maintain a site for its planned use. Maintaining low-growing grasses or other vegetation is almost always preferable to having the soil bare.

b. There are four major considerations in maintaining bare ground:

(1) No herbicide kills all species at reasonable rates of application.

(2) Reinfestation results from weed seeds in the soil after the herbicide has been leached below the surface.

(3) Desirable trees, ornamental plants, and turf in adjoining areas may be killed or injured if surface water drains across treated areas to untreated ones, or it tree roots extended into treated areas.

(4) Bare soil is subject to serious erosion where the terrain is steeply sloped and there is enough rainfall to cause runoff. You should meet these problems by using the most appropriate herbicide treatment for the situation, and by using soil binding or stabilizing treatments or structures to prevent erosion.

3-5. Using Soil Sterilants. There is no one herbicide available that meets all requirements for complete control of vegetation.

a. At practical rates of application, even the soil sterilants do not always kill all vegetation. There are two major reasons. First, each of the soil sterilants listed in this publication has one or more plant species that is tolerant to it; and, second, these herbicides do not behave equally well under all environmental conditions.

b. Soil sterilants prevent the growth of green plants. They do not actually sterilize the soil. To be effective, a soil sterilant must be soluble enough to be carried into the root zone by moisture in the soil. Also, it must remain in the soil long enough for a lethal dose to be absorbed by the plant. A soil sterilant's movement and persistence in the soil are influenced by (1) its solubility; (2) the rainfall in the area; (3) the physical and chemical properties of the soil, such as texture, structure, and pH; (4) organic matter; and (5) the micro-organisms in the soil that are able to deactivate the chemical.

c. The rate of application and the optimum time for treatment vary with soil, rainfall, and the weed species to be controlled. In most areas, it is better to make repeated annual applications of soil sterilants at relatively light rates than to rely on a single heavy treatment. Such a maintenance dosage results in a smaller annual expenditure than a "one-shot" method and keeps chemicals in the surface soil where they can kill weed seeds coming in from outside or that may have been dormant in the soil. The full effectiveness of some soil sterilants like bromacil, tebuthiuron, diuron, and simazine is most evident in the second or third year of use, especially in dry areas or with deep rooted weeds.

d. Broadleaf species are usually the first vegetation to reinfest sterilized areas. Relatively inexpensive supplemental treatments with esters 2,4-D at 1 to 2 pounds per acre, or other herbicides in attachment 7, will maintain areas free of tall vegetation for several additional years. Make spot treatments of the difficult-to-kill plants by hand at rates high enough to kill the tolerant weeds rather than making another general spray treatment.

e. Failure to get expected control may result from an incomplete distribution of the herbicide on the soil or from inadequate amounts in the soil solution to effect a kill. A chemical of low solubility may be adsorbed in the upper soil layer and not reach deeper roots. This may happen in soils with poor underdrainage, in dry regions, or when the treatment is made at the wrong time. A soluble chemical may leach out of the soil before the plant roots absorb a lethal dose. This occurs most commonly in sandy soils having excessive underdrainage and with high rainfall, seasons of heavy showers, or under irrigation. It may result from improper timing of the treatment. A number of actions can be taken when hard-to-kill species are a problem, or where environmental factors reduce the activity of a chemical: (1) increase the rate of application, (2) use a mixture of chemicals, or (3) repeat the treatment.

f. Runoff is an important hazard on treated slopes, bare ground, and pavements. Low viscosity asphalt, applied after application of a soil sterilant, helps hold the chemical in place. Use 40 gallons per 1,000 square feet, or 1,700 gallons per acre, or use a light covering of road oil. If there has been an excavation, add a layer of crushed rock. Trees that are some distance from soil treated with soil sterilants may be killed if their roots extend into the treated area.

3-6. Control With Combinations of Herbicides. A combination of herbicides may be more efficient for complete control of vegetation than a single chemical. Combinations of different herbicides effectively increase the range of weed species controlled; and, in some cases, reduced rates of herbicides are possible.

a. To obtain vegetation-free areas, certain foliar-applied herbicides are used together with persistent, soil-applied herbicides. These foliar herbicides include the contact herbicide paraquat and the translocated herbicides such as glyphosate and amitrole. Glyphosate is nonselective and kills many weeds, including perennial weeds. It readily translocates from the foliage to other parts of the plant, including the roots. It has no soil activity. Where the perennial weeds are susceptible to the growth-regulator herbicides, it may be economical to use a combination of a relatively insoluble soil sterilant like bromacil, simazine, or diuron to control annual weeds and 2,4-D, dicamba, or other such growth-regulator herbicide to kill the broadleaf perennials.

b. Soil sterilants are applied preemergence to moist soil at about 4 pounds per acre. The growth-regulator herbicides are applied to broadleaf perennials at 1 to 2 pounds per acre when they are in full leaf and growing rapidly to obtain the maximum translocation to their roots. For this combination method to be successful, the soil sterilant must remain near the soil surface, and there must be enough rainfall to activate it. Heavy rain will leach the herbicide from the topsoil and shorten the period of control. Incorporation of the chemical into the soil helps activate it in dry seasons, but this does not substitute for train.

Section C—Controlling Woody Vegetation

3-7. Practical Considerations. Each type of land use influences the methods that can be used for brush control.

a. On military reservations, trees and shrubs sometimes must be removed or controlled on weapons ranges, ammunition magazines, and similar areas. Woody plants must also be kept under control along highways, under power lines, along security fences, and at the end of aircraft runways.

b. Woody growth can be cut mechanically or manually. Stumps can be removed by bulldozer, if required. Root rakes may be used for more thorough removal of roots. Sprouts and stems less than 2 inches in diameter can be mowed with a heavy-duty rotary mower. If stumps are not removed or treated with herbicides, resprouting will require repeated rotary mowing. Mowing is impractical on rough and rocky terrain. One or two mowings per year are usually adequate, but such mowing becomes a continuing requirement.

c. Where mechanical removal is not possible or practical, herbicides may be applied from the air or the ground, using either sprays or pellets. Both selective and nonselective herbicides for killing woody plants are available and are applied in various ways, depending on the plants to be treated, their geographical location, and the proximity of valuable crop and ornamental plantings. Effective herbicides are shown in attachment 9.

3-8. Foliage Sprays. These may be applied as drenches or as low-volume treatments.

a. The drench treatment attempts to wet all foliage, twigs, and terminal limbs. Drenching sprays are used to kill brush along roads, rights-of-way, fences, and drainage ditches. Drenches are applied by high-volume sprayers capable of maintaining pressures up to 100 pounds per square inch. Higher pressures tend to form excessively by fine spray droplets that are more likely to drift off target. High-volume refers to 100 or more gallons per acre. The high-volume applications are often used in areas that are too small for aerial applications or in sites that are not practical for low-volume equipment. High-volume applications are usually made by hand-held or turret-mounted spray guns with adjustable nozzles.

b. Low-volume sprays, usually from 5 to 40 gallons per acre, are applied by aerial, ground, or hand-held sprayers equipped with booms, boomless nozzles, or mist blowers. Aerial spraying is best for treating rough terrain and large areas of tall and dense brush. Aerial spraying can give good coverage of the area being treated. In densely wooded areas, however, the spray that penetrates to the lower levels often is inadequate to kill understory plants. A second aerial spraying may be necessary a year or two after the first.

c. When applying spray by aircraft, instruct the pilot to fly as close to the top of the brush as safety allows. Use experienced flagmen or guides on the ground to mark individual spray swaths to guide the pilot. Flagmen should move upwind during flagging to minimize their exposure to spray drift. Swath width should not exceed 1.5 times the wing span or bladespan of the aircraft.

d. The possibility of drift, and in some case volatilization, must be dealt with in any spray application. None of the herbicides discussed in this publication are high-volatile esters. However, low-volatile esters of phenoxy herbicides can volatilize at high-temperatures, especially above 90°F. Even with products that do not volatize, proper precautions should be taken to avoid drift to nontarget areas in a spray application (figure 2-2).

e. All crewmembers should review applications techniques before the application season begins. Also, before application is begun on a site, a reconnaissance should be made of the area to be treated. Streams, impounded water, crops, gardens, dwellings, buffer zones, and roads should be delineated on a map. Avoid applying herbicides where they are not wanted. Except for herbicides registered for use on lawns and ornamental plantings, plan to leave unsprayed zones of vegetation around gardens, dwellings, or other buildings housing people or serving as public gathering places. Avoid spraying herbicides, other than aquatic herbicides, directly into flowing streams, drainage ditches, and impounded water.

3-9. Basal Sprays. Some herbicides kill trees if applied to the trees' lower trunks.

a. Basal sprays are applied to the bark of individual trees up to 5 inches in diameter. They can be used at any time of the year, but effectiveness is reduced when the bark or soil is wet.

b. Herbicides used in this manner include esters of 2,4-D and other phenoxy herbicides mixed in diesel oil or kerosene. Usually mix at a rate of 12 to 16 pounds of herbicide in 100 gallons of oil. Water is an ineffective carrier. Other herbicides are also used as basal sprays.

c. Apply basal spray to the lower 12 inches of the woody plant to be killed. Wet the bark thoroughly all around the stem. Apply until it runs down the stem to the base. One gallon of spray is enough to treat about 50 trees 2 inches in diameter or 33 trees 3 inches in diameter.

d. Apply the herbicide with a compressed air sprayer, knapsack sprayer, or power sprayer. Pressures from 10 to 40 pounds are adequate. A 15 to 20 degree fan-type nozzle set at a 45 degree angle to the spray wand is preferred.

3-10. Cut Surface and Injection Treatments:

a. Trees larger than 5 inches in diameter are treated with these methods because their bark often is too thick for basal sprays to penetrate. These treatments are also effective for lesser diameters. Frills or notches made by an ax into the sapwood, encircling the tree, act as cups to hold the herbicide. The frill can be filled with solutions of 2,4-D, dicamba, picloram, and triclopyr. Undiluted herbicides or AMS crystals (or a strong solution in water) can be used. There are also mechanical injection tools available that make the cut into the tree bark and inject the herbicide in one operation.

b. If trees are felled, the freshly cut stumps of sprouting species should be treated with the above herbicides to prevent sprouting. Most hardwood species will sprout after cutting.

3-11. Soil Treatments:

a. Herbicides are applied to the soil around and under woody plant canopies as dry granules or as water sprays. The soil should be moistened either by rainfall or irrigation shortly after herbicide application for best results. The herbicide must be one of those that are active through soil absorption and must be carried into the soil to be effective. Reduced effectiveness often results when there is a hot, dry season after treatment.

b. Herbicides can also be distributed in grid patterns or bands encircling the plants, or in any other suitable placement that will bring the herbicide into contact with the tree roots. Use strip applications to minimize damage to desirable grasses growing under and near trees to be killed.

c. Herbicides for soil treatment for brush control include: bromacil, picloram, and tebuthiuron.

d. Runoff water can carry herbicides to adjacent areas downslope and kill desirable plants.

Section D—Controlling Vegetation in Special Areas

3-12. Paved Areas. Vegetation that encroaches on the edges of concrete or asphalt pavement, or grows up through cracks and holes, causes premature breakdown of the pavement. Control with preemergence and postemergence applications of herbicides is possible.

a. Several herbicides can prevent the emergence of plants through cracks in pavement, but they vary in cost and in their potential to injure vegetation adjacent to the paving. Suitable herbicides can be selected from attachments 4 and 6 based on their activity and persistence in soil, and other characteristics. Bromacil, tebuthiuron, prometon, and borate-chlorate mixtures are recommended.

b. Shoulders immediately adjacent to the traffic way, medians separating divided highways, and islands at highway intersections are often surfaced with asphalt. On these and similarly lightly paved areas, apply soil-sterilant herbicides to the soil under the gravel base before it is "shot" with asphalt. Use the highest recommended rates in attachment 6. The herbicide should be incorporated into the soil to a depth of 4 to 6 inches, using a rototiller or disk. This will activate the herbicide and improve weed control.

c. Do not use herbicide under asphalt or concrete pavement where roots of existing or future landscaping shrubs and trees may extend into the treated areas.

d. Care should be exercised to prevent damage to desirable vegetation between the time of herbicide application and the time of paving. Drainage water running across treated areas can carry the herbicide to susceptible plants down slope.

e. Residual effectiveness of treatments under paving depends on the factors discussed earlier, but, because of only limited percolation of water from above, herbicides should remain effective under paving for 5, 10, or even more years.

f. Other treatments will be necessary to prevent encroachment of weeds from unpaved areas and to control vegetation growing up through cracks in old pavement. Weeds emerging through cracks can be killed by treatment with herbicides such as paraquat and glyphosate. These have no activity in soil, and they are not likely to injure adjacent plants through runoff water. Including 2 to 4 pounds per acre of oryzalin in such sprays will reduce establishment of subsequent germinating seedlings, especially the grasses. Oryzalin kills germinating seeds, is somewhat persistent in soil, but does not injure most established plants.

3-13. Roadsides and Rights-of-Way. Stump, basal-bark, and foliage applications are excellent for controlling brush and trees along roadsides and utility lines.

a. The greatest hazards in rights-of-way treatments are drift, runoff, improper application, and leaching to the roots of desirable species under the treated areas.

b. Runoff is an important hazard on slopes, bare ground, and pavements. Cutback asphalt, applied after application of a soil sterilant, helps hold the chemical in place. Desirable trees and shrubs some distance from soil treated with soil sterilants may be killed if their roots extend into this treated area.

c. Before spraying, make a survey of the area to locate slopes subject to erosion and desirable vegetation, and to determine size and density of brush to be controlled.

d. Cutting the trees and treating the stumps is most satisfactory for killing trees along roadsides, and for controlling brush over 30 feet tall. Considerable labor is required, but the danger from falling branches is removed, and there will be no standing dead trees.

e. Basal applications are practical for uncut brush and for regrowth from cut brush or trees. Make applications during the dormant season to avoid danger of injury from drift. There is less danger of injuring desirable plants during their dormant stage.

3-14. Weapons Ranges. When vegetation must be controlled on weapons ranges that contain unexploded ordnance, it may be cost-effective to apply herbicides aerially. Assistance may be obtained from the Air Force Aerial Spray Branch, 356 TAS/Aerial Spray, Rickenbacker ANGB OH 43217-5008, or commercial aerial applicators.

3-15. Railway Areas. Three distinct railway areas require weed control: the ballast, the roadbed, and the right-of-way.

a. The ballast is a 12- to 16-foot-wide strip, made up of coarse material such as cinders and gravel, that should be kept free of weeds. Because it is porous, it does not retain herbicides well. Insoluble herbicides, those absorbed through the leaves, and contact herbicides are most suitable (attachment 6).

b. To obtain vegetation free areas, certain foliar-applied herbicides are used together with persistent, soil-applied herbicides. These foliar herbicides include the contact herbicide paraquat and the translocated herbicides such as glyphosate and amitrole. Glyphosate is nonselective and kills many weeds, including perennial weeds. It readily translocates from the foliage to other parts of the plant, including the roots. To broaden the spectrum of weed species controlled by persistent soil-applied herbicides, such as bromacil, add foliar herbicides such as 2,4-D, dicamba, and picloram to control broadleaf weeds.

c. If control is accomplished during the first 2 years by heavy rates of herbicide application, it can then be maintained with reduced rates. The full effectiveness of some soil sterilants like bromacil, tebuthiuron, diuron, and simazine is most evident in the second or third year of use, especially in dry areas or with deep rooted weeds.

d. The roadbed (berm) beyond the ballast requires weed control to prevent tall vegetation, but elimination of all vegetation increases chances of erosion. Low-growing grasses are acceptable. The rest of the area, to the right-of-way fence, is similar in weed control requirements to roadsides.

Chapter 4

WEED CONTROL IN IMPROVED GROUNDS—TURF AND HORTICULTURAL PLANTINGS

Section A—Controlling Weeds in Turf

4-1. The Importance of Good Cultural Practices:

a. The best defense against weeds is a dense, vigorously growing turf. Weeds have difficulty gaining a foothold in good turf. To grow dense, vigorous turf, it is necessary to have the best varieties of adapted grass species, good soil conditions, correct soil acidity, proper fertilization, proper watering, correct mowing, and control of weeds, insects, diseases, and nematodes.

b. Weeds can become a problem if the turf is weakened or partially lost because of mechanical disturbances, excessive use, drought, or poor soil conditions. Also, some weed species are particularly strong competitors.

c. The first step in weed control is to correct any improper cultural practices that are causing thin, weedy turf. Turf maintenance practices vary with climate, soil type and condition, turf species, and management objectives. The installation land management plan and the county Agricultural Extension Service should be consulted for appropriate local practices.

4-2. Adjusting Soil pH. A pH in the range of 6.0 to 7.0 is considered best for turf grass because it provides the most favorable nutrient availability and microbial activity.

a. In acidic soils in the eastern United States there is frequently a need to apply ground agricultural limestone. Soil pH and the amount of lime needed should be determined by soil tests. In areas of higher rainfall, acid sandy soils generally require applications of about 25-50 lb per 1000 ft^2 of ground or pulverized limestone annually and clay soils require heavier applications of about 50-100 lb per 1000 ft^2 annually until the soil pH rises to about 6.5. Therefore, apply lime every 2 to 3 years based on soil test recommendations. Lime may be applied at any season, but late fall or winter is the best time. The rain and snow that fall after application will carry the lime into the soil before spring and summer, when the greatest growth of turf occurs.

b. In areas having soils with a high pH, chlorosis of turf may be a problem. Chlorosis is characterized by a yellowish appearance caused by a deficiency of chlorophyll. Agricultural grade sulfur may be used to lower the soil pH, but, if misapplied, it can injure turfgrasses. Other treatments include using ferric sulfate and acidifying nitrogen fertilizers, such as ammonium sulfate, to prevent iron chlorosis by allowing nutrient release during cool soil conditions. Obtain advice from the county agricultural extension agent on the treatment to be used.

4-3. Fertilizing Turf. Nitrogen is the nutrient most often needed in turf. It and the two more common fertilizer elements, phosphorus and potassium, should be in good supply when the turf is growing most rapidly. Fertilizing should be based on the results of soil testing. The Cooperative Agricultural Extension Service will make the analyses and recommend soil treatments.

a. In the northern temperate climate, fertilize cool-season grasses most heavily in the fall. Fertilize less, if at all, in early spring. In cool-season grass turf, nitrogen levels in the soil should be declining before periods of expected hot or dry weather. Nitrogen is seldom used in the summer. Annual rates of application range from 2 to 5 lb of nitrogen per 1000 ft^2.

b. Fertilize warm-season grasses much as bermudagrass, zoysiagrass, and St. Augustinegrass with nitrogen during the spring and summer. Use annual rates of 1 or 2 lb of nitrogen on zoysiagrass and 2 to 5 lb per 1000 ft^2 on St. Augustinegrass and bermudagrass.

c. Take extra precautions in applying fertilizer-herbicide "weed and feed" mixtures. Don't overtreat by making a second or third trip around trees and shrubs to give them an extra feeding of fertilizer. Such extra trips can apply too much herbicide and injure or kill the trees and shrubs. Do not use fertilizer-herbicide mixtures each time the grass needs fertilizer.

4-4. Watering Turf. Proper watering is important in maintaining high quality turf.

a. Watering must be frequent enough to ensure proper soil moisture. Sandy soils have low moisture-holding capacity and require frequent watering. Clay soils retain more water, and therefore, should be watered less frequently but in larger amounts. Do not water grass unless it shows signs of wilt. Then apply enough water, usually about an inch, to wet the soil 6 inches or more deep.

b. Water must not be applied faster than it can be absorbed by the soil. Avoid frequent, light watering. This is wasteful, causes shallow growth of grass roots, and stimulates germination and growth of weeds. For example, light, frequent watering encourages the invasion of annual bluegrass and crabgrass.

4-5. Mowing Turf. Mowing at the proper time and height greatly improves weed control.

a. Mow most cool-season turf grasses about weekly to a height of 2.5 to 3.5 inches. Closer mowing, especially in hot weather, weakens cool-season turf and invites weed invasion. Crabgrass infestations, in particular, can be reduced by the shading effect of a taller, denser stand of turf grass on the crabgrass seedlings. Invasion of spotted spurge, another warm-season weed, also can be reduced by high mowing.

b. Mow warm-season grasses, particularly bermudagrass, closer than most cool-season grasses. Bermudagrass should be cut to a height of 1.5 to 2 inches. Others, such as zoysiagrass, centipedegrass, and carpetgrass, should be mowed to a height of about 1 inch. St. Augustinegrass and bahiagrass should be cut to 2.5 to 3.5 inches.

c. Mow lawns frequently,and keep the mower blades sharp. Unless growth or thatch layers are excessive, and there are weeds setting seed in the lawn, leave the clippings on the grass. A mower with a mulching blade increases the rate of decomposition of the clippings. Do not let grass grow unusually high. No more than 1/3 the length of the grass leaf should be removed at a clipping. If a lawn is to be mowed to 2 inches, then mow the grass before it exceeds 3 inches in height.

4-6. Aerating, Verticutting, and Dethatching:

a. In some areas, turf requires aerating, verticutting, or dethatching to improve growing conditions. These operations should be performed when the turf will regenerate quickly. Furthermore, these operations should not uncover the soil or leave it bare at the time of year when seeds of crabgrass, annual bluegrass, or goosegrass germinate. These weeds rapidly invade open areas. Early fall is the best time to renovate cool-season turfs. Early summer is the best time to renovate warm-season grasses.

b. These management operations should not be performed following preemergence herbicide applications, or the weeds will not be controlled. If a preemergence herbicide is applied immediately after verticutting or dethatching, the regrowth of the grass may be suppressed.

4-7. Using Selective Herbicides. Herbicides are available for most of the weeds found in lawns and other turf areas, but they should be used only when necessary and as part of a complete turf management program.

a. General Information:

(1) Selective herbicides can be used to control most weed species without injuring turf grass, but they must be selected and applied with care. An excessive dose of almost any herbicide will damage lawn grasses, and a herbicide may kill one weed but not control others. To control some weeds it may be necessary to use herbicides that temporarily, or even permanently, injure lawn grasses.

(2) Most lawn weeds are either grasses or broadleafs. Crabgrass, goosegrass, foxtail, and barnyardgrass are examples of annual grass weeds. Dandelions, plantains, and chickweed are examples of broadleaf weeds. Nutsedge is a narrow-leaf weed that is not a grass.

(3) Each type of weed requires different herbicides for effective control; but the herbicides used for crabgrass are usually effective on most other annual grasses, and the herbicides used for dandelion, plantain, and chickweed are usually effective on most other broadleaf weeds. Herbicides for weed grasses in turf and for broadleaf weeds in turf are shown in attachments 10 and 11, respectively. The effectiveness of the herbicides varies, as shown in attachment 12.

(4) The herbicides chosen should be both effective for the weeds present and safe for turf and ornamental plants. Attachment 13 shows the soil persistence and potential hazards of herbicides to trees, shrubs, turf grass, and herbaceous broadleaf plants.

(5) The herbicides chosen must also be safe for people and animals using the area. Attachment 4 shows toxicities of herbicides. When used according to label directions, the recommended herbicides will not damage plants and will pose little hazard to the user, other persons, pets, and wildlife in the area. Always read and follow the directions and precautions on the label.

b. Applying Herbicides:

(1) There are three types of herbicide application: (1) Preplanting—application before seeding or sodding turf, (2) Preemergence—application before weed seeds germinate, and

(3) Postemergence—application after weeds emerge. Repeated treatments, or a sequence of treatments at set intervals, are sometimes required in order to kill weeds without excessive injury to the turf. Always read instructions on the label, and pay particular attention to limitations on use.

(2) Granular herbicides are ready to use as purchased. Granular herbicide particles are usually relatively large and drift less than liquid sprays. Granular materials are best applied with a spinner type spreader. Use the spreader setting recommended by the manufacturer or listed on the herbicide label. Take extra precautions in applying fertilizer-herbicide "weed and feed" mixtures. Do not make second or third trips around trees and shrubs to give them an extra feeding of fertilizer, and do not use a fertilizer-herbicide mixture each time the grass needs fertilizing.

(3) Liquid and wettable powder formulations are added to water and applied as sprays. use a sprayer that can be adjusted to make a coarse spray at a low pressure of less than 35 lb/in^2. On very small areas you can use a garden sprinkling can. Care must be taken in handling sprays, especially herbicides such as 2,4-D, dichloprop, mecoprop, and dicamba. Drift of even small amounts of these can damage trees, shrubs, flowers, and vegetables. Make treatments only when there is little or no wind. Usually 1 to 3 gallons of spray mixture per 1000 ft^2 of lawn are used. Within these limits, the volume of spray used is not important. It is extremely important, however, to use the proper dosage of herbicide per 1000 ft^2. (To convert a per acre rate to a per 1000 ft^2 rate, divide by 43.6.)

(4) The most convenient equipment for applying sprays to small areas is the pressure or knapsack sprayer of 1- to 4-gallon capacity. These sprayers provide a fairly consistent volume of spray at low pressure and provide good control in limiting the spray to the target area. Continuous agitation, by frequent shaking of sprayer tank, is necessary when using the wettable powder or emulsifiable formulations, or they will settle out.

(5) One method of treating small patches and individual weeds is to use a small paint brush or sponge nailed or wired to a broomstick or dowel. Mix a small amount of herbicide in a container that has a large enough opening so that the sponge or brush can easily be dipped. After dipping, squeeze out the excess by pressing the brush or sponge against the inside of the container. Simply "paint" or dab the weed. Such devices are available commercially. When using this method, dilute the herbicide as if it were to be sprayed. Do not use full strength chemical, or turf injury will result.

(6) *Do not use equipment that has been used for herbicides to spray fungicides or insecticides on other plants such as flowers or vegetables.* There may be enough herbicide residue in the sprayer to injure these plants.

c. Controlling Weed Grasses. Recommended herbicides are shown in attachment 10.

(1) Crabgrasses and other annual summer grasses can be a problem in lawns in most areas of the United States. Preemergence herbicides applied before seed germination give the best control. The best indicator of the right time for application is when the soil temperature reaches 50°F. A less precise indication is when forsythia is flowering or when lilacs are about to bloom. In most warm- and cool-season turf grasses, DCPA, benefin, bensulide, pendimethalin, siduron, and oxadiazon applied before the weed seeds germinate provide control. Only siduron can be used on newly seeded, cool-season turf areas. Other materials have a specified waiting period (2 months or more) before overseeding is recommended. If no rainfall is received within 2 or 3 days after treatment, sprinkle irrigation is recommended.

(2) In centipede, St. Augustine, and zoysia grasses, granular atrazine may be used (attachment 11) to control weeds such as crabgrass, *Paspalum spp.*, spotted spurge, and several other annual broadleaf weeds.

(3) Some of the other weedy annual summer grasses that can be controlled with preemergence herbicides include barnyardgrass, fall panicum, foxtail, and goosegrass. Goosegrass is usually the most difficult to control.

(4) Some control of seedling and juvenile plants of crabgrass, foxtail, goosegrass, sandburs, and other annual summer grasses can be gained with postemergence use of feroxaprop in a single application, or methanearsonate herbicides (DSMA, MSMA, CMA, and MAMA) repeated in two to three treatments at 7- to 10-day intervals. To be effective, and to minimize turf injury, soils should have enough moisture to support active growth.

(5) Goosegrass tends to be a problem where soils are compacted, turf is thin, and preemergence herbicides have not been used. Goosegrass

seeds germinate in spring and summer later than crabgrass. Preemergence treatments for crab grass control should be reinforced with a second application at 1/3 to 1/2 the initial rate in 4 to 5 weeks to provide better goosegrass control. Most herbicides give variable results, but oxadiazon tends to be more reliable than the others. Sometimes it may be best to till the fumigate the soil, correct the causes of the goosegrass problem, and reseed or sod in the fall to allow time for a dense turf to develop before the next spring.

(6) Annual bluegrass tends to be a major problem in closely mowed turf, such as putting greens, in thin turf, and along turf borders. It is a cool-season species whose seeds can germinate throughout the year, except in the deep South. Most preemergence herbicides used in cool-season grasses give only partial control. Good turf-management practices, including infrequent irrigation and high mowing, may limit infestation.

(7) Annual bluegrass can be well controlled in bermudagrass in the southeastern states by using metribuzin or pronamide as either a preemergence or postemergence treatment. Do not overseed treated areas for 90 days after application of pronamide. Pronamide will kill most cool-season turf species. Ethofumesate will safely control annual bluegrass in perennial ryegrass and dormant bermudagrass, but will injure other turf grass species.

(8) Bermudagrass, quackgrass, zoysiagrass, kikuyugrass nimblewill, and other perennial grasses that spread by horizontal stems, either below or above ground, often occur as weeds in cool-season turf grasses. They can be controlled by the methods of renovating turf that are discussed in section B. Glyphosate (3 to 6 tablespoons per gal water) is a good nonselective foliage spray for spot treatments. Such spreading perennial grasses often have dormant buds at the joints of the spreading stems that may not be killed by a single treatment of herbicide. When practical, a second application 1 to 2 months later increases the chance of eradicating these species. Close observation for any live plants should continue for many months or years after treatment. Because glyphosate is effective only when applied to leaves, an abundance of foliage on the weed grasses in necessary at the time of application. Treated spots can be seeded, sprigged, or sodded soon after treatment. Any reinfestation should be spot-treated as soon as observed.

(9) Tall fescue, timothy, orchardgrass, and other perennial bunch grasses give a clumpy appearance to fine turf because of their rapid growth. If only a few clumps occur, they can be removed by cutting under them shallowly with a spade, or the bunch grasses can be spot sprayed with glyphosate. The bare spots then can be resodded, or filled with topsoil and seeded.

(10) Dallisgrass and some other *Paspalum* species can be selectively controlled by repeated postemergence spraying with DSMA and other methanearsonate herbicides at the highest rates recommended on the label. Multiple methanearsonate treatments, however, may severely damage cool-season turf grasses such as Kentucky bluegrass.

d. Controlling Broadleaf Weeds. Recommended herbicides are shown in attachment 11.

(1) Broadleaf weed-control herbicides are usually applied as postemergence treatments to the foliage and stems of actively growing weeds. Most should be applied in early fall, to allow grass to fill the spaces left by dead weeds, or in the spring.

(2) Most broadleaf weeds can be controlled by using one of the commercially available products containing 2,4-D in combination with dicamba, mecoprop, dichlorprop, triclopyr, or chlorsulfuron. In newly seeded turf, bromoxynil (0.38 and 0.5 lb/a) will control many seedling broadleaf weeds. For weeds not controlled by these herbicides you may consult your local County Agricultural Extension Service for specific recommendations. Do not mow turf for at least 3 days before application so that there will be maximum weed foliage to receive the herbicide spray. Do not mow or water the turf for at least 2 days after treatment.

(3) When a granular 2,4-D or similar herbicide for broadleaf weed control is used, be sure to follow the instructions on the label. It is generally recommended that such formulations be applied either when the weed leaves are moist with dew in the early morning or just *after* the lawn is watered. The herbicide granules retained in water droplets on the leaves are readily absorbed.

(4) A high percentage of lawn weeds are controlled by 2,4-D, but there are some common weeds it does not control. Weeds that are not well controlled by 2,4-D, but that may be controlled by dicamba, include knotweed, red sorrel, white clover, henbit, chickweeds, black medic, ground ivy, yellow woodsorrell, wild

strawberry, knawel, and many others. Do not apply dicamba within the "drip line" of shrubs and trees.

(5) Speedwells and prostrate spurge are not well controlled with 2,4-D and the herbicides commonly sold in mixtures with it, except when the plants are quite young. These weeds can be suppressed, however, with sprays of DCPA (attachment 10) applied when forsythia is flowering or lilacs are about to bloom. Postemergence application of bromoxynil (0.38 to 0.5 lb/a) on young spurge plants may further reduce infestation.

(6) Yellow nutsedge is a perennial that reproduces in lawns mainly by underground nutlets that persist in the dormant stage. If there are only a few plants, persistently pulling the plants before each mowing will control them. Heavy infestations are controlled with difficulty, and often incompletely, but they can be reduced with two or three treatments of bemtazon or DSMA, or other methanearsonates, in late June and July (attachment 10). Allow 7 to 14 days between treatments. Repeated, heavy treatments with 2,4-D will also reduce stands of yellow nutsedge. Temporary, slight discoloration of the lawn may result.

(7) Wild garlic and onion produce hard-shelled bulbs that may lie dormant underground and continue to produce plants for about 3 years. Therefore, controlling this species requires three annual treatments with 2,4-D made in late winter or very early spring. Low-volatile ester formulations are more effective than amine salts. Early spring treatment with chlorsulfuron is also an effective control for wild garlic.

Section B—Renovating Turf and Treating New Seedings

4-8. Spot Infestations and Degraded Turf:

a. Sometimes a turf will have spot infestation of undesirable grasses or will be generally degraded with weeds and mixed grass species, and these conditions cannot be corrected with selective herbicides. For example, a Kentucky bluegrass turf may be invaded by a coarse grass such as tall fescue, or pernicious perennials such as bermudagrass, zoysiagrass, bentgrass, quackgrass, or nimblewill. These unwanted grasses cannot be controlled selectively in Kentucky bluegrass. They must be killed, and the desired turf must then be reestablished. Spot treatments may be sufficient, or entire lawns may need to be replaced, depending upon the situation.

b. The renovating should be done at a time that will favor establishing the desired turf grass species, i.e., when rainfall is expected to be adequate to germinate the selected grass seeds, especially if irrigation is not available, and when competing weeds will be least troublesome. Early fall (September in most regions) is best time to establish Kentucky bluegrass, tall fescue, and other cool-season grasses. The varieties of turf grass selected should be those best adapted to the region. In some situations, and with some turf species, sodding or sprigging will be done rather than seeding. The installation land management plan should be consulted, or local advice should be obtained, because conditions and the adapted turf grass species vary greatly among regions.

4-9. Renovating Turf With Herbicides:

a. A number of herbicides will kill all established vegetation. Some herbicides require no waiting period between treatment and seeding, while others leave toxic residues and require waiting periods of 20 to 50 days before seeding.

b. No seedbed tillage is necessary after vegetation is killed by herbicides, provided the turfgrass seeds are placed in contact with the mineral soil. A disk seeder accomplishes this task. Usually seed in two passes that cross one another at right angles. If excessive thatch is present, then tillage, verticutting, or thorough raking with a thatch rake will be necessary. When tillage is limited, germinating weed seeds can cause severe weed problems, and supplemental weed control is often required.

c. Glyphosate is used as a foliage spray and effectively controls grasses and broadleaf weeds (attachment 10). Plants should have well-developed foliage and be growing actively when sprayed. Glyphosate is translocated throughout the plant. Therefore, the vegetation should not be mowed, verticut, or cultivated for 3 or more days after treatment. Glyphosate is water soluble and will be partially washed off of plants if rainfall or sprinkle irrigation occurs within 6 hours of treatment.

d. When making spot treatments, be careful to confine the spray to the area that needs to be treated. For weed species that have rhizomes and stolons that grow outward, such as bermudagrass, the sprayed area should extend at least 12 inches beyond the observed plants.

e. Most cool-season grasses and annual grasses can be killed with glyphosate at 1.5 lb/a. Almost all plants of such strongly spreading grasses as bermudagrass can be killed with a single spraying with glyphosate at 4 lb/a under favorable conditions. In most regions, however, two treatments 1 to 2 months apart at 1.5 to 2 lb/a are slightly more effective in controlling bermudagrass and zoysiagrass. There should be enough moisture available to allow dormant buds to develop between treatments. Under drier conditions, the turf can be verticut or cultivated 7 days after treatment and the area completed dried out to kill any remaining dormant buds.

f. Turf grasses can be seeded soon after treatment with glyphosate, since it leaves no residues in the soil that are toxic to germinating grass seeds. Glyphosate does not move laterally in runoff water from the treated area, but do not let sprays or drift contact the foliage of desirable plants, or injury will result.

g. Amitrole is a foliage-applied, translocated herbicide which will control most annual and some perennial grasses when applied at 3 to 4 lb/a. Better control is achieved if the weeds are growing vigorously in moist soil. If rain or watering occurs within 12 hours after treatment, amitrole may be washed off of leaves, and reduced control will result. If it does not rain within 5 to 7 days after treatment, heavy irrigation should be applied. Ten to 14 days after treatment, when the grass or weeds are white or brown, the area should be cultivated. This can be done by digging, tilling, or otherwise loosening and drying the treated areas. Verticutting, aerating, or raking the area is not enough. If bermudagrass regrows, allow it to reach 2 to 3 inches in height and treat it again. The area should be tilled again in 10 days, and then seeded.

4-10. Renovating Turf by Tilling:

a. Existing turf can be removed by a sod cutter or a flat shovel in small areas, and the area can be cultivated with rotary-tillage equipment. Many weeds are easily killed by cultivating and drying. If time is available, fallowing the soil and cultivating at intervals of 3 to 5 weeks will eliminate many of the weeds arising from seeds and vegetative parts in the soil.

b. Lime and fertilizer should be applied, as needed, and the seed should be planted in a smooth, firm seedbed. Use high quality weed-free seed of a locally adapted turf variety. The seed may be broadcast on the surface and raked in, or it may be shallow drilled. It may be advantageous to cover the surface lightly with a straw mulch, peat, or compost. If seed is broadcast on the soil surface, wet the seed and soil with sprinkle irrigation daily for 7 to 14 days until seedling plants are visible. Then water less frequently. Sodded areas must be irrigated several times each day during hot and dry periods until the grass is well rooted in the soil.

c. Tillage is seldom adequate to control such pernicious perennial species as quackgrass, bermudagrass, zoysiagrass, and nutsedge. When renovating areas infested with such species, a herbicide such as glyphosate, that has little or no residual toxicity in the soil, should be used before tilling; or a soil fumigant should be used after tilling.

4-11. Controlling Persistent Weeds With Soil Fumigation. Soil fumigation before seeding or planting turf species is effective in controlling persistent weeds if used on moist, tilled soil.

a. Metham is a fumigant used to kill germinating seeds, rhizomes, tubers, roots, and stems of weeds in soil. The soil should be cultivated and kept moist for a week before applying metham. Then treat with 1 to 2 pints of commercial formulation mixed in 2 to 5 gallons of water, in a sprinkling can or sprayer, for each 100 ft^2 of soil. The treated area should then be irrigated until the soil is wet as deep as control is desired. An air-tight cover can be spread over the treated area and its edges covered with soil to substitute for a water seal. This greatly increases the effectiveness of the fumigant as a herbicide. The area can be seeded 14 to 21 days after treatment.

b. Methyl bromide is a RESTRICTED use that is very poisonous and may be used only by a certified applicator. It is particularly effective for controlling pernicious weed species having nutlets, bulbs, corms, and lateral underground stems. It also kills most seeds and disease organisms in the soil. It does not control hard seeds of clover, dichondra, or field bindweed. Apply methyl bromide at 1 lb/100 ft^2 when the soil temperature is above 60°F. and under a well sealed, air-tight cover. Because of the poisonous nature of the gas, strict precautions must be followed. The cover can be removed 2 days after treatment, and the area can be seeded 2 days later.

4-12. Controlling Weeds in New Seedings:

a. The most important steps in controlling weeds in new seedings is to thoroughly eradicate the existing weeds, to use high quality, weed-free seed, and to use good cultural practices in establishing the new turf. Every effort should be made to establish a vigorous turf in which weeds have difficulty becoming established.

b. In spring or early summer seedings of cool-season turf species, germinating crabgrass, foxtail, and bermudagrass can be controlled by an application of siduron at seeding.

c. Some weeds in new seedings can be controlled by a proper balance of mowing, irrigating, and fertilizing. If seedling broadleaf weeds threaten to shade out turf grass seedlings, even after one or two mowings, they can be controlled with herbicides. A mixture of 2,4-D with other herbicides can be used effectively on cool-season grass seedlings of such species as Kentucky bluegrass, red fescue, and tall fescue if applied at 1/4 to 1/3 the rate used in established turf (attachment 11). Such treatments should be delayed 5 weeks or more after seeding. Also, bromoxynil at 0.38 to 0.5 lb/a alone, or in combinations with dicamba at 0.13 to 0.25 lb/a, effectively controls many annual broadleaf weeds in new seedlings.

Section C—Controlling Weeds in Horticultural Plantings

4-13. Uses of Herbicides. Herbicides can be used in landscape plantings to reduce the hand labor required for maintenance. Sites that can be treated include shrubs and trees along roads, ornamental beds, windbreaks, ground covers, and shrubbery and flowers around buildings. Some herbicides may be used in bulbs and in herbaceous annuals and perennials. Because no one herbicide is effective and safe on all plants and in all situations, care must be taken in their selection and application.

4-14. Selecting Herbicides:

a. Important factors in selecting herbicides for landscape uses include: the weed species and their stages of growth, the ornamental plants to be maintained, the hazard to sensitive plantings downslope, and the hazard to trees and shrubs from root uptake. Most of these factors are addressed on the herbicide label.

b. Herbicides can be used effectively before planting (preplanting), after planting but before weed emergence (preemergence), or, in some instances on actively growing weeds (postemergence). Herbicides that are registered for these uses in ornamental plantings are given in attachments 14, 15, 16, and 17. Herbicides that are registered for use in ground covers and flowers are shown in attachments 18 and 19, together with the plants for which they are registered.

4-15. Measuring Small Quantities of Herbicides. Ornamental plantings usually occupy small areas, and only small quantities of herbicides are needed. Attachment 20 shows equivalent doses per acre and per 1000 ft^2 for some of the herbicides that are registered for ornamentals, and it also tells how to make the conversion.

Section D—Controlling Vegetation Around Structures

4-16. Hazards of Soil Sterilants:

a. Many of the soil sterilants that are used around buildings and other structures are hazardous in the root zones of trees and shrubs, and are hazardous to plants downslope. Tree roots may extend as far, or further, laterally as their tops grow high. They may be up to 60 to 100 feet from the trunks. A toxic herbicide can be absorbed by the roots, translocate to foliage, and kill or injure the tree.

b. Herbicides that are hazardous to use adjacent to landscape plantings include: atrazine, prometon, bromacil, diuron, tebuthiuron, hexazinone, dicamba, and picloram. The very low rates of dicamba (0.125 to 0.25 lb/a) used in turf are not hazardous to trees growing in the area. The relative hazards of many herbicides to desirable plants are listed in attachment 13.

4-17. Recommended Treatments. A safe herbicide mixture to use around buildings, parking lots, fence lines, guard rails, and other structures where root zones of desirable woody plants may be contacted is the foliage herbicide glyposate at 1 to 4 lb/a, plus simazine at 3 to 4 lb/a, plus oryzalin at 4 to 5 lb/a. The latter two are absorbed from the soil. Spray on actively growing weeds. Paraquat at 0.5 to 1 lb/a could substitute for glyphosate in this mixture. If the herbicide mixture is to be adjacent to turf, omit the simazine.

Chapter 5

PLANT GROWTH REGULATORS (PGR)

Section A—General Information

5-1. Uses of PGRs. PGRs are applied to turf grass to retard or inhibit the grass' vertical shoot growth. They have potential to reduce mowing costs. They can have other uses, including: (1) controlling grass growth during wet periods in the spring, when frequent mowing is necessary but difficult to accomplish; (2) reducing the frequency of mowing where visual quality is not important; (3) reducing the need for mowing on steep slopes, along drainage ditches, roads and runways, and in other areas where mowing is difficult or dangerous.

5-2. Limitations of PGRs. PGRs sometimes have harmful effects on turf, and in some locations they are not consistently effective.

a. PGRs frequently discolor or kill grass tissues, increase the susceptibility of turf to disease, stimulate higher than normal growth rates after their regulatory effects have dissipated, reduce the recuperative capacity of turf, and decrease turf density. Reduced recuperative capacity occurs because little, if any, leaf, root, tiller, rhizome, or stolon development occurs in turf during the 6 to 8 week period after a growth regulator is applied. This effect precludes using PGRs on heavily trafficked turf areas, such as parade grounds and athletic fields where the turf's recuperative potential must be high. The thinning of turf grasses by PGRs, and the stress, insects, and disease that may follow their use, lead to weed encroachment. Because of these disadvantages, PGRs are normally recommended for use in low-maintenance and difficult-to-mow areas.

b. Using PGRs on grass species not on the label, or under unusual or stressful (i.e., hot and dry) environmental conditions, has serious risks. Most research with PGRs has been conducted on fescues, Kentucky bluegrass, perennial ryegrass, bermudagrass, bahiagrass, and centipedegrass in cool and moist environments, or transitional zone climates, not in tropical or arid regions. Also, there is little information on their effects on nonturf grass species or on weed grasses.

c. Applying PGRs to mixed stands may suppress the growth of some, but not all, species or cultivars in the stand. Failure to suppress the growth of even one species in a mixed stand may forestall any significant reduction in mowing frequency. Also, continuous use of PGRs over several years may cause a shift from desirable turf grass species to other grasses and broadleaf weeds. Such a species shift can decrease the visual quality and utility of a stand, and could affect the foraging habits of birds and other wildlife.

5-3. Areas Where PGRs May Be Useful. There are many areas on military bases where PGRs might be used to advantage:

a. Along runways and taxiways.

b. In antenna fields.

c. Around taxiway and runway lights, runway distance markers, fences, guardrails, telephone poles, power lines, guy wires, and buildings.

d. On ammunition, weapon, and fuel storage embankments.

e. In and around drainage ditches.

f. In fenced-in areas such as electric transformers and radar antenna sites.

g. In rights-of-way.

h. On golf course roughs, driving ranges, and difficult to mow areas, such as adjacent to sand traps.

i. In cemeteries.

5-4. Available PGRs:

a. The PGRs currently labeled for use on turf grasses are amidochlor, chlorflurenol, maleic hydrazide, and mefluidide. Each has limitations on application rates and the species to which it may be applied. These limitations are listed on the label. Information on these PGRs and their use is in attachments 4 and 21.

b. Two other PGRs may be registered in the near future:

(1) American Cyanamid Company (Princeton NJ 08540) will market imazethapyr plus imazapyr (trade name is Event) in 1989. Event effectively suppresses foliar growth of tall fescue, perennial ryegrass, Kentucky bluegrass, and bahiagrass. It also controls seedhead production of tall fescue and perennial ryegrass, and suppresses seedhead production in Kentucky bluegrass for 60 to 90 days.

(2) Elanco Products Co. (Indianapolis IN 46285) is expected to register flurprimidol (tradename is Cutless) in 1989. Flurprimidol effectively suppresses the growth of cool-season

grasses, but does not suppress seedheads. Flurprimidol is root-absorbed and should be watered-in following application. It suppresses foliar growth for longer periods of time than other PGRs, but it may cause tip-browning of leaves. Flurprimidol may enhance tillering and rooting with continuous use, and it appears to have preemergence herbicidal activity against some weeds.

(3) The chemistry, toxicology, fate in the environment, suggested rates, and other pertinent information about these products can be obtained from the manufacturers after they have received full registration from the EPA.

Section B—Using PGRs

5-5. On-Site Evaluation. Using PGRs under local conditions for several years provides the best indication of their effectiveness and limitations.

a. On-site testing is the most reliable way to determine PGR usefulness and safety. Small test plots should be established at three or more locations containing vegetation that is representative of the general locale. Individual plots should be at least 200 ft^2 in size. An untreated check plot should be adjacent to the treated area for comparison. The PGRs should be applied to the same plots once or twice annually for a minimum of 2 years, following the directions on the label, so that the effects of different weather conditions on the response to the PGRs can be observed.

b. Notes and photographs taken before and after each application provide valuable information on the PGR performance and any adverse effects. Notes should be taken weekly until the growth regulator effects of the chemical have ended. Special attention should be given to the amount of discoloration and the length of time that it persists, the change in growth rate in comparison with the untreated turf, the length of time growth inhibition lasts, the presence or absence of seedhead production, the frequency of mowing needed, any thinning of the stand, any shifts in species present, weed encroachment, and any other adverse or beneficial effects. Although this is time consuming, it is the only means of developing a realistic program for using PGRs on large areas of land.

c. Judgement is required of the manager, if the use of PGRs is to be satisfactory. The following must be considered:

(1) Inhibition of growth persists for 6 to 8 weeks for most PGRs. However, inhibition may last 10 weeks or longer in some environments.

(2) Reapplication will be needed to achieve season-long growth inhibition.

(3) Reapplication, however, may cause severe discoloration and reduce stand density, and is generally not recommended for cool-season grasses in areas where heat and drought stress normally begin in late spring.

(4) Some periodic mowing will be needed to maintain the uniformity and appearance of treated turf, if its visual quality is a consideration.

(5) Mixed plant species, which would not be uniformly suppressed, may preclude the successful use of PGRs.

5-6. Complementary Practices. When PGRs are used, they should be part of an overall management program.

a. If the turf grass manager intends to use PGRs annually, he or she must be prepared to fertilize properly, to monitor and control weed encroachment, and to overseed areas where stand density begins to deteriorate. It is possible that some of the savings achieved in reduced mowings will have to be directed to such other management actions. It may be wise to skip PGR applications every third or fourth year to allow damaged turf to recuperate, particularly where it is growing on poor soil.

b. Because PGRs can injure turf, nitrogen fertilizers are important in enhancing the turf's recuperative capacity. This is important on droughty or low fertility soils. In low maintenance situations, it may be feasible to apply nitrogen only once annually. Nitrogen reduces the capacity of PGRs to inhibit growth. Therefore, it should be applied only after the desired growth regulator effects of the chemical have been achieved. The best time to apply nitrogen to Kentucky bluegrass, tall fescue, and other cool-season grasses in a single application is early autumn in temperate climates. For warm-season grasses, such as bermudagrass, nitrogen should be applied spring and early summer.

c. Weed encroachment into PGR-treated stands should be closely monitored and controlled with herbicides to enhance the competitive and recuperative capacity of the treated turfs. Weeds also greatly increase mowing frequency in PGR-treated areas and dramatically reduce the utility and aesthetic quality of turf.

Regulators can, and generally should be, tank-mixed with herbicides to control broadleaf weeds. When applying a PGR to cool-season grass containing broadleaf weeds, the PGR should be tank-mixed with 2,4-D in combination with at least one of the following: mecoprop (MCPP), dicamba (do not use dicamba adjacent to, or under the drip line of, trees, shrubs, and ornamentals), dichlorprop, or triclopyr (attachment 11). Tank-mixing two or three broadleaf herbicides with a PGR increases the spectrum of herbicidal activity against various weed species. Read the labels of all the chemicals before tank mixing to guard against possible incompatibilities and other hazards.

d. Avoid drought stress, if possible, and monitor disease and insect activity in treated turf.

e. It may be necessary to overseed when environmental stresses and pests have badly injured PGR-treated stands. Cool-season turf grass species should be overseeded in the autumn with equipment that will ensure proper seed contact with the soil.

f. Periodic mowing will be needed to maintain uniformity and improve turf appearance in highly visible areas such as roadsides. Periodic mowing becomes increasingly important where the stand contains a mixture of different species. As previously noted, not all grasses in a mixed stand will be similarly retarded. Orchardgrass, velvetgrass, tall oatgrass, and *Trisetums* are less affected than most other grasses. Small spots of PGR-resistant grasses can be trimmed with hand-held mowers.

g. Turf grass areas treated with PGRs should not be subjected to more than occasional traffic of people, animals, and vehicles. PGR-treated turf has a reduced capacity to recuperate from injury while the inhibitory effects of the chemical persist.

h. There may be situations when growth inhibition by PGRs must be reversed. An application of 40 to 50 lb/a of actual nitrogen in a water-soluble fertilizer will enhance growth and partially reverse growth inhibition. For these fertilizers to be effective, they must be watered-in by irrigation or by a timely rainfall.

5-7. Applying PGRs:

a. PGRs should be applied no later in the spring than 2 weeks before seedheads normally appear. Turf to be treated should be mowed 24 to 48 hours before application, and it should be mowed again 2 to 3 weeks after application. Growth retardation lasts about 6 to 8 weeks. Reapplication may be needed in late spring or early summer, if season-long inhibition is desired and if soil moisture is abundant. High visibility areas may require periodic mowing throughout the spring and summer to maintain a uniform appearance. Turf should not be allowed to develop severe drought stress, and the encroachment of weeds, insects, and diseases should be monitored.

b. PGRs appear to offer the most benefit when applied to cool-season grasses in early spring. An early application will greatly reduce the "spring flush" growth of Kentucky bluegrass, tall fescues, and other cool-season turf grasses. This may be particularly useful in the spring when frequent rainstorms can create difficult mowing conditions, especially on steep slopes, and when part-time labor for mowing may not be available.

c. In general, PGRs should be applied to cool-season turf grasses only once annually in areas where heat and drought stress begin by late spring. The single PGR application will inhibit the vigorous spring growth of the cool-season grasses, and environmental stress will inhibit the summer growth. A second application during the period of stress may be severely phytotoxic. Fall application to cool-season grasses should be considered only for dense, vigorously growing stands.

d. The warm-season grasses, unlike cool-season grasses, grow most vigorously during periods of high temperature in the summer. They generally are low-growing species such as bahiagrass, bermudagrass, carpetgrass, St. Augustinegrass, and zoysiagrass, that are maintained at low mowing heights in order to ensure vigorous, dense stands, and to reduce the potential for winterkill.

e. Warm-season grasses are normally treated to suppress seedheads rather than foliar growth. It is difficult to obtain season-long seedhead control with a single PGR application because many warm-season grasses produce seedheads continuously throughout the summer. Warm-season grasses also generally require higher application rates of PGRs than do the cool-season grasses.

f. Where warm-season grasses become dormant in winter, treatment should begin after spring greenup. In regions where warm-season grasses grow year-round, PGRs have had erratic effects, and therefore, they are generally not used on warm-season grasses in subtropical and tropical climates.

5-8. Step-by-Step Procedures. For best results, PGRs must be used correctly.

a. Mow turf to the desired height 24 to 48 hours before PGR application.

b. Apply PGRs to healthy, actively growing turf in the spring, about 2 weeks before seedheads appear.

c. Use the correct dosage and apply uniformly in 40 to 80 gallons of water per acre. Avoid runoff, skips, and overlaps.

d. Delay spraying if clippings or other debris are present, as they will prevent uniform distribution of the PGR.

e. Apply when rain is not expected for 4 to 8 hours and irrigation will not be provided for 8 hours. Amidochlor and flurprimidol, however, should be watered-in to improve their effectiveness.

f. Avoid high temperatures during or following PGR application, if possible. They will cause an increase in discoloration, and possibly thinning, of the turf grass.

g. Apply PGRs with a tractor-pulled, multinozzle, boom sprayer for best results. Spraying slopes and bunkers with a hand-held, single-nozzle boom often results in excessive or inadequate amounts of PGR being applied.

h. Do not apply PGRs to heat or drought stressed turf.

i. Do not apply PGRs to scalped turf.

j. Mow PGR treated turf 10 to 14 days after PGR application.

k. Do not scalp PGR-treated turf.

5-9. Diagnosing Common Problems. The most common problems associated with using PGRs may be diagnosed using the following chart:

Problem	Problem Causes
a. Poor growth suppression or poor seedhead suppression	(1) insufficient PGR applied, poor calibration.
	(2) Turf mowed too close before PGR application.
	(3) PGR applied to dormant, partially dormant, or drought-stressed turf.
	(4) Rain or irrigation too soon after PGR application.
	(5) Turf mowed too soon after PGR application.
	(6) Germination of grass or broadleaf weed seed following PGR application.
	(7) PGR applied too late, after seedheads developed and began to emerge.
b. Abnormal discoloration	(1) Higher than recommended rate applied.
	(2) Overlapping of nozzles or spray boom.
	(3) Applied to sensitive species.
	(4) Turf mowed too close before application.
	(5) Turf mowed with dull mower blade before or after application.

CHAPTER 6

DETERMINING THE COST-EFFECTIVENESS OF PGR

Section A—General Discussion

6-1. The Importance of Determining Cost-Effectiveness. The previous chapter emphasized the need to consider local conditions and to conduct local testing before adopting PGRs. Even when local conditions and the results of testing seem favorable, however, grounds maintenance practices should not be changed without comparing the costs of the alternatives. This cost-comparison, the demonstrated effects of PGRs, the availability of equipment and trained personnel, and safety should all be considered in deciding the most cost-effective maintenance practice.

6-2. Calculating and Documenting Costs of Alternatives:

a. The calculations described in this chapter can be made easily by hand. They can also be adapted readily to a personal computer. The factors considered are:

(a) The costs of mowing.

(2) The costs of applying PGRs.

(3) The length of time PGRs are expected to suppress the growth of the grass.

(4) The reduction in mowing that is expected when PGRs are used.

b. The calculations are made in four steps. First, the costs per hour are calculated for each type of worker employed in the mowing and spraying operations; next, the cost of the equipment used is calculated on a per hour basis; third, the costs of mowing and spraying operations on specific parcels of land are computed; and, fourth, the savings or cost that would result from using PGRs is computed. Finally, the results are evaluated to determine whether the savings that might be generated would result in real dollar savings, or if, instead, the freed personnel and equipment assets would be used for other worthwhile tasks.

c. Documents on which the calculations can be made are provided in attachments 22 through 25. Document A (attachment 22) is used to determine the hourly costs of personnel. Document B (attachment 23) is used to determine the hourly costs of equipment. Using the hourly costs of personnel and equipment, the grounds maintenance manager can use document C (attachment 24) to calculate the costs of mowing and spraying operations on particular parcels of land. Document D (attachment 25) is then used to compare costs and to determine the cost-effectiveness of using PGRs.

d. Documents A through D can also be used to calculate and compare the costs of other maintenance practices and equipment, to prepare budgets, and to determine manpower requirements.

6-3. An Illustrative Example. The use of documents A through D is illustrated in the remainder of this chapter with a fictitous example. Air Base Somewhere is located in the temperate zone, and PGRs are being considered for use on cool-season grasses on 2300 acres. The requirement without PGRs is to mow the parcels shown in table 6-1 every 2 weeks. In addition to the grass, there are large concentrations of weeds that would have to be controlled before the full effect of the plan growth regulators could be realized.

Table 6-1. Mowing Requirement at Air Base Somewhere.

Parcel No.	Description	Size	Equipment Used	Capability of Equipment
1	Runway & Taxiways	2,000 acres	Tractor Mower	2.5 a/h
2	Drainage Areas	200 acres	36" Riding Mower	0.5 a/h
3	Obstructed Areas	100 acres	21" Power Mower	1.15 a/h
4	Fence Borders	100,000 ft^2	Weedeater	1,615 ft^2/h

Section B—Determining Costs

6-4. Personnel Costs:

a. Document A (attachment 22) is used to record the hourly costs of the different types and grades of workers that will be used. Four basic types of workers are:

(1) Hourly Wage Workers. These are temporary helpers that are hired during the peak growing seasons. They do not accrue certain benefits, such as hospitalization and retirement. The composite wage scale for these workers is normally prescribed by the local command.

(2) Civil Service Employees. These are permanent employees hired under civil service regulations. They are entitled to civil service benefits.

(3) Military Personnel. These are active duty personnel assigned to grounds maintenance.

(4) Contractor-Supplied Labor. These are personnel that are supplied by local contractors. The labor costs are determined locally.

b. The costs of the different types of workers are recorded in dollars per hour and include both wages and benefit costs. Benefits include leave and holidays, incentive awards, and the employer's share of payments for insurance, retirement, social security, taxes, and the like. The costs of benefits are allocated to each worker on the same hourly basis as regular pay. The pay and benefits are summed to produce the hourly composite rate for each type of worker. When completed, document A is a catalog of operator and supervisor costs that can be used to determine personnel costs for different pieces of equipment and operations.

c. To estimate military and civil service personnel costs, use AFR 173-13, US Air Force Cost and Planning Factors; AR 37-115, Financial Administration—Accounting for Special Facilities Engineering Projects; and DA Pamphlet 420-6, Facilities Engineering—Resource Management System. Base budget, personnel, and contracting offices can also help in determining personnel costs.

d. The completed document A for the example of Air Base Somewhere is shown in figure 6-1. It shows the pay rates of all the types of personnel who would be used in the example.

e. If growth regulators were to reduce the amount of labor required for mowing, there would not necessarily be a reduction in the budget. If growth regulators permitted a grounds manager to reduce pesonnel in mowing operations, he or she would be able to dip lower into his or her priority list and accomplish other tasks. The calculations would show a savings in labor costs, but the labor and equipment, and thus the costs, might be assigned to other tasks.

f. The use of military personnel for the task poses the question of whether their labor cost should be charged at military pay scales. If there are military requirements to staff the base at a specific level to perform functions in wartime, then there is the possibility that there will be military manpower surpluses during peacetime. Under these circumstances, military labor in peacetime could be considered a free good. In the cost model presented here, however, costs represent the assignment of resources to specific tasks rather than signaling areas of budget reduction; and, therefore, military personnel are included in the costs.

6-5. Equipment Costs:

a. Document B (attachment 23) is used to calculate the hourly costs of the different types of equipment to be used. If desired, document Bs can be completed to create a catalog of equipment costs for all the different types of equipment the base uses in ground maintenance, such as weedeaters, small riding mowers, hand-operated lawn mowers, and the different types of tractor mowers.

b. The entries on document B are made as follows:

(1) Lines 1a to 1e. The purchase price of equipment (line 1a) should be available in local records. The purchase price usually quoted will include the freight on board (f.o.b.) charge but not the charge for shipping from the warehouse to the base. Add any shipping charges to the purchase cost. The service life in years (line 1b) is estimated for each type of equipment. Local experience may be used, particularly if local operating conditions are adverse; or normal service lives can be taken from Office of Management and Budget (OMB) Circular No. A-76, "Performance of Commercial Activities." An estimate of the number of hours the equipment is operated each year (line 1c) is then used to calculate the equipment's service life in hours (line 1d). The hourly investment cost of each piece of equipment (line 1e) is calculated by dividing its purchase cost (line 1a) by its estimated service life in hours (line 1d).

(2) Lines 2a to 2c. The fuel cost per hour (line 2c) is calculated by multiplying the estimated fuel consumption of the equipment per hour (line 2a) by the local cost of fuel (line 2b).

DOCUMENT A*

Personnel Cost Factors

Place: Air Base Somewhere Date: 08/03/84

	A	B	C	D
1. Temporary Worker				
Grade	Basic WG-2	Step 1 WG-4	WG-6	WS-6
Basic pay	$ 8.30	$ 9.08	$ 9.86	$ 13.29
Benefits**	+ 2.24	+ 2.45	+ 2.66	+ 3.58
Composite pay	$ 10.54	$ 11.53	$ 12.52	$ 16.87
2. Permanent Employee				
Grade	GS-1	GS-2	GS-3	GS-7
Basic pay	$ 4.61	$ 5.10	$ 5.89	$ 9.66
Benefits**	+ 0.64	+ .72	+ .83	+ 1.36
Composite pay***	$ 5.25	$ 5.82	$ 6.72	$ 11.02
3. Military Member				
Rank	E-1	E-2	E-3	E-6
Composite pay***	$ 5.02	$ 5.62	$ 6.31	$ 10.48
4. Contract Labor				
Type	Basic Worker	Supervisor		
Hourly rate	$ 6.50	$ 12.50	$	$

*Fill in skill levels that might be used in applicable grounds maintenance roles, and give costs in dollars/hour. Hourly costs are based on local conditions. Use additional sheets if necessary.
**Include any quarters allowance, incentive awards, employer's share of payment for insurance, retirement, FICA, health insurance, taxes, and similar payments. Individual benefit costs should be calculated on an hourly basis, summed, and recorded here.
***Published in AFR 173-13, AR 37-115, and DA Pamphlet 420-6.

Figure 6-1. Personnel Cost Factors for "Air Base Somewhere."

(3) Line 3a to 3c. Maintenance costs include all labor and parts, including lubricants, blades, cutting line, etc., used to maintain and repair the equipment. The costs of labor and parts can be determined by examining local maintenance records for any period of time, but an annual basis will probably be most convenient. The labor and parts for the piece or type of equipment for that period of time are each divided by the estimated service hours of the equipment for the same time period to arrive at the labor (line 3a) and parts (line 3b) costs per operating hour. The sum of these costs is the total maintenance cost per operating hour (line 3c).

(4) Line 4. The total equipment cost per hour of operation is the sum of the investment, operating, and maintenance costs per operating hour. (Note that the costs of PGRs and herbicides are not calculated here. They are considered in document C.)

c. The completed document B for the example of Air Base Somewhere is shown in figure 6-2. In this example, comparing the cost of mowing with the cost of using a PGR requires costing out four types of mowing equipment and one type of spraying equipment. The line entries are fictitious and are only meant to illustrate the method of calculation. Equipment costs will vary at each base. Operating and maintenance costs are influenced by the local price of fuel, the climate, the terrain, local operator experience, and other factors.

6-6. Cost of Grounds Maintenance Operations:

a. Document C (attachment 24) is used to calculate the cost of a maintenance operation on a specific parcel of land. It has space for two different types of equipment and for personnel with two different pay scales. More types of equipment and personnel can be accommodated with additional columns or forms. The location and size of the parcel and the operation being costed should be identified on the form, as should any special characteristics of the parcel, such as "rocky and hilly," "fire break," etc. Separate columns are used for each piece of equipment.

DOCUMENT B

Equipment Cost Factors*

Place: Air Base Somewhere Date: 08/03/84

Types of Equipment

		TRACTOR MOWER	36″ RIDING MOWER	21″ POWER MOWER	
1.	Investment Cost				Source**
	a. Purchase cost (total)	$8400.00	$2600.00	$ 420.00	
	b. Service life (years)	12	3	3	***
	c. Expected use (hours/year)	480	480	480	local records
	d. Service life (hours)	5760	3840	1440	(1b) × (1c)
	e. Investment cost ($/hour)	$ 1.46	$ 0.68	$ 0.29	(1a) ÷ (1d)
2.	Operating Cost Per Hour				
	a. Fuel consumption (gal/hour)	2.40	0.80	0.25	****
	b. Cost of fuel ($/gal)	$ 1.00	$ 1.00	$ 1.00	local records
	c. Fuel cost ($/hour)	$ 2.40	$ 0.80	$ 0.25	(2a) × (2b)
3.	Maintenance Cost Per Operating Hour				
	a. Labor cost ($/hour)	$ 5.60	$ 2.80	$ 2.50	local records
	b. Parts cost ($/hour)	$ 9.00	$ 4.50	$ 2.00	local records
	c. Total cost ($/hour)	$ 14.60	$ 7.30	$ 4.50	(3a) + (3b)
4.	Total Equipment Cost per Hour of Operation	$ 18.46	$ 8.78	$ 5.04	(1e) = (2c) + (3c)

*Fill in types of equipment that might be used in applicable grounds maintenance operations, and give costs in dollars/hours.

**This column indicates the source of information. The figures in parentheses indicate lines of this document.

***Local conditions prevail. Guidelines are provided in Office of Management and Budget (OMB) Circular No. A-76, "Performance of Commercial Activities," August 1983.

****Based on local experience or manufacturers' manuals.

Figure 6-2. Equipment Cost Factors for "Air Base Somewhere."

DOCUMENT B

Equipment Cost Factors*

Place: Air Base Somewhere | Date: 08/03/84

Types of Equipment

		Weedeater	Spray Equipment		
1.	Investment Cost				Source**
	a. Purchase cost (total)	$360.00	$2600.00	$	
	b. Service life (years)	3	8		***
	c. Expected use (hours/year)	288	480		local records
	d. Service life (hours)	864	5760		(1b) × (1c)
	e. Investment cost ($/hour)	$ 0.42	$ 0.68	$	(1a) ÷ (1d)
2.	Operating Cost Per Hour				
	a. Fuel consumption (gal/hour)	0.12	0.80		****
	b. Cost of fuel ($/gal)	$ 1.00	$ 1.00	$	local records
	c. Fuel cost ($/hour)	$ 0.12	$ 1.80	$	(2a) × (2b)
3.	Maintenance Cost Per Operating Hour				
	a. Labor cost ($/hour)	$ 1.25	$ 2.80	$	local records
	b. Parts cost ($/hour)	$ 0.25	$ 4.50	$	local records
	c. Total cost ($/hour)	$ 1.50	$ 7.30	$	(3a) + (3b)
4.	Total Equipment Cost per Hour of Operation	$ 2.04	$ 8.78	$	(1e) = (2c) + (3c)

*Fill in types of equipment that might be used in applicable grounds maintenance operations, and give costs in dollars/hours.

**This column indicates the source of information. The figures in parentheses indicate lines of this document.

***Local conditions prevail. Guidelines are provided in Office of Management and Budget (OMB) Circular No. A-76, "Performance of Commercial Activities," August 1983.

****Based on local experience or manufacturers' manuals.

Figure 6-2. Continued

b. The line entries are made as follows:

(1) Lines 1a to 1d. These lines are used to calculate the equipment costs of the maintenance operation. Hourly operating costs from document B are entered on line 1a for each type of equipment to be used. Then, an estimate of how many hours it would take to treat an acre with each type of equipment in the kind of terrain found in the parcel is entered on line 1b. The number of acres to be treated with each type of equipment is entered on line 1c. The cost of using each type of equipment is obtained by multiplying line 1a by line 1b and by line 1c and is entered on line 1d. The total equipment cost for the maintenance operation is also entered on line 1d.

(2) Lines 2a to 2d. These lines are used to calculate the costs of spraying PGRs, and are only completed for that particular operation. On line 2a, the gallons per acre of the PGR is entered. Line 2b is the cost per gallon of the PGR, and line 2c is the number of acres to be

treated. The product of these three lines is entered on line 2d. The total chemical cost of the maintenance operation is also entered on line 2d.

(3) Lines 3a to 3k. These lines are used to calculate labor costs for each type of work and equipment. The operator hours for each type of equipment is calculated by multiplying line 1b by line 1c and is entered on line 3b. The equipment operator's estimated time spent traveling between the maintenance yard and the work site, waiting for transportation, loading and unloading equipment, and any other unproductive time, is subtracted from the workhours scheduled per day. The resulting number of productive operator hours per workday is entered on line 3c. The number of operator days required for the maintenance operation is calculated by dividing line 3b by line 3c, and this is entered on line 3d. The total number of operator hours required is then obtained by multiplying line 3d by the number of operator hours per workday (normally 8), and this is entered on line 3e. The foregoing procedure ensures that the labor cost includes all idle or unproductive time. The hourly labor cost for the type of worker is taken from document A and is entered on line 3f. Operator costs are calculated by multiplying line 3e by 3f and are entered on line 3g. Supervisory costs are estimated in a similar manner and are entered on lines 3h, 3i, and 3j.

(4) Lines 4a to 4j. These lines are used to calculate the cost of transportation to and from the work site. An estimate of the number of round trips required to service the operation at the site is entered on line 4a. The miles traveled in one round-trip are entered on line 4b. The total miles to be traveled is the product of lines 4a and 4b and is entered on 4c. Tractor mowers and tractor sprayers are usually driven to and from the work site by their operators. For these, enter the total hours of travel time on line 4c and the total cost per hour from document B on line 4d. For the trucks needed to transport other equipment and operators, enter the total miles traveled on line 4c and the vehicle cost on line 4d. Account for all the vehicles used. The vehicle costs per mile are estimated from figures available locally and include investment, operating, and maintenance costs, as discussed in the instructions for document B. Line 4c is multiplied by line 4d to obtain the total vehicle cost, which is entered on line 4e. The truck drivers' time is entered on line 4g, based on the number of hours needed for a round-trip to the site (line 4f) and the number of round-trips (line 4a). The hourly driver cost, from document A, is entered on line 4h. The total driver cost is the product of lines 4g and 4h, and is entered on line 4i. This cost is added to the vehicle costs (line 4e) to provide the total transportation cost on line 4j. Tractor drivers' travel time was accounted for as non-productive time in 3e, so it is not included again in 4g.

(5) Lines 5a to 5e. The equipment, chemical, labor, and transportation costs on lines 1d, 2d, 3k, and 4j are entered on lines 5a, 5b, 5c, and 5d and are summed to obtain the total cost of the maintenance operation. This is entered on line 5e.

c. The completed document C for the mowing operation in our example of Air Base Somewhere is shown in figure 6-3. Four kinds of mowing equipment were used. A tractor mower mowed the large grassy areas around the main runway and taxiways, 36-inch riding mowers operated on the inclined drainage areas, and 21-inch power mowers and weedeaters mowed smaller areas. Their costs are calculated individually and are totaled at the bottom of the document. We will explain the calculations line-by-line:

(1) Equipment Costs. Line 1a shows the operating costs of the tractor mower and 36-inch riding mower. These figures are obtained from line 4 of document B (figure 6-2). On line 1b, the number of hours required to maintain one acre of each type of area is estimated. The tractor mower is estimated to mow 2.5 acres per hour, or to take 0.4 hours for an acre. The riding mower requires 2 hours to mow an acre. The parcel sizes of 2000 and 200 acres are shown on line 1c. Multiplying the three lines, 1a, 1b, and 1c, yields the equipment cost for mowing each parcel. Those figures are entered on line 1d. The equipment costs for the 21-inch power mowers and the weedeaters were calculated similarly.

(2) Labor Costs.

(a) Line 3b shows the estimated time to complete the job with tractor mowers to be 800 hours (the product of lines 1b and 1c). Line 3c is the productive hours per workday. This is the scheduled hours per day, less the nonproductive time used in getting people organized in the morning, waiting for the trucks, loading the equipment, being transported to the site, unloading the equipment, and getting into operation. In the evening, the process is repeated as the equipment is secured and returned to the storage yard. The nonproductive time is estimated in our

DOCUMENT C

Cost of Grounds Maintenance Operations

Place: Air Base Somewhere — Date: 08/03/84

Location: Runways and Taxiways

Type of area:	Grass Turf		Unimproved Drainage Ways			
Size of area:	2000 acres		200 acres			
	Types of Equipment					*Source**
	Tractor Mower		36″ Riding M ower			
1. Equipment Costs						
a. Cost per operating hour	$ 18.46		$ 8.78			Document B
b. Equipment-hours per acre	0.4		2.0			
c. Acres mowed (or other)	2000		200			
d. EQUIPMENT COST	$14,768	+	$3,512	=	$18,280.	(1a) × (1b) × (1c)
2. Chemical Costs						
a. Gallons per acre	N/A					
b. Cost per gallon	$ N/A		$			
c. Acres treated	N/A					
d. CHEMICAL COST	$	+	$	=	$	(2a) × (2b) × (2c)
3. Labor Costs						
a. Type of Labor	WG-4		BASE H/W			Document A
b. Working operator-hours required	800		400			(1b) × (1c)
c. Productive operator-hours per day	6		6			**
d. Operator-days required	133		67			(3b) ÷ (3c)
e. Total operator-hours required	1066		534			(3d) × (8 hours per day)
f. Labor cost per hour	$ 11.53		$ 9.55			Document A
g. Operator cost	$12,290.98	+	$5,099.70	=	$17,390.68	(3e) × (3f)

Figure 6-3. Cost of Mowing Operations for "Air Base Somewhere."

							Source*
	h. Supervisor-hours required	80		—			
	i. Supervisor cost per hour	$ 16.87		$ —			Document A
	j. Supervisor cost	$1,349.60	+	$ —	=	1,349.60	(3h) x (3i)
	k. LABOR COST					$18,740.28	(3g) + (3j)
4.	Transport Costs						
	a. No. round trips to site	133		68			3(d) x 2
	b. Rnd. trip miles to site	6		6			
	c. Total hours or miles***	79.8		408			(4a) x (4b)
	d. Vehicle cost per hour or mile***	18.46		0.35			
	e. Total vehicle cost	$1,473.11	+	$142.80	=	$ 1,615.91	(4c) x (4d)
	f. Rnd. trip hours to site	—		1			
	g. Total drive time	—		68			(4a) x (4f)
	h. Drive cost per hour	—		$ 11.53			
	i. Total driver cost	—	+	$784.04	=	$ 784.04	(4g) x (4h)
	j. TRANSPORT COST =		+		=	$ 2,399.95	(4e) + (4i)
5.	Total Cost of Maintenance Operations (sum all applicable Document Cs)						
	a. Equipment cost					$18,280.00	(1d)
	b. Chemical cost						(2d)
	c. Labor cost					$18,740.28	(3k)
	d. Transport cost					2,399.95	(4j)
	e. TOTAL COST					$39,420.23	(5a) + (5b) + (5c) + (5d)
	f. SUM OF DOCUMENT Cs						

*The figures in parentheses indicate lines of this document.

**Nonproductive time includes time used in transport to and from the work site, refueling and greasing equipment, and making repairs and adjustments. This time is subtracted from the normal 8-hour day to derive "productive operator-hours per day."

***Computed on an hourly basis for tractormowers if they are the prime movers of the mowers to and from the work site. The tractor-drivers' time is included in the 2 hour "nonproductive time" or in-transit time and is therefore not included again in 4g.

Figure 6-3. Continued.

DOCUMENT C

Cost of Grounds Maintenance Operations

Place: Air Base Somewhere — Date: 08/03/84

Location: Runways and Taxiways

Type of area:	Obstructed Areas		Fence Borders			
Size of area:	100 acres		100,000 sq. ft.			
	Types of Equipment					*Source**
	21″ Power Mower		Weedeater			
1. Equipment Costs						
a. Cost per operating hour	$ 5.04		$ 2.04			Document B
b. Equipment-hours per acre	6.67		.00062 per sq. ft.			
c. Acres mowed (or other)	100		100,000 sq. ft			
d. EQUIPMENT COST	$3,361.68	+	$126.48	=	$ 3,488.16	(1a) × (1b) × (1c)
2. Chemical Costs						
a. Gallons per acre	N/A					
b. Cost per gallon	$ N/A		$			
c. Acres treated	N/A					
d. CHEMICAL COST	$	+	$	=		(2a) × (2b) × (2c)
3. Labor Costs						
a. Type of Labor	WG-2		WG-2			Document A
b. Working operator-hours required	667		62			(1b) × (1c)
c. Productive operator-hours per day	6		6			**
d. Operator-days required	111		10			(3b) ÷ (3c)
e. Total operator-hours required	888		80			(3d) × (8 hours per day)
f. Labor cost per hour	$ 10.54		$ 10.54			Document A
g. Operator cost	$9,359.52	+	$ 43.20	=	$10,202.72	(3e) × (3f)
						*Source**
h. Supervisor-hours required	—		—			

Figure 6-3. Continued

	i. Supervisor cost per hour	$ —		$—			Document A
	j. Supervisor cost	$ —	+	$—	=	—	(3h) x (3i)
	k. LABOR COST					$10,202.72	(3g) + (3j)
4.	Transport Costs						
	a. No. round trips to site	56		4			3(d) x 2
	b. Rnd. trip miles to site	6		6	•		
	c. Total hours or miles***	336		24			(4a) x (4b)
	d. Vehicle cost per hour or mile***	0.35		0.35			
	e. Total vehicle cost	$117.60	+	$ 8.40	=	$ 126.00	(4c) x (4d)
	f. Rnd. trip hours to site	1		1			
	g. Total drive time	56		4			(4a) x (4f)
	h. Drive cost per hour	11.53		$11.53			
	i. Total drive cost	645.68	+	$46.12	=	$ 691.80	(4g) x (4h)
	j. TRANSPORT COST =		+		=	$ 817.80	(4e) + (4i)
5.	TOTAL COST OF MAINTENANCE OPERATIONS (sum all applicable Document Cs)						
	a. Equipment cost					$ 3,488.16	(1d)
	b. Chemical cost						(2d)
	c. Labor cost					$10,202.72	(3k)
	d. Transport cost					817.80	(4j)
	e. TOTAL COST					$14,508.68	(5a) + (5b) + (5c) + (5d)
	f. SUM OF DOCUMENT Cs					$53,928.91	

*The figures in parentheses indicate lines of this document.

**Nonproductive time includes time used in transport to and from the work site, refueling and greasing equipment, and making repairs and adjustments. This time is subtracted from the normal 8-hour day to derive "productive operator-hours per day."

***Computed on an hourly basis for tractormowers if they are the prime movers of the mowers to and from the work site. The tractor-drivers' time is included in the 2 hour "nonproductive time" or in-transit time and is therefore not included again in 4g.

Figure 6-3. Continued.

example to be 2 hours per day. Therefore, the normal 8-hour day is reduced to 6 productive workhours. Six is divided into the required 800 hours of tractor mowing time to obtain the number of operator days that are required, 133.3, which is entered on line 3d. The number of days required, 133.3, is multiplied by the scheduled hours per day, 8, and shows that 1,066 total operator hours must be budgeted to accomplish the job. This figure is entered on line 3e.

(b) The labor costs on line 3f are taken from document A (figure 6-1). A worker at the WG-4 grade level is used as the tractor opera tor. An hourly wage worker, hired on a temporary basis, operates the riding mower. The operator cost computed on line 3g is $12,290.98 (1,066 hours x $11.53 per hour) for the tractor mower and $5,099.70 for the riding mower. Operator costs for the 21-inch power mower and the weedeater are computed similarly.

(c) The cost of providing a supervisor is calculated on lines 3h, 3i, and 3j. In this case, it is assumed that one supervisor will handle all four operations on a full-time basis and that the job will take 2 weeks to complete. The supervisor is a WS-6, and document A (figure 6-1) indicates this wage to be $16.87 per hour. The 80-hour work period costs $1,349.60 for the supervisor, as shown on line 3j. The supervisor cost and operator costs are combined in the total column to produce a total labor cost of $28,943.00 on line 3k.

(3) Transportation Costs:

(a) The tractor mower is driven to the site by its operator. Line 3d indicates that it must be driven to the work site 133 times, and this is entered on line 4a. In 133 trips, it is driven 798 miles, and at 10 miles an hour this takes 79.8 hours. Document B (figure 6-2) shows that the tractor operating cost is $18.46 per hour, so the 79.8 hours spent traveling to and from the site incurs a cost of $1,473.11, which is entered on line 4e.

(b) The calculations for those operations requiring trucks to transport workers and equipment to the site are somewhat different. The trucks are assumed to take them to the work site in the morning and to pick them up in the afternoon. Therefore, the trucks make two round trips each day. The riding mowers need 67 mower-days to do the job (line 3d) and thus require 34 truck-days since each truck transports 2 riding mowers. At 2 round-trips per truck per day, 68 total round-trips are required. This is entered on line 4a. Line 4b shows an average round-trip distance of 6 miles, yielding a total of 408 miles on line 4c. A cost of $0.35 per mile for the truck, multiplied by the 408 miles, gives us a cost of $142.80, which is entered on line 4e.

(c) The truck drivers will spend about an hour driving over to pick up the riding mowers, waiting as they are loaded, driving them to the site, and returning. This 1 hour figure is shown on line 4f. This figure is multiplied by the number of round-trips (line 4a), and the result, 68, is entered on line 4g. The truck drivers are WG-4s, with a composite pay rate of $11.53 per hour, as shown by document A (figure 6-1). This figure is entered on line 4h. The total driver cost of $784.04 (68 hours x $11.53 per hour) is entered on line 4i. T he transportation costs for the 21-inch power mowers and the weedeaters are computed similarly. There is no driver cost for the tractor mowers since their time spent driving to and from the site was accounted for earlier in their nonproductive time. Transportation costs are totaled on line 4j.

(4) Total Cost. The total mowing cost of $53,928.91 is shown on line 5f.

d. The completed document C for applying a PGR in our example is shown in figure 6-4. The calculations are made in the same way as for the other operations. The cost of the PGR (and herbicides, if needed) is calculated under line 2. It is the dominant cost factor in the spraying operation.

(1) The gallons per acre are, in our example, a combined PGR and herbicide. (The two could be calculated separately, if they were applied that way.) In this case, a gallon covers 5 acres, so only 0.2 gallons are required per acre (line 2a). The cost of the combined agents is estimated at $78,00 per gallon (line 2b), and the operation is to cover the total area of 2300 acres (line 2c). The total chemical cost on line 2d is the product of lines 2a, 2b, and 2c.

DOCUMENT C

Cost of Grounds Maintenance Operations

Place: Air Base Somewhere   Date: 08/03/84

Location: Runways and Taxiways

Type of area:	Runway Areas	

Figure 6-4. Cost of PGR Application for "Air Base Somewhere."

Size of area: 2300acres

		Types of Equipment					Source*
		Spray Equipment					
1.	Equipment Costs						
	a. Cost per operating hour	$ 8.78		$			Document B
	b. Equipment-hours per acre	0.20					
	c. Acres mowed (or other)	2,300					
	d. EQUIPMENT COST	$4,038.80	+	$	=	$ 4,038.80	(1a) × (1b) × (1c)
2.	Chemical Costs						
	a. Gallons per acre	0.20					
	b. Cost per gallon	$ 78.00		$			
	c. Acres treated	2300					
	d. CHEMICAL COST	$	+	$	=	$35,880.00	(2a) × (2b) × (2c)
3.	Labor Costs						
	a. Type of Labor	WG-4					Document A
	b. Working operator-hours required	460					(1b) × (1c)
	c. Productive operator-hours per day	6					**
	d. Operator-days required	77					(3b) ÷ (3c)
	e. Total operator-hours required	614					(3d) × (8 hours per day)
	f. Labor cost per hour	$ 11.53		$			Document A
	g. Operator cost	$7,079.42	+	$	=	$ 7,079.42	(3e) × (3f)
							Source*
	h. Supervisor-hours required	80					
	i. Supervisor cost per hour	$ 16.87		$			Document A
	j. Supervisor cost	$1,349.60	+	$	=	1,349.60	(3h) × (3i)
	k. LABOR COST					$ 8,429.02	(3g) + (3j)
4.	Transport Costs						
	a. No. round trips to site	77					3(d) × 2
	b. Rnd. trip miles to site	6					
	c. Total hours or miles***	462					(4a) × (4b)

Figure 6-4. Continued.

d. Vehicle cost per hour or mile***	0.35					
e. Total vehicle cost	$161.70	+		=	$ 161.70	(4c) x (4d)
f. Rnd. trip hours to site	1					
g. Total drive time	77					(4a) x (4f)
h. Drive cost per hour	$ 11.53					
i. Total drive cost	$887.81	+		=	$ 887.81	(4g) x (4h)
j. TRANSPORT COST =		+		=	$ 1,049.51	(4e) + (4i)

5. TOTAL COST OF MAINTENANCE OPERATIONS (sum all applicable Document Cs)

a. Equipment cost	$39,918.80	(1d)
b. Chemical cost		(2d)
c. Labor cost	$ 8,429.02	(3k)
d. Transport cost	1,049.51	(4j)
e. TOTAL COST	$49,397.33	(5a) + (5b) + (5c) + (5d)
f. SUM OF DOCUMENT Cs	$49,397.33	

*The figures in parentheses indicate lines of this document.

**Nonproductive time includes time used in transport to and from the work site, refueling and greasing equipment, and making repairs and adjustments. This time is subtracted from the normal 8-hour day to derive "productive operator-hours per day."

***Computed on an hourly basis for tractormowers if they are the prime movers of the mowers to and from the work site. The tractor-drivers' time is included in the 2 hour "nonproductive time" or in-transit time and is therefore not included again in 4g.

Figure 6-4. Continued.

(2) This part of the analysis should receive special attention because of the variations in price and effectiveness of PGRs. The choice of a PGR will depend on both the PGR's cost and its effectiveness under local conditions. A PGR which may be more effective on a pound-per-acre basis may not be recommended because of its disproportionately greater cost. (Mefluidide is about equal to maleic hydrazide in terms of equivalent cost.)

Section C—Determining Cost-Effectiveness

6-7. Effectiveness-Rates and Effectiveness-Periods of PGRs. It is necessary to know how much and how long a PGR is likely to suppress the growth of grass before we can estimate its cost-effectiveness.

a. We will assume that prescribed application procedures are followed and that the effectiveness of a PGR can be expressed in terms of an effectiveness-rate and an effectiveness-period. These terms provide a basic description of how much a PGR application is expected to reduce plant growth and, thus, mowing requirements, over a certain period of time.

b. The effectiveness-rate is simply the percentage by which total growth will be reduced over a specified period of time. The specified period of time is the effectiveness-period. For example, if a PGR application would reduce total growth by 50 percent over an 8-week period, then the effectiveness-rate would be 50 percent, and the effectiveness-period would be 8 weeks. We can specify either the effectiveness-rate or the effectiveness-period and then estimate the other based on local experience, manufacturers' literature, or research reports.

c. Data on the effectiveness of PGRs, and the normal mowing frequencies on military bases, indicate that using an effectiveness-rate of 50 percent is reasonable under most circumstances. The corresponding effectiveness-periods of currently available PGRs are given in table 6-2.

d. There are many factors that influence the effectiveness of PGRs. Two of the more significant are climatic conditions and the type of grass being controlled. These factors were considered in determining the effectiveness-periods in table 6-2.

Table 6-2. Effectiveness-Periods of PGRs on Grass.

Type of Grass	PGR	EFFECTIVENESS-PERIOD (Weeks) Spring	Summer	Fall
Cool-Season Grasses*	Amidochlor	7	5	7
	Flurprimidol	10	8	10
	Maleic hydrazide	8	6	8
	Mefluidide	8	6	8
Warm-Season Grasses**	Flurprimidol	10	8	10
	Maleic hydrazide	4-6	4-6	4-6
	Mefluidide	6	6	6

*Cool-Season Grasses:
Annual and Kentucky bluegrasses, tall and red fescues, perennial ryegrass, timothy, and bromegrasses.

**Warm-Season Grasses:
Bahiagrass, bermudagrasses, zosiagrass, centipedegrass, St. Augustinegrass, kikuyugrass (not labeled for maleic hydrazide), and carpetgrass.

Note: Orchardgrass, velvetgrass, and tall oatgrass are not affected by PGRs. Performance of the commercially available PGRs in regions where these grasses do not enter a state of winter dormancy has been erractic, and the use of PGRs is usually not recommended.

6-8. Calculating the Cost-Effectiveness of Using PGRs:

a. Document D (attachment 25) is used to compare maintenance costs with and without usisng PGRs. The general information at the top of the document should be recorded so that the cost comparison can be retained for future reference.

(1) Line 1. The effectiveness-period is discussed in paragraph 6-7. Table 6-2 may be used for the PGRs and conditions listed therein.

(2) Line 2. The normal interval between mowings is based on local requirements.

(3) Line 3. The number of mowings that would normally be required during the effectiveness-period is obtained by dividing line 1 by line 2.

(4) Line 4. The cost of one mowing operation is taken from line 5 of document C. Use the total cost of mowing the areas where PGRs would be applied.

(5) Line 5. The cost of all the mowing that would normally be required during the effectiveness-period is obtained by multiplying line 3 by line 4.

(6) Line 6. The savings recorded here is the cost of the mowings that would be eliminated by using PGRs.

(7) Line 7. Like the cost on line 4, the cost of a PGR application is taken from document C.

(8) Line 8. The net savings is the difference between the savings in mowing costs and the cost of applying the PGR (and herbicide, if needed).

(9) Line 9. The recommended use of the savings is recorded on line 9.

b. The completed document D for our example at Air Base Somewhere is shown in figure 6-5.

DOCUMENT D

Determination of Cost Effectiveness

Mowing Versus PGRs

PLACE: Air Base Somewhere DATE: 08/03/84

Description of Area:

Location: Runways and Taxiways

Size: 2300 acres

Special Considerations: Includes main grassy areas—between the runways, taxiways and aprons.

Time between operations: 2 weeks

Time of year: SPRING SUMMER FALL RAINY DRY
(Circle the most appropriate)

Grass Type: COOL SEASON WARM SEASON
(Circle the most appropriate)

		*Source**
1. EFFECTIVENESS PERIOD	8	From Table 6-2
2. NO. WEEKS BETWEEN PRESENT MOWING OPERATIONS	2	Local estimate
3. NO. OF MOWING OPERATIONS	4	(1) ÷ (2)
4. COST PER MOWING OPERATION	$ 53,928.91	Document C, line 5f
5. TOTAL COST DURING EFFECTIVENESS PERIOD	$215,715.64	(3) × (4)
6. SAVINGS	$107,587.82	(5) ÷ (2)
7. COST OF SPRAYING OPERATION	$ 49,397.33	Document C, line 5f

IF LINE 6 GREATER THAN LINE 7, THEN PGR IS COST-EFFECTIVE.

8. SAVINGS = $107,857.82 (LINE 6) − $49,397.33 (LINE 7) = $ 58,460.49

9. USE OF PROJECTED SAVINGS:

Project	*Cost*
Increase mowing on obstructed areas and fenced borders by 3 mowings to give once a week coverage during rapid growth season (100 acres @ $14,582.56 each mowing)	$ 43,747.68

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*The figures in parentheses indicate lines of this document.

Figure 6-5. Determining Cost Effectiveness for "Air Base Somewhere."

(1) On line 1, the effectiveness-period of the PGR is shown in weeks. It is obtained from table 6-2.

(2) Line 2 shows that the parcel would normally be mowed every 2 weeks. The normal number of mowing operations during the effectivness-period of the regulator is then calculated by dividing line 1 by line 2, and the result is entered on line 3.

(3) The total cost of each mowing operation is found on line 5f of figure 6-3 to be $53,928.91, and this is recorded on line 4. The cost of the 4 normal mowing operations during the effectiveness-period is computed to be $215,715.64 on line 5. The effectiveness-period is based on an effectiveness-rate of 50 percent, so the PGR is expected to reduce growth, and thus the number of mowings, by 50 percent during this 8 week period. The expected savings in mowing costs because of using the PGRs is, therefore, found by dividing line 5 by 2 and is entered on line 6. Comparing the savings of $107,852.82 with the $49,397.33 cost of the regulator application (line 5f in figure 6-4), shows a net savings on line 8 of $58,460.49. The use of the PGR, therefore, appears to be cost-effective in this example.

(4) The manager should consider his or her project priority list and determine if the freed assets can be usefully employed elsewhere. On line 9, a recommendation is made to use the anticipated savings to increase the frequency of mowing obstructed areas and fenced borders on the base. It is explained that those areas could be maintained every week during the rapid growth season rather than once every 2 weeks.

6-9. A Method of Estimating Cost-Effectiveness:

a. The information in document C can also be used to develop a table of costs that give a quick estimate of when it would be cost-effective to use regulators. For our example at Air Base Somewhere, we have used costs in document C (figures 6-3 and 6-4) to develop table 6-3, showing the costs of individual mowing and spraying operations.

b. In table 6-3, it can be seen that it costs $19.13 an acre to apply the PGR, and it costs $14.27 to mow the large grassy area with tractor mowers. The mowing costs increase significantly, however, as the cutters become smaller. When an effectiveness-rate of 50 percent is used, we can estimate that PGRs can save about half the mowing cost. The question is whether this cost reduction be greater than the cost of applying the PGRs. With table 6-3, the manager can quickly estimate the cost-effectiveness of using PGRs in a given parcel.

c. For example, using growth regulators in the large grassy area along the runways and taxiways, which are normally mowed with tractor mowers, would require a savings of about two mowing operations to be cost-effective. (Actually, it would require $19.13 divided by $14.27, or 1.34 mowings). If the mowing operation were normally carried out every 4 weeks, there would be two mowings during the effectiveness-period. One of those mowings would be eliminated, for a savings of $14.27 per acre. Inasmuch as the cost of applying the regulator is calculated in this illustration to be $19.13 per acre, it would not be cost-effective to use PGRs in this case. If the mowing frequency were every 2 weeks, however, then there would normally be four mowings during the 8-week effectiveness-period. Two of these mowings would be eliminated, for a savings of $28.54 per acre, if the regulator were used. In this case, the $19.13 per acre cost of applying the regulator would be offset by the $28.54 savings per acre, and it would be marginally cost-effective.

Table 6-3. Costs of Operations for "Air Base Somewhere."

Cost Category	Spray PGR	Tractor Mower	Riding Mower	Power Mower	Weedeater	Source Doc. C
Equipment	$4,038	$14,768	$3,512	$3,362	$126	line 1d
Chemicals	35,880	-	-	-	-	line 2d
Operators	7,079	12,290	5,100	9,360	843	line 3g
Vehicles	162	1,473	143	118	8	line 4e
Drivers	888	-	784	646	46	line 4i

Cost Category	Spray PGR	Tractor Mower	Riding Mower	Power Mower	Weedeater	Source Doc. C
Total cost*	$44,000	$28,531	$9,539	$13,486	$1,015	
Acres	2,300	2,000	200	100	2.3	
Cost per acre	$19.13	$14.27	$47.70	$134.86	$441.30	

*Supervisor costs were not included under the separate tasks.

d. Applying PGRs would be cost-effective in the areas where the smaller mowers are used, even if only one mowing were saved. Applying a PGR on these smaller areas, however, may be more costly per acre than it was for the entire 2300 acre area. Therefore, realistic costs must be developed for each parcel being considered before a final decision is made.

Chapter 7

CONTROLLING AQUATIC WEEDS

Section A—General Considerations

7-1. Aquatic Environments. Aquatic weeds vary greatly in their nature and in the type of aquatic environment in which they grow. Examples of different aquatic environments are: (1) banks above the waterline of canals and ponds; (2) shallow edges of canals, lakes, and ponds in which emersed plants grow rooted in bottom mud, extending their leaves and stems above the waters surface, (3) deeper areas of lakes and ponds, and (4) flowing water in canals and drainage ditches. The environment largely determines what weeds will be present and what methods will be most effective for their control.

7-2. Growth Habits of Aquatic Weeds. An aquatic weed may be a grass or grass-like plant (e.g., common reed, cattail, or sedge), a broadleaf (dicot), an emersed or floating plant with all or most of its foliage above the water, or a submersed plant growing entirely under the water surface. The submersed weeds vary from those rooted in bottom mud to the leafless, rootless algae. The microscopic algae give water a greenish color that varies in intensity from a barely discernible tinge to a pea-soup color and density. It may cause objectionable odors and tastes in drinking water. Filamentous algae produce threadlike or surface scums that interfere with fishing and obstruct underwater screens and sprinkler systems. Some algae grow on submerged rocks and on the bottoms and walls of concrete swimming pools, making them slippery and hazardous. The growth habit of an aquatic weed greatly influences the choice of control methods.

Section B—Construction Aids

7-3. Depth and Gradient. Deepening the edges of ponds, lakes, and reservoirs to 2 feet or more will prevent or reduce the growth of emersed weeds such as cattails, bulrushes, and water primrose. Deepening is also likely to narrow the border of submersed weeds so that they can be managed more easily. Providing a uniform gradient in the bottom of a canal or pond, eliminating high and low spots, permits thorough draining and marginally effective control of many submersed waterweeds (but not hydrilla) after 3 or 4 days of drying.

7-4. Bottom Liners. Lining ditches and canals with concrete or asphalt usually prevents or reduces the growth of rooted submersed weeds. Filamentous algae may grow on concrete linings and structures, however, and greatly reduce waterflow capacity. Also, silt deposits in lined canals can support obstructive growths of rooted submersed weeds in water as deep as 8 to 10 feet. A few species can grow at depths of 25 to 30 feet.

7-5. Shaping Banks and Reducing Obstructions. Shaping ditch-banks to provide uniform crowns and slopes, and maintaining roadways on one or both banks, are essential for efficient chaining, dragging, mowing, or spraying operations to control aquatic weeds. Careful designing and spacing of checks, weirs, turnouts, bridges, and other structures along canals minimizes interference with equipment used for mechanical or chemical control of aquatic weeds. Similar consideration can be given to the construction of pond and lake shorelines. Removing stumps, logs, and other obstructions from ponds, lake margins, and access channels facilitates using underwater mowers and weed harvesters.

Section C—Management Practices

7-6. Draining and Drying. To control cattails in ponds and marshy areas, remove the water, plow the ground, and let the area dry for a few weeks. Then maintain a water depth of 3 feet or more for several months, if possible. To control submersed weeds in canals with uniform flow gradients, drain the canals and allow them to dry for 3 to 5 days. Repeat this as necessary, when drainage or irrigation water is not needed.

7-7. Fertilizing and Shading:

a. In the southern states, mineral fertilizers are frequently applied in ponds to stimulate the growth of planktonic algae that shades the pond bottom and prevents or reduces the growth of rooted submersed weeds. This is a very useful practice in ponds that are used as fisheries. Fertilizing does not control submersed weeds, however, where the outflow or change of water in a month exceeds the water storage capacity of the canal or pond. Nor will fertilizing control weeds in cooler waters of the central and northern states.

b. To control rooted submersed weeds and waterlilies in ponds with stable water levels, apply 100 to 200 lb/a of nitrogen, phosphorous, and potassium fertilizer with an analysis of 8-8-2 beginning in late winter or early spring. Apply every 2 weeks until a white disc or plate placed 12-14 inches below the water surface is invisible. Then apply fertilizer as necessary to maintain the density of the algae. Do not overfertilize. An excessive algal growth is unattractive, can cause oxygen depletion and kill fish, and may clog pump inlet screens with filamentous algae. Growth of filamentous algae is a sign of overfertilizing.

c. Physical shading-out of submersed weeds can be achieved with floating styrofoam planks or balls, or plastic sheeting. It can also be achieved by using dyes such as nigrosine or eosine black.

Section D—Mechanical Removal

7-8. Hand Pulling. Although the traditional hand and mechanical methods of controlling aquatic weeds have been replaced to a large extent by herbicides, the hand and mechanical methods are still advantageous in many situations. Young plants of cattail, buttonbush, willow, and certain other emersed or marsh species can be eliminated by hand pulling. Frequent inspection of the channel, pond, or marsh, and pulling when plants are young and few in number, however, are necessary for effective and economical control.

7-9. Mowing and Draglining:

a. Self-propelled and float-mounted sickle-bar mowers, and harvesters that cut off submersed weeds below the water surface at depths of 6 inches to 6 feet, are available. They are restricted to operating in open water areas that are unobstructed by stumps and trees, and they are often limited by difficulty of access and the topography of the shoreline.

(1) To eliminate cattails, cut the stems off below the water surface during the early heading stage and again 1 to 2 months later when all regrowth is emersed. A third cutting is necessary if regrowth occurs a second time.

(2) Small patches of weeds such as waterlilies and watershield can be eliminated by cutting the leaves off below the water surface at frequent intervals. Five or six cuttings a year may be necessary.

(3) For temporary control of submersed waterweeds in large canals and rivers, around boat docks, and in fishing and swimming areas of ponds and lakes, mow as deeply as possible and remove dislodged weeds. In canals, the dislodged weeds should be trapped downstream and removed by draglining or other means to prevent them from lodging against structures, clogging the canal, and causing overflows, canal breaks, or washed-out structures. In ponds and lakes, weed debris that accumulates along the shoreline can be removed by draglining, cabling, conveying, harvester-type devices, or other mechanical means. Removing and disposing of mowed and harvested weeds is both difficult and costly.

(4) One or two harvests per year may be sufficient in the northern states, but two to four may be required in southern areas because of the longer growing season.

(5) A small harvester consisting of a cutter head and a conveyor belt to deposit cut weeds on a deck may cost less than $10,000, but sophisticated equipment costs more. It may be most cost-effective to accomplish this work by contracting with an aquatic-harvester company.

b. In canals with flows of water greater than 70 cubic feet per second, control of submersed weeds by mechanical methods often is less costly than chemical methods. In canals that supply water for sprinkler irrigation, however, mechanical methods are undesirable because fragments of dislodged weeds often clog sprinkler heads, valves, screens, and other irrigation equipment. Also, spread of infestations downstream may result.

c For removal of submersed waterweeds from irrigation and drainage canals, pull a heavy chain, drag, or disk upstream along the bottom of the canal with a tractor on each bank. Several trips are usually necessary to dislodge all weed growth. Trap the floating masses of weeds at strategic places downstream, and remove them mechanically or by hand.

Section E—Biological Control

7-10. Herbivorous Fish:

a. Several species of fish, notably the Chinese grass carp (white amur) and several species of *Tilapia*, are presently used to control algae and rooted aquatic weeds. *Tilapia* are tropical and are suitable only for certain warm waters in southern states. Adult *Tilapia* can survive and reproduce in fresh or brackish water that does not fall below 50° F.

b. The Chinese grass carp is adapted to a wide range of climatic conditions, and it has performed very well as a biological control for aquatic weeds. Few states now permit the introduction of the Chinese grass carp (and then only the sterile triploid form) because of uncertainty regarding its possible detrimental effects on native fish and the aquatic environment. In some of the southern states the Israeli carp is stocked to control filamentous algae.

c. Grass carp are normally stocked at a rate of 10 to 20 fish per acre. They eat submerged plants, but, if there is an inadequate supply of their preferred food, they will even feed on lily, cattail, and other emergent species. Do not stock them where aquatic plants are desired, and use a conservative stocking rate regardless of the severity of the weed problem.

d. These fish could be harmful in wetland areas and waterfowl habitat. Be sure to comply with state and federal regulations.

7-11. Other Biological Control Agents. The *Agasicles* beetle and stemborer, introduced to the United States from South America, are currently providing excellent control of Alligatorweed throughout much of this weed's range. Other biological control agents, such as plant pathogens and competitive vegetation, are under study.

Section F—Using Herbicides

7-12. Recommended Herbicides:

a. Herbicides often give more effective, longer lasting, and less expensive control of aquatic weeds than do mechanical or hand methods. In some ways, however, using herbicides to control aquatic weeds is more difficult and perhaps more hazardous than their terrestrial use. Copper sulfate was first used to control algae in 1904, and sodium arsenite was used to control waterhyacinth in 1902 and submersed weeds in 1927. However, most of the herbicides now registered by the Environmental Protection Agency for use in controlling one or more aquatic weeds were discovered since 1945.

b. Attachments 26 through 29 show herbicides that are recommended for use in ponds, lakes, and reservoirs; in drains and irrigation canals; on ditch-banks; and in reservoirs and canals carrying drinking water. Rates and times of application are given in general terms because local climates, water temperatures, site conditions, and water uses affect the performance and persistence of the herbicides and the procedures required for their safe and effective use.

c. Specific guidance should be obtained from state or federal aquatic weed specialists who are familiar with these local conditions. The county extension agent and the state fish and wildlife department are excellent sources of information.

d. Special precautions must be observed if the water is to be subsequently treated and used for human consumption. Normally, the chemical of choice in or near potable water is copper sulfate, fosamine, or AMS. Other compounds should be used only with prior approval of a MAJCOM or EFD pest management consultant.

7-13. Safety Considerations:

a. A few aquatic herbicides, such as acrolein, are poisonous to humans and other warm-blooded animals, and must be handled and used with caution and according to special procedures. Some herbicides are toxic to fish, but most do not injure fish at the concentrations required for weed control. Some injure fish food organisms, and a few may injure crops at low concentrations if they are used carefully.

b. Only limited information is available on the persistence and fate of herbicides in water, in aquatic soil, in fish, and in aquatic plants. Judgments on herbicide residues are subject to continual change on the basis of new information on the persistence of residues, toxicity to fish, etc. Labels on herbicide packages are kept up-to-date on such changes. Therefore, in addition to following all the precautions in chapter 1 for safely using herbicides, the user of an aquatic herbicide must determine that the treatment is necessary, and must carefully follow all instructions and restrictions on the label regarding aquatic situations in which the herbicide should and should not be used. The user must know how much time should elapse after herbicide treatment before treated water is used for drinking, fishing, swimming, or irrigating crops.

c. Local water quality regulations also must be considered. Herbicides should not be used in or near marshes and other wetland habitats unless their use has been clearly determined to be necessary.

Chapter 8

APPLICATION EQUIPMENT

8-1. General Information. The effectiveness of a herbicide depends largely on how well it is applied, and this, in turn, depends on the operator and the equipment.

a. Various types of equipment are available for applying herbicides (1) wet in sprays or mists, (2) dry, in dusts, pellets, or granules, and (3) as fumigants. An ideal applicator would distribute the herbicide uniformly on foliage, on or in the soil, or in water.

b. Spraying is the most common application method, and may be used for all herbicides except for some fumigants and aquatic treatments. Spraying not only permits reasonably uniform application, but a spray can be directed at a specific area. Sprays may be applied from sprinkler cans, hand pumps, and compressed-air and power sprayers.

c. The backpack sprayer is the most popular type of hand-operated sprayer. Many backpack sprayers use compressed air or gas to force the liquid out of the tank. Others have a pump with a hand-lever that is operated with one hand while the spray wand is held with the other. Hand-operated sprayers usually have a tank capacity of 3 or 4 gallons, and are most useful for spraying small, scattered weed patches and areas that are inaccessible to power equipment. Backpack sprayers are generally not appropriate for very toxic sprays.

d. Power-driven sprayers range from small, wheel-mounted rigs that are useful in turf and gardens, to large field sprayers. Field sprayers may be trailer-mounted, truck- or tractor-mounted, or self-propelled.

e. Sprayers are classified as low-volume or high-volume, depending on the amount of liquid (carrier and herbicide) they normally apply per unit area. Spray volumes range from 0.1 gallon to several hundred gallons per acre. Most weed sprayers are of the low-volume type (40 gallons or less per acre). High-volume sprayers are usually used where vegetation must be saturated.

f. Any water supply line used to fill sprayer tanks should have a backflow prevention device to prevent contamination of the facility water system.

8-2. Ground Spraying Equipment. Most sprayers consist of a container or tank to hold the spray liquid, some type of nozzle or nozzles to direct the spray, and a pump to force the spray through the nozzles. They usually have a pressure regulator, pressure gauge, shutoff valve, strainers or filters, and chemical-resistant connecting hoses.

a. Tanks and Agitators.

(1) The trend in sprayers is toward using corrosion-resistant materials throughout the system. Mild steel rusts and flakes off, causing delays and poor weed control because of frequent nozzle-clogging. Three materials currently used for spray tanks are stainless steel, aluminum, and fiberglass-reinforced plastic (FRP). Type 304 stainless steel and FRP resist corrosion by almost all types of agricultural chemicals. Aluminum is vulnerable to attack by some herbicide solutions.

(2) Agitation is always desirable to ensure homogeneity of the spray liquid, even if totally soluble materials are used. The two types of agitation are mechanical and hydraulic.

(a) Mechanical agitation is achieved by a series of paddles on a shaft running horizontally through the tank, or by means of a propeller on one end of the tank. The paddles or propeller are power-driven at low speed. Mechanical agitation is generally used for emulsions with a high percentage of oil and for wettable powders.

(b) Hydraulic agitation is accomplished by routing some of the pressurized spray liquid back into the tank. The number, size, and location of the orifices through which the liquid is routed back into the tank depends on the size and shape of the tank. Hydraulic agitation is most often used for readily soluble or self-emulsifying materials.

(3) All tanks should have a large filler opening to facilitate cleaning between uses of different chemicals.

b. Nozzles and Tips:

(1) Nozzles and nozzle tips are made of brass, aluminum, stainless steel, nylon, plastics, and rubber. For chemicals that are corrosive or abrasive, materials harder than brass should be used. Most wettable powders are abrasive, and AMS, for example, is corrosive to brass.

(2) The nozzle tip converts the sprary liquid into droplets and is thus the most important component of the sprayer. Nozzle tips should be selected to produce the spray pattern best suited to the particular application. The three basic spray patterns are fan-shaped, cone-shaped, and flooding.

(a) Nozzles producing a flat, fan-shaped spray are the most popular for weed control. They produce an even distribution across the width of the spray. When evenly spaced on spray booms, they distribute the herbicide across the boom swath. Sometimes they are designed to produce a lighter spray at the edges of the spray pattern, resulting in more uniform application where nozzle patterns overlap within the boom swath.

(b) Hollow-cone nozzles produce a cone-shaped spray, with the heaviest droplet distribution on the outer edges of the pattern. Coverage is less uniform than with the flat-fan nozzle, but cone nozzles operate more satisfactorily at low application rates of about 2 to 3 gallons per acre.

(c) Flooding nozzles deliver coarse droplets of spray under low pressure, thus minimizing drift. They produce a wide-angle fan pattern. Because the nozzle orifices are large, clogging is also reduced.

(3) There are a number of nozzles for special situations. The boomless or cluster nozzle, for example, is often used on rights-of-way where obstructions would interfere with the operation of a spray boom, and in grasslands where scattered trees would interfere with a boom. It provides a rather varible distribution of spray because its wide range of droplet sizes are affected differentially by wind. It is particularly useful on rough terrain that would be hazardous to spray booms.

(4) The pressure in the system determines the rate of flow through the nozzle orifice. Increasing or decreasing the pressure affects the size of spray droplets. Increasing the pressure produces a finer spray; to increase volume it is more effective to increase the size of the orifice. The distance that the spray is projected depends primarily on the pressure being delivered by the pump.

c. **Types of Pumps.** The four most common types of pumps are piston, centrifugal, gear, and impeller.

(1) Piston pumps are probably the most versatile, and before 1945 they were used on nearly all sprayers. They can deliver a wide range of pressures, from 40 to 1,000 lb/in^2 making them useful for chemicals other than herbicides. They are easily repaired, are resistant to wear by abrasive materials such as wettable powders, and have long service lives. Each stroke of the pump delivers a given amount of spray liquid, and, therefore, the output of the pump is directly proportional to its speed. Disadvantages of piston pumps are their low delivery rate and high initial cost, but their long service life usually offsets the latter. The low delivery rate, however, means that mechanical agitation is necessary if wettable powders are used.

(2) Centrifugal or turbine pumps develop pressure through centrifugal force created by rapidly rotating blades, fins, or disks. They are inexpensive and handle abrasive materials well. They provide a high delivery rate with enough excess flow to provide hydraulic agitation in the spray tank. To maintain adequate pressure, however, centrifugal pumps must be operated at higher speed than other pumps. They generally are not self-priming, and must be placed below the spray tank to ensure gravity flow to the pump.

(3) Gear pumps develop both vacuum and pressure through meshing gear teeth. They may be used advantageously for oil emulsions and other nonabrasive materials, but have a limited life under adverse usage, such as with wettable powders. Because they are cheap, gear pumps are usually replaced rather than repaired. Their delivery rate varies with size, but is usually adequate for hydraulic agitation.

(4) Impeller pumps have a rotor set to one side within the pump housing. The rotor has flexible rubber vanes or rollers that maintain contact with the wall of the housing. The space between the rotor and pump housing expands for half of every revolution and contracts for the other half, thus creating an alternation of vacuum and pressure. In recent years, the roller-type of impeller pump has become extremely popular. The rollers are made of nylon or rubber, and work best with oil emulsions and nonabrasive materials. Rubber rollers are the most satisfactory with abrasive materials. Worn parts can be replaced in most instances. Impeller pumps are moderately priced and provide sufficient volume for most applications.

d. **Pressure Regulators and Control Valves:**

(1) Pressure regulators, or relief valves, are used to maintain a relatively constant pressure at the nozzle. It generally consists of a ball that is held against an orifice by a spring that can be screw-adjusted to vary the pressure. Variations include a double-spring type and a combination of spring and diaphragm. Excess liquid is released back into the spray tank through a bypass port. A pressure gauge is usually placed on the outlet side of the regulator, between the regula-

tor and the spray boom, to indicate nozzle pressure.

(2) Two types of control valves are in general use. A quick-opening valve is used to turn the flow on or off to all nozzles, and selector valves control the flow to individual sections of a spray boom. Selection valves enable an operator to spray from any or all sections of a boom.

e. Hoses and Strainers:

(1) Hoses on sprayers should be of a material that will withstand the chemicals used, particularly petroleum solvents. Synthetic rubber and plastic are most common. Heavy-walled hoses or metal pipe are used for extremely high pressures.

(2) Strainers or filters are used between the tank and the pump as line filters and behind each nozzle orifice. Some have built-in valves to prevent nozzle dripping. In filling the tank, a coarse strainer should be used to filter the spray liquid. Wettable powders rarely pass through screens finer than 50 mesh. Screens for emulsions should be about 100 mesh.

f. Boomless Sprayers. Boomless sprayers with cluster nozzles are well adapted for spraying roadsides, ditchbanks, rights-of-way, fence rows, and areas where trees would interfere with the operation of booms.

(1) Boomless sprayers are less expensive, simpler to operate, and have less nozzle trouble than boom sprayers. They can pass between trees and shrubs, be maneuvered close to obstacles, and are practical for rough ground. They spray a 20- to 30-foot swath with large volumes that provide moderately good coverage.

(2) The equipment can be mounted on a four-wheel-drive vehicle or caterpillar-type tractor. The chief disadvantage of boomless sprayers is that the spray swath is greatly affected by wind. They should not be used when the wind may cause drift to nearby sensitive vegetation.

g. Boom Sprayers:

(1) Boom sprayers are adapted for large areas where completed coverage is necessary, and for turf areas adjacent to roads where applications can be made from tractor- or truck-side-mounted booms. These units have spray booms with evenly spaced nozzles.

(2) For roadside or ditchbank spraying, remotely controlled truck-mounted side-arm booms are advantageous. The boom may have nozzles evenly spaced along each segment of the arm, and may terminate in a boomless-type spray nozzle. It may be horizontal for roadside or ditch spraying, or vertical to spray above trees, shrubs, and tall weeds. Each boom segment is hydraulically controlled by an operator sitting next to the driver.

(3) For roadside spraying, two or more nozzles are grouped together and mounted on an arm that reaches over mailboxes, highway signs, and similar obstacles. A truck-mounted boom designed to spray under guard rails reaches over the rail and sprays from the outside toward the pavement.

h. Mist Blowers. Mist blowers disperse highly concentrated sprays in a finely atomized form at low volumes per acre. The herbicide is carried principally in an airstream instead of a liquid. These sprayers are free of boom and nozzle problems, require minimal amounts of water, cover vegetation rapidly, can be used for areas that are inaccessible to other power equipment, and are cheaper than conventional hydraulically powered equipment. They are very useful for spraying under fences, around stone piles, along roadsides, in drainage ditches, and under powerlines. The use of mist blowers for herbicides, however, is limited by the serious hazard of drift. Mist blowers in 5 to 12 horsepower sizes are useful for brush spraying where drift is not a problem. A 2-horsepower knapsack mist blower is useful for brush up to 30 feet tall, and for spot spraying.

i. Wipe-on Equipment. This equipment is a means of using nonselective herbicides with no drift hazard and with almost no soil residues. It is especially useful for controlling taller weeds and brush sprouts in low-growing grass and other ground covers.

(1) The rope wick applicator consists of several loosely woven wicks, the ends of which are inserted into holes in a large plastic pipe. The pipe contains the herbicide solution. The applicator is adjusted to a height just above the lower-growing, desirable vegetation, and kills only the taller plants that are wiped by the rope wick as it goes through the field. There are variations for specialized uses, such as around shrubs, small trees, and other obstructions. One such is the hand-held "hockey stick" applicator which has special padding fashioned for the curved lower end of a stick. This is moistened with herbicide through a plastic tube having a hand-operated valve. Such items are available commercially.

(2) The rolling carpet applicator is used in the same way as the rope wick applicator. It consists of a horizontal rotating, carpet-covered

roller that is continuously moistened by herbicide solution. The roller may be a foot or more in diameter.

j. Controlling Drift. No discussion of spray application would be complete without mentioning drift problems. Drift can result in considerable damage to susceptible plants outside the treatment area, and can lead to costly litigation.

(1) Drift is a function of droplet size and atmospheric conditions. Droplets 10 micrometers in diameter can drift up to 1 mile when released at a height of 10 feet in a 3 mi/h wind. The small the droplets, the more likely they are to be carried by air movement. Larger drops drift less, but they do not provide as uniform plant coverage.

(2) Research indicates that droplet size is affected by operating pressure; nozzle design; nozzle orientation; properties of the spray liquid; and atmospheric conditions.

(3) Few nozzles used for spraying will produce uniform droplets large enough to minimize drift, yet small enough to provide even coverage. A spray nozzle designed to produce a mean droplet diameter of 150 micrometers also produces many tiny droplets ranging from 1 to 2 micrometers and coarser droplets ranging from 300 to 400 micrometers. Efforts have been made to formulate sprays so that the drops produced by a particular type of nozzle will be large enough to reduce drift. These efforts have been only partly successful, because small drops commonly form from fluid pulled from the surface of the larger droplets. Also, evaporation of spray droplets decreases their size as they fall.

(4) The spray operator can use various measures to control droplet size. Water-soluble thickening agents are often added to spray liquids to increase average droplet size. A water-imbibing polymer is sometimes used to create particulated gel spray. The smallest droplet of such a spray is predetermined by the size of the polymer particle. The use of an invert-emulsion spray (water droplets suspended in a continuous oil phase) that has high viscosity will reduce drift. Decreasing the delivery pressure in spray systems will produce large droplets, and relatively high-volume "dribble bars" have been designed that operate under minimum pressure. Also, a vibrating nozzle designed to provide uniform droplet distribution from low-pressure streams offers promise for relatively drift-free applications.

8-3. Granule Application Equipment. A wide variety of applicators are used to broadcast granular herbicides. They are generally refined fertilizer applicators or seeders, and some simultaneously plant seeds, distribute fertilizers, and apply herbicides. Some include incorporation equipment. The major components are a band distributor or spatter plate that distributes the granules laterally and uniformly over the desired bandwidth, and an easily calibrated device that meters the granules.

a. Meters and Nozzles:

(1) Metering devices have reached a high level of precision, and several different types are used. Among these are a variable orifice with a rotor-bar agitator between the hopper and the orifice, a variable orifice with a rubber-flanged impeller, a variable orifice between the hopper and an oscillation plate, and a fixed orifice with a variable-speed screw-conveyor auger.

(2) Five types of nozzles or distributors are available for spreading granules. Distribution patterns in the field are usually more uneven than laboratory patterns, because some granules move laterally after hitting the ground. A chain drag may reduce the lateral movement of granules by roughening that convex surface left by press wheels. Studies have shown that down-the-row distribution is more uniform than across-the-row distribution.

(3) Wind speeds of 10 mi/h or more may cause considerable shifting of the distribution pattern. Special wind guards have been developed to prevent lateral movement of the granules under windy conditions.

b. Soil Incorporation Equipment:

(1) Granular herbicides are often mechanically incorporated into the soil to reduce their loss and to bring them into contact with germinating weed seedlings. Incorporation is needed if thiocarbamates or other volatile herbicides are applied. The incorporation method varies with the chemical and physical nature of the herbicide, the soil conditions and properties, the method of water application, and the crops and weeds involved.

(2) Attempts have been made to incorporate herbicides with almost every implement used to till the soil. Under proper conditions, desired results can be obtained with harrows, disks, subsurface blades, bed shapers, and power-driven rotary-tillers.

(3) With overhead irrigation, shall incorporation with a harrow or rotary-tiller may suffice to prevent the loss of volatile herbicides until water carries them deeper into the soil. With furrow irrigation, deeper and more thorough

mechanical incorporation is required. Disks or power-driven rotary-tillers usually provide the best results. Subsurface blades have been used under special conditions, but are still experimental.

8-4. Aquatic Application Equipment. Aquatic herbicide applicators may be boat- or barge-mounted blowers, sprayers, booms with injection systems, or granule spreaders having essentially the same features as ground equipment. Liquid aquatic herbicides also can be applied with a venturi pump/injector powered by propwash. Slow-release granular herbicides can be applied by a Buffalo turbine or by dragging them in a porous bag behind a boat. Aerial applications are sometimes made for general control of aquatic weeds.

8-5. Aerial Spraying Equipment. Aerial application equipment has improved steadily with the increased use of chemical sprays in all areas of agriculture. The use of appropriate equipment, its proper adjustment, and skill in carrying out the spraying operation are vital for satisfactory results. Because most aerial spraying will be done by specialists such as the Air Force Aerial Spray Branch (356 TAS/Aerial Spray, Rickenbacker ANGB OH 43217-5008) or contractors, this description is brief.

a. The components of airborne sprayers are much the same as those of ground equipment, and calibration methods are similar (see chapter 9). The application speeds of fixed wing aircraft, however, usually range from 90 to 200 mi/h, in contrast to ground sprayer speeds of 3 to 5 mi/h.

b. Spray pumps on aircraft are driven by a V-belt drive from the main engine, a small direct-connected propeller, an electric motor, or some other power source. Centrifugal pumps are usually used because of the high delivery rates required, and agitation is usually by hydraulic bypass from the pump.

c. Booms are generally shorter than the aircraft's wingspan so as to reduce the effects of the wingtip vortices. Although spray booms extending beyond the wingtips are used in applying some insecticides, they are not recommended for the precision swaths required for herbicide treatments. Nozzles should not be extended more than within 2 or 3 feet of the wingtips, because upward movement of air at the wingtip vortices results in considerable loss of spray to upper air currents and creates a serious drift hazard.

d. Some distortion of the swath by the slipstream occurs with all aircraft. This is especially true with single-engine aircraft, and the larger the aircraft engine, the greater is the amount of distortion. Nozzles that are evenly spaced on the boom do not provide an even spray pattern with some aircraft. Instead, they result in an uneven and streaked swath. To compensate for these effects, additional nozzles (or nozzles with larger tips) should be placed at certain points along the boom, as determined experimentally.

e. The nozzles are usually designed and placed to control droplet size. Too many droplets below 100 micrometers in diameter increases the risk of drift. High-velocity air passing over the face of a standard nozzle has more influence on droplet size than does orifice size or pressure. Droplet size can be altered by changing the angle or position of the nozzle in relation to the airstream. For herbicide application, nozzles should always be pointed away from the direction of flight.

f. Because aerial sprays are released from a greater height than ground sprays, drift hazards are an even greater problem. Also, the aircraft creates turbulence, propwash, and wingtip vortices, all of which increase the potential for drift to nontarget areas. Aerial spraying should always be carried out when the air is relatively still. Drift retardant additives are used to minimize the risk of drift under less than optimum spraying conditions.

g. Precise flagging is necessary to guarantee proper swaths during field spraying. Flagmen should always be equipped with an accurate measuring device for checking swath spacing. Flagmen should move upwind of the spraying to minimize exposure to the spray.

h. Ground-to-air communications enhance aerial application by allowing adjustments of spraying altitude and swath spacing, reporting of nozzle malfunctions, etc.

8-6. Fumigation Equipment:

a. Increased use of soil fumigants to control weeds, plant-feeding nematodes, and soil-inhabiting insects has resulted in numerous modifications of fumigant injectors to meet special requirements. Fumigant injectors may be hand- or power-operated and can be thought of as underground sprayers.

b. Fumigant injectors have a reservoir, a pump, and a metering device to control the delivery rate. The pump acts as the metering device in hand-operated injectors. Power injectors apply a continuous stream of fumigant in the bottom of the plow furrow or behind the shanks of a chisel cultivator. The delivery rate is determined by line pressure and the size of the orifice. Both the delivery rate and the speed of the tractor determine how many gallons of fumigant are applied per acre.

c. Various means may be used to prevent too rapid a loss of toxic vapors from the soil. Some power-operated fumigant injectors are equipped with devices that tamp and pack the soil. One such device consists of a float and a roller that simultaneously smooth and pack soil over the treated area. Other equipment has been designed to lay plastic sheeting behind the injector to cover the treated area.

d. For small area, special devices can be used to release fumigants under plastic covers that are sealed with soil at the edges. One such device punctures a 1-pound can of methyl bromide with a metal tube, the other end of which is connected to a plastic hose that extends under the edge of the plastic cover. Methyl bromide, being a liquid under pressure in the can, is discharged through the hose under the cover. Another device holds a can of methyl bromide in an upright position on top of a sharpened spike. After lightly placing a can of methyl bromide in the holder and placing both under the sealed cover, the operator releases the methyl bromide by applying enough pressure on the top of the can to puncture it.

8-7. Cleaning Equipment and Preparing It for Storage:

a. All spraying equipment should be cleaned after each use. If the chemical is water soluble, a thorough flushing and rinsing with water is sufficient. Herbicides such as 2,4-D, picloram, and dicamba, however, are very difficult to clean from equipment. In such cases, remove and clean the nozzles and then clean the rest of the equipment with an ammonia or charcoal rinse:

(1) Remove nozzles and scrub with kerosene.

(2) Ammonia rinse:

(a) Add 8 to 16 ounces of nonsudsing detergent to 30 to 40 gallons of water, run through the pump and bypass for 5 minutes, and then run out through the boom.

(b) Partly fill the tank with a solution of 1 to 2 percent household ammonia (1 to 2 quarts of household ammonia in 25 gallons of water, or 2 teaspoons per quart of water).

(c) Leave this solution in the sprayer (including hoses and boom) overnight.

(d) Rinse thoroughly with clean water.

(3) Charcoal rinse:

(a) Use at least one-third of a tank of water. For each 10 gallons of water, add 4 ounces of 100-mesh activated charcoal and 2 to 4 ounces of laundry detergent. Agitate this mixture vigorously to distribute the charcoal through the water.

(b) Wash the equipment for 2 minutes by swirling the liquid around so that it reaches all parts of the tank. Pump some of the liquid through the hoses and nozzles.

(c) Drain the tank and rinse the equipment with clean water.

b. Dispose of excess herbicide mixtures and rinseate according to Armed Forces Pest Management Board Technical Information Memorandum 21, Pesticide Disposal.

c. Preparing Equipment for Storage:

(1) Scrub the sprayer with a stiff-bristle brush. Coat all iron parts that were exposed to the chemical with a rust inhibitor or light oil. Remove all nozzles and disassemble, clean, and store them in light oil. (Before using the sprayer the next year, wash the nozzle(s) in a degreaser or high flash-point solvent to remove the oil).

(2) Fill the pump with a rust preventive.

(3) Remove the caps from the ends of booms, and stand the booms on end to remove sediment. Remove, clean, and reassemble all filters.

(4) If the sprayer is powered by a gasoline engine, drain the fuel tank and carburetor and pour a tablespoon of engine oil into each spark plug hole. Turn the engine over by hand to distribute oil on the cylinder walls.

(5) If the sprayer is to be stored outside, remove all rubber hoses and keep them in a cool dark place.

(6) Thoroughly clean dusters and spreaders before storage.

Chapter 9

MIXING MATERIALS, CALIBRATING EQUIPMENT, AND CALCULATING AQUATIC HERBICIDE REQUIREMENTS

Section A—Mixing Materials

9-1. Determining Tank Capacity:

a. When the capacity of a spray tank is not known, or the tank is not marked to indicate the number of gallons it contains, set the sprayer or tank on a level place and gradually fill it with known quantities of water. Mark the water levels in gallons or fractions of a gallon on the side of the tank or on a calibration rod or stick held upright in the center of the tank. The marks can then be used to determine the quantity in the tank when it is partially filled.

b. To quickly approximate the capacity of a spray tank in gallons, use the following calculations. All tank measurements are in inches.

(1) For rectangular tanks:

$$\text{Capacity in gallons} = \frac{\text{length x width x depth}}{231}$$

Example:

If a tank is 60 inches long, 36 inches wide, and 30 inches deep, the capacity is about $\frac{60 \text{ x } 36 \text{ x } 30}{231} = 280$ gal

(2) For cylindrical tanks:

$$\text{Capacity in gallons} = \frac{\text{length x square of radius}}{73}$$

Example:

If a tank is 60 inches long and 30 inches in diameter, the capacity is about $\frac{60 \text{ x } 15^2 = 197 \text{ gal}}{73}$

(3) For tanks with an elliptical cross section:

$$\text{Capacity in gallons} = \frac{\text{length x (square of long diameter + square of short diameter)}}{462}$$

Example:

If a tank is 60 inches long, 36 inches wide, 24 inches deep, and elliptical in shape, the capacity is about

$$\frac{60 \text{ x } (36^2 + 24^2)}{462} = 243 \text{ gal}$$

9-2. Mixing Procedures:

a. Never pour a liquid concentrate or dry herbicide formulation into an empty tank. Either fill the tank with half of the water to be used, add the herbicide, agitate, and complete the filling, or add the herbicide gradually as the tank is filled. Agitate or stir until all solid material is dissolved or suspended.

b. If a water-soluble powder or crystalline form of herbicide is to be used with a liquid herbicide, dissolve the solid material in the water first, and then add and mix the liquid.

c. If oil is to be used in an oil-water or invert emulsion, premix the emulsifier and the oil-soluble herbicide with the oil in a separate container, and then add it slowly to a partly filled tank of water with constant stirring or agitation. Before using, circulate the mixture until it is uniformly white.

d. Agitate suspensions of water-dispersible powders and oil-water emulsions constantly or frequently during spraying to maintain a uniform spray mixture. Use the spray mixture within 1 or 2 days because some herbicides mixtures lose strength and deteriorate when standing.

e. Recommendations for herbicide application rates are based on the active ingredient or acid equivalent contained, not on the total weight of the product.

Section B—Calibrating Equipment

9-3. The Importance of Calibration:

a. The results of using herbicides depend greatly on how well, or poorly, the herbicides are applied. This, in turn, depends on the suitability of the equipment for the particular situation and the skill and care with which the operator uses the equipment. This is especially true of sprayers. Accurate application at the desired rate and uniform distribution of the material are essential for good results. A sprayer must uniformly distribute any quantity from 5 to 100 gallons or more per acre, because various weeds and situations may require a wide range of dilution for proper plant coverage.

b. Sprayer and spreader outputs should be calibrated for each particular treatment operation. A good procedure is to make initial adjustments to suit the machine and job requirements, and then to make a trial run to determine the machine's actual output. The herbicide mixture should then be prepared accordingly. The calibration should be repeated frequently to guard against nozzle orifice wear and other factors that affect performance. This is especially important when wettable powders and abrasive sprays are used.

c. There are many methods of calibrating a sprayer. A method is given here for each of the basic types of ground and aerial sprayers. Equivalent measures are shown in attachment 30.

9-4. Boom-Type Power Sprayers:

a. Determine that all nozzles are discharging uniformly by spraying water through them at a uniform pressure and catching the discharge from each nozzle in a separate container. If the amount of discharge varies widely, replace all nozzle tips that give a much larger or smaller discharge.

b. Place the sprayer on level ground, and fill the spray tank completely with water. Adjust the pressure of the sprayer to what it will be when used in the field.

c. Drive and spray exactly one-eighth of a mile (660 ft) in a field or along a road, ditchbank, or other typical spray area at the speed that will be used when spraying, usually 3 to 5 mi/h. Begin measuring the distance at the point where the spraying begins. Mark the throttle settings and the gear used, or make a note of the speed, and use this when spraying.

d. Shut off the spray, return the sprayer to its original position on level ground, and measure the water that is required to refill the tank (a quart jar is satisfactory).

e. Calculate the output per acre as follows:

$$\text{Gallons per acre} = \frac{\text{Number of quarts used x 16.5}}{\text{width of spray swath in feet}}$$

Example:

Water used = 7.5 qt

Spray swath width = 20 ft

$$\text{Output per acre} = \frac{7.5 \text{ x } 16.5}{20} = 6.2 \text{ gal}$$

f. To determine the amount of herbicide needed in each tankful, divide the number of gallons the tank holds by the number of gallons per acre that your sprayer applied. This is the number of acres each tankful will spray. Multiply this by the amount of herbicide recommended per acre.

Example:

Tank capacity = 55 gal

Output = 6.2 gal/a

Recommended rate per acre = 2 pt

Herbicide needed per tank = $\frac{55}{6.2}$ x 2 = 17.7 pt, or 2.2 gal

g. In some row plantings, only narrow bands are sprayed, centered over each row, and the rate of treatment is in terms of the area actually treated and not acres of the crop. The rate of treatment is easily converted to a rate per acre of crop, however, if this is needed to calculate costs. With a 36-inch row spacing, if a 12-inch band is treated at a rate of 1.5 lb/a, the amount of chemical used per acre of cropland is $\frac{12}{36}$ x 1.5 = 0.5 lb.

9-5. Boom-Type Hand Sprayers:

a. Fill the sprayer to a marked point with water, maintain a constant tank pressure, and spray while walking steadily for 330 feet at the pace that will be used when spraying. Multiply 330 by the width of the spray swath in feet to obtain the area sprayed, and divide this by 43,560 (the number of square feet in an acre) to obtain the fraction of an acre sprayed.

b. Measure the amount of water required to refill the tank to the marked point. Convert pints or quarts to gallons by dividing by 8 or 4, respectively, and divide the gallons required by the fraction of an acre sprayed to find how many gallons were applied per acre.

Example:

Two nozzle boom, 20 inch spacing = swath width of 40 inches or 3.33 ft

Water required to refill = 5.5 pt, or 0.69 gal

Area sprayed = $\frac{3.33 \text{ x } 330}{43{,}560}$ = 0.025 acre

Applied per acre = $\frac{0.69 \text{ gal}}{0.025}$ = 27.6 gal

c. If too much spray is applied, walk faster or use smaller nozzle tips. Do the opposite to obtain more volume. For larger volumes, use nozzle tips that have larger orifices. Small changes in volume can be obtained with changes in pressure, but too low a pressure gives a poor spray pattern, and too high a pressure results in fine droplets prone to drift.

d. Determine the amount of herbicide required for each tankful by multiplying the area in acres that each tankful will spray by the recommended application rate per acre.

Example:

Tank capacity = 3 gal

Output = 27.6 gal

Area per tank = $\frac{3}{27.6}$ = 0.1 acre

Recommendedrate per acre = 2 pt

Herbicide needed per tank = 2 x 0.1 = 0.2 pt

9-6. Single-Nozzle Hand Sprayers. Fill the sprayer with water and apply it uniformly, in the same manner the herbicide will be applied, to a 1/100 acre area. An area measuring 43.6 feet by 10 feet is suitable. Determine the gallons applied per acre, and the amount of herbicide required per tankful, in the same manner as explained for boom-type hand sprayers.

9-7. Aerial Sprayers:

a. To determine the rate of flow per acre and per minute, put a known amount of spray or water in the tank or mark the level in the tank. Spray for a timed interval, for example 60 seconds (0.017 hours), while flying straight and level at the speed that will be used for spraying. Subtract the velocity of any headwind (or add any tailwind) from the airspeed to obtain the groundspeed. When the airplane lands, either measure the liquid remaining in the tank or measure the amount required to refill the tank to the same level. Compute the rate of spraying and the amount of herbicide needed as follows:

Area sprayed =

$$\frac{\text{groundspeed (mi/h) x ft per mile x swath width x time in hours}}{43{,}560 \text{ ft}^2 \text{ per acre}}$$

Applied per acre = $\frac{\text{gal used}}{\text{acres sprayed}}$

Herbicide needed per tank =

$\frac{\text{tank capacity in gal}}{\text{gal spray per acre}}$ x application rate per acre

Example:

Groundspeed = 75 mi/h

Width of effective swath = 40 ft

Time sprayed = 60 sec, or 1 min, or 0.017 hr

Gal used = 12.5

Tank capacity = 120 gal

Recommended rate per acre = 3 pt

Feet per mile = 5,280

Area sprayed = $\frac{75 \text{ x } 5{,}280 \text{ x } 40 \text{ x } 0.017}{43{,}560}$ = 6.18 acres

Applied per acre = $\frac{12.5}{6.18}$ = 2.0 gal

Herbicide needed per tank = $\frac{120}{2.0}$ x 3 = 180 pt, or 22.5 gal

b. Before spraying, equipment should be calibrated for swath width, volume and distribution of spray particles, and droplet size. Swath widths and droplet distribution patterns may be determined during calibration and at the application sites by using water-soluble marking dyes and rolls or sheets of white paper. The same drift-retardant additive should be used during the calibration as will be used during the actual application. A spray mixture of 8 ounces of nigrosine black per 50 gallons of water provides a distinctive pattern. With the boom and nozzle dispersing systems employed on mist aircraft, the effective swath width for uniform coverage is about the same as the wingspan, and should not exceed 1.5 wingspan width.

9-8. Dry Granule Spreaders. To obtain acceptable accuracy, mechanical broadcasters or spreaders for applying dry herbicide formulations must be calibrated with the actual material to be used and under the conditions that will be encountered in the field. Calibration is a simple procedure when calibration pans are available to catch the material for weighing during trial runs. A more complicated and wasteful procedure is required for spreaders that are not so equipped.

a. Mechanical Spreaders With Calibration Pans:

(1) Use a calibration pan, or, if one is not available, make one by cutting house gutter to the proper length, blocking the ends, and hanging it under the spreader with string or wire.

(2) Fill the spreader at least half full of the material to be applied. With the calibration pan in place, push or pull the spreader at the speed that will be used during application. Do this over terrain that is typical of that which will be treated, and go far enough to cover 1/100 acre, or 435.6 ft^2. For a spreader 3 feet wide, the distance should be 435.6 divided by 3, or 145.2 ft. For a spreader 8 feet wide, the distance would be 435.6 divided by 8, or 54.45 ft.

(3) Weigh the material in the calibration pan and multiply the weight by 100 to find the amount applied per acre.

(4) Adjust the feed mechanism as necessary and repeat the procedure until the desired rate is achieved.

b. Hand and Mechanical Spreaders Without Calibration Pans:

(1) Begin with a weighed amount of herbicide formulation. Apply the material to a measured area, preferably 435.6 ft^2 or 1/100 acre. Weigh the material remaining in the spreader, and subtract the weight from the initial weight to determine how much was applied. A shop vacuum-cleaner facilitates recovering the unused herbicide formulation. Make appropriate adjustments in the spreader, and repeat the procedure until the desired rate can be approximated in repeated trials.

(2) If the treatment period extends over several hours or days, occasionally check the rate being applied by weighing the amount to a measured area, and make any necessary adjustments.

Section C—Calculating Aquatic Herbicide Requirements

9-9. Applications Based on Water Surface Area. When the application rate is expressed in pounds or other units per surface acre, it is necessary to know the surface area of the body of water in acres. The amount of herbicide to be applied is determined by multiplying the application rate by the surface area.

a. The surface area of a rectangular body of water can be calculated by multiplying the length in feet by the width in feet and dividing the result by the number of square feet in an acre (43,560).

$$\text{Area in acres} = \frac{\text{length in ft x width in ft}}{43{,}560 \text{ ft}^2 \text{ per acre}}$$

b. The surface area of a circular body of water is calculated by multiplying the square of the radius in feet by 3.1416 and dividing the result by the number of square feet in an acre.

$$\text{Area in acres} = \frac{\text{3.1416 x square of radius in ft}}{43{,}560 \text{ ft}^2 \text{ per acre}}$$

c. The radius is one-half the diameter. For bodies of water that are somewhat round, but not perfectly so, an approximate radius can be determined by measuring the perimeter in feet and dividing it by 6.28. The area in acres can then be determined from the formula above.

9-10. Applications Based on Water Volume. For herbicide treatments based on pounds of herbicide per acre-foot of water, it is necessary to know the surface area of the body of water in acres and the average depth of the water. The volume of water to be treated can then be determined in acre-feet. An acre-foot of water is the amount of water that can cover an acre to a depth of 1 foot. The amount of herbicide to be applied is determined by multiplying the application rate by the acre-feet of water to be treated.

Example:

Water surface area = 2.5 acres
Average water depth = 3 ft
Total volume of water = 2.5 x 3 = 7.5 acre-feet
Application rate = 4 lb per acre-foot
Herbicide required = 7.5 x 4 = 30 lb

9-11. Applications Based on Concentration. To determine the amount of herbicide required to treat a body of water when the application rate is expressed in parts per million (p/m) by weight, use the following calculations:

1 acre-foot of water weighs 2,722,500 lb

1 p/m by weight of an acre-foot of water =

$$\frac{2{,}722{,}500 \text{ lb}}{1{,}000{,}000} = 2.7 \text{ lb}$$

Herbicide required = acre-feet of water to be treated x p/m by weight desired x 2.7 lb

Example:

Water surface area = 5 acres
Average water depth = 4 ft
Water to be treated = 5 x 4 = 20 acre-feet
Application rate = 2 p/m by weight
Herbicide required = 20 x 2 x 2.7 = 108 lb

9-12. Applications in Flowing Water. The volume of waterflow must be accurately determined before treating flowing water to control aquatic weeds. Herbicide requirements are based on the volume of flow.

a. Weirs and other devices can provide accurate measurements of waterflow, or, in the absence of such devices, the approximate volume of flow can be obtained by determining the cross-sectional area of the channel in square feet (average water depth in feet x average width of the channel in feet) and the velocity of flow. A convenient and fairly accurate measurement of velocity of flow may be made by placing a dense floating object, such as a waterlogged stick, in the center of the channel and measuring the length of time in seconds that are required for the object to travel a known number of feet. The velocity of the water in feet per second is found by dividing the distance traveled by the time required. This process should be repeated several times to obtain an average velocity in the section of channel where the width and depth measurements were made. The volume of flow can then be calculated as follows:

Water flow in ft^3/s = width in ft x depth in ft x velocity in ft/s x 0.9

b. When the application rate is expressed in terms of p/m by volume and minutes of treatment, then the amount of herbicide needed can be determined by the formula:

application rate in p/m by volume x water flow in ft^3/s x mins of treatment/2,220 = herbicide needed over a period of minutes.

Example:

$$\frac{740 \text{ p/m by volume} \times 10 \text{ ft}^3\text{/s} \times 30 \text{ minutes}}{2,220} =$$

100 gal of herbicide applied over a period of 30 minutes

c. When the application rate is expressed in terms of p/m by weight and minutes of treatment, then the following formula may be used:

Herbicide needed over a period of minutes = application rate in p/m by weight x water flow in ft^3/s x minutes of treatment/267

d. The amount of herbicide to be applied per minute during the treatment can be calculated as follows:

Volume (or weight) of herbicide to be applied per minute =

$$\frac{\text{total volume (or weight) of herbicide}}{\text{minutes of treatment}}$$

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SUMMARY OF CHANGES

This revision adds information on plant growth regulators and weed control in turf (chaps 5 & 6), horticultural plantings (chap 4, sec C), and aquatic sites (chap 7); and updates the text throughout.

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GLOSSARY OF TERMS

The definitions and explanations in this glossary apply to words as they are used in this manual. Some words have more comprehensive meanings when used in other contexts.

Absorption—The process by which a herbicide passes from one system into another, e.g., from the soil solution into a plant root cell or from the leaf surface into the leaf cells.

Acid equivalent (ae)—The theoretical yield of parent acid from the active ingredient content of a formulation.

Acre-foot—The amount of water that will cover an acre 1 foot deep.

Activate—The process by which a surface-applied herbicide become phytotoxic after a rainfall. Activation results from movement of the herbicide into the soil where it can be absorbed by roots, stems, or seeds, and not from any chemical change in the active ingredient.

Active ingredient (ai)—The chemical in a herbicide formulation primarily responsible for its phytotoxicity, and which is identified as the active ingredient on the product label.

Acute toxicity—The quality or potential of a substance to cause injury or illness shortly after exposure to a relatively large dose. (See chronic toxicity.)

Adjuvant—Any substance in a herbicide formulation, or added to the spray tank, to improve herbicidal activity or application characteristics.

Adsorption—The process by which a herbicide associates with a surface, e.g., a soil colloidal surface.

Annual—A plant that completes its lifecycle from seed to death in 1 year.

Aquatic weeds—Undesirable plants that grow in water.

Ballast—A strip 12 to 16 feet wide made up of coarse material or gravel on a railroad roadbed.

Band treatment—Applied to a linear restricted strip on or along a crop row rather than continuously over the field area.

Basal treatment—Applied to encircle the stem of a plant above and at ground-level such that foliage contact is minimal. A term used mostly to describe treatment of woody plants.

Berm—A narrow band along a bank, along the pavement on a highway, or along the ballast of a railroad.

Biennial—a plant that completes its lifecycle in 2 years.

Broadleaf plants—Botanically, those classified as dicotyledons. Morphologically those that have broad, often compound leaves.

Brush control—Control of woody plants such as brambles, sprout clumps, shrubs, trees, and vines.

Carrier—A gas, liquid, or solid substance used to dilute or suspend a herbicide during its application.

Chemical Name—The name applied to a herbicide active ingredient that describes its chemical structure according to rules prescribed by the American Chemical Society and published in the Chemical Abstracts Indexes.

Chlorosis—Absence of green color (chlorophyll) from foliage.

Chronic toxicity—The quality or potential of a substance to cause injury or illness after repeated exposure to small doses over an extended period of time. (See acute toxicity.)

Common name—An abbreviated name applied to plants or to a herbicide active ingredient. Often agreed on by the American National Standards Institute and the International Organization for Standardization.

Compatibility—Mixable in the formulation, or in the spray tank, for application in the same carrier without undesirably altering the characteristics or effects of the individual components.

Concentration—The amount of active ingredient or herbicide equivalent in a quantity of diluent, expressed as percent, lb/gal, kg/l, etc.

Contact herbicide—A herbicide that causes localized injury to plant tissue where contact occurs and that is not appreciably translocated within plants.

Cultivar—A variety of plant that has been produced only under cultivation.

Cultivation—Mechanical soil disturbance after the crop has been planted, and usually after crop emergence for the purpose of killing weeds.

Cut-surface applications—Treatments made to frills or girdles that have been made with an ax or other tool through the bark and into the wood of woody plants or to freshly cut stumps.

Desiccant—Any substance or mixture of substances used to accelerate the drying of plant tissue.

Detergent—A chemical (not soap) having the ability to remove soil or grime. Household detergents can be used as surfactants in herbicide sprays.

Diluent—Any gas, liquid, or solid material used to reduce the concentration of an active ingredient in a formulation.

Directed application—Precise application to a specific area or plant organ, such as to a row or bed or to the leaves or stems of the plants.

Dispersible Granule—A dry granular formulation which will separate or disperse to form a suspension when added to water.

Dormant spray—A herbicide applied during the period after leaf-fall or death of leaves and before bud-break or deciduous trees.

Emergence—The event in seedling or perennial growth when a shoot becomes visible by pushing through the soil surface.

Emulsifier—A substance which promotes the suspension of one liquid in another.

Emulsifiable concentrate (ec)—A single phase liquid formulation which forms an emulsion when added to water.

Emulsion—One liquid suspended as minute globules in another liquid; i.e., oil dispersed in water.

Epinasty—That state in which more rapid growth on one side of a plant organ or part (especially the leaf) causes it to bend or curl downward.

Extruded—A process in which a powdered carrier mixed with the herbicide is moistened until it becomes plastic and then is extruded as rods. These rods are dried, ground, and screened to the required size for a granular or pelleted formulation.

Flash point—The lowest temperature at which a liquid gives off ignitable vapors.

Floating plant—A free-floating or anchored aquatic plant adapted to grow with most of its vegetative tissue at or above the water surface, and lowering or rising with the water level.

Flowable—A two-phase formulation that contains solid herbicide suspended in liquid and which forms a suspension when added to water.

Formulation—(1) A herbicidal preparation supplied by a manufacturer ready for practical use. (2) The process, carried out by manufacturers, of preparing herbicides for practical use.

Fumigant—A volatile chemical that can be applied on or in soil to kill seeds and plant parts.

Germination—The process of initiating growth in seeds.

Granular—A dry formulation consisting of discrete particles generally less than 10 cubic millimeters and designed to be applied without a liquid carrier.

Growth regulator—An organic substance effective in minute amounts for controlling or modifying plant growth processes.

Herbaceous plant—A vascular plant that does not develop persistent woody tissue above ground.

Herbicide—A chemical used to control, suppress, or kill plants, or to severely interrupt their normal growth processes.

Herbicide Resistance—The tolerance of a population of plants for a particular herbicide. Sometimes resistance has developed because of natural selection of plants that are less susceptible to the herbicide than the average of the species when exposed through several reproductive cycles.

High volume spray—Refers to 100 or more gallons per acre, usually made by spray gun with adjustable nozzle(s) and either held by hand or mounted on turret.

Incorporate—To mix or blend a herbicide into the soil.

Invert emulsion—The suspension of minute water droplets in a continuous oil phase.

Label—The directions for using a pesticide approved as a result of the registration process.

Lateral movement—Movement of a herbicide through soil, generally in a horizontal plane, from the original site of application.

Layby application—Applied and incorporated with, or applied after, the last cultivation of a crop.

LC_{50}—The concentration of a chemical(s) in air (inhalation toxicity) or water (aquatic toxicity) that will kill 50 percent of the organisms in a specific test situation.

LD_{50}—The dose (quantity) of a chemical(s) calculated to be lethal to 50 percent of the organisms in a specific test situation. It is expressed in weight of the chemical (mg) per unit of body weight (kg) and the toxicant may be fed (oral LD_{50}), applied to the skin (dermal LD_{50}), or administered in the form of vapors (inhalation LD_{50}).

Leaching—Movement of a substance in solution downward through soil.

Low-volatile ester—Chemically, an ester with a heavy molecular weight, such as the butoxy-ethanol, iso-octyl, or propylene-glycol-butyl-ether esters.

Metabolite—A compound derived from metabolic transformation of a herbicide by plants or other organisms.

Mutagenic—Capable of causing genetic changes.

Necrosis—Localized death of tissue, usually characterized by browning and desiccation.

Nonselective herbicide—A herbicide that is generally toxic to all plants. Some selective herbicides may become nonselective if used at very high rates.

Nontarget species—Species not intentionally treated by a pesticide.

Noxious weed—A weed specified by law as being especially undesirable, troublesome, and difficult to control. Precise definition varies according to legal interpretations.

Overtop application—Applied over the top of transplanted or growing plants such as by airplane or a raised spray boom of ground rigs. A broadcast or banded application above the plant canopy.

Pelleted formulation—A dry formulation consisting of discrete particles, usually larger than 10 cubic millimeters, and designed to be applied without a liquid carrier.

Persistent herbicide—A herbicide that, when applied at the recommended rate, will harm susceptible plants planted in normal rotation after harvesting the treated plants, or that interferes with regrowth of native vegetation in noncrop sites for an extended period of time. (See residual herbicide.)

Pesticide interaction—The action or influence of one pesticide upon another, and the combined effect of the pesticides on the pest(s) or crop system.

Phytotoxic—Injurious or lethal to plants.

Plant growth regulator—A substance used for controlling or modifying plant growth processes without appreciable phytotoxic effect at the dosage applied.

Phloem—The living tissue in plants that functions primarily to transport metabolic compounds from the site of synthesis or storage to the site of utilization.

Postemergence (poe)—(1) Applied after emergence of the specified weed or seeded plants. (2)-Ability to control established weeds.

Preemergence (pe)—(1) Applied to the soil prior to emergence of the specified weed or ornamental plants. (2) Ability to control weeds before or soon after they emerge.

Preplant application—Applied before seeding or transplanting a crop, either as a foliar application to control existing vegetation or as a soil application.

Preplant incorporated (ppi)—Applied and tilled into the soil before seeding or transplanting.

Rate—The amount of active ingredient or acid equivalent applied per unit area or other treatment unit. Rates of formulation per area should not be sued in scientific publications.

Registration—The process designated by FIFRA and carried out by EPA by which a pesticide is legally approved for use.

Residue—That quantity of a herbicide remaining in or on the soil, plant parts, animal tissues, whole organisms, and surfaces.

Residual herbicide—A herbicide that persists in the soil and injures or kills germinating weed seedlings over a relatively short period of time. (See persistent herbicide.)

Selective herbicide—A chemical that is more toxic to some plant species than to others. Some nonselective herbicides at low rates may be selective.

Soil injection—Placement of the herbicide beneath the soil surface with a minimum of mixing or stirring of the soil, as with an injection blade, knife, or tine.

Soil-layered—Placement of the herbicide beneath the soil surface in a continuous layer with a minimum of mixing.

Soluble concentration—A liquid formulation that forms a solution when added to water.

Soluble powder—A dry formulation that forms a solution when added to water.

Solution—A homogeneous or single phase mixture of two or more substances.

Spot treatment—A herbicide applied to a restricted area(s) of a whole unit, i.e., treatment of spots or patches of weeds within a larger field.

Spray drift—Movement of airborne spray from the intended area of application.

Stem-foliage application—An application of a herbicide to both stems and leaves of a plant, usually a woody plant.

Submersed plant—An aquatic plant that grows with all or most of its vegetative tissue below the water surface.

Surfactant—A material which improves the emulsifying, dispersing, spreading, wetting, or other surface-modifying properties of liquids.

Susceptibility—The sensitivity to, or degree to which a plant is injured by, a herbicide treatment. (See tolerance.)

Suspension—A mixture containing finely divided particles evenly dispersed in a liquid.

Systemic herbicide—Synonymous with translocated herbicide, but more often used to describe the action of insecticides or fungicides.

Tank-mix combination—Mixing of two or more pesticides or agricultural chemicals in the spray tank at the time of application.

Tolerance—(1) Ability to withstand herbicide treatment without marked deviation from normal growth or function. (See susceptibility.) (2) The concentration of herbicide residue that will be allowed in or on agricultural products.

Toxicity—The quality or potential of a substance to cause injury or illness.

Toxicology—The study of the principles or mechanisms of toxicity.

Teratogenic—Capable of producing birth defects.

Trade name—A trademark applied to a herbicide formulation by its manufacturer.

Translocated herbicide—A herbicide that is moved within the plant. Translocated herbicides may be either phloem-mobile or xylem-mobile, but the term is frequently used in a more restrictive sense to refer to herbicides that are applied to the foliage and move downward through the phloem to underground parts.

Vapor drift—The movement of chemical vapors from the area of application. Some herbicides, when applied at normal rates and normal temperatures, have a sufficiently high vapor pressure to change them into a vapor that may cause injury to susceptible plants distant from the site of application. NOTE: Vapor injury and injury from spray drift are often difficult to distinguish.

Volatile—Capable of being readily vaporized.

Weed—Any plant that is objectionable or that interferes with the activities or welfare of man.

Weed control—The process of reducing weed growth or infestation to an acceptable level.

Weed eradication—The elimination of all live plant parts and viable seeds of a weed from a site.

Wetting agent—(1) A substance that reduces interfacial tensions and causes spray solutions or suspensions to make better contact with treated surfaces. (See surfactant.) (2) A substance in a wettable powder formulation that causes it to wet readily when added to water.

Wettable powder (wp)—A finely divided dry formulation that can be readily suspended in water.

Xylem—The nonliving tissue in plants that functions primarily to conduct water and mineral nutrients from roots to the shoot.

CROSS LISTING OF TRADE NAMES AND COMMON NAMES

Trade Name	Common Name	Trade Name	Common Name
AATREX	atrazine	AMIZOL	amitrole
AMDON	picloram	AMMATE X-NI	AMS
AMIBEN	chloramben	AQUATHOL	endothall
AMINO-TRIAZOLE	amitrole	AQUAZINE	simazine
AMITROL-T	amitrole	ASULOX	asulam
BALAN	benefin	BOLLS-EYE	cacodylic acid
BALFIN	benefin	BOROCIL	boron compounds
BANAFINE	benefin	BROADSIDE	methane arsonate
BANVEL	dicamba	BROMINAL	bromoxynil
BASAGRAN	bentazon	BROZONE	methyl bromide
BASF BASAMID	dazomet	BUCTRIL	bromoxynil
BETASAN	bensulide	BUENO	methane arsonate
BLUESTONE	copper compound		
CASORON	dichlobenil	CALAR	methane arsonate
CF 125	chlorflurenol	CUTLES	flurprimidol
CHIPCO TURF	mecoprop	CUTRINE PLUS	copper alkanolamine complex
CHLORO IPC	chlorpropham	CYTROL AMITROL-T	amitrole
DACONATE	methane arsonate	DEVRINOL	napropamide
DACTHAL	DCPA	DOWFUME	methyl bromide
DAL-E-RAD	methane arsonate	DUAL	metolachlor
DE-CUT	maleic hydrazide	DREXEL DIURON	diuron
ELANOLAN	trifluralin	ENIDE	diphenamid
EMBARK	mefluidide	EPTAM	EPTC
FURLOE	chlorpropham		
FUSILADE	fluazifop		
GARLON	triclopyr	GRAMOXONE	paraquat
GESAFRAM	prometon	GRASLAN	tebuthiuron
GESAPRIM	atrazine	GRAZON	picloram
GOAL	oxyfluorfen		
HYDOUT	endothall		
HYDROTHAL	endothall		
HYVAR-X	bromacil		
ISO-CORNOX	mecoprop		
KARMEX	diuron	K-LOX ALGACIDE	copper compound
KERB	pronamide	KOMEEN AQUATIC HERB	copper compound
KLEENUP	glyphosate	KRENITE	fosamine
LASSO	alachlor		
LIMIT	amidochlor		
LONTREL	clopyralid		

CROSS LISTING OF TRADE NAMES AND COMMON NAMES—CONTINUED

LOROX	linuron		
MAGNACIDE H	acrolein	MESAMATE	methane arsonate
MAINTAIN CF 125	chlorflurenol	MICO-FUME	dazomet
MAINTAIN 3	maleic hydrazide	MONOBOR-CHLORATE	boron compounds
MCPP	mecoprop	MYLONE	dazomet
METHAR	methane arsonate		
NAMATE	methane arsonate		
NEMASTER	methyl bromide		
NORTRON	ethofumesate		
OUST	sulfometuron		
PESTMASTER	methyl bromide	PRAMITOL	prometon
PHYTAR	cacodylic acid	PREFAR	bensulide
POAST	sethoxydim	PRINCEP	simazine
POLYBOR	boron compounds	PROGRESS	ethofumesate
QUILAN	benefin		
RAD-E-CATE	cacodylic acid	RONSTAR	oxadiazon
RETARD SLO-GRO	maleic hydrazide	ROUNDUP	glyphosate
REGLONE	diquat	RYZELAN	oryzalin
RODEO	glyphosate		
SLO-GRO	maleic hydrazide		
SPIKE	tebuthiuron		
SURFLAN	oryzalin		
TELAR	chlorsulfuron		
TREFANOCIDE	trifluralin	TRANS-VERT	methane arsonate
TREFLAN	trifluralin	TUPERSAN	siduron
TORDON	picloram		
UREABOR	boron compounds		
UROX	boron compounds		
VAPAM	metham		
VELPAR	hexazinone		
WEEDAZOL	amitrole		
WEED-E-RAD	methane arsonate		
WEED-HOE	methane arsonate		

TOXICITY RATINGS

	Extremely Toxic	Very Toxic	Moderately Toxic	Slightly Toxic
Oral LD_{50}[1]	$\leq$50 mg/kg	51-500mg/kg	501-5000 mg/kg	>5000 mg/kg
Inhalation LC_{50}[2]				
Dust or mist	$\leq$2 mg/1	3-20 mg/1	21-200 mg/1	>200 mg/l
Gas or vapor	$\leq$200 p/m	201-2000 p/m	2001-20,000 p/m	>20,000 p/m
Dermal LC_{50}	$\leq$200 mg/kg	201-2000 mg/kg	2001-20,000 mg/kg	>20,000 mg/kg
Eye effects	irreversible corneal opacity at 7 days	corneal opacity reversible within 7 days or irritation persisting for 7 days	no corneal opacity irritation reversible within 7 days	no irritation
Skin irritation	severe irritation or damage at 72 h	moderate irritation at 72 h	mild or slight irritation at 72 h	no irritation at 72 h
Probable lethal oral dose for humans	a taste to a teaspoon	2 tablespoon	1 pint	>1 pint
Human hazard signal word	Danger; Poison in red and skull and cross bones	Warning	Caution	no signal word required

[1] LD_{50} is the dose of a chemical calculated to be lethal to 50 percent of the organisms in a specific test situation. For comparative purposes, the LD_{50} for aspirin is 1240 mg/kg (moderately toxic) and for table salt is 3320 (moderately toxic).

[2] LC_{50} is the concentration of a chemical in air (inhalation toxicity) or water (aquatic toxicity) that will kill 50 percent of the organisms in a specific test situation.

CHEMICAL, PHYSICAL, AND BIOLOGICAL PROPERTIES OF HERBICIDES AND PLANT GROWTH REGU

Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Remar
Acrolein 2-propenal ($2.40/lb;water-miscible liquid)	MAGNACIDE H HERBICIDE Magnacorp.	46 extremely toxic	extremely toxic	A RESTRICTED HERBICIDE. C submersed and floating weeds ir and ditches. A highly reactive cher ization can proceed with explosiv ence of alkaline materials and s under oxygen-free nitrogen in ap Special closed system application t to transfer herbicide into flowing v general cell toxicant and destroys tems. Depending on temperature i in water 6 days. Deadly to fish organisms.
Alachlor 2-chloro-2′, 6′-diethyl-N-(methoxymethyl) = acetanilide ($5.60/lb; granular, emulsifiable concentrate)	LASSO Mons anto	930 moderately toxic	slightly toxic	Preemergence, soil treatment for s annual grasses, certain broadleaf nutsedge in broadleaf crops and ings. It is absorbed mainly by shoots and appears to inhibit p susceptible plants. It is a volatil adsorbed by soil colloids. It is bro ally, and usually persists in soil f
Amidochlor N-[acetylamino)methly]-2-chloro-N-(2,6-diethyl = phenyl) acetamide 4 F ($28.00/lb; water-based flowable)	LIMIT Monsanto	3,100 slightly toxic	slightly toxic	Is root absorbed and moves upwa resulting in reduced growth. Is colloids and is not susceptible to soils. Mocrobially degraded, with than 1 week. No known unic poisoning.

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CHEMICAL, PHYSICAL, AND BIOLOGICAL PROPERTIES OF HERBICIDES AND PLANT GROWTH REGULATORS—Continued

Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Remarks
Amitrole (3-amino-*s*-triazole ($10.25/lb; water soluble powder or liquid)	AMITROL-T AMIZOL WEEDAZOL Union Carbide AMINO TRIAZOLE CYTROL AMITROLE-T American Cyanamid Corporation	2,500 moderately toxic	moderately toxic	Nonselective, translocated, foliage applied, growth-regulator herbicide. Particularly effective in controlling poison ivy and certain other broadleaf weeds, grasses, and aquatic plants. Should not be applied if rain is expected within 12 hours. New leaves that appear after a plant has been treated may be bone white. Amitrole inhibits chlorophyll formation. It is broken down in soil within 2 to 3 weeks. Two-year feeding studies with rats show that amitrole is a weak goitrogen.
AMS Ammonium sulfamate ($1.00/lb; water-solluble crystals)	AMMATE X-NI DuPont	3,900 moderately toxic	slightly toxic	Used as a high-volume foliage spray for nonselective control of most woody plants, both hardwood and coniferous species. Also controls many herbaceous perennials. Crystals or concentrated solutions kill trees when placed in frills around trunk or on cut stumps. Can be used in areas adjacent to potable water reservoirs. Toxicity in soil disappears in about 6 to 8 weeks. AMS is very corrosive on equipment, and special cleaning and care is required. Stainless steel, aluminum, and bronze resist corrosion.
Asulam methyl sulfanilycar= bamate ($11.70/lb; water solution)	ASULOX ASULOX F (Canada) ASILAN (Japan) Rhone-Poulenc/ May & Baker	>8,000 slightly toxic	moderately toxic	Foliage spray, but may also be taken up by roots. Controls a number of perennial grasses, bracken fern, and a few broadleaf weeds. Site of action appears to be in meristem of plants, in which it interferes with cell division and expansion. It has a half-life in soil of 6 to 14 days.

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CHEMICAL, PHYSICAL, AND BIOLOGICAL PROPERTIES OF HERBICIDES AND PLANT GROWTH REGULAT

Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Rema
Atrazine 2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine ($2.20/lb; wettable powder, water dispersible granules, flowable liquid)	AATREX 80 W AATREX Nine-0 AATREX 4L AATREX 4LC GESAPRIM Ciba-Geigy Atrazine 4L Herbicide Atrazine 80W Shell CO-OP Liquid Atrazine CO-OP Atrazine 80WP Farmland Industries	3,080 moderately toxic	slightly toxic	Used as a preemergence soil tre control of broadleaf and grass many other crops, and for non weeds when used at higher ra areas, especially if mixed with ot as sodium chlorate and sodium n is absorbed through both roots a the latter may be small. It i inhibitor, but may have additi readily adsorbed on muck and c movement is thus limited. It i microorganisms. At low rates i persist from one season to the longer at higher rates and un conditions.
Benefin *N*-butyl-*N*-ethyl-α,α,α-trifluoro-2,6-dinitro-p-toluidine ($10.00/lb; granular, emulsifiable concentrate)	BALAN BALFIN BANAFINE (Japan) QUILAN (Spain) ELANCO	10,000 slightly toxic	none	Preemergence, soil-applied herbi annual-grass and certain broadle broadleaf corps and in establish weed control if it is incorporated affects growth processes associat nation. It is not translocated i strongly adsorbed on soil, and le Benefin gives season-long weed c persist beyond a single season. N mals and birds, but toxic to fish water. No hazard under normal u

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CHEMICAL, PHYSICAL, AND BIOLOGICAL PROPERTIES OF HERBICIDES AND PLANT GROWTH REGULATORS—Continued

Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Remarks
Bensulide *O,O*-diisopropyl phos= phorodithioate-*S*-ester with *N*-(2 mercaptoethyl) benzenesulfonamide ($7.00/lb; granular, emulsifiable concentrate)	PREFAR BETASAN Stauffer LESCOSAN Lesco	770 moderately toxic	moderately toxic	Bensulide is a preemergence, selective, soil-applied herbicide for control of annual-grasses and some broadleaf weeds in some vegetable crops, and grass and dichondra lawns. A small amount is absorbed by roots of weeds, but little or none is translocated upward to leaves. It inhibits the growth of weed roots, but the mechanism of action is not known. Bensulide is degraded slowly by microorganisms in the soil. There is little loss from the soil surface by volatilization, but there is a small amount of photodecomposition. There is little leaching in soil. Its half-life in moist soil is 4 to 6 months.
Bentazon 3-isopropyl 1*H*-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide (19.50/lb; water solution of sodium salt)	BASAGRAN BASF	1,100 moderately toxic	moderately toxic	Selective foliage treatment that controls a number of broadleaf weeds and nutsedge by contact action in most turfgrasses and many large-seeded legume crops. Rain shortly after application may decrease effectiveness. Little basal movement with foliar application, but movement upward through xylem tissue is rapid after root absorption. It inhibits the Hill reaction, and thus interferes with photosynthesis.

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CHEMICAL, PHYSICAL, AND BIOLOGICAL PROPERTIES OF HERBICIDES AND PLANT GROWTH REGULATORS—Continued

Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Remarks
Boron compounds such as sodium metabo= rate tetrahydrate, sodium tetraborate, disodium octaborate tetrahydrate, borate-bromacil mixtures ($1.80/lb; granular, soluble powder, miscible liquid)	BOROCIL MONOBOR-CHLORATE UREABOR Occidental POLYBOR U.S. Borax UROX Hopkins	2,000 moderately toxic	slightly toxic	Nonselective soil sterilants for control of herbaceous weeds in noncropland sites and for use under asphalt paving. It is adsorbed by mineral portion of soil and is slowly leached. It usually persists for more than a year. Less persistent with the coarser soils, low pH, and high rainfall. Usually mixed with more phytotoxic herbicides, such as sodium chlorate, bromacil, and diuron, to increase range of weed species controlled and for greater effectiveness.
Bromacil 5-bromo-3-*sec*-butyl-6-methyluracil ($13.75/lb; wettable powder)	HYVAR-X Weed Killer DuPont	5,200 slightly toxic	slightly toxic	Soil-applied soil sterilant when used at higher rates on noncropland for control of annual and perennial weeds and certain woody plants; and, at lower rates, for selective control of annual and perennial weeds in citrus orchards, and for seedling weeds in pineapple. It is sprayed or spread dry as granules on the soil surface, preferably just before or during active growth period of weeds. It is readily absorbed through roots. It inhibits photosynthesis. Bromacil is less subject to adsorption on soil colloids than many other herbicides. It leaches slowly, and, at soil sterilant rates, it persists for more than 1 year.
Bromoxynil 3,5-dibromo-4-hydroxybenzonitrile ($21.25/lb; emulsifiable concentrate)	BUCTRIL Rhone-Poulenc/ May & Baker BROMINAL Union Carbide	440 very toxic	moderately toxic	Foliage-applied herbicides for control of seedling broadleaf weeds in cereal crops and flax, and newly seeded turfgrasses. Also registered for control of such weeds as Russian thistle on noncropland sites. It is a contact herbicide and acts as a photosynthetic and respiratory inhibitor. It has no residual activity in soil.

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CHEMICAL, PHYSICAL, AND BIOLOGICAL PROPERTIES OF HERBICIDES AND PLANT GROWTH REGULATORS—Continued

Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Remarks
Cacodylic acid hydroxydimethylarsine oxide ($7.00/lb; water-soluble liquid)	RAD-E-CATE Vineland PHYTAR 560 BOLLS-EYE Crystal Chemical	830 moderately toxic	slightly toxic	Contact foliage herbicide which rapidly defoliates or desiccates a wide variety of plant species. It is used in cotton defoliation, lawn renovation, and general weed control in noncrop areas, such as around buildings, near perennial ornamentals, and along fence rows. Quickly inactivated in the soil.
Chlorsulfuron 2-chloro-*N*-[(4-meth= oxy-6-methyl-1,3,5-triazin-2-yl)amino-carbonyl] benzenesul= fonamide ($264.00/lb; dry flowable)	TELAR GLEAN DuPont	5,545 slightly toxic	moderately toxic	Postemergence treatments control annual and some perennial broadleaf weeds. Some annual-grasses are also controlled. Spring treatments control wild garlic. Can be used in noncroplands such as airports, fencerows, parade ground turf, and storage areas. Bahiagrass, bermudagrass, bluegrass, fescue, and smooth brome are tolerant species. Do not apply where runoff water will drain across treated areas to any body of water, agricultural lands, flower beds, or where roots of shrubs and trees grow into contaminated soil. Primary mechanism of action is inhibition of cell division. Tolerant species metabolize the compound to nonherbicidal metabolites. Hydrolysis into nonherbicidal compounds is major form of degradation, followed by normal soil, microbial processes. Half-life in soil is 4 to 6 weeks. Rate of degradation is increased by high soil temperature, pH, oxygen level, and moisture.

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CHEMICAL, PHYSICAL, AND BIOLOGICAL PROPERTIES OF HERBICIDES AND PLANT GROWTH REGULATORS—Continued

Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Remarks
Chloramben 3-amino-2,5-dichloro= benzoic acid ($8.25/lb; granular, emulsifiable concentrate)	AMIBEN AMIBEN GRANULAR ORNAMENTAL WEEDER WEEDONE GARDEN WEEDER Union Carbide	3,500 moderately toxic	moderately toxic	Preemergence weed control in soybeans, vegetable crops, and ornamentals. Some foliar absorption resulting in epinasty. It inhibits root development of seedling weeds. It is broken down by microorganisms. Effective weed control for about 6 weeks.
Chlorflurenol methyl 2-chloro-9- hydroxy-fluorine-9- carboxylate ($90.00/lb; IEC, emulsifiable concentrate)	CF125 Maintain CF125 Uniroyal	>12,800 slightly toxic	slightly ltoxic	Growth regulator applied in a tank mix with maleic hydrazide for foliar growth and seedhead suppression and broadleaf weed control in turf. Has a short soil residual, is not readily leached, and is degraded by microorganisms and light. Does not provide as good foliar and seedhead suppression alone as maleic hydrazide.

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CHEMICAL, PHYSICAL, AND BIOLOGICAL PROPERTIES OF HERBICIDES AND PLANT GROWTH REGULATC

Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Remar
Chlorpropham isopropyl *m*-chloro= carbanilate ($19.50/lb; granular, emulsifiable concentrate)	FURLOE CHLORO IPC SPROUT NIP PPG	3,800 moderately toxic	slightly toxic	Preemergence, soil-applied herbi germinating annual-grasses and weeds in leguminous crops, vege mental plantings, and established seed. It controls chickweed and pu of growth. Chlorpropham is abs coleoptiles of emerging grass plan roots of older plants. It is re upward in the plant. It inhibits growth, and suppresses transpirati It also disrupts cell division, and protein synthesis. It is adsorbed and broken down by microorganis herbicide with a half-life in soil of
Clopyralid 3,6-dichloro-2-pyridinecarboxylic acid ($130.00/lb; dispersible granule)	LONTREL Dow	>4,300 moderately toxic	slightly toxic	Auxin-type selective herbicide use for control of many annual and p woody plants. Absorbed by both Especially effective against membe ceae, compositae (Canada thistle (mesquite) families while show against species of grasses and cr Its use with 2,4-D, MCPA, and d spectrum of species controlled. P thought to be similar to the phenc strongly adsorbed by soil and co leaching. It is degraded by micro half-life of 12 to 70 days.

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CHEMICAL, PHYSICAL, AND BIOLOGICAL PROPERTIES OF HERBICIDES AND PLANT GROWTH REGULATORS—Continued

Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Remarks
Copper compounds cupric sulfate penta= hydrate; CopperII alkanolamine complex ($135/lb elemental copper for aminecomplex, $110/lb elemental copperas; copper sulfate pentahydrate)	COPPER SULFATE Crystals Cities Service BLUESTONE at least 22 companies CUTRINE-Plus Applied Bio-chemists KOMEEN AQUATIC HERBICIDE K-LOX ALGACIDE Sandoz	Copper sulfate 470; very toxic	very slight toxicity	Used mainly for control of algae growths in water. When applied in continuous low doses, controls pondweed in irrigation canals. When applying in fish-containing waters, note cautions on rates tolerated by different fish species. Potable water has a tolerance of 1 ppm of copper. Effectiveness of copper decreases as water hardness increases. Very corrosive to plain steel and galvanized pipe. Use 304 stainless steel, monel, or plastic. Copper is strongly adsorbed by clay and humus. It is precipitated on clay particles.

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CHEMICAL, PHYSICAL, AND BIOLOGICAL PROPERTIES OF HERBICIDES AND PLANT GROWTH REGULAT

Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Remar
2,4-D (2,4-dichlorophenoxy)= acetic acid ($2.50/lb; water soluble liquid, emulsifiable concentrate, granular)	many	300–1,000; very toxic to moderately toxic	slight, some formulations may cause skin irritation	2,4-D is a foliage applied, syste selectively controls most broadle crops and other grasses. It also aquatic plants. Most dicot cro killed. The salt and low volatile are of sufficiently low volatility tl may be used near fairly suscepti drift is prevented. Salt formulati cantly volatilize even on the warı plications are of marginal effecti absorption, 2,4-D translocates along with photosynthates. It caus responses and increases respirat reserves, and affects cell divisio mode of action has not been 2,4-D undergoes microbial bre moist soil. It generally persists in
Dazomet tetrahydro-3,5-dimethyl-2*H*-1,3,5-thiadiazine-2-thione ($4.00/lb; granular, wettable powder, emulsifiable concentrate)	MYLONE 50D MYLONE 85W Hopkins MYLONE Stauffer Chemical Co. DAZOMET Powder BASF BASAMID MICO-FUME Miller Chemical & Fertilizer	650 moderately toxic	moderately toxic	A preplant soil fumigant that kil nematodes, soil fungi, and certa should be cultivated and moist. rated in the soil, using convent weeks before planting in summ weeks in spring. If soil is dry, field with 1/2 inch of water. irritation to skin and eyes. Use gles, dust respirator, and label. It closer than within 3–4 feet of desi dripline of trees and shrubs.

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CHEMICAL, PHYSICAL, AND BIOLOGICAL PROPERTIES OF HERBICIDES AND PLANT GROWTH REGULATOR

Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Remarks
DCPA (Chlorthal) dimethyl tetrachloro= terephthalate ($6.35/lb; granular, wettable powder)	DACTHAL Fermenta	>3,000 moderately toxic	slightly toxic	Preemergence, soil-applied herbicid weed grasses and certain broadleaf ornamentals, and certain other cro tive and safe on many annual and mentals. It is not absorbed by folia ted in the plant. It kills germinating mechanism of action is not know volatize nor leach in soil. It is broke ally in the soil; average half-life is 10
Dicamba 3,6-dichloro-*o*-anisic acid ($13.75/lb; granular, water-soluble liquid)	BANVEL BANVEL II Velsicol	2,900 moderately toxic	moderate, highly irritating to eye	Dicamba is used either as soil tre foliage spray for selective contr weeds. It is more effective on s 2,4-D, less so on others. It is used s crops, turf, grazing lands, and non leaf crops and ornamental and g quite sensitive. Injury can occur fro of dicamba residue in soil, or from of drift or vapor. It is absorbed by and is translocated. The killing act 2,4-D. It inhibits development of b swelling, and eventually kills all p camba is water soluble and mob persists longer than 2,4-D. Persis under cool and dry, or very moist, broken down by soil microorganisms

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CHEMICAL, PHYSICAL, AND BIOLOGICAL PROPERTIES OF HERBICIDES AND PLANT GROWTH REGULATORS—Continued

Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Remarks
Dichlobenil 2,6-dichlorobenzo = nitrile ($31.00/lb; granular, wettable powder)	CASORON Philips-Duphar Uniroyal	3,160 moderately toxic	moderately toxic	A soil-applied herbicide on established plants and in aquatic situations. Main uses are in fruit crops and ornamentals. Applied to soil before expected rain or irrigation. Dichlobenil is absorbed from the soil by roots and is rapidly translocated to the tops. It inhibits growth of growing points and root tips, with gross disruption of plant tissues. It leaches slowly in the soil, but there is considerable diffusion in the vapor phase. Loss of dichlobenil from the soil surface can be rapid by volatility. Its half-life in soil ranges between 1.5 and 12 months.
Diphenamid *N,N*-dimethyl-2,2- diphenylacetamide ($8.00/lb; wettable powder)	ENIDE Upjohn	970 moderately toxic	slightly toxic	A selective preemergence herbicide that controls grasses and several broadleaf weeds mainly in vegetable crops, fruit crops, woody ornamentals, and dicondra. Rain, sprinkler irrigation, or soil incorporation soon after application increases effectiveness. It is mainly absorbed by roots and translocated upward in the plant. It leaches rapidly in sandy soil and more slowly in finer soils. Diphenanid is nonvolatile, but is degraded in soil microbially. Normal persistence in soil is 3 to 6 months.
Diquat 6,7-dihydrodipyrido = [1,2-α:2′b ,1′-c] = pyrazinediium ion ($34.00/lb; water-soluble liquid)	ORTHO Diquat Chevron Chemical Co. REGLONE I.C.I.	230; very toxic	very toxic	A nonselective, foliage-applied, contact herbicide for control of weeds in noncropland. Also a general aquatic herbicide and a preharvest desiccant of seed crops. Very rapidly absorbed by foliage and rapidly kills contacted plant tissues. Translocation via xylem can occur. Diquat is rapidly and completely inactivated by soil.

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Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Remark
DSMA (see methane arsonates)				
Diuron 3-(3,4-dichlorophenyl)-1,1-dimethylurea ($4.70/lb; wettable powder, flowable liquid)	KARMEX Weed Killer DuPont; DREXEL DIURON 4L Drexel	3,400 moderately toxic	moderately toxic	Soil-applied herbicide for control leaf and grass weeds in cotton, s apples, pears, citrus, and alfalfa. can be used as a general weed kille less effective than bromacil. It has uses. Diuron is a strong inhibitor Adsorption on soil increases as organic matter content increases. primary cause of diuron disappe Leaching is very slow. When appli rates, it may persist for more than
Fenoxaprop-ethyl (±)-ethyl 2-[4-[(6-Chloro-2-benzoxazolyl) oxyl] phenoxy] propanoate ($276.41/lb emulsifiable concentrate liquid)	ACCLAIM Holchst-Rousell Agri-Vet	2,500 moderately toxic	slightly toxic	Selective postemergence annual an control in several cool season Approved for use in sod farms, residential turf and rights-of-way primarily through foliage, but is from one tiller to another. There that all exposed foliage be thoroug covered. The product should not periods of severe drought stress. K should not be seeded for a mini following application.

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Endothall 7-oxabicyclo[2.2.1] heptane-2,3-di= carboxylic acid ($14.00/lb; granular, water-soluble liquid)	ACCELERATE DES-I-CATE Endothal Turf Herbicide Endothal Weed Killer HYDROTHOL HYDOUT AQUATHOL	38–51 extremely toxic	very toxic	Postemergence and preemergence h weeds such as speedwells, but r control of aquatic weeds. It disappe water by microbial degradation. Ra is dependent upon temperature. amine formulations are used for ac trol. It has a short residual life in v formulation is more toxic to fish.
EPTC *S*-ethyl dipropyl= thiocarbamate ($4.85/lb; emulsi= fiable concentrate)	EPTAM ERADICANE Stauffer	1,630 moderately toxic	slightly toxic	A soil-applied, selective, preemerge control of germinating grass seedl broadleaf weeds in many crops plants. Effectiveness is improved b tion immediately after application sprinkler application. EPTC is absor translocated to leaves and stems. action is not known. It readily vol surface of wet soil. Microbial degra responsible for disappearance in soi soil is about 1 week.
Ethofumesate (±)-2-ethoxy-2,3- dihydro-3,3-dimethyl-5- benzofuranyl methane= sulfonate ($42.00/lb; emulsifiable concentrate, flowable liquid, granular)	NORTRON BFC Chemicals PROGRASS Nor-am	>6,400 slightly toxic	slightly toxic	Pre- and postemergence herbicide i ryegrass for control of broadleaf an including annual bluegrass. Absorb emerging shoot and by roots of m of action is not known. Sugarbe metabolize ethofumesate. It does r having 1 percent or more organic r by microorganisms in about 3 montl

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CHEMICAL, PHYSICAL, AND BIOLOGICAL PROPERTIES OF HERBICIDES AND PLANT GROWTH REGULATOR

Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Remarks
Fluazifop (±)-2-[4-[[5-(trifluoro= methyl)-2-pyridinyl]oxy] phenoxy]propanoic acid ($74.75/lb; water-miscible liquid)	FUSILADE I.C.I. Americas Inc.	3,328 moderately toxic	moderately toxic	A highly selective, postemergence g kill both annual and perennial gras no injury to broadleaf plants. Nonic crop oil concentrate is recommended the water carrier. Fluazifop is c through the leaf surface, and rain hour after application reduces e slightly. All broadleaf crops test tolerant. Fluazifop is rapidly degrad with a half-life of less than a wee residual activity depends on soil c rainfall. Susceptible rotational crop 60 days after treatment.
Fosamine ethyl hydrogen (aminocarbonyl)= phosphonate ($10.00/lb; water-miscible liquid)	KRENITE DuPont	1,690 moderately toxic	slightly toxic	A late summer to fall foliage-appl control of woody plants. Add a no to the spray mixture. It is somew brass or copper sprayer parts. C sorbed by foliage, stems, and bu plants; with little or no apparent following spring, when bud devel prevented or severely limited to pr spindly leaves. Some plants, such pines, may show response soon Susceptible woody plants fail to ref quently die. Fosamine is rapidly de microorganisms and has a half-life i week.

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CHEMICAL, PHYSICAL, AND BIOLOGICAL PROPERTIES OF HERBICIDES AND PLANT GROWTH REGULATO

Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Remark
Glyphosate N-(phosphonylmethyl) = glycind ($26.30/lb water-soluble liquid)	RODEO ROUNDUP Monsanto KLEENUP ORTHO (Chevron Chemical Co.)	4,320 moderately toxic	slightly toxic	A nonselective, foliage-applied herb deep-rooted perennials and annual cies of grasses, sedges and broadlea safely applied as a directed spra plants, and is adapted for use wit ment where there is a height differe weeds and shorter crops. It should spray only before emergence of crop destruction will result. It can also aquatic weed herbicide. It is inacti used in spray mixtures with herbicid triazines, and others, its activity m is absorbed through foliage a throughout the plant. Visible effect 7 to 10 days. Rainfall occurring wit treatment reduces effectiveness. It through roots. It is strongly adsor degraded microbially. Most crops ca treated soil directly after treatment. iron and galvanized steel.
Glyphosate, Sodium sesquisalt of N-(phosphonomethyl) glycine ($40.00/lb; 75 percent water soluble powder)	MANAGE Monsanto	same	same	For foliar growth and seedhead su fescue and smooth bromegrass gr rights-of-way and industrial sites. lawns or other turf sites where ae important.

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Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Remar
Hexazinone 3-cyclohexyl-6-(dimethyl= amino)-1-methyl-1,3,5-triazine-2,4(1*H*,3*H*)-dione ($22.50/lb; water-soluble powder, miscible liquid, pellets)	VELPAR DuPont	1,690 moderately toxic	slightly toxic	It is applied as a foliage spray or a control of many broadleaf and gr as woody vines in noncropland ar on Johnsongrass. At higher rates woody plants. Where properly app selectively in Christmas tree plant tation west of the Rocky Mount absorbed through both foliage translocated primarily upward thr appears to be a photosynthesis i graded in soil microbially, and ha ranging from 1 to 6 months.
Linuron 3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea ($13.00/lb; wettable powder, flowable suspension)	LOROX DuPont	1,500 moderately toxic	moderately toxic	Applied as a preemergence soil tre of broadleaf and some grass weed soybeans, cotton, corn, sorghum carrots, and parsnips, and in orn turf. It is readily absorbed by foliage. It is translocated upward It is a photosynthesis inhibitor. It similar to diuron. It is degraded Half-life in soil is 2 to 5 months.
Maleic hydrazide or MH 1,2-dihydro-3,6-pyrida= zinedione ($4.40/lb; 2S, 3S, or 4S; water-soluble liquid)	DE–CUT Maintain 3 MH 30 Retard Slo-Gro Slo-Gro Uniroyal Drexel Fairmont	6,950 slightly toxic	slightly toxic	Growth regulator that provides seedhead suppression in turf. M with chlorflurenol to provide broa Has no soil residual when used rapidly degraded by microorganism

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CHEMICAL, PHYSICAL, AND BIOLOGICAL PROPERTIES OF HERBICIDES AND PLANT GROWTH REGULAT

Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Remar
Mecoprop 2-[(4-chloro-o-tolyl)= oxy]propionic acid ($6.50/lb; liquid salt solutions)	ISO-CORNOX 64 BFC Chemicals CHIPCO Turf Herbicide MCPP Rhone-Poulenc MCPP K-4 Fermenta	1,060 moderately toxic	moderately toxic	Applied as a foliage spray, most 2,4-D, for control of broadleaf w cereal crops. It is translocated, an similar to 2,4-D. Care should spray drift to susceptible orn plants. Herbicidally significant soil for less than 1 month.
Mefluidide *N*-[2,4-dimethyl-5-[(tri= fluoromethyl) sulfonyl] amino]phenyl]-acetamide ($39.00/lb; 2S, water-soluble liquid)	EMBARK 3 M	>4,000 moderately toxic	slightly toxic	Growth regulator that provides seedhead suppression in turf. seedheads of bahiagrass. Has a leaches slightly in soil, and is posed.
Metham sodium methyldithio= carbamate ($2.25/lb; water- soluble liquid)	VAPAM Stauffer	820 moderately toxic	moderately toxic	Soil fumigant applied to moist, mediately sprinkle irrigate to wet activity is desired. Covering soil gives superior control. Kills gern zomes, roots, and stems of weeds nematodes, plant disease organis sects. It is often used as a prepla lawn grasses, ornamental beds, f corrosive to mild steel and stain breaks down in soil by chemica hours to methyl isothiocyanate. place 14 to 21 days after treatmen

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Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Remark
Methane Arsonates methanearsonic acid and other formulations DSMA disodium methane arsonate MSMA monosodium methanearsonate CMA Calcium methane= arsonate AMA octyl-dodecyl ammonium methane= arsonate ($2.00/lb; water-soluble liquid)	TRANS-VERT Union Carbide CALAR DAL-E-RAD WEED-HOE WEED-E-RAD Vineland BUENO DACONATE Fermenta NAMATE MESAM ATE Crystal Chemical BROADSIDE METHAR Cleary	1,359 to 3,630; moderately toxic	slight to very low toxicity	Selective postemergence herbicides grass, dallisgrass, and other weed Also used extensively as selective p bicide in cotton and noncrop are Johnsongrass, nutsedge, sandbur, pigweeds, and other weeds. No Augustine grass and centipedegras used in water carriers that are magnesium, or iron because of insc Inactivated in soil by surface ad exchange. Short soil residual.

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Methyl bromide ($6.00/lb in cans, $1.00/lb in bulk containers; liquid under pressure in cylinders or cans)	DOWFUME MC-33 Fumigant BROZONE DOW Chemical Co. WR GRACE & Co. NEMASTER PESTMASTER Stauffer Velsicol M8C Soil Fumigant Hendrix and Dail, Inc., and others	35 extremely toxic	extremely toxic	A RESTRICTED FUMIGANT he poisonous and may be used only b tor. It is applied as a liquid unde gas-tight cover, sealed at the edges most weed seeds, bulbs, corms, ground stems of weeds, as well as disease organisms, and some inse applied when soil temperature is cover can be removed 2 days aft seeding can be done 2 days after contains low percentage of chlorc odor warning.
Metolachlor 2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methyl = ethyl) acetamide ($3.00/lb; emulsi fiable concentrate)	DUAL Ciba-Geigy	2,780 low toxicity	moderate to very toxic	Soil-applied, preplant-incorporatec mergence herbicide. Treatments ar nation with atrazine for control grasses, yellow nutsedge, and certa in corn. It is also used in peanu horticultural crops. It is corrosive can cause eye damage; wear goggle is a general growth inhibitor, elongation. High organic and cla sorb metolachlor and above 2 perc no leaching occurs. Its half-life in in northern areas and 15 to 25 in s

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CHEMICAL, PHYSICAL, AND BIOLOGICAL PROPERTIES OF HERBICIDES AND PLANT GROWTH REGULATC

Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Remar
Napropamide 12-(a-naphthoxy)-*N*,*N*-diethylpropionamide ($16.75/lb; wettable powder)	DEVRINOL Stauffer	>5,000 slightly toxic	slightly toxic	Soil-applied preemergence herbici annual grass weeds and many b certain fruit and nut crops, man and ornamental crops. It is rapidly and translocated upwards throug inhibits the development and gr annual grass plants. It resists leac slowly broken down by soil mic composes about 50 percent in 4 surface. When incorporated in so to 12 weeks.
Oryzalin 3,5-dinitro-N^4,N^4-dipropylsulfanilamide ($14.70/lb; aqueous suspension, wettable powder)	RYZELAN SURFLAN Elanco	>10,000 slightly toxic	moderately toxic	A soil-applied, preemergence herbi annual grasses and some broadl beans, nonbearing trees, vineyards shrubs, flowers and noncropland use around guard rails, fence lines other structures adjacent to gr advantageously combined with phosate, and used as a directed sp It does not volatilize from soil leaches to a limited extent. It is de in the soil. It usually does not pe one season.

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Oxadiazon 2-*tert*-butyl-4-(2,4-dichloro-5-isopropoxy= phenyl)-Δ^2-1,3,4-oxa= diazolin-5-one ($42.50/lb; granular, emulsifiable concentrate)	RONSTAR CHIPCO RONSTAR G Rhone Poulenc	>8,000 slightly toxic	slightly toxic	Soil-applied preemergence treatm and turf for control of certain broadleaf weeds. Do not use fescue, centipedigrass, and zoys dichondria. It is strongly adsor and organic matter, and leaches l
Oxyfluorfen 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-tri= fluoromethyl) benzene ($33.50/lb; emulsifiable concentrate)	GOAL Rohm and Haas Co.	>5,000 slightly toxic	moderately toxic	Selective preemergence herbicid peanuts; preemergence for rice, c citrus, nuts, grapes and horticult many broadleaf and grass weeds. mask in handling. It is strongly a leaches little. Half-life in soil is 3
Paraquat 1,1′-dimethyl-4,4′-bi= pyridinium ion ($23.50/lb; water-soluble liquid)	GRAMOXONE I.C.I. ORTHO PARAQUAT Chevron Chemical Co.	150; very toxic (if taken internally or inhaled, it causes irreversible fibrosis of lungs)	very toxic (avoid prolonged contact)	A RESTRICTED HERBICIDE applied contact herbicide that treated. Used noncropland, prepl spray in orchard and ornamental used as a crop desiccant and def is very rapid. Should be used w or equivalent. It is tightly bound inactive in soil.

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Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Remarl
Pendimethalin (N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine ($10.70/lb; water dispersible granule)	PRE-M LESCO	1620 moderately toxic	slightly toxic	Preemergence control of annual g broadleaf weeds in turfgrasses. established turfgrass with a dense a Do not use on newly seeded or overseeded, or turfgrass thinned b not use on bentgrass or dichondra.
Picloram 4-amino-3,5,6-tri= chloropicolinic acid ($42.50/lb; granular, pellets, liquid)	GRAZON TORDON Dow Chemical AMDON K Union Carbide	8,200 slightly toxic	slightly toxic	A RESTRICTED HERBICIDE. A or soil-applied herbicide that con leaf herbaceous and woody plants to most grasses. Higher rates of quired for soil treatments than f Picloram is extremely mobile in pl cated, particularly to new growth. similar to that of 2,4-D. Sympton and stunting of leaves, bending stems, and deterioration of roots. plant species, such as mustards, sp are resistant to picloram, others a amounts. Picloram is often used phenoxy herbicides such as 2,4-D. in soil longer than 2,4-D. It disap under high rainfall or high temper coarse textured soils. In cool, d residues may injure sensitive crop year. Drift of sprays to nontarge great loss. Special care should b contamination of irrigation wate may move from the treated area v water to affect sensitive plants al and downslope.

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Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Remarl
Sethoxydim 2-[1-(ethoxyimino) butyl]-5-[2-(ethylthio) propyl]-3-hydroxy-2-cyclohexen-1-one ($74.00/lb; emulsifiable concentrate)	POAST Herbicide BASF/Nippon Soda	2,676–3,125; moderately toxic	moderately toxic	Foliage-applied selective herbicide nual and perennial grasses withou leaf plants. Use of a crop oil in effectiveness. Rainfall 4 to 5 hour does not decrease grass control. foliage and translocated througho persistence is short.
Siduron 1-(2-methylcyclo = hexyl)-3-phenylurea ($14.00/lb; wettable powder, granular)	TUPERSAN Weed Killer DuPont	5,000 slightly toxic	moderately toxic	A soil-applied selective herbicide f annual grasses such as crabgrass, yardgrass in new seedings or est cool season turfgrasses. Should no bentgrass strains or bermudagrass just before germination of weeds Readily absorbed by roots; less inhibits photosynthesis and root graded in soil microbially and do more than one season.
Prometon 2,4-bis(isopropyl = amino)-6-methoxy-*s*-triazine ($1.75/lb; wettable powder, miscible liquid)	PRAMITOL CONQUER Liquid vegetation Killer GESAFRAM PRIMATOL Ciba-Geigy CO-OP Pramitol Farmland Industries	2,276 moderately toxic	slightly to moderately toxic	A RESTRICTED HERBICIDE. A applied herbicide which controls br weedgrasses on noncropland. It is and to some degree by foliage, a upward. It is a photosynthetic i have additional effects. Prometo adsorbed on muck and clay th particles. It is broken down in s persists in soil for more than one s

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Pronamide 3,5-dichloro(*N*-1,1-dimethyl-2-propynyl) = benzamide ($26.00/lb; wettable powder)	KERB Rohm and Haas	5,620–8,350; slightly toxic	slightly toxic	A selective, soil-applied preeme control of broadleaf and gra legumes, small fruit trees, C woody ornamentals. It controls annual ryegrass in bermudagra and postemergence treatments. when there is rain or sprinkler treatment. Shallow incorporatio in dry areas. Pronamide is ab translocated upward. It is a mitosis in cells, but may have a readily adsorbed on organic ma dal exchange sites. It is degra under hot, dry conditions it vol soil ranges from 2 to 9 months.
Simazine 2-chloro-4,6-bis = (ethylamino)-*s*-triazine ($4.00/lb; wettable powder, flowable liquid, granule)	PRINCEP AQUAZINE GESATOP PRIMATOL Ciba-Geigy SIMAZINE 4G Miller Chemical Co.	>5,000 slightly toxic	slight ly toxic	A soil-applied herbicide for t gence control of broadleaf weed many crop and aquatic weed rates, it is a nonselective, nonc has little foliar activity, being plant roots. It is translocated xylem of the plant. It is a ph and may have additional effe sorbed on muck and clay s because of its low water solubi the soil microbially. At higher for more than a year. Its half- 30 days.

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Sodium Chlorate $NaCLO_3$ ($0.45/lb; water-soluble crystals)	SODIUM CHLORATE Penwalt Corp. DEFOL Drexel	5,000 slightly toxic	very toxic	A soil-applied herbicide used as noncrop situations. It is a stron contact with combustible material Clothing and vegetation contami or its solutions are DANGER BLE. Follow instructions on th Often mixed with fire suppressan persists in soil for more than a ye
Sulfometuron methyl 2-[[[[(4,6-di= methyl-2-pyrimidinyl)= amino]-carbonyl]amino]= sulfonyl]benzoate ($152.50/lb; dry flowable granules)	OUST DuPont	5,000 slightly toxic	slightly toxic	A soil- or foliage-applied herbici control of herbaceous broadlea grasses. At moderate rates in control broadleaf weeds selecti bermudagrass. It is not very toxi of most trees and many woody useful as directed spray at low vegetation under trees. It is abs foliage of weeds, and transloca plant. It arrests cell division in roots and tops, and gradually the lower the soil pH, the higher the greater the adsorption on soil. and microbial activity decompo soil. The half-life during summe Little decomposition occurs in fr

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Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Remar
Tebuthiuron *N*-[5-(1,1-dimethyl= ethyl)-1,3,4-thiadiazol-2-yl]-*N*,*N*′-dimethylurea ($18.50/lb; pellets, granules, wettable powder)	GRASLAN SPIKE Elanco	644 moderately toxic	moderately toxic	A soil treatment, either sprayed o soil surface, preferably just befor of active growth of weeds and b is enhanced by rainfall. It contro and woody plants. Low rates selectively control some weed and can leave some grass species for c At higher rates it is a soil ste absorbed by roots, less so throug photosynthesis. It has a half-lif months in ares receiving 40–60 in It is considerably greater in area In field studies, tebuthiuron ha tected below the top 12 inches breakdown has been shown to dominant mode of degradation involve soil microbes. Loss fro composition and volatilization is carried to adjoining areas by runo

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Common and Chemical Designations[1] (Cost per Pound; and Commercial Formulation	Trade Name and Manufacturer[2]	Acute Oral Toxicity, LD_{50} (mg/kg) and Rating	Dermal Toxicity	Biological Information and Remarl
Triclopyr [(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid ($15.50/lb; emusifiable ester, water solution of amine salt)	GARLON Dow	713 moderately toxic	moderately toxic	A foliage-applied herbicide used se many broadleaf herbaceous and v out injury to grasses. It is also us surface treatments on woody pla by both foliage and roots of plan both up and down in plants. meristematic tissue. Its mode of a similar to 2,4–D. It is not strong and some leaching may occur in high rainfall conditions. It is microbes and is photodecompo average half-life in soil is 46 days.
Trifluralin α,α,α-trifluoro-2-6-dinitro-*N*,*N*-dipropyl-*p*-toluidine ($6.85/lb; emulsifiable concentrate, granules)	TREFLAN TREFANOCIDE (Japan) ELANCOLAN (West Germany) Elanco	10,000 slightly toxic	moderately toxic	A preemergence and preplanting cide used for control of annual some broadleaf weeds in many fiel crops and in ornamental planting soil soon after treatment increase tiveness. It is volatile at high tem no significant absorption and tra ralin by plants. It does not di germination, but it affects phys associated with seed germinati strongly adsorbed on soil and sho ing. It is degraded microbially, an ing on the soil surface can be subj position. It does not usually per one season.

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WEED SPECIES AND HERBICIDES FOR THEIR CONTROL

Weed Species	Growth Habit	Herbicides
Absinthe (see wormwood)		
Alder (Alnus spp.) and speckled (*A. rugosa*)	W*	AMS; 2,4-D; triclopyr
Algae		
bluegreen (many genera)	Aq*	Copper sulfate
green		
nonfilamentous	Aq	Copper sulfate
filamentous		
Chara	Aq	Dichlobenil, copper sulfate, diquat, endothall (dimethylamines)**
Cladophora, *hydrodictyon*, *spirogyra*, et al	Aq	Copper sulfate, diquat, endothall (amine salts)**, simazine
Pithophora	Aq	Endothall (amine salts)**, simazine
Alyssum, hoary (*Beteroa incana*)	B* or P*	amitrole, dicamba, picloram, glyphosate
Amaranth (see pigweed)		
Ammannia, purple (*Ammannia coccinea*)	A*	2,4-D; dicamba; picloram; glyphosate
Arrowgrass, seaside (*Triglochin maritima*)	P	2,4-D; dicamba; picloram; amitrole; glyphosate
Arrowhead		
California (*Sagittaria montevidensis*)	Aq	Diquat; 2,4-D; dicamba; picloram; amitrole; glyphosate
Gregg (*S. longiloba*)	Aq	Diquat; 2,4-D; glyphosate
Ash (*Fraxinus* spp.)	W	AMS, bromacil, glyphosate, triclopyr, fosamine, hexazinone, tebuthiuron
Aspen (*Populus* spp.)	W	AMS, picloram, tebuthiuron, triclopyr, amitrole
trembling (*P. tremuloides*)	W	AMS; 2,4-D; amitrole; bromacil; dicamba; glyphosate, fosamine; tebuthiuron
Aster		
heath (*Aster ericoides*)	P	Bromacil; tebuthiuron; 2,4-D; dicamba; picloram; amitrole; glyphosate; hexazinone, chlorsulfuron
western (*A. occidentalis*)	P	Dicamba, picloram, amitrole, glyphosate
white heath (*A. pilosus*)	P	Tebuthiuron; 2,4-D; dicamba; picloram; amitrole; glyphosate
Baccharis (*Baccharis* spp.) (see coyotebrush)	W	DSMA; MSMA; simazine; trifluralin; 2,4-D; bromacil
eastern (*B. halimifola*)	W	2,4-D
Baileya, desert (*Baileya multiradiata*)	P	2,4-D
Ballmustard (*Neslia paniculata*	A	2,4-D
Balsam (*Impatiens* spp.)	W	Picloram
Barberry		
American (*Berberis canadensis*)	W	2,4-D; AMS; bromacil; dicamba; picloram
Colorado (*B. fendleri*)	W	2,4-D
Barley, foxtail (*Hordeum jubatum*)	B or P	Amitrole, glyphosate

*A, annual; Aq, aquatic; B, biennial; P, perennial; W, woody.
**Toxic to fish in concentrations required to control weeds.

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Barnyard grass (*Echinochloa crus-galli*)	A	AMA, atrazine, benefin, bensulide, chlorpropham, DCPA, diphenamid, DSMA, EPTC, MSMA, siduron, simazine, trifluralin, diuron, oryzalin, pronamide, oxadiazon, oxyfluorfen, sulfometuron, fluazifop, sethoxydim, hexazinone, metolachlor, napropamide
Bassia, fivehook (*Bassia hyssopifolia*)	A	2,4-D; dicamba; picloram, amitrole, glyphosate, bromoxynil
Basswood, American (*Tilia americana*)	W	Dicamba, AMS, bromacil, picloram, fosamine
Bearberry (*Arctostaphylos uvaursi*)	W	Bromacil, picloram
Bearmat (*Chamaebatia foliolosa*)	W	2,4-D; dicamba
Bedstraw		
catchweed (*Galium aparine*)	A	Mecoprop, tebuthiuron, oxyfluorfen, dicamba, picloram, glyphosate, chlorsulfuron
smooth (*G. mollugo*)	P	Dicamba, picloram, glyphosate, ·tebuthiuron, chlorsulfuron
Beech (*Fagus* spp.)	W	AMS, bromacil, glyphosate, picloram, triclopyr, tebuthiuron
Beeplant, Rocky Mountain (*Cleome serrulata*)	A	2,4-D
Beggarticks (*Bidens frondosa* and *B. vulgata*)	A	2,4-D; dicamba; picloram; amitrole; glyphosate
Bellflower, creeping (*Campanula rapunculoides*)	P	Dicamba, picloram, amitrole, glyphosate
Bellwort, common (*Colchicum autumnale*)	P	2,4-D
Bermudagrass (*Cyndon dactylon*)	P	Bromacil, EPTC (seedlings only), herbicidal oils, fumigants, glyphosate, sethoxydim
Bindweed		
(species not designated		Dichlobenil
field (*Convolvulus arvensis*)	P	Atrazine; dicamba; 2,4-D; picloram; glyphosate; sodium chlorate; fosamine; diuron; triclopyr
hedge (*Calystegia sepium*)	P	Atrazine; 2,4-D; dicamba; picloram; glyphosate
Birch (*Betula* spp.)	W	AMS, dicamba, glyphosate, picloram, triclopyr, fosamine
Birdrape, mustard (*Brassica rapa*)	B	2,4-D
Biscuitroot, bicolor (*Lomatium bicolor*)	P	2,4-D
Bistort, American (*Polygonum bistortoides*)	P	2,4-D
Bittercress (*Cardamine* spp.)	Aq	2,4-D; dicamba; oxyfluorfen; oxadiazon; picloram
Bitter sneezewood or Bitterweed (*Helenium amarum*)	A	AMS; 2,4-D; dicamba; picloram; glyphosate

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Blackberry (*Rubus* spp.)	W	AMS, picloram, bromacil, dicamba, glyphosate, amitrole, sodium chlorate, triclopyr, sulfometuron, fosamine, tebuthiuron
Blackeyed-susan (*Rudbeckia hirta*)	P	Atrazine; 2,4-D; dicamba; picloram; amitrole; glyphosate
Bladderwort (*Utricularia* spp.)	Aq	Acrolein**, aromatic solvents**, diquat, endothall (amine)**
Blessed thistle (*Cnicus benedictus*)	A	2,4-D, dicamba, picloram
Bluebur (see stickseed or sticktight, European)		
Bluegrass (*Poa spp.)*	P	Hexazinone, atrazine, glyphosate, paraquat
annual (*P. annua*)	A	Benefin, bensulide, sulfometuron, oryzalin, napropamide, oxadiazon, oxyfluorfen, chlorpropham, DCPA, dichlobenil, diphenamid, EPTC, paraquat, trifluralin, simazine, pronamide, tebuthiuron
Bluemustard (*Chorispora tenella*)	A	Dicamba; picloram; 2,4-D; amitrole; glyphosate
Bluestem, little (*Andropogon scoparius*)	P	Atrazine, bromacil
Blueweed (*Echium vulgare*)	B	2,4-D; dicamba; picloram; amitrole; glyphosate
Blueweed, Texas (*Helianthus ciliaris*)	P	AMS; amitrole; dicamba; picloram; 2,4-D; glyphosate
Bouncing-bet (*Saponaria officinalis*)	P	Tebuthiuron, bromacil, dicamba, picloram, amitrole, glyphosate, chlorsulfuron
Boxelder (*Acer negundo*)	W	2,4-D; glyphosate; picloram; tebuthiuron; bromacil; sulfometuron
Brackenfern (*Pteridium aquilinum*)	P	AMS, bromacil, glyphosate, dicamba, picloram
Brambles (see blackberry)		
Briers (see smilax)		
Bristlegrass (see foxtail)		
Bromegrass		
smooth (*Bromus inermis*)	P	Bromacil, glyphosate, pronamide
downy (*B. tectorum*)	A	Atrazine, bromacil, amitrole, chlorpropham, tebuthiuron, diphenamid, pronamide, diuron, endothall, glyphosate, simazine, prometon, trifluralin, sulfometuron, hexazinone
Broomsedge (*Andropogon virginicus*)	P	Atrazine, bromacil, MSMA, amitrole, glyphosate, hexazinone, tebuthiuron
Broomweed		
common (*Gutierrezia dracunculoides*)	A	2,4-D; dicamba; picloram; amitrole; glyphosate
threadleaf (*G. microcephala*)	P	2,4-D
Browntop millet (*Panicum ramosum*)	A	DCPA

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Buckbrush (*Symphoricarpos orbiculatus*)	W	AMS; 2,4-D; tebuthiuron
snowberry, western (*S. occidentalis*)	W	AMS; 2,4-D
Buckeye		
Texas (*Aesculus arguta*)	W	AMS, bromacil, dicamba, picloram
California (*A. californica*)	W	Dicamba, picloram
Buckthorn		
California (*Rhamnus californica*)	W	Picloram
European (*R. Cathartica*)	W	2,4-d; bromacil; picloram
Buckwheat		
tartary (*Fagopyrum tataricum*)	A	Endothall, amitrole, picloram, glyphosate, bromoxynil
wild (see wild buckwheat)		
Buffalobur (*Solanum rostratum*)	A	Dicamba, picloram, glyphosate
Bugleweed, American (*Lycopus americanus*)	P	2,4-D
Bullnettle (*Cnidoscolus stimulosus*)	P	DSMA; 2,4-D; dicamba; simazine; picloram; amitrole; glyphosate
Bullthistle (*Cirsium vulgare*)	B	Picloram; 2,4-D; dicamba; amitrole; glyphosate
Bulrush (*Scirpus* spp.)	Aq	Amitrole; MSMA; 2,4-D
Burclover, California (*Medicago hispida*)	A	Endothall, paraquat, tebuthiuron, sulfometuron, oxyfluorfen, chlorsulfuron
Burcucumber (*Sicyos angulatus*)	A	Picloram, amitrole, glyphosate
Burdock		
common (*Arctium minus*)	B	Atrazine; 2,4-D; dicamba; picloram; glyphosate; triclopyr; hexazinone
great (*A. lappa*)	B	2,4-D; dicamba; picloram; glyphosate
Burhead (*Echinodorus cordifolius*)	A	2,4-D
Burning-bush (see kochia)		
Burreed, threesquare (*Sparganium americanum*)	Aq	Endothall; diuron; 2,4-D
Burroweed (*Haplopappus tenuisectus*)	P	2,4-D; dicamba; picloram
Bursage		
skeletonleaf (*Ambrosia tomentosa*	P	2,4-D
wollyleaf (*A. grayi*)	P	Amitrole; 2,4-D
Bush-honeysuckle (*Diervilla lonicera*)	W	2,4-D
Buttercup		
celeryleaf (*Ranunculus scleratus*)	A	2,4-D; mecoprop
corn (*R. arvensis*)	A	2,4-D; mecoprop; dicamba; amitrole
creeping (*R. repens*)	P	Sodium chlorate; MCPA; 2,4-D; dicamba; amitrole
small flower (*R. abortivus*)	A or B	2,4-D
tall (*R. acris*)	P	2,4-D; dicamba; picloram; amitrole; glyphosate
Buttonbush, common (*Cephalanthus occidentalis*)	W	Picloram
Cactus, pricklypear (*Opuntia* spp.)	W	Picloram
Camphorweed (*Heterotheca subaxillaris*)	A or B	2,4-D; hexazinone; tebuthiuron
Campion bladder (*Silene vulgaris*)	P	Dicamba, picloram, amitrole, glyphosate

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Canary grass, reed (*Phalaris arundinacea*)	P	Amitrole-T, atrazine, glyphosate, bromacil, linuron, simazine, sulfometuron, pronamide, tebuthiuron
Caragana or pea-tree (*Caragana arborescens*)	W	AMS, diuron, simazine
Caraway (*Carum caryi*)	B	2,4-D
Carlessweed (see pigweed, Palmer)		
Carpetgrass (*Axonopus affinus*)	P	Amitrole, oxadiazon
Carpetweed (*Mollugo verticillata*)	A	Atrazine; benefin; chlorpropham; dichlobenil; diphenamid; trifluralin; linuron; oxadiazon; oxyfluorfen; simazine; 2,4-D; tebuthiuron; pronamide; oryzalin
Carrot, wild (*Daucus carota*)	B	AMS; atrazine; bromacil; 2,4-D; picloram; dicamba; amitrole; glyphosate; sulfometuron; hexazinone; tebuthiuron
Catbrier (see smilax)		
Catchfly, nightflowering (*Silene noctiflora*)	A	Dicamba, glyphosate, picloram
Catclaw, mimosa (*Mimosa buncifera*)	W	Picloram, bromacil, tebuthiuron
Catnip (*Nepeta cataria*)	P	2,4-D; dicamba; picloram; glyphosate
Catsear, spotted (*Hypochoeris radicata*)	P	2,4-D; dicamba; picloram; amitrole; oxadiazon; tebuthiuron
Cattail (*Typha* spp.)	Aq	Amitrole; 2,4-D; esters; glyphosate
Ceanothus		
deerbrush (*Ceanothus integerrimus*)	W	2,4-D; bromacil; picloram
varnishleaf (*C. velutinus var. laevigatus*)	W	2,4-D
wedgeleaf (*C. cuneatus*)	W	2,4-D; picloram; tebuthiuron
Centipedegrass (*Eremochloa ophiuroides*)	P	Glyphosate
Chamise (*Adenostoma fasciculatum*)	W	2,4-D; bromacil; glyphosate; picloram; tebuthiuron
Chamomile		
corn (*Anthemis arvensis*)	A or B	Dicamba, picloram, picloram, amitrole, glyphosate, bromoxynil
false (*Matricaria maritima*)	A	Amitrole, sodium chlorate
mayweed (*A. cotula*)	A	Atrazine; dicamba; 2,4-D; picloram; glyphosate
Charlock (see mustard, wild)		
Cheat or chess (*Bromus secalinus*)	A	Bromacil, diphenamid, trifluralin, amitrole, glyphosate, pronamide, tebuthiuron
Cherry (*Prunus* spp.)	W	AMS, dicamba, picloram, glyphosate, triclopyr, tebuthiuron
Chestnut (*Castanea* spp.)	W	AMS, dicamba, picloram
Chickweed		
species not designated	A	Dichlobenil, DSMA, paraquat, chlorsulfuron

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
common (*Stellaria media*)	A	Atrazine; benefin; chloropropham; dicamba; dichlobenil; DCPA; picloram; diphenamid; EPTC; linuron; glyphosate; tebuthiuron; sulfometuron; hexazinone; napropamide; oryzalin; oxyfluorfen; pronamide; simazine; sodium chlorate; trifluralin; 2,4-D
field (*Cerastium arvense*)	P	MSMA; 2,4-D; dicamba; picloram; glyphosate
mouse-ear (*C. vulgatum*)	P	Dicamba; 2,4-D
Chicory (*Cichorium intybus*)	P	2,4-D; dicamba; amitrole; glyphosate; triclopyr; tebuthiuron; picloram
Chokecherry (*Prunus virginiana*)	W	AMS, bromacil, picloram, fosamine, tebuthiuron
Cholla, jumping (*Opuntia fulgida*)	W	Triclopyr, picloram
Christmasberry (*Photinia arbutifolia*)	W	2,4-D; bromacil; picloram
Cinquefoil		
blueleaf (*Potentilla diversifolia*)	P	2,4-D; glyphosate
common (*P. canadensis*)	P	2,4-D; dicamba; picloram; glyphosate; tebuthiuron; chlorasulfuron
creeping (*P. reptans*)	A	Atrazine
rough (*P. norvegica*)	A or B	Chlorpropham; 2,4-D; dicamba; picloram; amitrole; glyphosate
sulfur (*P. recta*)	P	2,4-D; dicamba; picloram; amitrole; glyphosate
Cleavers (see bedstraw, catchweed)		
Clover		
red (*Trifolium pratense*)	B or P	Oxyfluorfen; tebuthiuron; picloram; 2,4-D; hexazinone, chlorsulfuron
sweet (*Melilotus* spp.)	B	Picloram; 2,4-D; hexazinone
Cockle, white (*Lychnis alba*)	P	Dicamba, amitrole, picloram, glyphosate, chlorsulfuron
Cocklebur, common (*Xanthium strumarium*)	A	Atrazine; DSMA; MSMA; dicamba, 2,4-D; linuron; benefin; mecoprop; picloram; tebuthiuron; amitrole; glyphosate; oxyfluorfen; bromoxynil; hexazinone
Coffeetree, Kentucky (*Gymnocladus dioicus*)	W	AMS, bromacil
Coffeeweed (*Daubentonia texana*)	A	DSMA; MSMA; 2,4-D; dicamba; picloram; glyphosate
Coltsfoot (*Tussilago farfara*)	P	Sodium chlorate; 2,4-D
Coneflower, cutleaf (*Rudbeckia laciniata*)	P	2,4-D
Conifers (species not designated)	W	Picloram
Coontail (*Certophyllum demersum*)	Aq	Acrolein**; aromatic solvents; diquat; endothall (dipotassium or disodium); simazine; 2,4-D
Coralberry (see buckbrush)		
Coreopsis, plains (*Coreopsis tinctoria*)	A	2,4-D; dicamba; picloram; amitrole; glyphosate

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Cornflower (*Centaurea cyanus*)	A	2,4-D
Cottonwood, eastern (*Populus deltoides*)	W	AMS; 2,4-D; triclopyr; tebuthiuron
Coyotebrush (*Baccharis pilularis*)	W	2,4-D
Crabgrass (*Digitaria* spp.)	A	AMA, atrazine, benefin, linuron, bensulide, bromacil, DCPA, fenoxaprop, metolachlor, napropamide, oryzalin, oxadiazon, oxyfluorfen, pendimethalin, siduron, DSMA, MSMA, chlorpropham, dichlobenil, diphenamid, DSMA, EPTC, MSMA, benefin, paraquat, trifluralin, simazine, fluazifop, sethoxydim, pronamide
Cranesbill (see geranium, Carolina)		
Crazyweed, Lambert (*Oxytropis lambertii*)	P	2,4-D
Creeping-charlie (see ground ivy)		
Creosotebush (*Larrea tridentata*)	W	2,4-D; tebuthiuron
Crotolaria, showy (*Crotolaria spectabilis*)	A	2,4-D
Croton		
Lindheimer (*Croton lindheimeri*)	A	2,4-D; dicamba; picloram
Texas (*C. texensis*)	A	2,4-D; dicamba; picloram
wooly (*C. capitatus*)	A	2,4-D; dicamba; picloram
Crowfootgrass (*Dactyloctenium aegyptium*)	A	Tebuthiuron, benefin, diphenamid, metolachlor, trifluralin, oryzalin
Cudweed (*Gnaphalium* spp.)	A	Dichlobenil, dicamba, picloram, glyphosate
Cupgrass (*Eriochloa* spp.)	A	Fluazifop, oryzalin, sethoxydim, napropamide
Currants (*Ribes* spp.)	W	AMS; 2,4-D
Cutgrass (*Leersia* spp.)	P	Amitrole
Daisy		
English (*Bellis perennis*)	P	2,4-D; dicamba; picloram; glyphosate
oxeye (*Chrysanthemum leucanthemum*)	P	Atrazine; dicamba; 2,4-D; picloram; amitrole; glyphosate; sulfometuron
Dallisgrass (*Paspalum dilatatum*)	P	AMA, bromacil, DSMA, MSMA, amitrole, diuron, glyphosate
Dandelion, common (*Taraxacum officinale*)	P	Bromacil; dichlobenil; picloram; 2,4-D; dicamba; amitrole; glyphosate; triclopyr; sulfometuron; hexazinone, chlorsulfuron
Dayflower, Asiatic (*Commelina communis*)	A	2,4-D; amitrole; glyphosate; linuron
Deadnettle, purple (*Lamium purpureum*)	A or B	Dicamba, picloram, amitrole, glyphosate
Deathcamas		
foothill (*Zigadenus paniculatus*)	P	2,4-D
grassy (*Z. gamineus*)	P	2,4-D; dicamba; picloram; glyphosate
Deervetch, broom (*Lotus scoparius*)	W	2,4-D
Desert-baileya (see baileya, desert)		
Devilsclaw (*Proboscidea louisianica*)	A	2,4-D; dicamba; picloram; glyphosate
Dewberry (see blackberry)		

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Dichondra (*Dichondra repens*)	P	2,4-D
Dock		
species not designated	P	Picloram; 2,4-D
broadleaf (*Rumex obtusifolius*)	P	2,4-D; amitrole; glyphosate; dicamba; picloram
curly (*R. crispus*)	P	Atrazine; dichlobenil; dicamba; 2,4-D; picloram; amitrole; glyphosate; triclopyr, sulfometuron; tebuthiuron; chlorsulfuron
fiddleleaf (*R. pulcher*)	P	2,4-D; dicamba; picloram; amitrole; glyphosate
pale (*R. altissimus*)	P	2,4-D; dicamba; picloram; amitrole; glyphosate
veiny (*R. venosus*)	P	2,4-D
Dodder (*Cuscuta* spp.)	A	Chlorpropham; DCPA; diquat; herbicidal oils
Dogbane		
hemp (*Apocynum cannabinium*)	P	Atrazine; picloram; amitrole; 2,4-D; dicamba; glyphosate; sulfometuron
spreading (*A. androsaemifolium*)	P	Bromacil, dicamba, picloram, amitrole, glyphosate
Dogfennel		
(*Eupatorium capillifolium*)	A	Bromacil; dicamba; picloram; tebuthiuron; 2,4-D; linuron; glyphosate; sulfometuron; hexazinone
yellow (see bitterweed or bitter sneezeweed)		
Dog mustard (*Erucastrum gallicam*)	A	2,4-D
Dogwood (*Cornus* spp.)	W	Dicamba, bromacil, AMS, triclopyr
flowering (*C. florida*)	W	Bromacil, picloram, tebuthiuron
Dokewood (see oak, post)		
Ducksalad (*Herteranthera limosa*)	A	2,4-D
Duckweed, common (*Lemna minor*)	A, Aq	Copper sulfate, diquat
Eelgrass (see wild celery)		
Elder (*Sambucus* spp.)	W	AMS; 2,4-D
Elm (*Ulmus* spp.)	W	AMS, dicamba, bromacil, tebuthiuron, picloram, fosamine, triclopyr, hexazinone
winged (*U. alata*)	W	Picloram, AMS, tebuthiuron, bromacil, triclopyr
Elodea		
Canada or common (*Egeria canedensis*)	Aq	Acrolein**, aromatic solvents**, dichlobenil, diquat, endothall
densleaved (*E. densa*)	Aq	Acrolein**, aromatic, solvents**, dichlobenil, diquat, endothall
Eucalyptus (*Eucalyptus* spp.)	W	AMS, bromacil, picloram
Euonymus (*Euonymus fortunei* var. *vegetus*)	W	AMS, diuron, simazine, TCA
Evening-primrose, common (*Oenothera biennis*)	B	Dichlobenil; 2,4-D; dicamba; picloram; glyphosate; oxadiazon

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Falseflax (*Camelina* spp.)	A	Amitrole; 2,4-D; dicamba; picloram; bromoxynil
False helebore, western (*Veratrum californicum*)	P	2,4-D
Fanweed (see pennycress, field)		
Fanwort (*Cabomba caroliniana*)	Aq	Simazine; 2,4-D
Fescue (species not designated)	P	Atrazine, dichlobenil, sulfometuron, sethoxydim, tebuthiuron
Fiddleneck, coast (*Amsinckia intermedia*)	A	2,4-D; bromoxynil; hexazinone; dicamba; tebuthiuron; oxyfluorfen; napropamide; picloram; glyphosate; sulfometuron
Fieldcress, Austrian (*Rorippa austriaca*)	P	2,4-D
Filaree, redstem (*Erodium cicutarium*)	A or B	Atrazine; DCPA; paraquat; 2,4-D; dicamba; picloram; tebuthiuron; amitrole; glyphosate; sulfometuron; oxfluorfen; hexazinone; napropamide; chlorsulfuron
Fir		
balsam (*Abies balsamea)*	W	AMS, picloram, bromacil, tebuthiuron
white (*A. concolor*)	W	2,4-D
Fireweed (*Epilobium angustifolium*)	A	Simazine
Fleabane		
annual (*Erigeron annus*)	A	Tebuthiuron; atrazine; amitrole; 2,4-D; dicamba; picloram; glyphosate
Oregon (*E. speciosus*)	P	2,4-D; dicamba; picloram; glyphosate
rough (*E. strigosus*)	A or B	2,4-D; dicamba; picloram; amitrole; glyphosate
Flixweed (*Descurainia sophia*)	A or B	2,4-D; picloram; oxyfluorfen
Florida pusley (*Richardia scabra*)	A	Benefin; DCPA; EPTC; trifluralin; simazine; 2,4-D; chlorpropham
Four-o'clock, prairie (*Mirabilis nyctaginea*)	P	2,4-D
Foxtail (*Setaria* spp.)	A	AMA, atrazine, benefin, bromacil, fenoxaprop, oryzalin, chlorpropham, DCPA, DSMA, EPTC, MSMA, linuron, siduron, simazine, trifluralin, sulfometuron, tebuthiuron, pronamide, oxyfluorfen, oxadiazon, napropamide, sethoxydim, fluazifop, metolachlor, hexazinone
bristly (*S. verticillata*)	A	Amitrole, diuron, napropamide, oryzalin
knotroot (*S. geniculata*)	A	Amitrole, diuron
Frenchweed (see pennycress, field)		
Galinsoga, hairy (*Galinsoga ciliata*) and smallflower (*G. parviflora*)	A	Atrazine; 2,4-D; dicamba; picloram; amitrole; oxadiazon; glyphosate; linuron
Gallberry (*Ilex glabra*)	W	AMS, bromacil, picloram
Garlic, wild (*Allium vineale*)	P	Dicamba; methyl bromide; 2,4-D; picloram, chlorsulfuron

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Geranium, Carolina (*Geranium carolinianum*)	A or B	Atrazine; 2,4-D; tebuthiuron; dicamba; picloram; amitrole; glyphosate, sulfometuron
Goatstrue (*Galega officinalis*)	P	2,4-D; dicamba; picloram
Goatweed (see croton, Lindheimer)		
Goldenrod (*Solidago* spp.)	P	AMS; atrazine; bromacil; picloram; 2,4-D; tebuthiuron; dicamba; glyphosate; sulfometuron; hexazinone; prometon, chlorsulfuron
Goldenfleece, fleece (*Haplopappus arborescens*)	W	2,4-D
Gooseberries (*Ribes oxyacanthoides, R. roezlii* and most other *Ribes* spp.)	W	2,4-D
Goosefoot		
species not designated	A	Trifluralin; 2,4-D
Jerusalem-oak (*Chenopodium botrys*)		2,4-D; dicamba; picloram; amitrole; glyphosate
nettleleaf (*C. murale*)	A	EPTC; 2,4-D; dicamba; napropamide; linuron; picloram; amitrole; glyphosate
oakleaf (*C. glaucum*)	A	2,4-D; dicamba; picloram; amitrole; glyphosate
perennial (*C. bonus-henricus*)	A	2,4-D
Goosegrass (*Eleusine indica*)	A	Bensulide, oxadiazon, chlorpropham, DCPA, benefin, EPTC, diphenamid, fenoxaprop, linuron, oryzalin, simazine, oxadiazon, pronamide, oxyfluorfen, trifluralin, napropamide, DSMA, MSMA, fluazifop, sethoxydim, prometon
Gooseweed (*Sphenoclea zeylandica*)	A	2,4-D
Gorse (*Ulex europaeus*)	W	2,4-D; glyphosate; picloram
Greasewood (*Sarcobatus vermiculatus*)	W	2,4-D; dicamba; picloram
Greenbrier, saw (*Smilax bona-nox*)	W	AMS
Gromwell		
pearl (*Lithospermum officinale*)	P	Dicamba
corn (*L. arvense*)	A	2,4-D; bromoxynil
Groundcherry (*Physalis* spp.)	P	DCPA, diphenamid, picloram, trifluarlin
clammy (*P. heterophylla*)	P	Dicamba, picloram
smooth (*P. subglabrata*)	P	Dicamba
wrights (*P. wrightii*)	P	2,4-D; dicamba; oxyfluorfen; picloram; glyphosate
Ground-ivy (*Glechoma hederacea*)	P	Dicamba; 2,4-D; picloram; glyphosate
Groundsel		
species not designated	A & P	Dichlobenil, paraquat, glyphosate, oxadiazon, napropramide, chlorsulfuron
arrowleaf (*Senecio triangularis*)	P	2,4-D; glyphosate
common (*S. vulgaris*)	A	Dicamba; glyphosate; sodium chlorate, oxyfluorfen, linuron, bromoxynil
cressleaf (*S. glabellus*)	A	2,4-D; glyphosate
Riddell (*S. riddellii*)	P	2,4-D; picloram; glyphosate

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Tansy ragwort (see tansy-ragwort)		
threeleaf (*S. longilobus*)	P	2,4-D; dicamba; picloram; glyphosate
Gum, black (*Nyssa sylvatica*)	W	AMS, triclopyr, fosamine
Gumweed (*Grindelia squarrosa*)	P	2,4-D; dicamba; picloram; tebuthiuron; amitrole; glyphosate
Hackberry, western (*Celtis occidentalis*)	W	AMS, bromacil, dicamba, picloram, tebuthiuron
Halogeton (*Halogeton glomeratus*)	A	2,4-D
Hawkbit		
fall (*Leontodon autumnalis*)	P	2,4-D
rough (*L. leysseri*)	P	2,4-D
Hawkweed		
mouse-ear (*Hieracium pilosella*)	P	2,4-D
orange (*H. aurantiacum*)	P	2,4-D; dicamba; picloram; glyphosate
yellow (*H. pratense*)	P	2,4-D; dicamba; picloram; glyphosate
Hawthorn (*Crataegus* spp.)	W	AMS, picloram, triclopyr, fosamine, hexazinone, tebuthiuron
fleshy (*C. succulenta*)	W	2,4-D
Hazel (*Corylus* spp.)	W	2,4-D; glyphosate; picloram; bromacil; triclopyr
Healall (*Prunella vulgaris*)	P	2,4-D; dicamba; glyphosate
Hedgemustard (*Sisymbrium officinale*)	A	2,4-D; dicamba; picloram; amitrole; glyphosate
Hemlock, eastern (*Tsuga canadensis*)	W	AMS, dicamba, picloram
Hemp (*Cannabis sativa*)	A	2,4-D; dicamba; picloram; amitrole; glyphosate
Hempnettle, common (*Galeopsis tetrahit*)	A	Amitrole
Henbit (*Lamium amplexicaule*)	A	Dicamba, picloram, dichlobenil, amitrole, tebuthiuron, pronamide, glyphosate, bromoxynil, napropamide, oxyfluorfen, chlorsulfuron
Hickory (*Carya* spp.)	W	AMS, picloram, glyphosate, bromacil, triclopyr, amitrole, fosamine, tebuthiuron
Hoary cress (*Cardaria draba*)	P	Amitrole; atrazine; 2,4-D; diuron; sodium chlorate; dicamba; amitrole; glyphosate; sulfometuron, chlorsulfuron
Hogpeanut, southern (*Amphicarpa bracteata*)	P	2,4-D
Honeylocust (*Gleditsia triacanthos*)	W	AMS, bromacil, dicamba, glyphosate, picloram
Honeysuckle (*Lonicera* spp.)	W	AMS; amitrole; 2,4-D; picloram; glyphosate; dicamba; sulfometuron; tebuthiuron; hexazinone
Hophornbeam, eastern (*Ostrya virginiana*)	W	AMS; picloram; 2,4-D; bromacil; glyphosate; triclopyr; hexazinone
Hornwort (see coontail, common)		
Horsebrush, littleleaf (*Tetradymia glabrata*)	W	Dicamba, picloram
Horsenettle, Carolina (*Solanum carolinense*)	P	Amitrole, picloram, atrazine, simazine, dicamba

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Horsetail, field (*Equisetum arvense*)	P	Atrazine, bromacil, picloram, dichlobenil, amitrole, sodium chlorate, glyphosate, sulfometuron
Horseweed (*Conyza canadensis*)	A	Atrazine; 2,4-D; dicamba; picloram; tebuthiuron; amitrole; glyphosate; bromoxynil
Houndstongue (*Cynoglossum officinale*)	B	Diuron; dicamba; 2,4-D; picloram
Huisache (*Acacia farnesiana*)	W	Picloram, bromacil, glyphosate, tebuthiuron
Hydrangea, smooth (*Hydrangea arborescens*)	W	2,4-D
Hydrilla (*Hydrilla verticulata*)	Aq	Acrolein**, aromatic solvents**, diquat + copper sulfate, endothall (amine)**
Indian mallow (see velvetleaf)		
Indian-rushpea (see hogpotato)		
Indian-tobacco (*Lobelia inflata*)	A	2,4-D; dicamba
Iris, Rocky Mountain (*Iris missouriensis*)	P	2,4-D
Ironweed, western (*Vernonia baldwinii*)	P	Amitrole; 2,4-D; dicamba; picloram; glyphosate
Ironwood (see hophornbeam)		
Ivy, English (*Hedera helix*)	P	2,4-D
Jerusalem-artichoke (*Helianthus tuberosus*)	P	2,4-D; picloram; glyphosate; sulfometuron
Jimmyweed (*Haplopappus pluriflorus*)	P	2,4-D
Jimson weed (*Datura stramonium*)	A	Atrazine, dicamba, picloram, amitrole, glyphosate, bromoxynil, oxyfluorfen
Johnson grass (*Sorghum halepense*) (established plants)	P	Bromacil, DSMA, MSMA, fenoxaprop, sodium chlorate, glyphosate, sulfometuron, sethoxydim
Jointvetch, northern (*Aeschynomene virginica*)	A	2,4-D
Jungle rice (*Echinochloa colonum*)	A	Benefin, diphenamid, simazine, trifluralin, sethoxydim
Juniper (*Juniperus* spp.) (see also redcedar, eastern)	W	Amitrole, diuron, bromacil, glyphosate, AMS, simazine, picloram
creeping (*J. horizontalis*)	W	Simazine, picloram
Kidneywort baccharis (see coyotebrush)		
Kikuyugrass (*Pennisetum clandestinum*)	P	Sodium chlorate, glyphosate
Kinghead (see ragweed, giant)		
Klamath-weed (see St. John's-wort)		
Knapweed (*Centaurea* spp.)	P	Dicamba, picloram, sodium chlorate, tebuthiuron
black (*C. nigra*), brown (*C. jacea*), and spotted (*C. maculosa*)	P, P & B	Atrazine; dicamba; picloram; sodium chlorate; 2,4-D
Russian (*C. repens*) and squarrosa (*C. squarrosa*)	P	Dicamba, picloram, sodium chlorate, amitrole, glyphosate
Knawel, annual (*Scleranthus annus*)	A	Chlorpropham, dicamba, picloram, amitrole, glyphosate, bromoxynil, linuron

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Knotweed		
Japanese (see smartweed, Japanese)		
Polygonum spp.	A	Benefin, dichlobenil, diphenamid, pronamide, trifluralin, dicamba
prostrate (*P. aviculare*)	A	Atrazine, chlorpropham, glyphosate, dicamba, picloram, napropamide, oxyfluorfen, sodium chlorate
sakhalin (*P. sachalinense*)	P	2,4-D; picloram, amitrole; glyphosate
silversheath (*P. argyrocoleon*)	A	2,4-D; picloram; amitrole; glyphosate
Kochia (*Kochia scoparia*)	A	Atrazine; dicamba; trifluralin; 2,4-D; sulfometuron; tebuthiuron; hexazinone; bromoxynil; amitrole; glyphosate, chlorsulfuron
Kudzu (*Pueraria lobata*)	P	2,4-D; amitrole; picloram; glyphosate; sulfometuron
Ladysthumb (see smartweed, ladysthumb)		
Lambsquarters, common (*Chenopodium album*)	A	Atrazine; benefin; bensulide; bromacil; DCPA; dichlobenil; diphenamid; EPTC; oxyfluorfen; oxadiazon; trifluralin; napropamide; simazine; 2,4-D; oryzalin; tebuthiuron; pronamide; dicamba; picloram; amitrole; glyphosate; triclopyr; bromoxynil; linuron; chlorsulfuron
Lantana (*Lantana camara*)	W	Hexazinone, tebuthiuron
Larch (*Larix* spp.)	W	Bromacil, tebuthiuron
Larkspur		
species not designated	P	Picloram
menzies (*D. menziesi*)	P	2,4-D
Leatherwood (*Dirca palustria*)	W	2,4-D; AMS; bromacil
Leptotaenia, carrotleaf (*Leptotaenia dissecta*)	P	2,4-D
Lettuce		
blue (*Lactuca pulchella*)	P	Atrazine; dicamba; picloram; amitrole; 2,4-D; glyphosate
prickly (*L. serriola*)	A	Oxyfluorfen; atrazine; simazine; triclopyr; napropamide; hexazinone; bromoxynil; sulfometuron; 2,4-D; dicamba; picloram; amitrole, chlorsulfuron
tall (*L. canadensis*)	P	Atrazine, glyphosate
Licorice, wild (*Glycyrrhiza lepidota*)	P	2,4-D
Lilac (*Syringa vulgaris*)	W	AMS, bromacil
Linden (see basswood)		
Locoweed		
bigbend (*Astragalus earlei*)	A or P	2,4-D
Locust, black (*Robinia pseudoacacia*)	W	Amitrole; dicamba; 2,4-D, picloram; triclopyr; tebuthiuron; glyphosate; fosamine; AMS

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
London rocket (see rocket, London)		
Loosestrife		
spiked (*Lythrum salicaria*)	Aq	2,4-D
swamp (see swamp loosestrife)		
Lotebush, condalia (*Condalia obtusifolia*)	W	2,4-D; tebuthiuron
Lotus, American (*Nelumbo lutea*)	Aq	AMS; dichlobenil; 2,4-D
Lupine		
stream (*Lupinus rivularis*)	W	2,4-D; tebuthiuron
silvery (*L. argenteus*)	P	Tebuthiuron; dicamba; 2,4-D; picloram; amitrole; glyphosate
tailcup (*L. caudatus*)	P	2,4-D; tebuthiuron
Madrone, Pacific (*Arbutus menziesii*)	W	2,4-D; picloram
Magnolia (*Magnolia* spp.)	W	Bromacil, picloram, triclopyr
Maidencane (*Panicum hemitomon*)	Aq	Glyphosate
Mallow		
alkali (see sida, alkali)		
common (*Malva neglecta*)	A	Dicamba, picloram, amitrole, glyphosate, chlorsulfuron
dwarf (*M. rotundifolia*)	P	2,4-D; dicamba; picloram; amitrole; glyphosate
Indian (see velvetleaf)		
little (*M. parviflora*)	A	Oxyfluorfen; 2,4-D; dicamba; picloram; amitrole; glyphosate; sulfometuron
venice (*Hibiscus trionum*)	A	2,4-D; dicamba; picloram; amitrole; glyphosate
Manzanita (*Arctostaphylos* spp.)	W	2,4-D; bromacil
greenleaf (*A. columbiana*)	W	Picloram
Maple (*Acer* spp.)	W	AMS, picloram, bromacil, glyphosate, diuron, triclopyr, tebuthiuron
Norway (*A. Plantanoides*)	W	Tebuthiuron
Marestail (see horseweed)		
Marshelder (*Iva xanthifolia*)	A	2,4-D; dicamba; picloram; amitrole; glyphosate
Marshmarigold (*Caltha palustrus*)	P	2,4-D
Meadowrue, purple (*Thalictrum dasycarpum*)	P	Atrazine
Meadowsweet (see spirea)		
Medic, black (*Medicago lupulina*)	A	Tebuthiuron, 2,4-D plus MCPP
Medusahead (*Taeniatherum asperum*)	A	Simazine, amitrole, glyphosate
Mesquite		
honey (*Prosopis juliflora* var. *glandulosa*)	W	Clopyralid Dicamba
velvet (*P. juliflora* var. *veluntina*)	W	Picloram, tebuthiuron, dicamba
Mexicanweed (*Caperonia castaneafolia*)	A	2,4-D
Milkvetch (*Astralagus* spp.), narrowleaf (*A. pectinatus*), and twogrooved (*A. bisulcatus*)	P	2,4-D

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Milkweed		
species not designated	P	Picloram; 2,4-D; amitrole; glyphosate
bloodflower (*Asclepias curassavica*)	P	2,4-D; amitrole
broadleaf (*A. latifolia*)	P	Amitrole; 2,4-D; picloram; glyphosate
climbing (*Sarcostemma cynanchoides*)	P	Amitrole, glyphosate
common (*A. syriaca*)	P	Amitrole, picloram, glyphosate
eastern whorled (*A. verticillata*)	P	Dicamba, picloram, amitrole, glyphosate
showy (*A. speciosa*)	P	Dicamba, picloram, amitrole, glyphosate
Mint, field (*Mentha arvensis*)	P	Picloram, amitrole, glyphosate, dicamba
Mockorange (*Philadelphus virginalis*)	W	Diuron, simazine
Moneywort (*Lysimachia nummularia*)	P	2,4-D; glyphosate
Morning glory (*Ipomoea* spp.)	A	Atrazine; DSMA; simazine; 2,4-D; tebuthiuron; bromoxynil; chlorpropham; linuron; sodium chlorate; dicamba; picloram; pronamide; oxyfluorfen; amitrole; glyphosate
smallflower (*Jacquemontia tamnifolia*)	A	Atrazine, DMSA, MSMA,
Mountain-mahogany (*Cercocarpus montanus*)	W	Picloram
Mugwort (*Artemisia vulgaris*)	P	Dicamba, picloram, glyphosate
Muhly, wirestem (*Muhlenbergia frondosa*)	P	Atrazine, sethoxydim
Mulberry (*Morus* spp.)	W	Bromacil, picloram, triclopyr, hexazinone
Mulesears (*Wyethia amplexicaulis*)	P	2,4-D
Mullein		
common (*Verbascum thapsus*)	B	Dicamba, picloram, amitrole, glyphosate, tebuthiuron
moth (*V. blattaria*)	P	2,4-D; dicamba; amitrole; glyphosate
turkey (*Eremocarpus setigerus*)		Bromacil, sulfometuron, chlorsulfuron
Muskgrass (see algae, Chara)		
Mustard		
species not designated	A	Chlorpropham, sulfometuron, pronamide, linuron
black (*Brassica nigra*)	A	Atrazine; 2,4-D; glyphosate; dicamba; picloram; amitrole; hexazinone
haresear (*Coringia orientalis*)	A	Chlorpropham; 2,4-D; dicamba; picloram; amitrole; glyphosate
Indian (*Brassica juncea*)	A	2,4-D; dicamba; picloram; amitrole; glyphosate
white (*Sinapis alba*)	A	2,4-D
wild (*Brassica kaber*)	A	Dichlobenil; oxyfluorfen; 2,4-D; bromoxynil, chlosulfuron
Naiad (*Najas* spp.)	Aq	Acrolein**, aromatic solvent**, diquat, endothall (amine)**
Natalgrass (*Rhynchelytrum repens*)	P	Hexazinone
Needlerush (*Juncus roemerianus*)	Aq	Diuron; 2,4-D

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Nettle		
species not designated	A	Pronamide, paraquat, oxadiazon
burning (*Urtica urens*)	A	Trifluralin; 2,4-D; oxyfluorfen
stinging (*U. dioica*)	P	2,4-D; sodium chlorate; dicamba; picloram; amitrole; glyphosate
tall (*U. procera*)	A	2,4-D; dicamba; picloram; amitrole; glyphosate
Niggerhead (*Rudbeckia occidentalis*)	P	2,4-D; dicamba; picloram
Nightshade		
species not designated	A	Pronamide, simazine, trifluralin
black or purple (*Solanum nigrum*)	A	EPTC; dicamba; picloram; amitrole; glyphosate; bromoxynil; oxyfluorfen; 2,4-D
cutleaf (*S. triflorum*)	A	2,4-D
hairy (*S. villosum*)	A	EPTC
silverleaf (*S. elaeagnifolium*)	P	Dicamba, tebuthiuron, picloram, amitrole, glyphosate, bromoxynil
Nimblewill (*Muhlenbergia schreberi*)	P	Atrazine, glyphosate
Nut sedge		
species not designated	P	Bromacil, DSMA
purple (*Cyperus rotundus*)	P	Amitrole, EPTC, methyl bromide, MSMA, glyphosate
yellow (*C. esculentus*)	P	EPTC; methyl bromide; MSMA; bentazon; atrazine; 2,4-D; picloram; amitrole; glyphosate; sulfometuron; metolachlor
Oatgrass, tall (*Arrhenatherum elatius*)	P	Atrazine
Oak		
species not designated	W	Dicamba, triclopyr, picloram, fosamine
black (*Quercus veluntina*)	W	AMS, bromacil, dicamba, glyphosate, picloram
blackjack (*Q. marilandica*)	W	Bromacil, picloram, glyphosate, tebuthiuron
blue (*Q. douglasii*)	W	Tebuthiuron, dicamba, picloram, glyphosate
canyon live (*Q. chrysolepsis*)	W	Tebuthiuron; 2,4-D; AMS; picloram
Gambel (*Q. gambelii*)	W	AMS, picloram, dicamba
live (*Q. virginiana*)	W	AMS, bromacil, glyphosate, picloram, tebuthiuron
Oregon (*Q. garryana*)	W	2,4-D
post (*Q. stellata*)		AMS, bromacil, dicamba, picloram, glyphosate, hexazinone, tebuthiurone
red, northern (*Q. rubra*)	W	AMS, bromacil, dicamba, glyphosate, picloram, tebuthiuron
scrub, California (*Q. dumosa*)	W	AMS, tebuthiuron
shinnery (*Q. havardii*)	W	Dicamba, bromacil, picloram, tebuthiuron
shrub live (*Q. turbinella*)	W	Bromacil, picloram

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Turkey (*Q. laevis*)	W	Diuron, bromacil, picloram
white (*Q. alba*)	W	AMS, bromacil, dicamba, picloram, glyphosate, fosamine, hexazinone, tebuthiuron
Oats, wild (*Avena fatua* and *A. ludoviciana*)	A	Atrazine, bromacil, chlorpropham, diuron, EPTC, paraquat, napropamide, simazine, amitrole, glyphosate, hexazinone, oryzalin, oxyfluorfen, tebuthiuron
Onion		
tapertip (*Allium acuminatum*)	P	2,4-D
wild (*A. Canadense*)	P	Dicamba; metham; methyl bromide; 2,4-D; amitrole; glyphosate
Orache (*Atriplex patula* var. *hastata*)	A	2,4-D
Orchard grass (*Dactylis glomerata*)	P	Atrazine, dichlobenil
Osage orange (*Maclura pomifera*)	W	AMS, picloram
Oxalis (see wood sorrel, yellow)		
Panicum (*Panicum* spp.)	P	Benefin, DCPA, atrazine, simazine
fall (*P. dichotomiflorum*)	A	DCPA, diphenamid, MSMA, oryzalin, trifluarlin, fluazifop, pronamide, oxadiazon, sethoxydim, linuron, metolachlor
Texas (*P. texanum*)	A	DCPA, dichlobenil, linuron, tebuthiuron, trifluralin, sethoxydim, napropamide, oryzalin
Paragrass (*Brachiaria mutica*)	Aq, P	Amitrole-T, simazine, glyphosate, hexazinone
Parrotfeather (*Myriophyllum aquaticum*)	Aq	Acrolein**; aromatic solvents**; diquat; endothall; (amine)**; 2,4-D
Parsnip, wild (*Pastinaca sativa*)	B	Atrazine; 2,4-D; dicamba; picloram; hexazinone, chlorsulfuron
Partridgepea (*Cassia fasciculata*)	A	2,4-D
Paspalum		
knotgrass (*Paspalam distichum*)	Aq	Amitrole-T, DSMA
Panama (*P. fimbriatum*)	Aq	MSMA
water (*P. fluitans*)	Aq	Amitrole-T, DSMA
Passionflower, maypop (*Passiflora incarnata*)	P	Dicamba; picloram; 2,4-D; glyphosate
Pea, wild (*Lathyrus aphaca*)	P	2,4-D
Pea-tree (see caragana or pea-tree)		
Pecan (*Carya illinoensis*)	W	AMS, bromacil
Pennycress, field (*Thlaspi arvense*)	A	Atrazine; diphenamid; 2,4-D; dicamba; picloram; amitrole; glyphosate; bromoxynil
Pennywort		
lawn (*Hydrocotyle sibthorpioides*)	P	2,4-D; dicamba
water (*H. umbellata*)	Aq	Diquat; 2,4-D
Penstemon, Rydberg (*Penstemon rydbergii*)	P	2,4-D

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Pepperweed or peppergrass (*Lepidium* spp.)	A	Dichlobenil, diphenamid, bromoxynil
field (*L. campestre*)	A	2,4-D; dicamba; picloram; amitrole; glyphosate
green flower (*L. densiflorum*)	A	2,4-D
perennial (*L. latifolium*)	P	2,4-D; dicamba; picloram
Virginia (*L. virginicum*)	A	2,4-D; dicamba; picloram; amitrole; glyphosate; tebuthiuron
yellow flower (*L. perfoliatum*)	A	2,4-D
Persimmon		
common (*Diospyros virginiana*)	W	AMS, amitrole, bromacil, tebuthiuron, dicamba, picloram, triclopyr, fosamine
Texas (*D. texana*)	W	Picloram
Pickerelweed (*Pontederia cordata*)	Aq	2,4-D; glyphosate
Pigweed		
species not designated	A	Atrazine; benefin; diphenamid; DSMA; MSMA; paraquat; picloram; glyphosate; 2,4-D; simazine; trifluralin; amitrole; linuron; chlorpropham; sulfometuron; hexazinone; metolachlor; tebuthiuron
Palmer (*Amaranthus palmeri*)	A	Benefin; CDEC; diphenamid; prometryne; dicamba; picloram; simazine; trifluralin; amitrole; 2,4-D; glyphosate
prostrate (*A. blitoides*)	A	Atrazine; EPTC; picloram; 2,4-D; dicamba; amitrole; glyphosate
redroot (*A. retroflexus*)	A	Atrazine; bensulide; dicamba; oxadiazon; oryzalin; DCPA; dichlobenil; EPTC; picloram; oxyfluorfen; napropamide; 2,4-D; amitrole; glyphosate
smooth (*A. hybridus*)	A	2,4-D; dicamba
spiny (*A. spinosus*)	A	Picloram, amitrole, dicamba, glyphosate, oryzalin
tumble (*A. albus*)	A	Atrazine; dicamba; EPTC; 2,4-D; dicamba; picloram; amitrole; glyphosate
Pimpernel, scarlet (*Anagallis arvensis*)	A	2,4-D; dicamba; amitrole; glyphosate
Pincherry (*Prunus pensylvanica*)	W	2,4-D
Pine		
species not designated	W	Dicamba, bromacil, picloram, glyphosate, triclopyr
jack (*Pinus banksiana*)	W	Picloram, tebuthiuron
lodgepole (*P. contorta*)	W	Picloram
red (*P. resinosa*)	W	Amitrole, picloram, tebuthiuron
white (*P. strobus*)	W	Picloram, fosamine
Pineappleweed (*Matricaria matricarioides*)	A	Dichlobenil; 2,4-D; dicamba; picloram; amitrole; glyphosate
Pinque (see rubberweed, Colorado)		

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Plantain (*Plantago* spp.)	A or P	Dichlobenil; paraquat; 2,4-D; picloram; triclopyr; prometon; hexazinone
blackseed (*P. rugelii*)	P	2,4-D; dicamba; picloram; amitrole; glyphosate
bracted (*P. aristata*)	A	2,4-D; dicamba; picloram; amitrole; glyphosate
broadleaf (*P. major*)	P	Atrazine; 2,4-D; dicamba; picloram; amitrole; glyphosate
buckhorn (*P. lanceolata*)	P	Tebuthiuron; atrazine; 2,4-D; dicamba; picloram; amitrole; glyphosate; sulfometuron, chlorsulfuron
slender (*P. pusilla*)	A	2,4-D
woolly (*P. purshii*)	A	2,4-D
Plum		
chickasaw (*Prunus angustifolia*)	W	AMS, bromacil, glyphosate, picloram
wild (see cherry)		
Poison hemlock (*Conium maculatum*)	B	2,4-D; dicamba; picloram; amitrole; glyphosate; tebuthiuron; dicamba
Poison ivy (*Toxicodendron radicans*)	W	Amitrole; AMS; glyphosate; 2,4-D; picloram; bromacil; triclopyr; sulfometuron; tebuthiuron; dicamba
Poison oak, Pacific (*Toxicodendron diversiloba*)	W	Amitrole; AMS; picloram; dicamba; 2,4-D; bromacil; glyphosate
Poison sumac (*Toxicodendron vernix*)	W	Amitrole, AMS
Pokeweed (*Phytolacca americana*)	P	Dicamba; picloram; 2,4-D; amitrole; glyphosate
Pondweed (*Potamogeton* spp.)	Aq	Acrolein**; aromatic solvents**; diquat; endothall (amine)**; 2,4-D
American (*Potamogeton nodosus*)	Aq	Dichlobenil
giant (*P. virginatus*)	Aq	Dichlobenil
horned (*Zannichellia palustris*)	Aq	Aromatic solvents**; endothall (amine)**; simazine; copper sulfate; 2,4-D
leafy (*P. foliosus*)	Aq	Acrolein**, aromatic solvents**, diquat, endothall (amine)**
sago (*P. pectinatus*)	Aq	Acrolein**, aromatic solvents**, dichlobenil, diquat, endothall (amine)**
waterthread (*P. diversifolius*)	Aq	Dichlobenil
Poolmat, common (see pondweed, horned)		
Poorjoe (*Diodia teres*)	A	2,4-D; dicamba; picloram; amitrole; glyphosate
Poplar, or popple (see aspen, trembling)		
balsam (*Populus balsamifera*)	W	2,4-D; AMS; bromacil; triclopyr
Poppy, Roemer (*Roemeria refracta*)	A	2,4-D
Povertyweed (*Iva axillaris*)	P	Picloram; dicamba; amitrole; 2,4-D; glyphosate
Prairie grass (see rescue grass)		
Pricklepoppy, bluestem (*Argemone albiflora*)	A	2,4-D

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Prickly-ash, common (*Zanthoxylum americanum*)	W	AMS, bromacil
Primrose-willow (*Ludwigia peruviana*)	Aq	Diuron; 2,4-D
Puncturevine (*Tribulus terretris*)	A	2,4-D; dicamba; picloram; bromacil; MSMA; tebuthiuron; amitrole; glyphosate; sulfometuron; bromoxynil; prometon, chlorsulfuron
Purpletop (*Tridens flavus*)	P	Bromacil
Purslane, common (*Portulaca oleracea*)	A	Atrazine; benefin; chlorpropham; DCPA; dichlobenil; diphenamid; EPTC; MSMA; paraquat; napropamide; oxadiazon; simazine; pronamide; trifluralin; picloram; dicamba; 2,4-D; amitrole; glyphosate; hexazinone; linuron; oryzalin
Quackgrass (*Agropyron repens*)	P	Amitrole-T, atrazine, bromacil, dichlobenil, EPTC, simazine, sodium chlorate, TCA, amitrole, sethoxydim, hexazinone, pronamide, prometon
Rabbitbrush, gray (*Chrysothamnus nauseosus*) and Douglas (*C. viscidiflorus*)	W	2,4-D; dicamba; bromacil; picloram
Radish, wild (*Raphanus raphanistrum*)	A	2,4-D; dicamba; picloram; amitrole; bromoxynil; glyphosate; linuron
Ragweed (*Ambrosia* spp.)	A	Bromacil; dichlobenil; 2,4-D; MSMA; sulfometuron; bromoxynil; hexazinone; linuron; picloram; triclopyr; simazine
blood (*A. aptera*)	A	2,4-D; dicamba; picloram
common (*A. artemisiifolia*)	A	Atrazine; dicamba; picloram; 2,4-D; amitrole; glyphosate
giant (*A. trifida*)	A	Atrazine; 2,4-D
perennial (*A. psilostachya*)	P	AMS; 2,4-D; dicamba; picloram; amitrole; glyphosate
Ragwort, golden (*Senecio aureus*)	P	Diuron, oxadiazon
Rape, wild (*Rapistrum rugosum*)	A or B	2,4-D
Raspberry, wild black or red (see blackberry)		
Rattail fescue (*Festuca myuros*)	A	Chlorpropham, simazine
Rattleweed (*Rhinanthus* spp.)	A	2,4-D
Redbud (*Cercis canadensis* and *C. occidentalis*)	W	AMS, glyphosate, bromacil, dicamba, picloram
Redcedar, eastern (*Juniperus virginiana*)	W	Diuron, picloram, tebuthiuron
Red clover (*Trifolium pratense*)	B	Paraquat, chlorsulfuron
Redmaids, rock purslane (*Calandrinia caulescens*)	P	Benefin
Redstem (*Ammannia auriculata*)	A	2,4-D
Redtop (*Agrostis* spp.)	A or P	Amitrole, bromacil, glyphosate, diuron, methyl bromide
Redvine (*Brunnichia ovata*)	P	Dicamba, picloram, glyphosate
Redwood (*Sequoia sempervirens*)	W	2,4-D

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Reed, common (*Phragmites communis*)	Aq & P	Amitrole, glyphosate, tebuthiuron
Rocket		
London (*Sisymbrium irio*)	A	Pronamide; 2,4-D; oxyfluorfen, chlorsulfuron
yellow (*Barbarea vulgaris*)	B or P	Dichlobenil; 2,4-D; dicamba; picloram; bromoxynil; amitrole; glyphosate; sulfometuron
Rose		
California (*Rosa californica*)	W	2,4-D; picloram
Cherokee (*R. laevigata*)	W	Picloram
Macartney (*R. bracteata*)	W	2,4-D; picloram
multiflora (*R. multiflora*)	W	Picloram, glyphosate, tebuthiuron, fosamine
prairie (*R. arkansana* var. *suffulta*)	W	Glyphosate
sweetbrier (*R. rubiginosa*)	W	Picloram
Rubberweed		
bitter (*Hymenoxys odorata*)	A	2,4-D; dicamba; picloram
pingue (*H. richardsoni*)	P	2,4-D; dicamba; picloram
Rush (*Juncus* spp.)	Aq	Amitrole; atrazine; diuron; sodium chlorate; 2,4-D
slender (*J. tenuis*)	P	2,4-D
Russian pigweed (*Axyris amaranthoides*)	A	2,4-D
Russian thistle (*Salsola iberica*)	A	Atrazine; bromacil; amitrole; dicamba; glyphosate; simazine; picloram; trifluralin; 2,4-D; sulfometuron; bromoxynil; tebuthiuron, chlorsulfuron
Ryegrass (*Lolium* spp.)	A or P	Benefin, bromacil, diphenamid, EPTC, simazine, glyphosate, tebuthiuron, pronamide, sulfometuron, hexazinone, linuron, oxyfluorfen
Sage		
meadow (*Salvia pratensis*)	P	2,4-D
Sonoma (*S. sonomensis*)	P	2,4-D
white (*S. apiana*)	P	2,4-D
whiteleaf (*S. leucophylla*)	P	2,4-D
Sagebrush		
big (*Artemisia tridentata*)	W	2,4-D; tebuthiuron; glyphosate; picloram
California (*A. californica*)	W	2,4-D
fringed (*A. frigida*)	W	2,4-D; picloram
sand (*A. filifolia*)	W	2,4-D
silver (*A. cana*)	W	2,4-D
St-Johns-wort		
Klamath weed (*Hypericum perforatum*)	P	Sodium chlorate, sulfometuron
spotted (*H. punctatum*)	P	Atrazine; simazine; 2,4-D
Salmonberry (*Rubus spectabilis*)	W	Amitrole, picloram, triclopyr, fosamine
Salsify (*Tragopogon* spp.)	B or P	2,4-D
common (*T. porrifolius*)	B or P	2,4-D
meadow (*T. pratensis*)	B	2,4-D; dicamba; picloram
western (*T. dubius*)	B	2,4-D
Saltbush (see orache)		

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Saltcedar (see tamarisk)		
Saltgrass		
species not designated	P	Bromacil
seashore (*Distichlis spicata*)	P	Diuron; sodium chlorate
Saltwort, common (see Russian thistle)		
Sandburs (*Cenchrus* spp.)	A	Atrazine, benefin, chlorpropham, diphenamid, DSMA, EPTC, fortified oils, MSMA, napropamide, trifluralin, amitrole, glyphosate, fluazifop, tebuthiuron
Sandwort, thymeleaf (*Arenaria serpyllifolia*)	A	2,4-D; dicamba; glyphosate
Saskatoon serviceberry (*Amelanchier alnifolia*)	W	2,4-D
Sassafras (*Sassafras albidum*)	W	AMS; dicamba; 2,4-D; bromacil; picloram; triclopyr; fosamine
Scotch broom (*Cytisus scoparius*)	W	2,4-D
Sedge (*Carex* spp.)	P	Amitrole; 2,4-D (heavy rate); glyphosate; atrazine
Sesbania, hemp (*Sesbania exaltata*)	A	Dicamba, picloram, glyphosate, linuron
Shadblow serviceberry (*Amelanchier canadensis*)	W	2,4-D; bromacil; picloram; dicamba
Shepherd's purse (*Capsella bursa-pastoris*)	A	Atrazine; bensulide; dichlobenil; diphenamid; paraquat; dicamba; simazine; 2,4-D; tebuthiuron; pronamide; oxyfluorfen; picloram; amitrole; napropamide; glyphosate; bromoxynil
Sicklepod (*Cassia obtusifolia*)	A	DSMA; MSMA; 2,4-D; linuron
Sida, prickly (*Sida spinosa*)	A	Tebuthiuron, linuron, oxyfluorfen
Signalgrass (*Brachiaria* spp.)	A or P	Diuron, DSMA, MSMA, amitrole, trifluralin, glyphosate, oxyfluorfen, fluazifop, napropamide
Silverberry (*Elaeagnus commutata*)	W	2,4-D; dicamba
Silvergrass (*Miscanthus* spp.)		Simazine
Skeletonweed (*Lygodesmia juncea*)	P	Atrazine; 2,4-D
Skunkbrush (*Rhus trilobata*)	W	2,4-D
Skunkcabbage (*Symplocarpus foetidus*)	P	2,4-D; glyphosate
Skunkweed (see croton, Texas)		
Smartweed		
species not designated	A or P	Atrazine, dichlobenil, diphenamid, triclopyr, hexazinone, linuron, oryzalin, pronamide
green (*Polygonum scabrum*)	A	Chlorpropham; dicamba; 2,4-D; bromoxynil
Japanese (*P. cuspidatum*)	P	AMS; dicamba; 2,4-D picloram
ladysthumb (*P. persicaria*)	A	Atrazine; chlorpropham; dicamba; 2,4-D; picloram; oxyfluorfen; amitrole; glyphosate
marshpepper (*P. hydropiper*)	Aq	Amitrole, diuron

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Pennsylvania (*P. pensylvanicum*)	A	Atrazine; chlorpropham; 2,4-D; dicamba; picloram; amitrole; glyphosate; bromoxynil; oxadiazon; oxyfluorfen
swamp (*P. coccineum*)	P	Chlorpropham, diuron, tebuthiuron
water (*P. amphibium*)	Aq & P	Chlorpropham, dicamba, picloram, amitrole, glyphosate
Smilax (*Smilax* spp.)	W	AMS, picloram, tebuthiuron
Smutgrass (*Sporobolus indicus*)	A or P	Amitrole, hexazinone
Snakeroot, white (*Eupatorium rugosum*)	P	2,4-D
Snakeweed broom (*Gutierrezia sarothrae*)	P	2,4-D; dicamba; picloram; amitrole; glyphosate
threadleaf (see broomweed, threadleaf)		
Snapweed, pale (*Impatiens pallida*)	A	2,4-D
Sneezeweed, bitter (see bitterweed)		
Snowberry, western (see buckbrush)		
Snowbrush, ceanothus (*Ceanothus velutinus*)	W	2,4-D
Snow-on-the-mountain (*Euphorbia marginata*)	A	Dicamba; picloram; 2,4-D; amitrole; glyphosate
Sorrel		
green (*Rumex acetosa*)	P	2,4-D; dicamba
heartwing (*R. hastatulus*)	P	2,4-D; dicamba; picloram; glyphosate
red (*R. acetosella*)	P	Atrazine, chlorpropham, dicamba, diphenamid, picloram, amitrole, glyphosate
Sourwood (*Oxydendrum arboreum*)	W	Dicamba; 2,4-D
Sowthistle		
annual (*Sonchus oleraceus*)	A	Tebuthiuron; oxyfluorfen; napropamide; 2,4-D; dicamba; picloram; amitrole; glyphosate; sulfometuron, chlorsulfuron
perennial (*S. arvensis*)	P	Atrazine; dicamba; simazine; sodium chlorate; picloram; amitrole; diuron; 2,4-D; tebuthiuron
spiny (*S. asper*)	A	2,4-D; dicamba; picloram; amitrole; glyphosate
Spanish needles (*Bidens bipinnata*)	A	Simazine; 2,4-D; dicamba; picloram; amitrole; glyphosate; sulfometuron; hexazinone
Spatterdock (*Nuphar luteum*)	Aq	Glyphosate; 2,4-D
Speedwell (*Veronica* spp.)	P	Atrazine, DCPA, sodium chlorate, endothall, oxadiazon, chlorsulfuron
Speedwell, purslane (*V. peregrina*)	P	Endothall, DCPA
Spicebrush, common (*Lindera benzoin*)	W	AMS; dicamba; 2,4-D; bromacil; picloram
Spikegrass (see saltgrass, seashore)		
Spikerush (*Eleocharis* spp.)	P	2,4-D
dwarf (*E. parvula*)	Aq	Simazine; 2,4-D
Spirea (*Spiraea* spp.)	W	Diuron; simazine; 2,4-D; bromacil; tebuthiuron
Sprangletop (*Leptochloa* spp.)	A	Trifluralin, sulfometuron
Spruce (*Picea* spp.)	W	Picloram

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Spurge		
flowering (*Euphorbia corollata*)	P	Dicamba, picloram
leafy (*E. esula*)	P	AMS, atrazine, dicamba, picloram, dichlobenil, amitrole, glyphosate
spotted (*E. maculata*)	A	DCPA, dicamba, tebuthiuron, picloram, glyphosate, oxadiazon, bromoxynil, oryzalin
Spurry, corn (*Spergula arvensis*)	A	Chlorpropham, dicamba, picloram, EPTC, oxyfluorfen
Stargrass (*Aletris* spp.)	P	MSMA
Star-of-Bethlehem (*Ornithogalum umbellatum*)	P	Amitrole, glyphosate
Star-thistle, yellow (*Centaurea solstitialis*)	A	2,4-D; dicamba; picloram; amitrole; tebuthiuron; glyphosate
Stickseed, or sticktight, European (*Lappula echinata*)	A	2,4-D
Stinkgrass (*Eragrostis cilianensis*)	A	Chlorpropham, DCPA, diphenamid, EPTC, trifluralin, chlorsulfuron
Stinking-willie (see tansyragwort)		
Stinkweed (see pennycress, field)		
Stonewort (*Chara* spp.)	Aq	Copper sulfate
Strawberry, wild (*Fragaria* spp.)	P	Atrazine, dicamba, amitrole, picloram, glyphosate, tebuthiuron
Sumac (*Rhus* spp.)	W	AMS; picloram; 2,4-D; bromacil; amitrole; triclopyr; dicamba; hexazinone; tebuthiuron
Sumpweed, rough (*Iva ciliata*)	A	2,4-D; dicamba; picloram
Sunflower		
common (*Helianthus annus*)	A	Atrazine; picloram; dicamba; amitrole; tebuthiuron; 2,4-D; glyphosate; sulfometuron; bromoxynil, chlorsulfuron
prairie (*H. petiolaris*)	A	2,4-D
Sweetclover, yellow annual (*Melilotus indica*)	A	2,4-D; dicamba; picloram; amitrole; glyphosate, chlorsurfuron
Sweetfern (*Comptonia peregrina*)	W	2,4-D; AMS; glyphosate; picloram; bromacil
Sweetgum (*Liquidambar styraciflua*)	W	AMS, bromacil, glyphosate, picloram, triclopyr, tebuthiuron
Swinecress (*Coronopus didymus*)	A	2,4-D; dicamba; picloram; glyphosate; oxadiazon
Switchgrass (*Panicam virgatum*)	P	Atrazine
Sycamore, American (*Platanus occidentalis*)	W	AMS; dicamba; 2,4-D; bromacil; glyphosate; picloram; triclopyr; tebuthiuron
Tamarack (*Larix laricina*)	W	2,4-D; tebuthiuron
Tamarisk, French (*Tamarix gallica*)	W	AMS; bromacil; 2,4-D
Tanoak (*Lithocarpus densiflora*)	W	2,4-D; picloram
Tansy (*Tanacetum vulgare*)	P	2,4-D; dicamba; picloram; glyphosate
Tansymustard (*Descurainia pinnata*)	A	2,4-D; dicamba; picloram; amitrole; glyphosate; sulfometuron, chlorsulfuron

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Tansy-ragwort (*Senecio jacobaea*)	P	Sodium chlorate; 2,4-D; diuron; sulfometuron
Tanweed (see smartweed, swamp)		
Tarbush (*Flourensia cernua*)	W	AMS; 2,4-D; bromacil; dicamba; picloram
Tarweed, fiddleneck (see fiddleneck, coast)		
Tarweed, showy (*Madia elegans*)	A	Atrazine
Thimbleberry (*Rubus parviflorus*)	W	Picloram, triclopyr, fosamine
Thistle		
species not designated	B or P	Paraquat; picloram; 2,4-D
bull (see bullthistle)		
Canada (*Cirsium arvense*)	P	2,4-D; clopyralid; dicamba; picloram; glyphosate; amitrole; AMS; atrazine; dichlobenil; sodium chlorate; diuron; sulfometuron, chlorsulfuron
musk (*Carduus nutans*)	B	2,4-D; dicamba; sulfometuron; picloram; amitrole; glyphosate, chlorsulfuron
pasture (*Cirsium pumilum*)	B	Atrazine; 2,4-D; dicamba; picloram; glyphosate
wavyleaf (*C. undulatum*)	P	2,4-D; dicamba; picloram; glyphosate
yellow (*C. horridulum*)	B or P	2,4-D; dicamba; picloram; amitrole; glyphosate
Thornapple (see hawthorn)		
Timothy (*Phleum pratense*)	P	Atrazine, dichlobenil
Toadflax, yellow (*Linaria vulgaris*)	P	Diuron; picloram; 2,4-D
Torpedo grass (*Panicum repens)*	P	Amitrole, glyphosate
Tree-of-heaven (*Ailanthus altissima*)	W	Bromacil; AMS; 2,4-D; picloram; tebuthiuron; glyphosate; fosamine
Trumpetcreeper (*Campsis radicans*)	W	AMS; dicamba; amitrole; 2,4-D; picloram; glyphosate; tebuthiuron
Tule (see bulrush)		
Tuliptree (*Liriodendron tulipfera*)	W	AMS, bromacil, glyphosate, picloram, triclopyr, fosamine
Tumblemustard (*Sisymbrium altissimum*)	A	2,4-D; dicamba; picloram; amitrole; glyphosate, chlorsulfuron
Tumbleweed (see pigweed, tumble)		
Tupelo (see gum, black)		
Umbrella plant, smallflower (*Cyperus difformis*)	A	2,4-D
Vaseygrass (*Paspalum urvillei*)	A or P	Bromacil, hexazinone, diuron
Velvetleaf (*Abutilon theophrasti*)	A	2,4-D; dicamba; chlorpropham; picloram; amitrole; glyphosate; bromoxynil; linuron; oryzalin; oxyfluorfen
Venus's looking-glass (*Specularia perfoliata*)	A	2,4-D
Vervain (*Verbena* spp.)	P	2,4-D; dicamba

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Vetch		
narrowleaf (*Vicia angustifolia*)	A	Atrazine; 2,4-D; dicamba; picloram; amitrole; glyphosate
wild (*Vicia* spp.)	A	2,4-D; dicamba; picloram; tebuthiuron; sulfometuron; amitrole; glyphosate; triclopyr
Viburnum, mapleleaf (*Viburnum acerifolium*)	W	AMS, bromacil, picloram
Virginia creeper (*Parthenocissus quinquefolia*)	W	2,4-D; glyphosate; tebuthiuron
Violet (*Viola* spp.)		2,4-D plus triclopyr
Walnut, black (*Juglans nigra*)	W	2,4-D; AMS; dicamba; bromacil; picloram
Waterchestnut (*Trapa natans*)	Aq	2,4-D
Watercress (*Nasturtium officinale*)	Aq	2,4-D
Water crowfoot (*Ranunculus aquatilis*)	Aq	Acrolein**, aromatic solvents**, diquat, endothall (amine)**
Water fern (*Azolla* spp.)	Aq	Diquat; 2,4-D
Water hemlock		
spotted (*Cicuta maculuta*)	P	2,4-D; amitrole; glyphosate; dicamba; picloram
western (*C. douglasii*)	P	2,4-D
Waterhemp (*Amaranthus rudis*)	A	Atrazine; 2,4-D; dicamba; picloram; glyphosate
Water-hyacinth (*Eichornia crassipes*)	Aq	Amitrole-T; diquat; 2,4-D; glyphosate
Waterlettuce (*Pistia stratiotes*)	Aq	Diquat; 2,4-D esters in oil or oil-water emulsion
Water lily (*Nymphaea* spp.)	Aq	Dichlobenil; 2,4-D
Watermilfoil		
broadleaf (*Myriophyllum heterophyllum*)	Aq	Acrolein*; diquat; endothall; simazine; 2,4-D (granular)
Eurasian (*M. spicatum*)	Aq	2,4-D (butoxy ethanol ester or granules); diquat; endothall (amines)**
northern (*M. exalbescens*)	Aq	Dichlobenil; diquat; endothall; 2,4-D (granular)
Waterplantain		
common (*Alismia plantagoaquatica*)	Aq	2,4-D
narrowleaf (*A. graminuem*)	Aq	Acrolein**, aromatic solvents**, dichlobenil
Water primrose (*Ludwigia* spp.)	Aq	Acrolein**; dichlobenil; diuron; 2,4-D
Water shield (*Brasenia schreberi*)	Aq	Endothall (all formulations); 2,4-D
Water-stargrass (*Heteranthera dubia*)	Aq	Acrolein**, aromatic solvents**
Waterwillow (*Justicia* spp.)	A	Diquat
Wedgleaf (see ceanothus, wedgeleaf)		
White clover (*Trifolium repens*)	P	Endothall; 2,4-D, chlorsulfuron
Whitehorn (*Acacia constricta*)	W	2,4-D; picloram

WEED SPECIES AND HERBICIDES FOR THEIR CONTROL—Continued

Weed Species	Growth Habit	Herbicides
Wild buckwheat (*Polygonum convoluvulus*)	A	Chlorpropham; dicamba; sodium chlorate; 2,4-D; picloram; linuron; glyphosate; bromoxynil; oxyfluorfen
Wild cane (*Sorghum bicolor*)	A	EPTC, trifluralin, glyphosate
Wild celery (*Vallisneria* spp.)	Aq	Endothall (amine granular)** dichlobenil
Wild cucumber (see burcucumber)		
Wild flax (see coreopsis, plains)		
Wild indigo (*Baptisia tinctoria*)	P	2,4-D
Wild rye, Canada (*Elymus canadensis*)	P	Atrazine
Willow (*Salix* spp.)	W	AMS; bromacil; dicamba; 2,4-D; triclopyr; fosamine; hexazinone; tebuthiuron
Willowweed (*Epilobium* spp.)	P	2,4-D
Windmill grass, tumble (*Chloris verticillata*)	P	Amitrole, glyphosate
Winter cress (see yellow rocket)		
Witchgrass (*Panicum capillare*)	P	MSMA, simazine, amitrole, glyphosate, atrazine, chlorpropham, oxyfluorfen, tebuthiuron
Witch-hazel (*Hamamelis* spp.)	W	AMS, dicamba, bromacil
Witchweed (*Striga asiatica*)	A	2,4-D; glyphosate; oxyfluorfen
Wolfberry (see buckbrush, snowberry)		
Woodsorrel, yellow (*Oxalis stricta*)	A or P	Atrazine, dichlobenil, dicamba, MSMA, terbacil, picloram, hexazinone, oxadiazon, oxyfluorfen
Wool grass (see bulrush)		
Wormseed mustard (*Erysimum cheiranthoides*)	A	2,4-D; dicamba; picloram; amitrole; glyphosate
Wormwood		
annual (*Artemisia annua*)	A	2,4-D; dicamba; picloram
biennial (*A. biennis*)	B	2,4-D; dicamba; picloram
common (*A. absinthium*)	A	Amitrole; 2,4-D
Yankeewood (*Eupatorium compositifolium*	P	2,4-D; picloram
Yarrow		
common (*Achillea millefolium*)	P	Atrazine, dicamba, picloram, amitrole, sulfometuron, glyphosate, chlorsulfuron
western (*A. lanulosa*)	P	2,4-d; Dicamba; picloram
Yaupon (*Ilex vomitoria*)	W	Tebuthiuron, AMS, bromacil, picloram
Yellow-rocket (*Barbarea vulgaris*)	B or P	2,4-D; dicamba; picloram; amitrole; glyphosate; sulfometron; dichlobenil; bromoxynil
Yerbasanta, California (*Eriodictyon californicum*)	W	2,4-D
Yucca (*Yucca* spp.)	W	Picloram