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Real Property
Operations and Maintenance

WEED CONTROL
AND
PLANT GROWTH
REGULATION

This manual replaces MO-314
“Control of Non-Cropland Weeds”

MO 314
24 May 1989

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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

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, ethoxyet hoxypropyl, 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

chemical composition of plants, and effects on organisms in the food chain. All herbicides have

life habitat by changing the species in the plant community.

but herbicides can also be useful in management. Openings in wooded areas, such as clear-

wildlife. Herbicides can be used to induce sprouting of browse species for deer. Herbicides

allow the increase of other desirable plants, such as in the selective control of brush in rights-of-

The control of submersed weeds in ponds and streams can be beneficial to fish populations.

of the chemical per million parts of water, vary widely with age, size, and species of fish.

ers should be consulted to determine appropriate uses and precautions. Management of fish and

and Wildlife Manual (TM 5-633, AFM 126-4, NAVFAC MO 100.3).

might endanger fish and wildlife, you should consult federal or state fish and wildlife agencies

gered or threatened species will be affected. Also check on local water quality regulations regarding pesticide use.

1-14. Damage to Equipment.
ing and cleaning of equipment with water and a detergent is sufficient protection against most

the metal parts of spraying equipment; and oils and solvents can injure rubber seals, gaskets,

purchase equipment with noncorrosive metals or coat the metal parts of the equipment with
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-l. 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 tile 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 vegetat ion 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 Irears. 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, re-sprouting 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) Post emergence -- 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 n 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 pots 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 trirlopyr (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:

(I) 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 la) 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 la 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 lb. 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 la by line lb 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 lb 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 la 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 lb, 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, la, lb, 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 Mower			
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

	Obstructed Areas		Fence Borders			
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

							Document A
i. Supervisor cost per hour	$ —		$—				
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 tempo- rary 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. The 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: Spray Equipment					Source*
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) × (4d)
f. Rnd. trip hours to site	1					
g. Total drive time	77					(4a) × (4f)
h. Drive cost per hour	$ 11.53					
i. Total drive cost	$887.81	+		=	$ 887.81	(4g) × (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	Amidochlor	7	5	7
Grasses*	Flurprimidol	10	8	10
	Maleic hydrazide	8	6	8
	Mefluidide	8	6	8
Warm-Season	Flurprimidol	10	8	10
Grasses**	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 using 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) x (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

*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 Dot. 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 Dot. 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 spray 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

HERBICIDES FOR MIXED HERBACEOUS BROADLEAF AND GRASS WEEDS—Continued

Treatment (pounds/ acre; cost/pound)	Time of Application	Vegetation Controlled	Remarks
Tebuthiuron(4-16; $18.50/lb)	During, or before, period of active weed growth.	Many plants, including woody plants, perennial grasses, and broadleaf weeds.	Can be sprayed (wettable powder) or spread dry (pellets or granules) on soil surface. Herbicide is mainly absorbed by plant roots, less so through foliage. Do not apply near trees or other desirable plants, nor on areas to which their roots extend or where runoff water may move herbicide to desirable tree roots. Initial control is enhanced by rainfall. Use only when persistent control is desired. Low water-solubility.

HERBICIDES FOR HERBACEOUS BROADLEAF WEEDS IN DESIRABLE GRASSES

Treatment (pounds/ acre; cost/pound)	Time of Application	Vegetation Controlled	Remarks
Dicamba(0.25-8; $13.75/lb)	Actively growing weeds. Perennial weeds are usually most effectively treated in bud to bloom stage.	Many annual and perennial broadleaf weeds.	Do not apply on or near desirable trees or plants, or in locations where herbicide may be washed or moved into contact with their roots. Rates in excess of 4 lb/acre may cause temporary injury to sensitive grass species. Dicamba is absorbed by both roots and foliage. Foliage treatments are more effective. Often used in mixtures with 2,4-D. Avoid drift of spray to nontarget areas, as minute amounts will severely injure some plants.
2,4-D(1-4; $2.60/lb)	Actively growing weeds. Perennials, bud to early bloom.	Many annual and perennial broadleaf weeds.	Low-volatile ester formulations are generally more effective, pound for pound, than amine salt formulations. However, vapors from ester formulations can kill susceptible plants growing near the area treated. Avoid drift of spray of either formulation. 2,4-D is absorbed by the leaves and other parts of the plant above ground. It is translocated within the plant. It is often mixed with dicamba, picloram, or other growth-regulator herbicides to increase range of plants controlled.
Picloram(0.3-5; $42.50/lb)	Soil treatments when soil is not frozen and when rainfall can be expected. Foliage treatments when weeds are actively growing.	Brush and woody plants. Annual and perennial broadleaf weeds.	A RESTRICTED USE PESTICIDE because of its residual properties, mobility in water and soil, and high toxicity to broadleaf plants. Picloram is extremely active in killing many broadleaf species, is water-soluble, can be carried in runoff water, and may persist for more than 1 year in heavy soil or in the more northern cool climates. A lower rate in foliage spray is as effective in killing weeds as higher rates in soil treatments. Avoid drift to nontarget plants, and avoid contamination of irrigation water. Do not apply on or near desirable plants and most field crops. Do not move soil to other untreated areas where you want to grow desired plants. Picloram is often mixed with 2,4-D and other growth regulator herbicides for control of some hard-to-kill weed and brush species.

HERBICIDES FOR HERBACEOUS BROADLEAF WEEDS IN DESIRABLE GRASSES -- Continued

Treatment (pounds/ acre; cost /pound)	Time of Application	Vegetation Controlled	Remarks
Triclopyr (1-9; $15.50/lb)	Actively growing weeds.	Broadleaf weed and brush species. Not effective on conifers.	Broad spectrum of weeds controlled when mixed with 2,4-D, or picloram. It is formulated as either the ester or amine salt and is used as a foliar spray. It usually does not persist in soil for more than one growing season. Prevent drift of spray to nontarget plants, as minute quantities of spray will injure them. Triclopyr is used on broadleaf weeds and woody plants in industrial sites, rangeland, permanent grass, aquatic sites, and rice.

HERBICIDES FOR WEEDY GRASSES

Treatment (pounds/acre; cost/pound)	Time of application	Vegetation Controlled	Remarks
Fluazifop(0.25-0.5; $74.75/lb)	Plants up to 12 inches tall and actively growing. Johnsongrass up to 20 inches tall.	Grasses. It is not effective on broadleaf plants.	Add 0.25 percent nonionic surfactant or 1 percent crop oil concentrate to the spray mixture. For control of perennial grasses, a second application to surviving plants will increase percentage control. Do not make application if rain is expected within 1-hour.
Sethoxydim(0.3-0.5; $74.00/lb)	Postemergence, up to 8 inches tall. Johnsongrass up to 20 inches tall, when actively growing.	Grasses. It is not effective on broadleaf plants.	Add 1 percent by volume crop spray oil to the spray mixture. Perennial grasses vary in their susceptibility, and repeated applications may be necessary.

HERBICIDES FOR WOODY PLANTS

Treatment (pounds/ acre; cost/pound)	Time of Application	Woody Plants Controlled	Remarks
Amitrole (3-6; $6.15/lb)	Actively growing plants in full leaf until plants begin to go dormant.	Poison ivy, poison oak, honeysuckle, kudzu, salmonberry, bigleaf maple, wild cherry, ash, locust, and sumac.	Apply as a drenching foliage and stem spray when rainfall is not expected for at least 24 hours. If regrowth appears, retreat in August or the following spring. Herbicide is absorbed by the leaves and is translocated through the entire plant. It is water-soluble and has short residual activity through the soil. It is a nonselective spray that may injure all vegetation in treated areas.
AMS (60 lb/100 gal $1.00/lb)	Full-leaf stage until foliage begins to discolor.	Most woody plants, including hardwood and coniferous species such as alder, ash, birch, cedar, elm, gum, hickory, maple, oak, pine, poison ivy, and willow.	Apply as a drenching foliage spray, frill, notch, or stump treatment. For the cut surface treatments use more concentrated solutions. Injures grasses and other vegetation in the area. Can be used adjacent to domestic water supply reservoirs, streams, drainage ditches, lakes and ponds. Extremely corrosive of most metals. Follow instructions on label for cleaning and protection of equipment.
Bromacil (5-25; $13.75/lb)	In spring or fall, before period of expected rainfall.	Many woody plants are susceptible. Plants somewhat resistant include greenbriar, mesquite, osage orange, and roses.	Bromacil is a soil treatment, and often kills all vegetation in the treated area. Because it persists in the soil, reseeding is not practical. It may be carried to adjoining areas by surface water that runs across treated sites, and injure susceptible plants downslope.
Clopyralid (0.5; $4.30/lb)	Full leaf stage and when plants are actively growing.	Especially effective on legume plants such as misquite. Some other woody plants such as big sagebrush can be controlled at higher rates.	Applied as a foliage spray. Can be absorbed from the soil. Use other herbicides such as 2.4-D, dicamba, and triclopyr in mixtures with clopyralid to increase spectrum of woody plants controlled.

HERBICIDES FOR WOODY PLANTS -- Continued

Treatment (pounds/ acre; cost/pound)	Time of Application	Woody Plants Controlled	Remarks
2,4-D (1-3; $2.60/lb)	Full-leaf stage and when plants are actively growing.	Most effective on such species as sagebrush, buckbrush, chamise, manzanita, and willow. Contributes to effectiveness of mixtures with other herbicides on many tree species.	The ester formulation is more effective on woody plants as a selective foliage spray that leaves grasses uninjured. Usually used in mixtures with other herbicides such as, picloram, triclopyr, and dicamba on most brush species. Can be used as basal spray when mixed in fuel oil on trees less than 5 inches diameter, and as notch or frill treatments. Follow all precautions to prevent drift of spray to nontarget susceptible plants. Not persistent in soil.
Dicamba + 2,4-D(3 + 3; $13.75/1b + $2.60/lb)	Full-leaf stage and when plants are actively growing. Cut surface treatments can be done at anytime.	Many species of woody plants. It is not effective on such species as red maple, red mulberry, blackjack oak, live oak, salmonberry, and southern waxmyrtle.	Applied as a foliage spray. Phytotoxic amounts can be absorbed from the soil. Take particular precautions to prevent drift of spray to nontarget sites. Dicamba is usually used in mixtures with many other herbicides. Different formulations are used in mixtures as basal spray and frill and cut stump treatments. Grasses will survive treatments with dicamba and maintain ground cover.
Fosamine (8-12; $10.00/lb)	Late summer and early fall during the 2-month period before fall leaf coloration.	Many woody species, including: birch, blackberry, black locust, pin cherry, red oak, salmonberry, sumac, sweet gum, vine maple, Virginia pine, water oak, and white oak.	Used as a foliage spray on noncropland sites including land adjacent to domestic water supply reservoirs, streams, lakes and ponds. Response to spraying is usually not observed until the following spring. Effectiveness may be reduced if rain occurs on the same day after spraying. It has a half-life residual period in the soil of about 1 week,

HERBICIDES FOR WOODY PLANTS -- Continued

Treatment (pounds/ acre; cost/pound)	Time of Application	Woody Plants Controlled	Remarks
Picloram(0.S-2; $42.50/lb)	Full-leaf stage when plants are actively growing. Also, soil treatments are effective anytime when enough rainfall is expected to leach herbicide to the roots.	Many species of woody plants, including: blackberries, buttonbush, cactus, acacias, cedar, chapparral species, dogwood, firs, gorse, guava, gums, hickory, juniper, kudzu, lantana, live oak, locust, maple, mesquite, oak, persimmon, pine, roses, salmonberry, sassafras, trumpet creeper, and willows.	A RESTRICTED HERBICIDE. Usually used as a foliage spray in mixtures with other herbicides such as 2,4-D; dicamba; and triclopyr. While more efficient when applied as a foliage spray, it is effective and used also as a soil treatment. Persistence time in the soil is greatest in cool climate and in heavy solids, and may exceed a year. Take particular care to avoid drift in nontarget sites, and avoid use on sites where runoff water can carry the herbicide to desirable broadleaf plant species or to streams or impounded water. Does not kill grasses.
Tebuthiuron(4-6; $18.50/lb)	Anytime when enough rain is expected to move herbicide into the root zone.	Most woody species, as well as other vegetation.	Nonselective soil treatment, and should be used only where bare soil is desirable. Herbicide persists in soil for more than a year. Do not use on areas such as walks, driveways, streets, patios, tennis courts, swimming pools, cemeteries or other landscaped areas. Do not apply in locations where the chemical may be washed by runoff or sheet erosion to areas having roots of desirable vegetation. Do not apply on an area into which the roots of desirable vegetation may extend. Roots of trees and shrubs may extend for beyond the drip line of the plants' branches.
Triclopyr(1-8; $15.50/lb)	Full-leaf stage and when plants are actively growing.	Many species including beech, birch, blackberry, cherry, cottonwood, hazel, hickory, locust, persimmon, poison oak, poplar, salmonberry, sassafras, sumac, sweetgum, sycamore, tulip poplar, and willow.	A selective foliage spray, but it can also be absorbed from soil. It does not kill grasses. It is often used in mixtures with 2,4-D and picloram to increase range of species controlled. Usually does not persist for more than one season. The ester formulation in fuel oil is effective as basal bark and dormant brush treatment. Take precautions to prevent drift to nontarget susceptible species.

HERBICIDES FOR WEED GRASSES IN TURF

Herbicide (pounds/acre)	Time of Application	Weeds Controlled	Remarks
Asulam (2)	Postemergence.	Annual grasses and certain broadleaf weeds.	Use only in St. Augustinegrass.
Atrazine (2–4)	January, February, or March, before weeds germinate.	Crabgrass, *Paspalum* spp., spotted spurge, and other broadleaf weeds.	Use granular formulation in centipede, St. Augustine, and zoysia grasses. Can be used soon after sprigging new lawn. Do not apply to root zone areas of trees and shrubs, nor to cool-season grasses.
Benefin (1.5–3)	Before germination of annual grasses. About time blossoms falls off forsythia.	Annual grasses such as crabgrass, barnyardgrass, and foxtails.	For use in established warm and cool season grasses. Do not reseed within 42 days. Injures bentgrasses and red fescue.
Bensulide (10–15)	Before germination of annual grasses. About time blossoms fall off forsythia.	Annual grasses such as crabgrass, fall panicum, and foxtails.	Apply to established turf only. Can be used on dicondra. Do not reseed for 4 months.
DCPA (10–15)	Before germination of annual grasses. About time blossoms fall off forsythia.	Annual grasses such as crabgrass and foxtails.	May be used in turfgrasses and flower gardens. Do not seed turfed area within 60 days. Injures bentgrasses, red fescue, and newly sprigged bermudagrass and zoysiagrass.
Diphenamid (10)	Before weed seed germination in established dichondra plantings. At seeding in new plantings.	Annual bluegrass, crabgrass, foxtail, ryegrass, lambsquarters, pigweed, smartweed, chickweed, carpetweed, and others.	In dichondra, fall applications control annual bluegrass; spring applications control crabgrass. Make applications usually at 6-month intervals.
DSMA, MSMA, and similar arsonates (1.5-2.5)	After emergence of weed grasses. Re-treat at 7- to 10-day intervals until controlled.	Crabgrass, dallisgrass, goosegrass, sandbur, foxtail, and nutsedge.	Follow instructions on label. May slightly discolor turf. Do not use on St. Augustine, carpetgrass, or centipedegrass. Avoid high temperatures. Repeat treatments are necessary.
Ethofumesate (1–2)	Before weed emergence to two-leaf stage.	Annual bluegrass and common chickweed.	Use in perennial ryegrass, and in fully dormant bermudagrass. Will injure other turf species.

HERBICIDES FOR WEED GRASSES IN TURF—Continued

Herbicide (pounds/acre)	Time of Application	Weeds Controlled	Remarks
Fenoxaprop (0.12–0.35)	After emergency of annual grass weeds.	Barnyardgrass, crabgrass, foxtails, goosegrass, johnsongrass.	Use on mature cool-season grasses and zoysiagrass. May discolor Kentucky bluegrass. Do not use on bentgrasses, bermudagrass, or other grasses not on the label.
Glyphosate (1.5–4)	When existing turf is actively growing. With at least a week's growth after mowing.	Bermudagrass, zoysia, quackgrass, tall fescue, nimblewill, bentgrass, Kentucky bluegrass, and others.	Nonselective, foliage spray used to kill existing vegetation to allow reseeding. Wait 7 days after treatment before cultivating or other preparation for reseeding.
Oxadiazon (2–4)	Before weed germination of annual grass weeds.	Goosegrass, crabgrass, certain other annual grasses, and broadleaf weeds.	Use granular formulation on Ky. bluegrass, bermudagrass, perennial ryegrass, and St. Augustinegrass. Do not apply to red fescue, bentgrass, dichondra, or centipedegrass, nor to putting greens.
Pendimethalin (1.5–3.0)	Before germination of annual weed grasses.	Crabgrass, foxtails, goosegrass, and other annual grasses.	May be used on most turfgrasses. Do not apply to bentgrasses and other grasses not on label. Do not reseed within 4 months.
Pronamide (0.5–1)	Before or after annual bluegrass emerges.	Annual bluegrass.	Use in bermudagrass turf in southern states. Injures bluegrass, ryegrass, fescues, bentgrass, and dichondra. Avoid spraying areas that drain on bentgrass greens or that have been over-seeded with cool-season grasses.
Siduron (6–12)	Before germination of annual weed grasses. Early postemergence control of annual grasses.	Crabgrass, foxtails, and other annual grasses.	Most useful where turf seed is seeded is spring to thicken turf. May injure bermudagrass.

HERBICIDES FOR BROADLEAF WEEDS IN TURF

Herbicide (pounds/acre)	Time of Application	Weeds Controlled	Remarks
Atrazine (2–4)	January, February, or March. Treat soon after sprigging new lawn.	Spotted spurge and other annual weeds.	Do not apply to root zone of trees and shrubs, not to cool-season grasses. Use granular formulation in centipede, St. Augustine, and zoysia grasses.
Bentazon (1-2)	June–Sept. Repeated treatments at 7- to 14-day intervals.	Yellow nutsedge.	Less effective in late summer. Does not control purple nutsedge. May require perennial ryegrass.
Chlorsulfuron (0.016–0.06)	Spring, soon after weeds have emerged.	Broadleaf weeds such as chickweed, speedwell, henbit, London rocket, and wild garlic.	Do not apply to root zone of trees and shrubs. Tolerant grasses include bahiagrass, bermudagrass, bluegrass, fescue, and smooth brome. May temporarily suppress grass growth. Do not use more than 0.03 lb/acre on fescue and smooth brome.
Dicamba (0.125–0.25)	When weeds are actively growing.	Chickweed, clover, henbit, knotweed, red sorrel, knawel, purslane, dog fennel, scentless chamomille, and others.	Do not exceed recommended rate. Keep away from shrubs and other ornamental plants. Dicamba is usually mixed with 2,4–D for broad-spectrum control.
Endothall (1-1.5) in 50–100 gal water	When weeds are actively growing.	Burclover, henbit, knotweed, speedwells, pennywort, and others.	May discolor foliage of turf grasses. Keep children and animals off sprayed areas until first rain or sprinkling.
Mecoprop (1–2)	When weeds are actively growing.	Chickweed, burclover, English daisy, whiteclover.	Used in mixtures with 2.4–D and/or dicamba. Follow same precautions in use as for 2.4–D.
2,4–D amine salts or low-volatile esters (1)	When weeds are actively growing in fall and spring.	Plaintains, dandelion, curly dock, and many others.	Spray only when there is no wind that will cause drift of spray to ornamental plants. Minute quantities will injure them. Treatments in fall allow the cool-season lawn grasses time to take over space left by dead weeds before next growing season

HERBICIDES FOR BROADLEAF WEEDS IN TURF—Continued

Herbicide (pounds/acre)	Time of Application	Weeds Controlled	Remarks
2,4-D amine salt, or low-volatile esters (2)	Early spring or fall	Wild garlic, wild onion, knotweed. To reduce stands of nutsedge, repeat treatments monthly in June, July, and August.	Follow directions on label. Hard-shell bulb of wild garlic lives in soil for 3 years. Treatments must be repeated annually for 3 years. Take particular precautions to prevent drift of spray onto ornamental plants.
Diclorprop amine or low volatile ester (1)	Fall and early spring	Clovers, dandelions, oxalis, and many other broadleaf weeds.	Available in pre-pack mixtures with 2,4-D. Broadspectrum control. Follow same precautions in use as for 2,4-D.
Triclopyr amine a low volatile ester (1)	Fall and early spring	Clovers, dandelions, plantairs, oxalis, violets, and many other broadleaf weeds.	Available in pre-pack mixtures with 2,4-D. Broadspectrum control. Follow same precautions in use as for 2,4-D.

RESPONSE OF LAWN WEEDS TO HERBICIDES

Weed	Type of plant	Control[1] 2,4-D	MCPA	dicamba	mecoprop
Bindweed, field *Convolvulus arvensis*	Perennial	G	F	F	G
Buttercup, creeping *Ranunculus repens*	Perennial	G	E	G	G
Chickweed, common *Stellaria media*	Annual	G	F	E	E
Chickweed, mouseear *Cerastium vulgatum*	Perennial	F	F	E	G
Cinquefoil, Canada *Potentilla canadensis*	Perennial	VG	G	E	-
Cinquefoil, sulphur *P. recta*	Perennial	VG	G	E	—
Clover, white *Trifolium repens*	Perennial	P	P	E	VG
Clover, bur *Medicago polymorpha*	Annual	F	F	E	E
Daisy, English *Bellis perennis*	Perennial	P	P	E	F
Dandelion *Taraxacum officinale*	Perennial	E	E	F	F
Dock, curly *Rumex crispus*	Perennial	VG	G	VG	F
Garlic, wild *Allium vineale*	Perennial	G	F	F	—
Ground ivy *Glecoma hederacea*	Perennial	G	F	G	—
Henbit *Lamium amplexicaule*	Annual	F	F	E	—
Ivy, English *Hedera helix*	Perennial	P	P	F	P
Knawel, annual *Scleranthus annuus*	Annual	P	P	E	—
Knotweed, prostrate *Polygonum aviculare*	Annual	F	F	E	F
Medic, black *Medicago lupulina*	Annual	G	G	G	G
Moneywort *Lysimachia nummularia*	Perennial	E	—	—	—
Nutsedge, purple *Cyperus rotundus*	Perennial	F	P	P	P
Nutsedge, yellow *C. esculentus*	Perennial	F	P	P	P
Pennywort, lawn *Hydrocotyle rotundifolia*	Perrenial	VG	—	E	—

[1]Indicates the general susceptibility of the weed to an herbicide; E = excellent, VG = very good, G = good, F = fair, and P = poor. For further information. consult individual labels and local authorities. Further research may result in change in some of the current effectiveness ratings. A dash indicates effectiveness is not known.

RESPONSE OF LAWN WEEDS TO HERBICIDES -- Continued

Weed	Type of plant	Control[1]			
		2,4-D	MCPA	dicama	mecoprop
Plantain, broadleaf *Plantago major*	Perennial	E	G	F	F
Plantain, buckhorn *P. Lanceolata*	Perennial	E	G	F	F
Plantain, blackseed *P. rugelii*	Perennial	E	G	F	F
Poison Ivy *Toxicodendron radicans*	Woody	G	G	G	—
Poison Oak *T. diversiloba*	Woody	G	F	F	—
Puncturevine *Tribulus terrestris*	Annual	VG	F	E	—
Sorrel, red *Rumex acetosella*	Perennial	P	P	VG	P
Speedwell, corn *Veronica arvensis*	Annual	F	P	F	—
Speedwell, purslane *V. peregrina*	Annual	G	P	F	—
Spurge, spotted *Euphorbia maculata*	Annual	F	F	F	P
Strawberry, wild *Fragaria* spp.	Perennial	F	P	G	—
Thistle, Canada *Cirsium arvense*	Perennial	G	G	E	—
Violet *Viola* spp.	Perennial	F	P	F	—
Woodsorrel, yellow *Oxalis stricta*	Perennial	F	P	F	P
Woodsorrel, creeping *O. corniculata*	Perennial	P	P	P	P

SOIL PERSISTENCE AND HAZARDS OF HERBICIDES TO DESIRABLE PLANTS

Herbicide	Persistence	Hazard in Root Zones of Trees and Shrubs	Hazard to Herbaceous Plants Downslope	
			Turfgrass	Broadleafs
amitrole (Weedazol, Cytrol	2-4 weeks	low	low	low
AMS (Ammate)*	1-2 months	low	0-low	0-low
atrazine (Atratol, Aatrex)	6-12 months	mod.	high	high
bromacil (Hyvar)	> 1 year	v. high	high	high
cacodylic acid (Phytar 560)	< 1 month	0	0-low	0-low
DCPA (Dacthal)	3-6 months	0	0	0
dicamba (Banvel)	2-6 months	high	0	low-mod.
dichlorprop (weedore)	< 1-2 months	0	0	0
diuron (Karmex)	6-16 months	moderate	high	high
fenoxaprop (Acclaim)	1 month	0	0	0
fosamine (Krenite)*	1-2 months	low	0	low
glyphosate (Roundup, Kleenup)	< 1 month	0	0-low	0-low
hexazinone	2-4 months	high	high	high
monuron-TCA (Urox)	6-12 months	high	high	high
napropamide (Devrinol)	3-9 months	0	low	0-low
oryzaline (Surflan)	3-9 months	0	low	0-low
oxadiazon (Ronstar)	3-9 months	0	0	0
paraquat, diquat	< 1 month	0	0-low	0-low
Pendimethalin (PRE-M)	306 months	0	0	0
Phenoxys:2,4-D; dichlorprop	< 1-2 months	low	0	0
picloram (Tordon, Amdon)	> 1 year	v. high	0	high
prometon (Pramitol)	6-12 months	high	high	high
simazine (Princep)	6-12 months	low	mod.	mod.
tebuthiuron (Spike, Graslan)	> 1 year	v. high	high	high
triclopyr (Garlon, Turflon)	2-4 months	low	0	low

*Approved for use in watersheds of public water supplies.

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PREPLANTING TREATMENTS TO CONTROL WEEDS IN ORNAMENTAL PLANTINGS

Herbicide (pounds/ acre; cost/pound)	Time of Application	Weeds Controlled	Remarks
Dazomet (240 - 300 ; $4.00/lb)	Four weeks before planting in spring, 3 weeks before planting in summer and fall.	Most weed species, nematodes, soil fungi, and certain soil insects.	A preplanting soil fumigant used in forest tree beds, ornamental beds, and turf and lawn seedbeds. Soil should be moist and cultivated 7 days before treatment. The herbicide is broadcast on the cultivated soil surface by spreader or by hand, and is incorporated by conventional equipment. Adequate moisture is important. If soil is dry, irrigate the treated area with 0.5 inch of water after treatment. Wait 3 to 4 weeks after treatment before planting.
Glyphosate (1-3; $26.30/lb)	Preplanting, grasses and other plants at least 6 to 8” tall, on a day when rain is not expected.	Quackgrass, and many other perennial grasses and broadleaf weeds, on new planting sites.	Glyphosate is a nonselective, translocated systemic, and is quickly inactivated in soil. The normal practice is to spray actively growing quackgrass or other plants before ornamental plants are set. With woody-plant ornamentals, tillage before planting is not necessary. Holes can be dug and the plants set into the dying sod. But with herbaceous plants, tillage not sooner than 3 days after spraying is beneficial. Following planting, use a preemergence residual herbicide, mulch, or a combination of herbicide and mulch, to provide residual control of the weeds that will emerge from germinating seeds.
Metham (218-435 qt commercial product; $2.25/qt)	Apply 14 to 21 days before planting; the soil should be between 60 and 90°F at 3-inch depth.	Most weed species, nematodes, plant disease organisms, and insects in soil.	Metham is used as a preplanting soil fumigant treatment in areas to be planted or replanted with lawngrasses, flowers, ornamentals, fruit trees, etc. The soil is cultivated and kept moist a week before applying metham. Application of 1 to 2 pints of commercial metham formulation to 100 ft^2 of soil area may be applied in a sprinkling can of water or by other methods. The treated area is immediately sprinkled with water until soil is wet 2-4 inches deep, or even better results are expected if area is covered immediately with plastic which is left on 2 days after treatment. Planting can be done 14 to 21 days later.

PREPLANTING TREATMENTS TO CONTROL WEEDS IN ORNAMENTAL PLANTINGS—Continued

Herbicide (pounds/acre; cost/pound)	Time of Application	Weeds Controlled	Remarks
Methyl bromide (218-435; $6.00/lb in can, $1.00/lb in bulk containers)	At least 4 days before planting; soil should be above 50°F at 4-inch depth.	Most weed species, nematodes, plant diseases, and insects in soil.	Methyl bromide, a soil fumigant, is a RESTRICTED HERBICIDE and is extremely poisonous. It is packaged as a liquid and gas under pressure and is considered extremely hazardous. It should be used only by experienced personnel who will read and follow all precautions. It is a very effective fumigant when applied to cultivated soil under a plastic cover. Soil should remain covered for 2 days. Soil must be uncovered at least 48 hours before planting.

PREEMERGENCE TREATMENTS TO CONTROL WEEDS IN ORNAMENTAL PLANTINGS

Herbicide (pounds/ acre; cost/pound)	Time of Application	Weeds Controlled	Remarks
Alachlor (4-6, G&EC[1], $5.60/lb)	Preemergence, preplant incorporated, early postemergence. Repeat for seasonal control.	Most grasses from germinating seeds and, under favorable conditions, germinating broadleaf species such as morning glory, chickweed, henbit, nightshade, purslane, and pigweed.	Control is improved if herbicide is incorporated into the soil. On established plants, granules should be applied on dry foliage to prevent plant injury. Safe on most woody plants, certain ground covers, and bulb plants. Low to moderate hazard to turfgrass downslope.
Bensulide (12,EC or G; $7.00/lb)	Preemergence	Annual grasses and purslane. Most broadleaf weeds are not controlled.	Safe on most woody plants, certain ground covers, and turfgrass.
Chloramben (4-6,G; $8.25/lb)	Preemergence, must be reapplied for control for more than 4 weeks.	Many annual grasses and broadleaf weeds.	Cultivation inactivates the herbicide. Safe on most woody plants, some ground covers, and certain flowers and bulbs. Low hazard to turfgrass from rundown.
Chlorpropham (4-8,G; $19.50/lb)	Dormant season preemergence herbicide	Many annual grasses and some broadleaf weeds, including chickweed and purslane.	Used in wide range of woody plants, ground covers, and bulbs, primarily as a dormant season herbicide. It volatilizes rapidly from soil in warm temperatures. Low hazard to turfgrass downslope.

[1] G = granular formulation; EC = emulsifiable concentrate; and WP = wettable powder.

NOTE: Combinations of preemergence herbicides often can be used to good advantage to provide broader spectrum of weed control or longer control. Grass herbicides such as DCPA, diphenamid, trifluralin, oryzalin, bensulide, alachlor, and metalachlor can be combined or followed with broadleaf-weed herbicides such as simazine at 1-1.5 lb/a ai, oxadiazon at 2 lb/a ai, or oxyfluorfen at 0.5-1 lb/a ai, *provided plant tolerance allows*.

PREEMERGENCE TREATMENTS TO CONTROL WEEDS IN ORNAMENTAL PLANTINGS -- Continued

Herbicide (pounds/ acre: cost/pound)	Time of Application	Weeds Controlled	Remarks
DCPA (10-12,WP or G; $6.30/lb)	Preemergence to weeds.	Many annual grasses, and some broadleaf weeds for 2-3 months.	A repeated treatment is needed for seasonal control. Resistant broadleaf weeds are ragweed, galinsoga, and many others. Registered for use on 52 ornamental annuals, perennials, and bulbs, several ground covers, and a broad range of woody plants and turfgrasses. It is no hazard downslope. It is a safe choice for pathways (baseball fields), patios, flower beds, and mixed plantings.
Dichlobenil (4-6, WP&G; $31.00/lb)	Late fall or early spring, preemergence.	Broad range of annual and perennial weeds, including nutsedge, quackgrass, field horsetail, mugwort, and dandelion.	Highly volatile, and has been consistently effective when applied in late fall or early spring just before snow or rain, or just before mulching in the spring. Safe on many woody plants and certain ground covers, but not herbaceous plants or bulbs. Also susceptible are azaleas, hemlocks, true firs *(Abies* spp) and Douglas-fir. Dormant applications should be followed in the spring with a preemergence annual grass herbicide. Moderate to high hazard to turfgrass downslope unless treated area is mulched. A good choice for control of many established perennial weeds in established tolerant woody plants.
Diphenamid (4-6, WP; $7.75/lb)	Preemergence, before light rain or sprinkler irrigation.	Annual grasses and several broadleaf weeds, such as carpet weed, chickweed, knotweed, lambsquarters, pigweed, purslane, and smartweed.	Controls weeds for 2-4 months. Resistant weeds are ragweed, galinsoga, and many other broadleaf weeds. Safe on several herbaceous plants, ground covers, dichondra, and a broad range of woody plants. Moderate hazard to turfgrass downslope.

PREEMERGENCE TREATMENTS TO CONTROL WEEDS IN ORNAMENTAL PLANTINGS -- Continued

Herbicide (pounds/ acre; cost/pound)	Time of Application	Weeds Controlled	Remarks
EPTC (4-6, EC&G; $4.85/lb)	Preemergence, incorporated in soil immediately or sprinkler irrigated.	Germinating seedling of grasses and some broadleaf weeds, including morning glory, chickweed, henbit, nightshade, lambsquarters, purslane, and pigweed, and nutsedge for about 6 weeks.	Highly volatile, so incorporation in soil is essential. The short residual activity and difficulty in incorporation often makes use limited. Many broadleaf weeds not adequately controlled. EPTC followed by simazine, on ornamentals tolerant to EPTC and simazine, can extend control. Very low hazard to turfgrass downslope. Some hazard if simazine is used.
Metolachlor (4-6, EC&G; $6.15/lb)	Preemergence or preplant incorporated.	Annual weed grasses, yellow nutsedge, and certain broadleaf weeds for 2 or 3 months.	Similar to alachlor but longer lasting. Resistant weeds include lambsquarters, groundsel, and many other broadleaf weeds. Granules are safe on most woody plants and some ground covers. EC formulations injure certain plants, such as actively growing pines, when sprayed on their foliage. Low to moderate hazard to turfgrass downslope.
Napropamide (4-6, WP&G; $14.50/lb)	Preemergence to the weeds, followed by rain or sprinkler irrigation, or incorporated in soil preplant.	Annual grasses, some broadleaf weeds and nutsedge.	Resistant weeds include woodsorrel and nightshade family. It is safe on a broad range of woody plants and ground covers and many herbaceous plants. Low hazard to turfgrass or bulbs downslope.
Oryzalin (2-4,WP; $14.70/lb)	Preemergence on soil surface. If no rain in 10 days after application, sprinkler irrigate.	Controls annual grasses, and many broadleaf weeds for 3 to 6 months.	Resistant weeds include ragweed and crucifers. Similar to trifluralin chemically but is not volatile and lasts longers. Safe on some ground covers, bulbs and most established woody plants. A good choice for woody plantings with bulbs interplanted. Not safe on turf but low hazard to turf from rundown.
Oxadiazon (3-4,G; $42.50/lb)	Preemergence to the weeds.	A broad spectrum of annual grasses, and broadleaf weeds for 3-4 months.	Resistant weeds include the chickweeds. Safe on dry foliage of several ground covers, most woody plants and bluegrass turf. Susceptible plants include many herbaceous plants and bulbs. A good choice on resistant ground covers and woody plants on slopes above turfgrass.

PREEMERGENCE TREATMENTS TO CONTROL WEEDS IN ORNAMENTAL PLANTINGS -- Continued

Herbicide (pounds/ acre; cost /pound)	Time of Application	Weeds Controlled	Remarks
Oxyfluorfen (0.5-2,EC; $33.50/lb)	Preemergence, and postemergence activity on seedling weeds.	Broadleaf weeds, including purslane and groundsel.	Useful for control of seedling broadleaf weeds and to prevent most weeds in plantings of junipers, yews, and dwarf conifers for example. Safe when sprayed only over narrow-leafed evergreens, but injures the early flush of growth of spruces and tree firs. A granular mixture of oxyfluorfen and pendimethalin or oryzalin (grass herbicides) is useful on a broad range of woody ornamental plants. Oxyfluorfen is of low hazard to turfgrass, unless applied directly on turf.
Pronamide (1-3,WP; $26.00/lb)	Preemergence, primarily in the dormant and cool seasons.	Quackgrass, chickweed, annual bluegrass, and other winter animals.	It is volatile, and effective only during late fall and winter just before rain or snow. Safe on many woody plants but not myrtle or boxwood. Dormant applications should be followed in the spring with preemergence herbicides for residual control of annual weeds. Hazardous to turfgrass, except bermudagrass, downslope unless mulched heavily.
Simazine (1-3,G,WP, flowable, water dispersible, granual; $4.70/lb)	Preemergence to the weeds.	Broad spectrum of annual weeds for 2-4 months.	Fails to control annual grasses at the lower rates. Safe on many woody plants, certain ground covers, and bulbs, but no? most annuals and perennials. Susceptible woody plants include azaleas, boxwood, burning bush, and flowering shrubs, except at very low rates. Moderate to high hazard to turfgrass downslope.
Trifluralin (1-4,EC or G; $6.90/lb)	Preemergence to the weeds.	Annual grasses and some broadleaf weeds.	Resistant weeds include ragweed, galinsoga, and many other broadleaf weeds. Because of high volatility, trifluralin requires preplant incorporation in the soil, rain, or sprinkler irrigation after surface application. It has registered uses for over 40 herbaceous annuals, perennials, some ground covers, and most woody plants. It is a good choice for mixed plantings. A very low hazard to turfgrass downslope.

POSTEMERGENCE TREATMENTS TO CONTROL WEEDS IN ORNAMENTAL PLANTINGS

Herbicide (pounds/ acre; cost/pound)	Time of Application	Weeds Application	Remarks
Amitrole (3-6, water soluble powder or solution; $6.10/lb)	Full-leaf stage of actively growing weeds and until plants begin to go dormant.	Poison ivy, poison oak, honeysuckle, kudzu, salmonberry, big-leaf maple, wild cherry, ash, locust, and sumac.	A systemic herbicide primarily used for woody plant control (i.e., poison ivy and poison oak). Spray when rainfall is not expected within 24 hours. It is a nonselective spray and may injure all vegetation in the treated area. Excessive application of amitrole in root zones of trees causes chlorotic injury. Low to moderate hazard to turfgrass downslope.
AMS (60 lb./100 gal, water soluble crystals; $1.00/lb)	Full-leaf stage, until foliage begins to discolor.	Most woody plants, including hardwood and coniferous species.	Apply as a drenching spray, frill, or stump treatment. A nonselective, contact herbicide for herbaceous and woody plant control. Not to be used on ornamental plants. It breaks down to ammonium sulfate {fertilizer) in the soil, and is one of only two brush killers approved for use adjacent to domestic water supply reservoirs. It is very corrosive to equipment.
Asulam (3-7, water soluble powder or liquid; $11.70/lb)	Postemergence to established plants.	Annual grasses and certain broadleaf weeds such as horseweed, mugwort, and Canada thistle.	A systemic spray that slowly kills susceptible plants. It is registered for, and may be safely sprayed over, yews and junipers; but most deciduous shrubs and certain other conifers are injured by foliar sprays. Other residual preemergence herbicide is also needed to provide continued weed control.
Cacodylic acid (3-10, water soluble liquid; $7.00/lb)	Foliage spray to established plants.	Annual broadleaf and grass weeds.	A contact herbicide of low acute mammalian toxicity. Not for use on ornamental plants. Useful to burn down weeds, safe around woody plants if suckers or foliage are not sprayed.

POSTEMERGENCE TREATMENTS TO CONTROL WEEDS IN ORNAMENTAL PLANTINGS -- Continued

Herbicide (pounds/ acre; cost/pound)	Time of Application	Weeds Application	Remarks
Glyphosate (1-5, water soluble liquid; $26.30/lb)	Postemergence for most perennials at bud to early bloom stage.	Most annuals and perennials, and some brush species.	Kills almost all plants treated. Will control most weed and brush species at the correct stage of growth: quackgrass, bermudagrass, and mugwort at 6-8 inches tall; bindweed, horsenettle, and Johnsongrass at flowering stages or later; poison ivy and other woody plants August to late September but before frost and when moisture is good and plants are actively growing; Japanese knotweed *(Polygonum cuspidatum)* at full height (6-8 feet tall) and cut down about 3 weeks later and then spray sparse regrowth. Glyphosate does not injure trees when applied to trunks with mature bark, but repeated spraying of suckers can kill the root system if suckers are large. In addition to sprays, wiper applications of glyphosate at 1-2 parts of water provide selective ways of controlling established weeds in many types of landscape plantings. Glyphosate presents little or no hazard to adjacent or downslope turf.
Paraquat (0.5-2, water soluble liquid; $23.50/lb)	When growth is young and succulent.	Nonselective, mostly annual species.	A nonselective herbicide that is a RESTRICTIVE HERBICIDE and not registered for use around homes. Handle carefully as per label. Repeated or concentrated sprays on barks of trees or shrubs cause girdling. Not active in soil.

POSTEMERGENCE HERBICIDES TO CONTROL GRASSES IN ORNAMENTAL PLANTINGS

Herbicide (pounds/ acre; cost/pound)	Time of Application	Weeds Controlled	Remarks
Fluazifop (0.25-0.5, EC; $74.75/lb)	Postemergence, when grasses are actively growing.	Annual grasses and some perennial grasses, such as quackgrass and bermudagrass up to 8 inches tail and Johnsongrass 15-20 inches tall.	Nonionic surfactant at 1 qt/100 gal spray increases effectiveness. This herbicide is mainly a foliage-absorbed systemic. Do not apply fluazifop if rainfall is expected within hour. It generally kills grasses without injuring associated broadleaf plants. Certain plants may be injured, such as certain varieties of azaleas (Hinocrimson and Poukhanensis). Directed sprays to avoid the foliage is recommended for these. Perennial grasses vary in their susceptibility, and repeated applications may be necessary. Other preemergence herbicides will be needed to control broadleaf weeds and to provide residual control of grasses that will come from seed.
Sethoxydim (0.3-0.5,EC; $74.00/lb)	Postemergence, when grasses are actively growing.	Annual grasses and some perennial grasses such as quackgrass and bermudagrass up to 8 inches tall and Johnsongrass 15-20 inches tall.	Use of a crop-oil concentrate at 1 qt/a or 1 percent by volume of herbicide spray increases effectiveness of the spray. This herbicide is a foliage-absorbed systemic herbicide and provides no residual weed control. It is generally without effect on broadleaf species and can thus be sprayed over most woody plants and many annual and perennial broadleaf plants. Perennial grasses vary in their susceptibility, and repeated applications may be necessary. Other preemergence herbicides will be needed to control broadleaf weeds and provide lasting control of grasses from seed.

HERBICIDES REGISTERED FOR USE IN GROUND COVERS

Herbicide (pounds/acre)	Ajuga	Contoneaster	Dicondra	Euonymus	Honeysuckle	Hypericum	Iceplant	Ivy, English	Juniper	Myrtle	Pachistima	Pachysandra	Periwinkle	Potentilla
Alachlor (4)		x		x		x	x		x	x				
Bensulide (12)	x					x	x	x	x	x		x		
Chloramben (4-6)		x		x				x	x					
Chlorpropham (6-10)		x		x	x			x	x	x	x			
DCPA (10-12)		x		x	x			x	x		x	x		
Dichlobenil (4-6)		x		x	x			x	x		x			
Diphenamid (8)		x	x	x	x	x	x	x	x	x				
EPTC (5)	x			x		x	x	x	x	x		x		
Fluazifop (0.5)	x	x						x	x	x			x	x
Metolachlor (2-3)		x		x	x			x	x			x		
Napropamide (4-6)			x	x		x		x	x					
Oryzalin (2-4)		x		x	x		x	x	x	x				
Oxadizon (2-4)	x	x		x				x	x	x		x		
Oxyfluorfen (l-2)									x					
Sethoxydim (0.29-0.48)		x		x					x	x			x	
Simazine (2-4)		x							x					
Trifluralin (l-4)		x		x	x				x					x

HERBICIDES REGISTERED FOR USE IN ANNUAL AND PERENNIAL FLOWERS

	Registered Herbicide (pounds ai/acre)							
Flower	Bensulide (10–12) [1]	Chloramben (4)	Chlorpropham (4–6) [2]	DCPA (9) [3]	Diphenamid (4–6) [4]	EPTC (5) [5]	Fluazifop (0.25–0.5)	Trifluralin [6]
Ageratum			x	x		x		x
Alyssum	x		x	x		x	x	x
Amaranthus						x		
Aster	x			x	x	x		x
Balsam					x			x
Begonia			x			x		
Bellflower				x				x
Candytuft	x			x				
Celosia		x						
Chrysanthemum		x	x	x	x	x		x
Columbine			x	x				
Coral bells	x		x	x				
Daffodil	x		x					
Daisy, painted	x							
" Shasta	x							x
Dahlia	x	x	x	x	x	x		x
Daylilly		x				x		
Dianthus			x			x		x
Foxglove				x				
Geranium			x	x			x	
Gladiolus	x		x	x				x
Impatiens			x				x	
Iris		x	x	x				
Loostrife								
Marigold	x	x	x	x	x	x		x
Nasturium				x		x		x
Pansy	x		x			x		
Peony		x	x	x				
Petunia			x		x	x		x
Phlox					x			x
Salvia					x			x
Snapdragon		x	x	x	x			x
Spiderwort				x				
Sweet William					x			
Tulip	x		x					
Y arrow								x
Zinnia	x	x	x		x	x	x	x

[1] Bensulide -- registered for use on 24 herbaceous plants and 7 bulbs.

[2] Chlorpropham -- established dormant herbaceous perennials, and newly planted or established bulbs, corms, and tubers before emergence.

[3] DCPA -- after planting, on 52 established flowers include several bulbs. Don't use on susceptible plants: geum, sweet william, phlox, carnation, pansy, and telanthera.

[4] Diphenamid -- use after planting.

[5] EPTC -- incorporate before planting.

[6] Trifluralin, EC or G -- incorporate at 1 lb/a before planting or apply granules at 4 lb/a ai post-planting. Registered for over 40 flowers.

WEIGHT AND VOLUME OF SOME HERBICIDES FOR APPLICATION IN SMALL AREAS

Herbicide name		Dose per acre		Dose of Commercial Product per 1000 sq feet [1]			
				Weight		Volume	
Active ingredient	Commercial product	Active ingredient (lb)	Commercial product	English (oz)	Metric (grams)	English	Metric (ml)
DCPA	Dacthal 75W	9	12 lb	4.4	125	10 oz.	—
DCPA	Dacthal 5G	9	180 lb	66.	1880	2 1/2 qt	—
diphenamid	Enide 50W	4	8 lb	3.	83	1 cup	—
" "	Enide 90W	4	4.4 lb	1.6	46	5 oz	—
" "	Dymid 80W	4	5 lb	1.8	52	5 oz	—
glyphosate	Roundup	0.375	1 pt	—	—	2 tsp	11
" "	"	1.0	1.33 qt	—	—	2 tbsp	29
" "	"	1.5	2 qt	—	—	3 tbsp	43
napropomide	Devrinol 50W	4	8 lb	3.	83	1 cup	—
" "	Devrinol 10G	4	40 lb	15.	420	2 1/2 cup	—
oryzalin	Surflan 75W	2	2.67 lb	1.	28	7 tbsp	—
oxadiazon	Ronstar 2G	4	200 lb	73.	2080	> 3 1/4 qt	—
" "	Ronstar 4G	4	100 lb	37.	1040	6 2/3 cup	—
oxyfluorfen	Goal 2E	0.25	1 pt	—	—	2 tsp	11
" "	Goal 2E	1.0	2 qt	—	—	3 tbsp	43
simazine	Princep 80W	1.0	1.25 lb	0.5	13	7 tsp	—
" "	Princep Cal. 90	1.0	1.1 lb	0.4	11	4 tsp	
" "	Princep 4L	1.0	1 qt	—	—	4 tsp	22
" "	Princep 4G	1.0	25 lb	9.	260	10 oz	—
trifluralin	Treflan 4L	1	1 qt	—	—	4 tsp	22
" "	Treflan 5G	1	20 lb	7.	210	6 oz	—

[1] 1 lb/a of any substance is equal to 10 grams per 960 ft^2. This can be rounded to 10 grams per 1000 ft^2 with only minor error. Volumes of dry materials are not determined with precision, because they settle erratically. These volume values are approximations based on an average of five samples. Different formulations of dry materials can differ in their volume weights. Whenever possible, it is best to weigh dry materials and to measure liquids by volumes. Equivalent volume measurements: 1 quart (qt) = 4 cups = 946.3 ml; 1 cup= 8 fluid ounces (oz); 1 oz = 2 tablespoon (tbsp); and 1 tbsp = 3 teaspoon (tsp).

Treatment, (pounds/acre; cost /pound)	Time of Application	Labeled Grass Species	Remarks
Amidiochlor (2.5; $28.00/lb)	Apply to mature coolseason grasses in the spring as vigorous growth begins.	Kentucky bluegrass, tall and fine fescue and perennial ryegrass.	For use on nonresidential, medium to low maintenance turf, such as cemeteries, parks, and administrative areas. Is root absorbed and must be watered-in within 5 days of application. Do not mow treated turf until it has been watered-in.
Chlorflurenol (2-3; $90.00/lb)	During cool periods following spring green-up of turf and during cool periods of fall.	Annual and Kentucky bluegrass, red and tall fescues, bahiagrass, crested wheatgreass, smooth bromegrass, quackgrass, timothy, perennial ryegrass.	Chlorflurenol applied alone does not give as good seedhead or foliar growth suppression as maleic hydrazide (MH) and mefluidide. It gives good broadleaf weed control and should be mixed (1.0 lb/a) with MH (3.0 lb/a) for best results.
Flurprimidol (0.75-3.0; cost not established)	Apply to mature coolseason grasses and bermudagrass in spring following the second mowing of the season.	Kentucky bluegrass; fine, sheeps and tall fescue; perennial ryegrass; creeping bentgrass; 328 and 419 bermudagrass; and common bermudagrass.	Is root absorbed, and should be watered-in within 24 hours of application. Does not suppress seedheads, but suppresses foliar growth for 10-12 weeks. May cause tip browning, which can be eliminated by occasional mowing.
Glyphosate, sodium sesqui salt (0.19; $50.00/lb)	Apply to mature stands of tall fescue or smooth bromegrass at spring green-up, before seedheads have emerged.	Tall fescue and smooth bromegrass.	For use on roadside rights-of-way and other industrial areas where coarse turfs are managed. Foliar absorbed. Rainfall within 6 hours after application may reduce effectiveness. Discolors turf and can cause severe injury if recommended rate is exceeded.
Maleic hydrazide (3-5; $4.40/lb)	Following spring green-up and during cool periods of fall on cool-season turfs.	Annual and Kentucky bluegrass, bromegrass, orchardgrass, quackgrass, and perennial ryegrass.	Effectively suppresses foliar growth and seedheads in cool-season and some warm-season grasses. Should be mixed with a herbicide if broadleaf weeds are present at application. MH may reduce root recuperative potential. Rain within 24 hours after application will reduce effectiveness.

PLANT GROWTH REGULATORS FOR GRASS—Continued

Treatment, (pounds/acre; cost/pound)	Time of Application	Labeled Grass Species	Remarks
Mefluidide (0.125-1.0; $39.00/lb)	Following spring green-up and during cool periods of fall on cool-season turfs. Following spring green-up of warm-season grasses.	Annual and Kentucky bluegrass; red, chewings and tall fescues; perennial ryegrass; timothy; reed canarygrass; quackgrass; centipedegrass; kikuyugrass; St. Augustinegrass; and common bermudagrass.	Effectively suppresses seedheads and foliar growth of cool-season grasses at rates of 0.25-0.50 lb/a. Is applied at 1.0 lb/a in bermudagrass, but does not adequately suppress growth or seedheads of bahiagrass.

DOCUMENT A

Personnel Cost Factors*

Place: **Date:**

	A	B	C	D
1. Temporary Worker				
Grade				
Basic pay	$			
Benefits**	+	+	+	+
Composite pay	$	$	$	$
2. Permanent Employee				
Grade				
Basic pay	$	$	$	$
Benefits**	+	–	+	+
Composite pay***	$	$	$	$
3. Military Member				
Rank				
Composite pay***	$	$	$	$
4. Contract Labor				
Type				
Hourly rate	$	$	$	$

* 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.

DOCUMENT B

Equipment Cost Factors*

Place: **Date:**

Types of Equipment

1.	Investment Cost				Source**
	a. Purchase cost (total)	$	$	$	
	b. Service life (years)				***
	c. Expected use (hours/year)				local records
	d. Service life (hours)				(1b) × (1c)
	e. Investment cost ($/hour)	$	$	$	(1a) ÷ (1d)
2.	Operating Cost Per Hour				
	a. Fuel consumption (gal/hour)				****
	b. Cost of fuel ($/gal)	$	$	$	local records
	c. Fuel cost ($/hour)	$	$	$	(2a) × (2b)
3.	Maintenance Cost Per Operating Hour				
	a. Labor cost ($/hour)	$	$	$	local records
	b. Parts cost ($/hour)	$	$	$	local records
	c. Total cost ($/hour)	$	$	$	(3a) + (3b)
4.	Total Equipment Cost per Hour of Operation	$	$	$	(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.

DOCUMENT C

Cost of Grounds Maintenance Operations

Place:				Date:

Location:

Type of area:

Size of area:

	Types of Equipment			Source*
1. Equipment Costs				
a. Cost per operating hour	$	$		Document B
b. Equipment-hours per acre				
c. Acres mowed (or other)				
d. EQUIPMENT COST	$	+ $	= $	(1a) × (1b) × (1c)
2. Chemical Costs				
a. Gallons per acre				
b. Cost per gallon	$	$		
c. Acres treated				
d. CHEMICAL COST	$	+ $	= $	(2a) × (2b) × (2c)
3. Labor Costs				
a. Type of Labor				Document A
b. Working operator-hours required				(1b) × (1c)
c. Productive operator-hours per day				**
d. Operator-days required				(3b) ÷ (3c)
e. Total operator-hours required				(3d) × (8 hours per day)
f. Labor cost per hour	$	$		Document A
g. Operator cost	$	+ $	= $	(3e) × (3f)
h. Supervisor-hours required				

Place: **Date:**

i. Supervisor cost per hour	$		$			Document A
j. Supervisor cost	$	+	$	=		(3h) × (3i)
k. LABOR COST					$	(3g) + (3j)
4. Transport Costs						
a. No. round trips to site						3(d) × 2
b. Rnd. trip miles to site						
c. Total hours or miles***						(4a) × (4b)
d. Vehicle cost per hour or mile***						
e. Total vehicle cost		+		=		(4c) × (4d)
f. Rnd. trip hours to site						
g. Total drive time						(4a) × (4f)
h. Drive cost per hour						
i. Total drive cost		+		=		(4g) × (4h)
j. TRANSPORT COST =		+		=		(4e) + (4i)
5. Total Cost of Maintenance Operations (sum all applicable Document Cs)						
a. Equipment cost						(1d)
b. Chemical cost						(2d)
c. Labor cost						(3k)
d. Transport cost						(4j)
e. TOTAL COST						(5a) + (5b) + (5c
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.

DOCUMENT D

Determination of Cost Effectiveness

Mowing Versus PGRs

PLACE: **DATE:**

Description of Area:

Location:

Size:

Special Considerations:

Time between operations:

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	____________	From Table 6-2
2. NO WEEKS BETWEEN PRESENT MOWING OPERATIONS	____________	Local estimate
3. NO. OF MOWING OPERATIONS	____________	(1) ÷ (2)
4. COST PER MOWING OPERATION	____________	Document C, line 5f
5. TOTAL COST DURING EFFECTIVENESS PERIOD	____________	(3) x (4)
6. SAVINGS	____________	(5) ÷ (2)
7. COST OF SPRAYING OPERATION	____________	Document C, line 5f

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

8. SAVINGS = $__________ - $__________ = ____________
(LINE 6) (LINE 7)

9. USE OF PROJECTED SAVINGS:

Project	*Cost*
a.	____________
b.	____________

*The figures in parentheses indicate lines of this document.

HERBICIDES FOR USE IN PONDS, LAKES, AND RESERVOIRS

Treatment (Application rate; cost per pound)	Time of Application	Weeds Controlled	Remarks
		FLOATING: GENERAL CONTROL	
Biological control with alligatorweed fleabeetle and alligatorweed stemborer.	Any time, but best results if released early in growing season.	Alligatorweed	Chemical control may not be necessary if these specific biocontrol insects are present. The fleabeetle is more active in the southern part of alligatorweed's range (Florida and across the Gulf Coast region to southern Louisiana), while the stemborer is active in both the southern and northern parts of alligatorweed's range (to southern Arkansas). These insects may not provide control in areas adjacent to fields subject to heavy insecticide use, such as near cotton fields. Contact your county agent or a qualified entomologist for positive identification.
2,4-D amine salts or low-volatile esters (2-4 lb/100 gal of spray; $2.60/lb)	When actively growing.	Alligatorweed (floating mats), duckweed, waterfern, waterlettuce, and waterhyacinth.	Spray to uniformly wet foliage. For hairy or hard-to-wet weeds, or during the rainy season, add 10 gal of fuel oil and 1 pt of emulsifier. Repeat treatments every 4 to 6 weeks as required for control. Do not use near crops sensitive to 2,4-D. Use 2,4-D esters and formulations that are least toxic to fish. Do not exceed tolerance of 0.1 p/m by weight in potable or irrigation water.
		FLOATING: NEAR CROPS SENSITIVE TO 2,4-D	
Amitrole-T (1-1.5 lb/a; $10.25/lb)	When actively growing.	Waterhyacinth	Apply as a surface spray in 150 to 200 gal water, or as an aerial spray in 7.5 gal water per acre. Use only in drainage ditches and marshes. Do not contaminate irrigation or domestic water, or water used for livestock.
Diquat (0.5-1 p/m by weight; $34.00/lb)	When actively growing.	Duckweed (in nonflowing water).	Inject diquat into water or spray on foliage. Do not use diquat in muddy water. Do not contaminate irrigation or potable water, or water used for livestock.

HERBICIDES FOR USE IN PONDS, LAKES, AND RESERVOIRS -- Continued

Treatment (Application rate; cost per pound)	Time of Application	Weeds Controlled	Remarks
Diquat (1-1.5 lb/a; $34.00/lb)	When actively growing.	Waterhyacinth and water-lettuce.	Apply as a surface spray in 150 to 200 gal water, or as an aerial spray in 7.5 gal water per acre. Do not contaminate irrigation or domestic water, or water used for livestock.
Glyphosate (1-3 lb/a; $26.30/lb)	When actively growing.	Emerged and floating broadleaf weeds and grasses.	Add 1 to 2 quarts of Ortho X-77 surfactant per 100 gallons spray solution. Avoid washoff by boat backwash or rainfall within 6 hours of application. Consult local state fish and game agency and water control authority before applying to public water.
EMERSED AND MARGINAL: ROOTED UNDERWEAR, TOPS ABOVE WATER (BROADLEAF WEEDS)			
Biological control with alligatorweed fleabeetle and alligatorweed stemborer.	Anytime, but best results if released early in growing season.	Alligatorweed, floating or rooted emersed.	See text.
Dichlobenil (4-8 lb/a; granules; $31.00/lb)	At or just before emergence.	Lotus, spatterdock, white waterlily, and others.	Spread granules evenly over the water surface. Do not use treated water for irrigation, livestock, or domestic purposes. Do not use fish for food or feed within 90 days after treatment.
2,4-D, low-volatile ester (2-4 lb/a; $2.60/lb)	When actively growing.	Arrowhead, lotus, pickerelweed, smartweed, spatterdock, spikerush, waterprimrose, white waterlily, and other plants with waxy leaves.	Apply in oil or in oil-water emulsion (1:10 or 1:20) in sufficient volume to give uniform coverage. Apply granular formulation evenly over water surface with spreader. Do not exceed 0.1 p/m by weight tolerance for irrigation, domestic water, or stock watering.
EMERSED AND MARGINAL: ROOTED UNDERWATER, TOPS ABOVE WATER (GRASS AND GRASSLIKE WEEDS)			

Treatment (Application rate; cost per pound)	Time of Application	Weeds Controlled	Remarks
Amitrole (6-12 lb/a; $6.10/lb)	When plants are 2 to 3 ft tall or during catkin development; for extended control, in late summer or early fall when plants are fully headed or during post-heading stage.	Bulrushes and cattails.	Use sufficient spray volume to give uniform coverage. Repeat as required to eradicate regrowth. Use only in drainage ditches and marshes. Do not contaminate potable water, or water used for irrigation or livestock.
Amitrole or Amitrole-T (8-16 lb/a; $10.25/lb)	When plants are 6 to 18 inches tall and before heading.	Perennial grasses and sedges, for example, common reed (Phragmites), cutgrass, johnsongrass, knotgrass, paragrass, quackgrass, and ripgut sedge.	Apply to foliage in 100 to 400 gal water per acre with ground spray equipment, or in 10 to 15 gal water per acre as aerial spray. Some grasses, for example, reed canarygrass, require 50 percent less amitrole-T than amitrole; use only in drainage ditches and marshes. Do not contaminate water used for livestock, irrigation, or domestic purposes.
2,4-D low volatile ester (4-6 lb/a; $2.60/lb)	Initial application at first heading, and repeat on regrowth before heading.	Bulrushes and cattails.	Apply to foliage in 1:20 oil-water emulsion at 150 to 300 gal per acre. Repeat as required to establish control. Do not contaminate livestock water. Do not exceed 0.1 p/m by weight tolerance for irrigation or potable water.
Glyphosate (1-3 lb/a; $26.00/lb)	When actively growing.	Nonselective on grasses and broadleaf weeds.	Add 1 to 2 quarts of Ortho X-77 surfactant per 100 gallons spray solution. Avoid washoff by boat backwash or rainfall within 6 hours of application.
		SUBMERSED: ALGAE	
Copper sulfate (pentahydrate) (0.5-1 p/m by weight copper ion $.90/lb)	On a sunny day when water temperature is above 70°F.	Planktonic, benthic, and filamentous algae.	Begin treatments around shallow edge of water body where growth first appears. If entire body of water is infested, treat only 1/3 to 1/2 of area and wait 2 weeks between treatments. Safe in potable water. In soft or acid waters, trout and certain other species of fish may be killed. Copper concentration should not exceed 1 p/m in potable water.

HERBICIDES FOR USE IN PONDS, LAKES, AND RESERVOIRS -- Continued

Treatment (Application rate; cost per pound)	Time of Application	Weeds Controlled	Remarks
Copper organic complex (for example, et hanola-mines) (0.2-0.5 p/m by weight copper ion; $135.00/lb)	On a sunny day when water temperature is above 70°F.	Planktonic algae.	Same as for copper sulfate above.
Copper organic complex (for example, et hanola-mines) (0.5-l p/m by weight; $135.00/lb)	On a sunny day when water temperature is above 70°F.	Benthic and filamentous algae.	Same as for copper sulfate above.
Dichlobenil, granules (10-15 lb/a; $31.00/lb)	When algae first appear.	*Chara* spp.	Apply evenly over water surface. May be used for spot or partial treatments of lakes and ponds. Do not use in irrigation water, or in livestock or domestic water. Do not use fish for 90 days after treatment. No H_2O tolerances have been established. Corps of Engineers approval required.
Endothall (dimethylalkylamine salts) (liquid: 0.5-0.8 p/m by weight; granules: 0.05-1.5 p/m by weight; $10.40/lb)	When algae first appear.	Benthic and filamentous algae.	Fish will be killed above 0.3 p/m by weight. Do not use fish for food or feed within 3 days after treatment. Do not use treated water for livestock or domestic purposes within 7 days after treatment of 0.3 p/m by weight, or within 14 days after treatments between 0.3 and 3 p/m by weight.
Simazine (0.5-1 p/m by weight; $4.00/lb)	When algae first appear.	Planktonic algae	Safe for fish and for swimming. Not for irrigation water, or for water used for animal or human consumption for 12 months posttreatment.
Simazine (1.3 p/m by weight; $4.00/lb)	When algae first appear.	Benthic and filamentous algae.	Safe for fish and for swimming. Not for irrigation water, or for water used for animal or human consumption for 12 months posttreatment.

HERBICIDES FOR USE IN PONDS, LAKES, AND RESERVOIRS -- Continued

Treatment (Application rate; cost per pound)	Time of Application	Weeds Controlled	Remarks
SUBMERSED: ROOTED OR ANCHORED WEEDS			
Copper-ethyl-enediamine complex (6.5-13 lb/a)	Before weeds reach water surface.	Hydrilla	Inject below the surface as solution or as an invert emulsion. Trout and other fish may be killed at rates recommended for control of hydrilla. Do not exceed tolerance of 1 p/m by weight copper in potable water.
Dichlobenil (7-10 lb/a; $31.00)	At or just before weeds emerge.	Coontail, elodea, naiad, pondweeds, watermilfoil, and others.	Apply temporarily exposed bottoms. May be used for spot or partial treatments. Use lower rates for shoreline or exposed bottoms. Do not use in irrigation water, or in livestock or domestic water. Do not use fish for 90 days after treatment.
Dichlobenil (10-15 lb/a; $31.00/lb)	At or just before weeds emerge.	Coontail, elodea, naiad, pondweeds, watermilfoil, and others.	Broadcast evenly over water surface. Take the same precautions as in dichlobenil above.
Diquat (2-4 lb/a, 0.25-2.5 p/m by weight; $34.00/lb)	Before weed growth becomes dense or reaches water surface.	Bladderwort, coontail, elodea, naiad, watermilfoil, hydrilla, and others.	Apply to surface or inject subsurface. Use higher rates for mixed weed species, and for elodea, coontail and widgeongrass. Do not use in muddy water. Do not use treated water for human or animal consumption, swimming, or irrigation within 10 days after treatment or until an approved assay shows diquat in water to be below tolerance concentration, 0.1 p/m.
Endothall (dimethylalkylamine salts) (0.5-2.5 p/m by weight; $10.40/lb)	Before weed growth becomes dense or reaches water surface.	Bladderwort, coontail, elodea, naiads, pondweeds, watermilfoil, wild celery, and Zannichellia.	Use only for spot treatments or where some fish kill is not objectionable. Do not use treated water for livestock or domestic purposes within 14 days after treatment. Do not use fish for food or feed within 3 days after treatment.

HERBICIDES FOR USE IN PONDS, LAKES, AND RESERVOIRS -- Continued

Treatment (Application rate; cost per pound)	Time of Application	Weeds Controlled	Remarks
Endothall (dipotassium) (1-5 p/m by weight; $10.40/lb)	Before weed growth becomes dense or reaches water surface.	Bladderwort, coontail, naiads, pondweeds, watermilfoil, waterstargrass, Zannichellia, and burreed.	Use lower concentrations in total area treatment and higher concentrations for margins, spot treatments or cold water. Follow label directions on use of treated water. Water may be used for swimming 12 hours after treatment and fish may be used for food or feed 3 days after treatment. Do not use treated water for irrigation, food crop sprays, or for livestock and domestic use within 7 days of treatment.
Simazine (1-2.5 p/m by weight; $4.00/lb)	At early stage of growth.	Fanwort, naiad, pondweeds, watermilfoil, and waterstargrass.	Apply to water surface. Do not use water for irrigation or for animal or human consumption until 12 months after treatment.
2,4-D ester, amine, sodium or potassium salts (20-40 lb/a; $2.60/lb)	At early stage of growth.	Bladderwort, coontail, naiads, waterchestnut, water-star-grass, watermilfoil, waterlilies, and watershield.	Apply uniformly over surface by boat or helicopter. Use heavy rates for more resistant species or extremely acid or alkaline water. Some esters of 2.4-D are toxic to some species of fish at these rates. Do not exceed 0.1 p/m by weight tolerance in domestic or irrigation water.

HERBICIDES FOR USE IN DRAINAGE AND IRRIGATION CANALS

Treatment (Application rate; cost per pound)	Time of Application	Weeds Controlled	Remarks
		SUBMERSED: FLOWING WATER	
Acrolein (1-2.5 gal/ft^3 water flow/sec; $2.40/lb, $14.50/gal)	Before weed growth becomes dense.	All submersed weeds except water plantain.	For canals smaller than 200 ft^3/sec, inject into canal at beginning of weed infestation. Apply for 1/2 hour using especially adapted equipment (otherwise application can be hazardous); effectively kills plants 6 to 20 miles downstream depending on weed density, water temperature, and rate of flow. Toxic to fish.
Acrolein (0.1-0.6 p/m by weight; $2.40/lb)	Before weed growth becomes dense.	All submersed weeds except water plantain.	Inject into large canals (200 to 2,000 or more ft^3/sec) at one location during a period of 8 to 48 hours. Within this range, use lower concentrations and longer periods of applications as size of canal increases. Apply from special cylinders under nitrogen gas pressure. May be toxic to fish.
		SUBMERSED: LITTLE OR NO WATER FLOW	
Acrolein (4-7 p/m by volume; $2.40 lb)	Before weed growth becomes dense.	Most submersed weed species.	Apply below water surface continuously along canal with specially adapted equipment (otherwise application can be hazardous). Toxic to fish.
Diquat (0.25-1 p/m by weight; $34.00/lb)	Before weed growth becomes dense.	Most submersed weed species.	Apply on or below water surface continuously along canal. Allow at least 12 hour exposure of weeds to treated water. Do not use in muddy or turbid water.
Endothall (dimethylalkylamine salt) (1.5-4 p/m by weight; $10.40/lb)	Before weed growth becomes dense.	Most submersed weed species.	Apply on or below water surface continuously along canal. Allow at least 12 hour exposure of weeds to treated water. Toxic to fish.
Diuron (16-48 lb/a; $4.70/lb)	While canals are not in use and before seasonal rains.	Grasses and broadleaf weeds.	Apply to exposed bottoms. Will injure trees with roots extending into ditch.

HERBICIDES FOR USE ON IRRIGATION AND DRAINAGE DITCHBANKS

Treatment (pounds/acre; cost per pound)	Time of Application	Weeds Controlled	Remarks
Amitrole (1-8 + ammonium thiocyanate; $10.25/lb)	After plants emerge; exact timing varies widely with species.	Many annual and perennial grasses and broadleaf plants; cattail and common reedgrass.	Use on drainage ditchbanks only.
2,4-D (1-3; $260/lb)	When weeds are young and growing.	Many annual and perennial broadleaf weeds.	One formulation registered for restricted use on irrigation ditchbanks in the Western States; other formulations for use on drainage ditchbanks only.
Dicamba (0.25-0.5 + 2,4-D 0.5-1; $13.75/lb)	When herbaceous weeds are actively growing; for woody plant control, after leaves are fully developed and until 3 weeks before first frost.	Many annuals and perennial broadleaf herbaceous weeds, vines, and woody species.	Use on drainage ditchbanks only.
Diuron (4-48; $4.70/lb)	Only when water is not in ditch.	Many annuals and perennials.	Apply before expected seasonal rainfall. Following treatment, if rainfall has not totaled at least 4 inches; fill ditch with water and allow to stand for 72 hours. Drain off and waste the remaining water before using ditch. Do not treat any ditch into which roots of trees or other desirable plants extend.
Fosamine (6-12; $10.00/lb)	2-month period before fall leaf coloration.	Many woody species.	Use on drainage ditchbanks only. Apply by ground equipment only.
Glyphosate (1-3; $26.30/lb)	When plants are actively growing.	Emerged and floating broadleaf weeds, grasses, and many woody plants.	Use with nonionic surfactant, do not overlap more than 1 foot into open water. Kills all vegetation. Grass can be seeded right after treatment.
Hexazinone (1.8-10.8; $23.80/lb)	After weeds emerge, during active growth.	Many annual and perennial herbaceous plants and woody vines.	Use on drainage ditchbacks only. Use low rate for short-term control and when growing season is short.

HERBICIDES FOR USE ON IRRIGATION AND DRAINAGE DITCHBANKS—Continued

Treatment (pounds/acre; cost per pound)	Time of Application	Weeds Controlled	Remarks
Prometon (10-60; $6.20/lb)	Before weeds emerge and up to 3 months after they emerge.	Many annuals and perennials.	Use on drainage ditchbanks only. Effectiveness depends on rainfall to move herbicides into the root zone. Higher rates required for perennials and for longer residual. Use only where bare ground is desired. Do not apply adjacent to desirable shrubs and trees.

HERBICIDES FOR USE IN RESERVOIRS AND CANALS CARRYING POTABLE WATER

Treatment (Application rate; cost per pound)	Time of Application	Weeds Controlled	Remarks
Copper sulfate (pentahydrate) (0.6–1 p/m by weight)	Early in growing season.	Most submersed weed species.	Continuous feed method. Begin applications at 1 p/m by weight; gradually reduce to 0.6 p/m by weight in late summer as water temperature rises. *May kill fish and fish organisms.*
Copper sulfate (pentahydrate) (0.3–2 $lb/ft^3/sec$)	Early in growing season.	Many submersed weed species.	Repeated "slug" treatments. Make initial application and repeat as necessary to maintain control. Use light rates for soft water and heavier rates for water high in salts, especially carbonates. Apply large crystals on concrete bottom or apron or suspend in water in burlap bags. Crystals dissolve very slowly. *May kill fish and fish food organisms.*

LIST OF EQUIVALENT MEASURES

Linear measures

1 inch = 2.54 centimeters
1 yard = 3 feet = 0.914 meters
1 rod = 16.5 feet = 5.5 yards = 5.03 meters
1 mile = 5,280 feet = 1,760 yards = 320 rods = 1.6093 kilometers
1 kilometer = 0.621370 mile
1 meter = 39.37 inches = 1.0936 yards

Square measures

1 square foot = 144 inches = 929 centimeters square square
1 square yard = 9 feet = 8,361 centimeters = square square 0.8361 square meters
1 square rod = 272.25 square feet = 30.25 square yards
1 acre = 43,560 square feet = 4,840 square yards = 160 square rods = 0.404687 hectare = an area 208.7 feet square = an area 16.5 feet (1 rod) x 0.5 mile
1 hectare = 2.47 acres
1 square mile = 640 acres = 259 hectares

Capacity measures (cubic)

1 cubic inch = 16.387 cubic centimeters
1 cubic foot = 1,728 cubic inches = 29.922 US liquid quarts = 25.714 US dry quarts = 0.80357 US bushel = 28.326 liters
cubic yard = 27 cubic feet

Capacity measures (liquid)

1 level tablespoon = 3 level teaspoons
1 fluid ounce = 2 tablespoons = 29.57 cubic centimeters
1 cup = 8 fluid ounces = 16 tablespoons
1 pint = 2 cups = 16 fluid ounces = 473.2 cubic centimeters
1 quart = 2 pints = 32 fluid ounces = 0.9463 liter
1 gallon = 4 quarts = 128 fluid ounces = 231 cubic inches = 0.1337 cubic feet = 3.785 liters = 16 cups = 256 tablespoons
1 milliliter = almost exactly 1 cubic centimeter
1 liter = 1,000 milliliters = 1,000 cubic centimeters = 1.057 liquid quarts

Capacity measures (dry)

1 quart = 2 pints = 67.20 cubic inches = 1.1012 liters
1 bushel = 32 quarts = 4 pecks = 1.244 cubic feet = 2150.42 cubic inches = 35.238 liters
1 liter = 0.9081 dry quart = 0.028378 bushel

Weights

1 grain = 64.7989 milligrams
1 ounce (avoirdupois) = 437.5 grains = 28.3495 grams
1 pound (avoirdupois) = 16 ounces = 7,000 grains = 453.59 grams
1 ton (short) = 2,000 pounds = 907.185 kilograms
1 ton (long) = 2,240 pounds = 1.120 short tons = 1,016.047 kilograms
1 microgram = 1 gamma = 0.001 milligram = 1000 nanogams
1 gram = 1,000 milligrams = 15.432 grains = 0.0353 ounce
1 kilogram = 1,000 grams = 35.27 ounces = 2.205 pounds
1 gallon water = 8.355 pounds
1 cubic foot water = 62.43 pounds
1 kilogram water = 2.2046 pounds

1 mg/kg or 1 mg/l = 1 p/m
1 ng/kg or 1 ng/l = 1 p/b

Speed

1 mile per hour = 1.6093 kilometers per hour = 44.70 centimeters per second = 88 feet per minute.

Temperature: Fahrenheit (F) and Celsius (C) equivalents

1°C = 1.8 °F   1 °F = 0.56 °C

To convert °F to °C, subtract 32 from °F and multiply by 5/9.

To convert °C to °F, multiply °C by 9/5 and add 32.

Relationship of Celsius to Fahrenheit Scales

°C		*°F*	*°C*		*°F*	*°C*		*°F*
-40	=	-40	0	=	32	40	=	104
-35	=	-31	5	=	41	45	=	113
-30	=	-22	10	=	50	50	=	122
-25	=	-13	14	=	59	55	=	131
-20	=	-4	20	=	68	60	=	140
-15	=	5	25	=	77	80	=	176
-10	=	14	30	=	86	100	=	212
-5	=	23	35	=	95			

ANNOTATED REFERENCES ON WEED CONTROL AND WEED IDENTIFICATION

There are many excellent references dealing with weed control and plant identification. The ones listed below are not necessarily better than others, but are examples of what is available. The Defense Pest Management Information Analysis Center (DPMIAC) can provide both technical information and additional references. All state universities and state agricultural extension services in the United States have weed scientists who can be helpful with local and regional problems. Many state universities also have weed identification manuals and taxonomists who can provide assistance in weed identification.

Beste, C. E., Ed. 1983. Herbicide Handbook of the Weed Science Society of America, 309 West Clark St., Champaign IL 61820. Fifth Edition, p. 515. Includes basic information on chemistry, toxicology, and use of all herbicides currently used in the United States, as well as other information relative to using herbicides. Revised periodically.

Bovey, R. W. 1977. Response of Selected Woody Plants in the United States to Herbicides. USDA Agr. Handbook NO. 493, p. 101. (Obtain from Superintendent of Documents, US Government Printing Office, Wash DC 20402.) Brief discussion of herbicides and their use for controlling woody plants. Responses of a great number of woody species to herbicides is presented in tabular format.

Correll, S. Donovan and Helen B. 1975. Aquatic and Wetland Plants of Southwestern United States. Stanford University Press, Vol. I & II, p. 1777. Well illustrated description of species of the southwestern United States. Many of the species covered are found in other regions. The Corrells broadly interpret aquatic and wetland environments to include rivers, streams, lakes, marshes, and swamps of the region. The two-volume set includes about 2,100 species, representing 567 genera, and 129 families. It has excellent drawings of about 800 species.

Gangstad, E. O., Ed. 1982. Weed Control Methods for Rights-of-Way Management. CRC Press Inc., Boca Raton, Florida, p. 280. Includes basic concerns for use of herbicides, weed control authorities and regulations; formulations, handling, and application of herbicides; research studies; and aquatic rights-of-way management.

Hodgson, Richard H., Ed, 1982. Adjuvants For Herbicides. Weed Science Society of America, 309 West Clark St., Champaign, IL 61820. p. 144. Includes terminology, classification, and chemistry of adjuvants; their uses, action, and fate in plants and soils; toxicology; regulation; and registration by EPA.

Klingman, C. C. and F. M. Ashton. 1982. Weed Science: Principles and Practices. 2nd ed. Wiley-Interscience, New York. p. 449. A textbook on history and methods of weed control, biology of weeds, science of herbicide-plant and herbicide-soil interactions, herbicide application technology, basic information on herbicides, and applied weed control in different plant sites.

Mulligan, G., Ed. 1979. The Biology of Canadian Weeds. Agriculture Canada publication 1693. p. 380. An indepth coverage of 32 weeds of Canada (that also occur in the northern United States) including: description, geographic distribution, habitat, growth, reproduction, response to herbicides, and cultural manipulation.

Skroch, Walter A. and Thomas J. Sheets, Eds. 1977. Herbicide Injury Symptoms and Diagnosis. The North Carolina Agricultural Extension Service, Raleigh, N.C. p. 31. Includes colored pictures and discussion of symptoms of action of 46 herbicides, and 11 other agents that cause similar symptoms, on numerous desirable plants.

US Army Corps of Engineers, Waterways Experiment Station, 1988. Aquatic Plant Identification and Herbicide Use Guide. Technical Report A-88-9 Vols I and II, p. 222. Volume I provides information on the use and fate of EPA approved and registered herbicides for managing nuisance aquatic vegetation. Volume

II is a plant identification and herbicide susceptibility guide for nuisance floating, emersed, and submersed aquatic plants.

US Department of Agriculture, 1970. Selected Weeds of the United States. Agr. Handbook No. 366. p. 463. Also available under the title, “Common Weeds of the United States.” Reprinted in 1971 by Dover Publications, New York. The 224 species, mostly herbaceous, were selected by weed scientists as being prevalent in croplands, turf, grazing lands, noncroplands, and aquatic sites. Excellent drawings of each species, semitechnical descriptions, and geographic distribution maps make this a useful reference.

US Department of Agriculture, Science and Education Administration. 1980. Suggested Guidelines for Weed Control. Agr. Handbook No. 565. p. 330. Largely a tabular presentation of methods of controlling weeds in crops and specific habitats. Revised periodically.

Weed Control Manual and Herbicide Guide. Meister Publishing Co., Willoughby, Ohio, 44094. Complete herbicide guide for over 200 crops, turf, grasslands, noncroplands and aquatic sites. Revised annually.