Agriculture Handbook No. 269

Herbicide Manual

For Noncropland Weeds

AGRICULTURAL RESEARCH SERVICE, U.S. DEPARTMENT OF AGRICULTURE
in cooperation with
BUREAU OF YARDS AND DOCKS, DEPARTMENT OF THE NAVY

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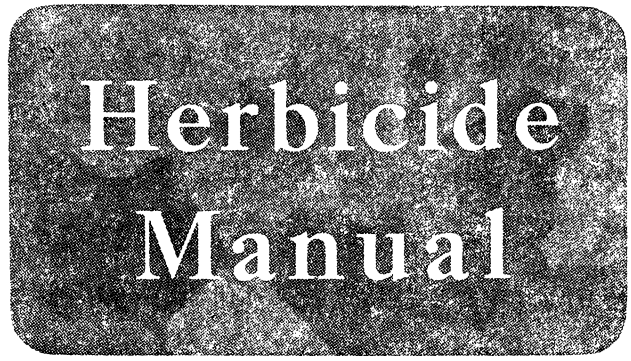

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By R. S. Dunham

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In the preparation of this handbook, more than a thousand publications, including reports, bulletins, journal articles, chemical company literature, and a few books, were reviewed and abstracted. The author is indebted to some 700 investigators whose research findings have been the main source of material. To all of these and to the many who wrote personal letters, he wishes to express his appreciation; and also to the members of the military technical advisory group, Department of Defense, for their constructive assistance.

Some chemicals used for weed control can be injurious to man if handled carelessly. They can also be injurious to desirable plants, livestock, wildlife, and fish if improperly applied. Care should be exercised in the use of herbicides and the disposal of unused herbicides to avoid polluting streams and water supplies. Precautions for handling and applying that are printed on the container label should be followed.

In this handbook general precautions for the use of herbicides are given in the section on "Hazards of Handling and Application." In the section on "Current Herbicides" dangers associated with the handling and application of specific herbicides are indicated by Roman numerals that refer to precautions given in the section on "Hazards of Handling and Application." Precautions for herbicides that require special warnings are given under "Application of Herbicides."

Use of product names in this handbook does not constitute a guarantee or warranty of the products named and does not signify that these products are approved to the exclusion of comparable products.

CONTENTS

Herbicide Manual for Noncropland Weeds

By R. S. DUNHAM, *research agronomist, Crops Research Division, Agricultural Research Service*

HOW TO USE THIS HANDBOOK

General Information.—This introductory material on growth habits and reproduction of weeds; use, mode of action, and hazards of herbicides; and herbicide labels applies to all phases of weed control and will be helpful in understanding what follows. There is also introductory material for each section of the handbook and for divisions of each section.

Current Herbicides.—In this section herbicides currently available (1963) are listed and described. They are arranged alphabetically by accepted common names; by chemical names, when no common name is available; or by groups, when two or more related herbicides are described together. The description includes the chemical, physical, and biological properties and the adaptation of the herbicide to aid the operator in making choice of a chemical best suited to his situation. A list of weeds known to be resistant to the chemical is given if this information is available. These weeds are considered so difficult to kill with the herbicide that its use for their control is not recommended.

Herbicides and Mixing of Spray Materials.—This section describes formulations of herbicides and gives directions for mixing with carriers and diluents. It discusses the bases for comparison of various commercial preparations of a herbicide and lists the requirements for good storage. The topics are indexed in the "General Index."

Application Equipment.—This section discusses kinds of application equipment: its parts, such as pumps and nozzles; its calibration; its operation; and its care. Topics are indexed in the "General Index."

Application of Herbicides.—In this section two kinds of weed problems are discussed: (a) weed sites, such as storage areas, ditchbanks, roadsides, and railroads; and (b) weed groups, such as woody weeds, turf weeds, and aquatic weeds. Where bare ground is the objective, discussion can be found under complete vegetation control and soil sterilants. Directions for using the herbicides instead of descriptions are given. Weed sites and weed groups are listed in the "General Index"; individual species of weeds together with the herbicides to which they are susceptible, intermediate, or resistant are listed in "Weed Species and Herbicides for Control" (table 5); and herbicides are listed in the "Herbicide Index."

Weed Species and Herbicides for Control.—In this section the response of weeds to herbicides is tabulated. The species mentioned in the text are listed alphabetically by common names. The botanical name is given for identification. Each species is classified as annual (A), aquatic (Aq), biennial (B), perennial (P), or woody (W). Response to applications of herbicides is indicated by S for susceptible, I for intermediate, and R for resistant.

Herbicide Index (pp. 87 and 88).—This index includes the names of all herbicides included in the handbook. They are listed alphabetically by common names or designations. Chemical names are also given for identification. Discussions referred to by page numbers comprise chemical, physical, and biological properties, and adaptation, and application.

General Index (pp. 89 and 90).—This index lists references of a general nature that are not included in table 5 or the "Herbicide Index."

GENERAL INFORMATION

Chemical control of weeds is not an exact science. Results cannot be predicted with the same accuracy as is expected in the physical sciences. Nevertheless, a knowledge and especially an appreciation of the factors that influence results in the use of herbicides are essential to the best control.

Growth Habits and Reproduction of Weeds

Annuals are plants that mature in one season. They are propagated by seed. Foxtail, crabgrass, common ragweed, wildbuckwheat, 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 the next season. Some plants of pennycress, common chickweed, corncockle, shepherds-purse, and yellow-rocket behave as winter annuals. The capacity of individual plants to produce thousands or, in some instances, hundreds of thousands of seeds that may shatter to the ground provides an enormous source of new plants the following season. Many of these seeds remain viable for years when they are buried in the soil. The prolific production of seed, the buildup of weed-seed populations in the soil, and the length of time seeds remain viable in the soil are nature's way of insuring that annual weeds will be perpetuated. It is these properties of annual weeds that make eradication almost impossible. If the topgrowth is killed before seed is produced, the life cycle of that plant is ended, since it cannot recover. However, the reservoir of seeds in the soil may produce new plants for many years.

Biennials require two seasons to complete the reproduction cycle. Their growth period is longer than that of winter annuals. Since they are propagated by seed only, seedlings can be treated as the seedlings of annuals. Burdock, evening-primrose, common mullein, and yellow goatsbeard are biennials.

Perennials are plants that live more than 2 years. Many have additional means of perpetuation; they are provided with storage organs in the form of stolons (prostrate stems), rhizomes (underground stems), bulbs, crowns, and roots. Supplies of food are laid up in these organs by the plant to feed a new growth the next year. The new shoot comes from a bud and lives on stored food until it becomes established. Unlike the annual plant, the topgrowth of a perennial may be killed and still the plant can live and propagate itself because of its storage organs. To control this vegetative reproduction, the food reserves must be materially reduced or the storage organs destroyed. The food stored by the plant 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. For control of perennials, the new growth is allowed to draw on food reserves until it becomes sufficiently established to manufacture its own food and then the topgrowth is killed. Quackgrass, Canada thistle, johnsongrass, buttercup, and nutgrass are perennials.

Classification of Herbicides

Herbicides are grouped, on the basis of use, into selectives and nonselectives and, on the basis of mode of action, into contact, translocated, and sterilant chemicals.

Selective and Nonselective Chemicals

Selective herbicides are those that kill certain weed species without seriously injuring the desirable plants among which they are growing. Those that kill crabgrass or dandelions in a grass sod are examples. The reasons for selectivity in some combinations of weeds and desirable plants are known; in other situations, they are unknown. Crabgrass can be killed in bluegrass sod because it is an annual growing among perennial plants that can recover from spray injury. Why dandelions can be killed in bluegrass sod is not fully known; certain herbicides kill broad-leaved weeds and not grasses and vice versa.

Nonselectives kill vegetation with little discrimination. Certain species, however, are resistant and some escape. Resistant species are physiologically resistant to the chemical; some escapes are perennials that have part of their root system below treated layers of soil; others are annuals and shallow-rooted perennials that reinfest an area after the chemical has leached below the surface layer.

Contact, Translocated, and Soil-Sterilant Chemicals

Contact herbicides kill the tissues that are wetted with the spray. Whether the plant dies or recovers depends on whether it has a protected growing point. Perennials usually have underground buds that will regrow.

Translocated chemicals are absorbed by the leaves and stems or by the roots and move through the vascular system to leaves, buds, and root tips. When absorbed by the leaves and stems, the chemical is commonly moved with the food materials that were manufactured in the leaves and stems. When absorbed by the roots, it moves in the 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 or oil.

A soil-sterilant herbicide makes a soil incapable of supporting higher plant life, but it does not necessarily kill all life in the soil, such as fungi, bacteria, and other micro-organisms. Its toxic effects may remain for only a short time or for years. Residual toxicity depends on: (1) the chemical and its rate of decomposition or leaching, (2) the colloidal and chemical content of the soil, (3) species tolerance, and (4) rate of application.

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

(2) Some herbicides are readily adsorbed by mineral and organic colloids and rendered unavailable or made slowly available for plant absorption. The fertility and pH of a soil are also influencing factors in the persistence or availability of toxic amounts of certain chemicals. For example, monuron and diuron are adsorbed on clay colloid particles so that leaching is difficult. Sodium chlorate is more easily absorbed by plants growing in soil low in nitrates.

(3) Plant species vary widely in tolerance to soil sterilants. Plants resistant to each herbicide are listed in section on "Current Herbicides," and hard-to-kill species are designated for each herbicide under "Application of Herbicides."

(4) Heavy rates of application generally last longer than light rates.

Hazards of Handling and Application

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. The dangers associated with the handling and application of these chemicals are of several kinds and possible injury is not limited to the operator. Any or all of the following may be affected: Operator and handler, livestock, desirable plants, equipment, and game and fish.

The following general discussions apply to classes of herbicides rather than individual chemicals. More specific information is given in sections on "Current Herbicides" and "Application of Herbicides." In addition:

Read the label on each container before using the contents. Follow instructions; heed all cautions and warnings. Store in original labeled containers. Dispose of empty containers by burying them at least 18 inches deep in an isolated area away from water supplies.

I. Operator and Handler

The person who mixes and applies the spray or spreads the dry product could be poisoned from swallowing the herbicide, from skin absorption, or from inhalation. In each case, there is greater danger from the concentrated material than from the diluted spray solution or suspension.

(a) If the concentrate or spray is swallowed, induce vomiting immediately. Dissolve a tablespoon of salt in a glass of warm water and administer repeatedly until the vomit fluid is clear. If salt is not available, tickle the throat by inserting a finger. Have the victim lie down and keep quiet. Call a physician.

The toxicity of herbicides varies widely. The relative degree of toxicity is indicated in table 1. The ratings describe the acute (not chronic) lethality of each herbicide when swallowed by laboratory animals. Usually toxicity in the field is less, because seldom is such a dose swallowed or absorbed and diluted sprays are handled more often than concentrates. Nevertheless, neither chemical concentrates nor dilute sprays should be kept in unlabeled containers, especially not in containers commonly used for potable liquids.

Unfortunately humans do not always react like small animals. It is always possible that a human will stand a correspondingly larger dose of a given chemical than results with animals would indicate or vice versa. There is no way to determine accurately whether a lethal dose for man is larger or smaller than the LD_{50} (lethal dose for 50 percent of animals tested) for a laboratory animal. But animal studies are the best guide available.

(b) Absorption by the skin and irritation of skin and eyes can largely be prevented. Keep exposure to a minimum until skin reaction to a new chemical is learned. Some individuals are hypersensitive to certain chemicals and have allergic reactions that are impossible to predict without skin tests. For most herbicides, washing hands and face with soap and water after handling is sufficient protection. Prolonged contact is more dangerous than short exposures. For the more readily absorbed chemicals and those that are irritating, wear clean clothing that covers the

TABLE 1.—*Relative acute toxicities of herbicides fed and dermal response when applied to laboratory animals*

Herbicide			Acute oral toxicity		Dermal response rating [4]	Chemical tested	
Approved common name [1]	Chemical	WSA designation [2]	Rating [3]	Test animal		Active ingredient	Commercial formulation
		Acrolein	1	Rats		x	
	Amine methylarsonate (AMA)		3	do	3		x
Amitrole			4	do	2	x	
	Ammonium sulfamate	AMS	3	do	1		x
	Aromatic solvents		2		3		x
	Arsenate, calcium		1–2	Rats	2		x
	Arsenate, lead		2–3	do	2		x
	Arsenite, sodium		1	do	4 and 5		x
Atrazine			3	do	1		x
	Borate–monuron	BMM	3	do	2	x	
	Borate–2,4-D	BDM	3	do	2	x	
	Carbon disulfide		2		2		x
	Chlorate–borate	CBM	4	Rats	2	x	
	Chlorate–borate–monuron	CBMM	3–4	do	2	x	
	Chlorate–chloride		4	do	2		x
Chlordane			2–3	do	5		x
	Chloropicrin		2–3	Rabbits			x
	Copper sulfate		2	Rats			x
Dalapon			4	do	2		x
	Dalapon–silvex		3	do	2		x
Dicamba			3	do			
		Dichlone	3	do	3	x	
Diquat			2	do			
	2,4-dichlorophenoxyacetic acid	2,4-D	3	do	2		x
	O-(2,4-dichlorophenyl)-O-methyl isopropylphosphoramidothioate.	DMPA	4	do	2		x
	3,5-dimethyltetrahydro-1,3,5,2H-thiadiazine-2-thione.	DMTT	3	do	2	x	
	Dinitros	DNAP, DNBP, DNC.	1	do	5	x	
	Disodium monomethylarsonate	DMA	3	do	1	x	
Diuron			3	do	2	x	
Endothall			1–2	do	3	x	
Erbon			3	do	3		x
		Fenac	3	do	1		x
Fenuron			4	do	2	x	
		Fenuron-TCA.	4	do	3	x	
	Gasoline		2	do			x
	Kerosene		1–2	Rabbits			x
	Maleic hydrazide diethanol amine.	MH	3	Rats			x
	Maleic hydrazide sodium salt	MH	4	do			x
	Methyl bromide		2		5		x
	2-methyl-4-chlorophenoxyacetic acid.	MCPA	3	Rats	2		x
Monuron			3	do	2	x	
	MonuronTCA		3	do		x	
	Octachlorocyclohexenone	OCH	2	Mice		x	
	Oil, petroleum		3		5		x
	Pentachlorophenol	PCP	2	Rats	5		x
	Phenylmercuric acetate	PMA	1	Mammals	4	x	
Silvex			3	Rats	2		x
Simazine			4	do	1	x	
	Sodium chlorate		4	do	2	x	
	Sodium-N-methyldithio-carbamate.	SMDC	2	do	3	x	
	2,3,5,6-tetrachloroterephthalic acid.	DCPA	3	do	1	x	
	Trichloroacetic acid	TCA	3	do	4		x
	2,3,6-trichlorobenzoic acid	2,3,6-TBA	3	do	1		x
	2,4,5-trichlorophenoxyacetic acid	2,4,5-T	3	do	2		x

See footnotes on p. 5.

body. Remove clothing after it has become contaminated with the chemical. Use synthetic rubber gloves. Where splashing may occur, wear goggles. If the spray or dust is spilled on the skin, wash thoroughly with soap and water; if in the eyes, wash with plain water and see a doctor.

Liquid concentrates and powders should be put into containers that can readily be lifted by the operator in the field. Packages of powders should be small enough so that it is unnecessary to remove the contents with a scoop.

(c) Inhaling vapors, dusts, and spray mists can also be avoided. Use a mask when label directions indicate the need. In the case of a severe exposure, move the patient into fresh air, administer artificial respiration if needed, and call a physician.

(d) Some chemicals are flammable or support fire. Avoid ignition from friction, sparks, and contact with combustible materials.

(e) Some are dyes that color skin and hair if not protected.

II. Livestock

The chief dangers of poisoning livestock are from consumption of herbicide remnants in open containers and of contaminated water.

2,4-D and similar compounds may increase the palatability of plants not ordinarily eaten. If these are poisonous species, sickness and death may result. The nitrate content of some plants may be increased when sprayed with 2,4-D. This nitrate is reduced to nitrite by micro-organisms in the intestinal tract of herbivorous animals. Because nitrite in the bloodstream interferes with the effective transport and use of oxygen, the animal suffocates. However, increased nitrate content of plants does not always follow spraying. Furthermore, some natural conditions also produce high nitrate, so that many weeds contain enough to cause poisoning whether sprayed or not.

III. Desirable Plants

Certain precautions are necessary to prevent damage to adjacent valuable plants. This damage may result from drift, washing, or leaching.

(a) Drift hazards are greatest when herbicides that affect the leaves of plants are used. These may be of the growth-regulating type, such as 2,4-D, 2,4,5-T, and silvex, or of the contact type, such as PCP, the petroleum oils, and dinitros. Danger is least when dry applications are made of nonvolatile herbicides. Drift occurs not only with volatile herbicides, such as the high-volatile esters of 2,4-D and 2,4,5-T, but also from a spray that has been atomized into a mist by high pressure and small nozzle opening whether the formulation is volatile or not. The control of drift is discussed on pages 30 and 46.

(b) Washing is an important hazard on slopes, bare ground, and pavements. The herbicide may be carried by surface runoff to valuable plants downslope. Do not drain or flush equipment where runoff to desirable plants may occur.

(c) Leaching moves chemicals downward through the soil. If they are readily absorbed by roots, plants whose roots extend under the treated area are likely to be injured. Avoid treating such areas with soil sterilants. Do not drain or flush equipment where leaching to the roots of desirable plants may occur.

IV. Equipment

Some chemicals corrode the metal parts of spraying equipment; oils and solvents injure rubber. Thorough draining and cleaning of equipment with water and a detergent is sufficient protection against most chemicals. When corrosive chemicals are used, coat the metal parts of the equipment with protective paint, oil, or undercoating after use or purchase equipment with noncorrosive metals. Neoprene rubber is resistant to oils and solvents.

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[1] Approved by the American Standards Association as an American Standard common name except chlordane, which was approved as a common name by the International Committee on Common Names for Pesticides.

[2] Accepted for use in Weed Society of America publications.

[3] Numerical rating is based on the following classification of the Federal Insecticide, Fungicide, and Rodenticide Act.

Rating	*Class*	*LD_{50}, mg./kg.*	*Lethal dose for 150-pound man*
1	Highly toxic	50 and below	Few drops to 1 teaspoon
2	Moderately toxic	above 50 to 500	1 teaspoon to 1 ounce
3	Toxic	above 500 to 5,000	1 ounce to 1 pint or 1 pound
4	Nontoxic	above 5,000	1 pint to over 1 quart

"Lethal dose for 150-pound man" is based on table in Clinical Toxicology of Commercial Products by Gleason, M. N., Gosselin, R. E., and Hodge, H. C., Williams and Wilkins Co., Baltimore, Md. 1957.

[4] Numerical rating is based on the following classification: 1, nonirritating; 2, mildly irritating; 3, moderately irritating; 4, causes burns and blisters; 5, absorbed and poisonous.

V. Game and Fish

Most herbicides are less dangerous than insecticides to wildlife. There are a few, however, such as the arsenicals and dinitros, that can poison animals. Most injury results from overdoses and spillage. Promiscuous spraying and spraying that results in vegetation of similar species can destroy cover, but herbicides can also be useful in management. Openings in wooded areas, such as the clearing for utility company rights-of-way and spraying of hardwoods in stands of pine can be beneficial to wildlife.

A few herbicides are very toxic to fish, but many can be used safely for the control of aquatic weeds. The control of submerged weeds in ponds or streams can be beneficial to fish populations. Safe amounts of herbicides, expressed in parts of the chemical per million parts of water, vary widely with age, size, and species of fish.

Whenever a proposed spraying program might endanger game and fish, consult Federal or State Fish and Wildlife Service for advice.

Herbicide Labels

Labels on the herbicide container are written with great care to state only facts. Recommendations on labels for materials sold interstate must be registered with the U.S. Department of Agriculture before the label can be authorized. The label should always be read by the operator. It tells, first, what the herbicide is. For instance, 2,4-D is sold as a sodium or amine salt or a volatile or low-volatile ester. Recommendations differ for various herbicides and for various formulations of the same basic chemical.

The label tells the amount of acid equivalent, phenol equivalent, or active ingredient in the product. This information permits a comparison of concentrations in various formulations, a comparison that is useful for figuring amounts to apply and for contrasting prices. The label also makes recommendations for use and gives rates and time of application. Certain warnings are stated when necessary to protect the operator from poison or irritation by the chemical and to protect susceptible plants from injury.

To Control Weeds With Chemicals

1. Identify the weeds you want to control. If in doubt, obtain assistance from a weed specialist or other authoritative source.
2. Select the right herbicide to control these weeds without harm to desirable plants nearby.
3. Mix the chemical according to mixing directions. Do not use more than recommended amounts.
4. Remember that weather conditions, the soil, and the growth stage of the weeds affect the action of many herbicides. So, follow directions on when and how to apply the materials.

CURRENT HERBICIDES: CHEMICAL, PHYSICAL, AND BIOLOGICAL PROPERTIES AND ADAPTATION

The dangers associated with the handling and application of certain herbicides are discussed on pages 3 to 6. Roman numerals in parentheses after the herbicide names in this section indicate the section in that discussion that applies to the chemical described. The small letters indicate the paragraph within the section.

Acrolein (acrylaldehyde) (I, II, V)

Acrolein is a highly reactive solution that controls submersed aquatic weeds in irrigation and drainage channels. It is extremely toxic to mammals, to fish, and to other aquatic animal life. It is highly volatile and flammable, and its vapor is a powerful irritant to the eyes and respiratory passages. Because of these properties, the chemical must be metered or pumped from the closed container into the water of the channel without contact with air. A formulation of acrolein is available for treatment of irrigation and drainage canals by licensed operators with especially adapted equipment.

Amitrole (3-amino-1,2,4-triazole) (III, a)

Amitrole is formulated as a water-soluble powder for applying in solution. The commercial product is sold in two concentrations: 50 percent and 90 percent amino triazole. It is not hazardous to handle, is not acutely toxic to mammals, and, at normal rates of application, is not harmful to fish.

Amitrole can be used for the control of herbaceous weeds, woody plants, and aquatic weeds either alone or in combination with other herbicides. It is safer than 2,4-D, 2,4,5-T, or silvex where drift would be injurious to nearby plants.

Resistant weeds are: alligatorweed; bindweed, field; caraway; cherry; chinquapin, golden; cot-

tonwood; dandelion; dogwood; elderberry; elm; fir, balsam; garlic, wild; greenbrier; gum, black; hackberry; hawthorn; hazel; Indian hemp; johnsongrass; kikuyugrass; knapweed, Russian; larkspur, tall; maidencane; maple; mesquite, honey; mulberry; nimblewill; nutgrass, purple; oak, red, shinnery, Turkey, and white; onion, wild; pine, white; plum, chickasaw; redcedar, eastern; sassafras; shadbush; smartweed, swamp; smilax; snowbrush; sorrel, red; spicebush; spruce, black; toadflax, yellow; trumpetcreeper; tuliptree; white-cedar; whitethorn, mountain; wildbuckwheat; willow; and yucca (*Y. smalliana*).

Amitrole is effective against such herbaceous weeds as horsenettle; thistle, Canada; and whitetop. Alone, it is adapted for land where long residuals are not required, where quick topkills are needed, and where spot treatment of weeds that have survived or escaped treatment with a soil sterilant is desirable.

Combined with residual-type herbicides, it makes a mixture that not only quickly kills plant growth above ground but also prevents weed growth for one or more seasons and acts more effectively than amitrole alone against deep-rooted perennial weeds. A mixture with dalapon often increases effectiveness against grasses. In combination with simazine, monuron, diuron, or dalapon it can be used in storage yards and parking lots, on railroad beds and ballast, under pipelines, under guide rails and surrounding signposts on highways, on public utility rights-of-way, around buildings and tank farms, along ditchbanks and fence rows, around radio antenna installations and airstrip runway lights, on crushed-rock blankets, and in similar areas where any plant growth is undesirable.

Amitrole is too specific to be a general brush killer. It is especially effective on ash, white; locust, black; poison-ivy; poison-oak; poison-sumac; and sumac, staghorn. It has been promising on some conifers. It is readily translocated, so it can be applied to the leaves; but it is not absorbed through the bark, so it can be used to kill vine growth on trees without injury.

Amitrole is more expensive than 2,4-D for the control of cattails and bulrushes, but it is safer to use near crops sensitive to 2,4-D.

AMITROLE-T (3-AMINO-1,2,4-TRIAZOLE-AMMONIUM THIOCYANATE)

This is a liquid formulation containing 2 pounds of 3-amino-1,2,4-triazole per gallon. The ammonium thiocyanate increases the sensitivity of grasses to amino triazole so that effective control results from lower rates than from amitrole alone. It is more effective than amitrole on quackgrass, Reed canarygrass, and water-hyacinth.

Resistant weeds are: bindweed, field; johnsongrass; knapweed, Russian; spurge, leafy; and thistle, Canada.

AMMONIUM SULFAMATE (IV)

Ammonium sulfamate, designated as AMS by WSA, is a granular material that is very soluble in water and that breaks down rapidly in moist soil. It is nonflammable, nonvolatile, and strongly toxic to plants. No special handling precautions are necessary. It is sold in a formulation containing 95 percent ammonium sulfamate in a crystal form and as a solution containing 5.3 pounds of 95 percent ammonium sulfamate per gallon.

Ammonium sulfamate is commonly substituted for the phenoxy compounds in areas where crops sensitive to these chemicals are grown. It is a contact, nonselective herbicide effective over a wide range of conditions and species. It is especially effective on poison-ivy, poison-oak, and poison-sumac. Ammonium sulfamate, in the crystal form or in concentrated solutions, is successfully used for stump applications. It is corrosive to metals, especially brass and copper. Stainless steel, aluminum, and bronze are resistant. Spray equipment must be protected, but corrosion of fences, guy wires, and telephone wires is negligible.

It is not effective against eastern redcedar, snowbrush, and Turkey oak.

ARSENICALS (I, II)

The arsenicals are among the cheapest herbicides, but they must be handled carefully.

Two groups of arsenicals are used for killing weeds: the inorganic and the organic.

Inorganic Arsenicals

The inorganic arsenicals include sodium arsenite, lead arsenate, and calcium arsenate. They are all highly poisonous to man and animals if swallowed. Their effectiveness for weed control depends on their arsenic content, which is commonly expressed in percent of arsenic trioxide (As_2O_3).

Sodium arsenite

Sodium arsenite is readily soluble in water. It is formulated as a dry powder or in stock solutions in concentrations up to 9.5 pounds As_2O_3 per gallon. Sodium arsenite is commonly the active ingredient of commercial arsenic preparations. Under conditions of light and intermittent rains, treated soil may remain sterile for 4 years. If steady rains or flooding follow treatment, additional applications are necessary to maintain bare ground. The sodium arsenite sprays or dried residues on vegetation are salty and may attract animals.

Sodium arsenite is best adapted for annual species and shallow-rooted perennials. Soil texture is the principal factor affecting its use. It is most effective in light, sandy soils and least effective in heavy calcareous clay soils, since arsenic is strongly adsorbed by soil colloids.

Resistant upland species are: bedstraw, cleavers; bracken; fiddleneck, coast; knotweed, prostrate; orache; paspalum; thistle, Canada; and Turks-rug. Resistant aquatics are: star-thistle, yellow; stonewort; waterlily; and watershield.

Lead arsenate and calcium arsenate

Both compounds are practically insoluble in water. They are used alone or mixed with other chemicals for control of crabgrass in turf. Both are somewhat incompatible with the dinitros. Lead arsenate is formulated as a paste containing not less than 14 percent As_2O_5 or as a powder containing not less than 32 percent As_2O_5. It is also mixed with chlordane for crabgrass control. Calcium arsenate can be substituted for lead arsenate at lower rates of application.

Organic Arsenicals

The organic arsenicals include disodium methylarsonate and amine methylarsonate. Both compounds are considerably less toxic than the inorganic arsenicals to humans and livestock, but they are harmful if swallowed. Both are applied postemergence for the control of crabgrass in turf.

Disodium monomethylarsonate (disodium methane arsonate hexahydrate)

This compound is designated as DMA by WSA. It is soluble in water, nonvolatile, and nonflammable. It is formulated as water-soluble powders containing 50 to 100 percent hexahydrate (31.5 to 63 percent disodium methylarsonate anhydrous), as 20 to 30 percent hexahydrate aqueous solutions (12.6 to 18.9 percent anhydrous), and as dry mixtures with vermiculite containing 2.5 to 4 percent hexahydrate (1.57 to 2.52 percent anhydrous). Total water-soluble arsenic in the 50- and 100-percent powders is 12.8 and 25.6 percent, respectively. Disodium methylarsonate is compatible with the salts and esters of 2,4-D.

Amine methylarsonate (octyl-dodecyl ammonium methylarsonate)

This compound is unofficially designated as AMA. It is formulated as an aqueous solution containing 8 percent octyl ammonium methylarsonate and 8 percent dodecyl ammonium methylarsonate. Total arsenic in water-soluble form is 4.1 percent. It is compatible with 2,4-D and silvex. In addition to crabgrass, sedge and seedlings of barnyard grass, dallisgrass, and foxtail can be controlled with AMA.

Benzoic Acid Compounds (III)

The benzoic acid compounds are readily translocated in the plant. They kill through both root and foliage absorption. They are good temporary soil sterilants for both perennial and annual weeds.

2,3,6-trichlorobenzoic acid

This compound is designated as 2,3,6-TBA by WSA. It is a mixture of isomers; 2,3,6 predominates with lower amounts of 2,3,4; 2,3,5; 2,4,5; 2,4,6; and 3,4,5. It is formulated as the dimethylamine salt of trichlorobenzoic acid, containing 2 pounds per gallon acid equivalent. It is nonvolatile, noncorrosive, and nonflammable. It is a mild skin irritant. It is compatible with 2,4-D amine, dalapon, diuron, and monuron.

This compound is more effective than 2,4-D, 2,4,5-T, or silvex on bindweed, field; bur-franseria; cockle, white; halogeton; knapweed, Russian; spurge, leafy; and thistle, Canada.

Resistant weeds are: broomsedge; cholla; greenbrier; hickory; horsenettle, Carolina; maidencane; mesquite, honey; nightshade, silverleaf; oak, bluejack, interior live, post, shinnery, and Turkey; panicum; redcedar, eastern; salmonberry; tarbush; waterchesnut; whitethorn (*Acacia*); and yaupon.

Polychlorobenzoic acid

This compound is designated as PBA by WSA. It is a mixture of a small amount of 2,3,6-trichlorobenzoic acid and a higher proportion of several other polychlorobenzoic acid derivatives. It is formulated as the dimethylamine salts of polychlorobenzoic acids, containing 4 pounds per gallon, acid equivalent. It is nonvolatile, noncorrosive, and nonflammable. It is a mild skin irritant. It is compatible with 2,4-D amine, dalapon, diuron, and monuron.

PBA is more effective than 2,4-D, 2,4,5-T, or silvex on bindweed, field; bur-franseria; cockle, white; halogeton; knapweed, Russian; spurge, leafy; and thistle, Canada.

Resistant weeds are: broomsedge; cholla; greenbrier; hickory; horsenettle, Carolina; maidencane; mesquite, honey; nightshade, silverleaf; oak, bluejack, interior live, post, shinnery, and Turkey; panicum; redcedar, eastern; salmonberry; tarbush; waterchestnut; whitethorn (*Acacia*); and yaupon.

Dicamba (2-methoxy-3,6-dichlorobenzoic acid)

This compound is formulated as the dimethylamine salt of 2-methoxy-3,6-dichlorobenzoic acid in water, containing 4 pounds, acid equivalent, per gallon.

It is very effective on several hard-to-kill broadleaved weeds, such as buckwheat, tartary; garlic,

wild; knotweed, prostrate; Russian-thistle; smartweed, green; sowthistle, perennial; spurry, corn; thistle, Canada; and wildbuckwheat.

Resistant weeds are: catchfly, nightflowering; cowcockle; and falseflax.

Chemical Combinations

Erbon (2-(2,4,5-trichlorophenoxy) ethyl-2,2-dichloropropionate) (I, b; III, a)

Erbon combines the properties of 2,4,5-T and dalapon in a single compound. A typical commercial product is an emulsifiable formulation containing 4 pounds technical erbon per gallon. Erbon is moderately toxic to man and livestock. There is little hazard of poisoning in ordinary handling, but it may cause skin and eye irritation.

Erbon is translocated, has the properties of a contact herbicide, and persists in the soil long enough to kill weed seedlings that germinate after treatment. It is effective against both grasses and nongrasses; hence, it is used to eliminate hand mowing around guide rails, guide posts, signposts, and bridges on highways and to control vegetation on tank farms; in lumber yards, railroad yards, and pulp-piling yards; along fences and athletic tracts and in similar areas.

Resistant weeds are: bindweed, field; bracken; dandelion; four-o-clock; kochia; milkweed, common; needlerush; nutgrass, purple; purslane, common; sorrel, red; and thistle, Canada.

FenuronTCA (3-phenyl-1,1-dimethylurea trichloroacetate) (I, b; III; IV)

This compound combines the properties of fenuron and TCA. Commercially, it is formulated as a 22-percent granular product, a 22-percent pelleted product, and a liquid concentrate containing 3 pounds active ingredient per gallon. It is only slightly toxic to mammals, but it is irritating to skin and eyes. It is readily soluble in water so that it is easily leached from the soil. The pelleted product is best adapted for control of brush and trees, especially hard-to-kill species such as greenbrier, hickory, and sassafras. The liquid formulation is used for a foliage spray or basal and stem applications. It kills topgrowth more quickly than the dry formulations.

MonuronTCA (3-(p-chlorophenyl)-1,1-dimethylurea trichloroacetate) (I, b; III; IV)

This compound combines monuron, which is less soluble than fenuron, with TCA. Commercially, it is formulated as an 11- and 22-percent granular product and an oil-soluble liquid concentrate containing 3 pounds active ingredient per gallon. It is irritating to skin and eyes. The liquid formulation is used for foliage spray.

The period of soil sterilization depends on soil and rainfall. Both constituents (monuron and TCA) are readily leached from porous soil in areas of high rainfall so that the herbicide is not effective on loose railroad ballast and on sandy soils in the Southeastern States.

Resistant weeds are: burdock; cotton, wild; greenbrier; hawthorn; horsetail, field; lantana; nimblewill; paspalum; poison-oak; smilax; toadflax, yellow; torpedograss; and yucca (*Y. smalliana*).

Copper Sulfate (I, IV, V)

Copper sulfate, often called blue vitriol or bluestone, is the most widely used herbicide for the control of most algae in ponds, lakes, and streams. It is formulated as a 98- to 99-percent salt that is soluble in water. It is corrosive to metals. Large quantities taken into the body may be fatal and small quantities taken continuously may be injurious. It is toxic to many species of fish at concentrations above 1 p.p.m., which is very close to rates required for aquatic weed control. Toxicity depends on the species of fish, the hardness of the water, and other factors that influence the amount in solution. The U.S. Public Health Service considers drinking water with over 7.5 p.p.m. dangerous for humans and over 100 p.p.m. dangerous for 2-year-old cattle.

Resistant weeds are: algae, *Pithophora;* bulrush; coontail, common; pondweed, horned and sago; sweetgrass, floating; waterplantain, common; watershield; and water-starwort.

2,3,5,6-Tetrachloroterephthalic Acid (I)

This compound is designated as DCPA by WSA. It is usually called Dacthal on the label. It is formulated as an odorless water-dispersible powder containing 75 percent active ingredient. It is applied preemergence to control crabgrass, some other annual grasses, and certain broadleaved weeds in established turf. DCPA is not corrosive. It is nonirritating. It is compatible with 2,4-D, chlordane, and the dinitros.

Since DCPA affects seeds, it prevents the germination of turf grass seeds if they are sown soon after the soil has been treated. Among weeds susceptible to DCPA are: alfilaria; carpetweed; chickweed, common; filaree, redstem; Florida-pusley; foxtail; lambsquarters; millet, Texas; panicum; purslane, common; and stinkgrass.

Resistant species are: bromegrass, downy; cheat; dandelion; galinsoga; Jimson-weed; mustard, black and wild; oats, wild; ragweed, common; smartweed, ladysthumb and Pennsylvania; and velvetleaf.

DALAPON (2,2-DICHLOROPROPIONIC ACID) (I, B, C; III, A)

Dalapon is formulated as the sodium salt of dichloropropionic acid. It is a water-soluble powder applied in solution for a foliage spray. A typical commercial product contains 85 percent of the salt or 74 percent of the acid equivalent. The acute oral toxicity is low. It is not absorbed through unbroken skin. Undiluted, it may cause skin irritation after prolonged contact, but spray concentrations are not irritating. The powder or concentrated solutions can cause painful irritation of the eyes.

Dalapon is used principally to control grasses, but it is also effective against cattails; pine, jack and white; phragmites; rushes; and white-cedar. It is a growth-regulator type of herbicide that is translocated from leaves to roots and rhizomes of perennial grasses. It is more effective in foliar applications than TCA, but it is also absorbed by the roots. For general weed control, it is mixed with a broad-leaved weedkiller such as 2,4-D, amitrole, or silvex. Dalapon disappears from the soil most rapidly in warm and humid regions. It persists longer in dry cool soils where microbial activity is low.

Most broad-leaved weeds are tolerant to resistant. Among the resistant species are: algae, *Oscillatoria;* bracken; euonymus; lotus, American; onion, wild; pagodatree; and waterlily.

DICHLONE (2,3-DICHLORO-1,4-NAPTHOQUINONE) (I, B, C)

Dichlone is formulated as a wettable powder used for aquatic-weed control. It is chemically stable, mixes well with oil, and remains active in water with a pH of 9 to 10. Dichlone does not kill fish at rates used for an algacide. It is effective on blue-green algae, filamentous green algae, milfoil, waterweed, hornwort, stonewort, and submersed pondweeds.

Resistant weeds are: *Chara* spp.; *Cladophora* spp.; fanwort; *Hydrodictyon* spp.; *Lemna minor;* and *Zygnema* spp.

O-(2,4-DICHLOROPHENYL)-O-METHYL ISOPROPYLPHOSPHORAMIDOTHIOATE (I)

This compound is designated as DMPA by WSA. It is formulated commercially as a granular material and as an emulsifiable liquid.

The granular product contains 4.4 percent active ingredient and is used for the selective control of crabgrass and knotweed in established turf of blue, St. Augustine, centipede, bermuda, and zoysia grasses. It is less liable than the liquid formulation to cause foliage burn of turf grasses.

The liquid formulation contains 3 pounds of active ingredient per gallon. It is used for the selective control of crabgrass; knotweed, prostrate; and nimblewill in established bluegrass turf. It may stunt bentgrasses or narrow-leaved fescues and thin stands.

Neither formulation controls buckwheat, tartary; catchfly, nightflowering; dallisgrass; dandelion; falseflax; purslane, common; quackgrass; or smartweed, green. Both prevent the growth of turfgrasses if seeded soon after treatment. DMPA does not corrode steel, iron, galvanized iron, or tin. It can cause mild irritation of the eyes and skin and can be absorbed through the skin if contact is prolonged. Vapors of highly concentrated liquid formulations can be harmful if inhaled.

DINITRO COMPOUNDS (I, II, III, V)

The dinitros are contact herbicides used alone and to fortify oils. The parent compounds do not dissolve in water but are soluble in oil. Sodium, ammonium, or amine salt formulations are water soluble.

The three parent compounds are designated by WSA as: DNAP, 4,6-dinitro-*o*-sec-amylphenol; DNBP, 4,6-dinitro-*o*-sec-butylphenol; and DNC, 3,5-dinitro-*o*-cresol.

All three compounds are yellow dyes that stain skin, hair, and clothing. They are highly poisonous if swallowed, if absorbed through the skin, or if any appreciable amount of spray mist is inhaled. Although they are not irritating, they are readily absorbed through the skin. They should be kept away from heat and open flame.

The parent compounds are used nonselectively for topkills of vegetation. The sodium, ammonium, and amine salts are used selectively. The parent compounds are very effective contact herbicides that control a wide range of herbaceous plants, including many oil-resistant plants. They require large amounts of water, and their effectiveness as weedkillers varies widely with the temperature.

The dinitros are not economical to use on perennial grasses and on coarse, vigorous annual grasses. Repeated applications are required for control in areas of long seasons and high rainfall.

DNBP is the most effective form, DNC the least effective, and DNAP intermediate.

DNBP

Typical commercial formulations contain 5 pounds DNBP per gallon plus 87.9 percent oil or an alkanolamine salt containing 3 pounds DNBP per gallon. Ammonium salts of DNBP contain 1 pound per gallon.

Resistant weeds are: carrot, wild; chamomile, stinking mayweed; chickweed, mouse-ear; fennel, common; mallow, dwarf; and pineappleweed.

DNAP

Typical commercial formulations contain 75 percent DNAP.

DNC

A typical commercial formulation contains 30 percent sodium salt of DNC. The effectiveness of DNC can be increased considerably by the addition of ammonium sulfate, aluminum sulfate, or sodium bisulfate.

DIQUAT (6,7-DIHYDRODIPYRIDO(1,2-A : 2',1'-C) PYRAZIDIINIUM SALT) (I)

This compound is a nonvolatile and nonflammable contact herbicide used for aquatic-weed control. Its acute oral toxicity to rats is high. Fanwort and southern naiad are resistant.

ENDOTHALL (3,6-ENDOXOHEXAHYDROPHTHALIC ACID) (I, II)

Endothall consists of three isomers, of which the exo-cis isomer shows the greatest biological activity. Its acute oral toxicity to mammals is high, and endothall must be handled with care. It is sold commercially as a 20-percent water solution containing 2 pounds per gallon of the disodium salt and as a water solution containing 6.3 percent of the disodium salt plus ammonium sulfate. Endothall is noncorrosive and nonflammable, but it is irritating to the skin.

Endothall is not completely nonselective, but combined with 2,4-D it provides complete vegetation control. It breaks down rapidly in the soil so that residual toxicity is short, especially in the humid areas. It is absorbed by plant roots, but it may be translocated in some plants.

Resistant weeds are: catchfly, nightflowering; chickweed, common and mouse-ear; goosefoot; lambsquarters, common; mustard, wild; orache; purslane, common; radish, wild; and smartweed, green.

Both liquid and granular formulations are used for aquatic-weed control. A typical liquid formulation is a water solution containing 19.2 percent disodium endothall. A granular formulation contains 5 percent disodium endothall on an inert clay carrier. Either may be fatal if swallowed and both are irritating to skin, eyes, nose, and throat.

They are contact herbicides effective on burreed, coontail, horned pondweed, watermilfoil, and pondweeds (*Potamogeton* spp.). In northern areas, *Pithophora*, *Cladophora*, and *Spirogyra* algae appear susceptible at the 2 to 5 p.p.m. rate. Because of its short residual life, treated areas that have conditions favorable for algae development may be subject to regrowth within the season. At rates of 1 to 2 p.p.m., there is a wide margin of safety for fish.

Resistant weeds are: *Chara* spp.; fanwort; and naiad, southern.

FENAC (2,3,6-TRICHLOROPHENYLACETIC ACID) (I, A)

Fenac consists of several isomers, of which the 2,3,6 isomer is the most toxic to plants. It is considered the active ingredient. It is formulated as a liquid containing 1½ pounds, acid equivalent, per gallon (the active ingredient is the sodium salt) and as a 10-percent granular product. The acute oral toxicity for rats is moderate, and fenac is nonirritating if handled with ordinary precautions.

Fenac causes growth-regulator type responses in plants, but drift hazards are less than with 2,4-D. Effects on plants are slow to appear, especially on deep-rooted perennials. Fenac is persistent in the soil, but conditions favoring microbial activity hasten its breakdown.

Weeds on which fenac has proved effective are: ash; basswood; bindweed, field; bur-franseria; franseria, woollyleaf; hogpotato; honeysuckle; knapweed, Russian; maple; puncturevine; Russian-thistle; sassafras; sida, alkali; sowthistle, perennial; spurge, leafy; thistle, Canada; wild-buckwheat; and witchweed.

Resistant weeds are: bracken; carrot, wild; nightshade, silverleaf; nutgrass; and many perennial grasses.

FUMIGANTS

Fumigants are volatile at ordinary soil temperatures and at atmospheric pressure. They are applied to the soil not only to kill the weeds but in some instances to kill soil micro-organisms, nematodes, and insects. There are three general classes: (1) Those that are mixed with the surface soil, sealed in with water, and do not require a gasproof cover; (2) those that do require a gasproof cover; and (3) those that are injected into the soil.

Carbon disulfide (I)

Carbon disulfide is a volatile liquid slightly soluble in water. It is highly flammable and poisonous as a gas. Emulsions or solutions with alkali (thiocarbonates) are available for soil treatment. It is very effective against deep-rooted perennials because the gas is heavier than air and penetrates deeply into the soil, but it is very expensive for large areas.

Chloropicrin (trichloronitromethane) (I)

Chloropicrin is a colorless, volatile liquid almost insoluble in water. It is highly toxic to

mammals—an exposure for 30 minutes can be lethal. It is nonflammable and noncorrosive to copper, brass, and bronze but attacks iron, zinc, and other light metals. The gas causes tears and is irritating to mucous membranes; it is, therefore, used as a warning agent in other fumigants.

Chloropicrin in vapor form kills weed seeds, nutlets of nutgrass, and soil-inhibiting insects and micro-organisms. It requires a cover for best results.

Methyl bromide (monobromomethane) (I)

Methyl bromide is a colorless, liquified gas that is slightly soluble in water. Although it is generally considered nonflammable and nonexplosive, some mixtures with air can be exploded by a spark. Both the liquid and gas are poisonous, and the effects of exposure are cumulative. Contact with skin causes severe burns. It is formulated as a solution in an inert solvent for soil applications. Usually it is mixed with a volatile substance that because of its odor or its irritating or lachrymose properties is a warning of the presence of methyl bromide.

Methyl bromide controls weeds, plant diseases, and insects in the soil. It is effective on nutgrass and perennial grasses, but seeds of whiteclover are resistant. It is used on soils contaminated with seeds, rhizomes, tubers, and other vegetative plant parts before seeding turf areas or setting out trees and shrubs. It is also used for renovating tees, greens, and fairways on golf courses. It makes reworking of old turf areas unnecessary. A cover is necessary to confine the vapor.

3,5-dimethyltetrahydro-1,3,5,2H-thiadiazine-2-thione (I; III, b)

This compound, designated as DMTT by WSA, is a solid slightly soluble in warm water. A commercial formulation contains 96 percent active ingredient plus a wetting agent.

DMTT breaks down in moist soil and releases gases and water-soluble materials that control soil fungi, weeds, and nematodes. It can be applied dry or as a water suspension. When used without a cover, it is sealed in with about an inch of water. The use of a cover, however, delays reinfestation after treatment. SMDC (p. 48) is more effective than DMTT when the water seal and no cover is used, but with water plus cover, DMTT is the more effective.

Purple nutgrass is difficult to control even with high rates.

Sodium-N-methyldithiocarbamate (I; III, b)

This compound, designated as SMDC by WSA, decomposes in moist soil and becomes toxic to insects and plants. It is readily soluble in water. A typical commercial formulation contains 4 pounds per gallon. It is toxic to mammals and irritating to eyes and mucous membranes.

SMDC kills germinating seeds of both grasses and nongrasses and controls nematodes, soil fungi, and insects. It can be sprayed on the soil surface and sealed in with water without a cover. Its residual toxicity disappears in about 2 weeks. It is used for preplanting treatment of seedbeds, potting soil, and areas for ornamentals and nursery stock, orchards, vineyards, and turf.

Hydrocarbons, Including Chlorinated Hydrocarbons

Aromatic solvents (I; V)

These products are also called solvent napthas or petroleum napthas. They include a variety of petroleum and coal distillates that can be used in heavy concentrations for aquatic-weed control. Kerosene, especially as sold in eastern United States, mineral spirits, tractor distillate, low-grade diesel oil, and similar aliphatic materials do not control submersed weeds. Most effective products are those with a flash point above 80° F., distillation between 278° and 420° F., and an aromatic content of at least 85 percent. These solvents are highly flammable and irritating to the skin and eyes or when inhaled. Livestock tend to avoid drinking treated water. Vegetation is not harmed when irrigated with treated water.

Aromatic solvents are deadly to fish. They are used in irrigation and drainage ditches especially in short ditches (6 to 8 miles or less) with even sides and bottoms and with flows of 1 to 70 c.f.s. Acrolein (pp. 6 and 56) is more practical in longer ditches. They are often mixed with emulsifiers to form a stable emulsion in the water.

Chlordane (1,2,4,5,6,7,8,8-octachloro-4,7-methane-3a, 4,7,7a-tetrahydroindane; 1,2,4,5,6,7,8,8-octachlor-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene) (I)

Technical chlordane contains 60 percent octachloro-4,7-methanotetrahydroindane and 40 percent related compounds. The mixture is required to contain 64 percent chlorine of compounds soluble in benzene. It is insoluble in water. It is absorbed through the skin and is harmful if swallowed or inhaled. Chlordane is formulated as 25- to 75-percent emulsion bases, 40- to 50-percent dusts, and 10-percent granules. Originally an insecticide, it is also used for the preemergence control of crabgrass in turf.

Herbicidal oils (I, d; II)

These compounds are used as vegetation top-killers, as solvents in the formulation of herbicides, and as carriers for herbicidal chemicals. Oils that kill by contact should not be used as solvents or carriers of translocated herbicides, since a quick kill of the conducting tissue prevents translocation of the chemical.

Oils vary widely in their composition, value for herbicides, and flammability. Generally, the toxicity to plants is greater with increased content of aromatics. Aside from composition, the value for herbicides is influenced by some physical properties. If the boiling point is low, the oil may evaporate too rapidly; if too high, it does not penetrate plant tissues. The viscosity, or flowing quality, should permit use in cool weather. Specific gravity is important in aquatic-weed control. The flammability is indicated by the flash point; the lower the temperature at which an oil-vapor-air mixture ignites, the greater the danger of explosion. A weed oil that meets the following specifications is satisfactory for nonselective use.

Aromatics	Minimum 50 percent
Boiling range	302° to 527° F.
API gravity	20° to 30°
Flash point	Minimum 180° F.

For convenience in handling during cold weather, the oil should have a maximum pour point of −10° F. Oils below API 27° are heavy and do not pour well in cold weather. However, if oils are too light—above API 38°—they do not have the persistent action needed for chronic poisoning. There are five general classes of oils.

(a) Medium-to-heavy, viscous, aromatic oils for general weed control: diesel oils, burner oils, low-grade oils, and oil extracts. They are safe to use and noncorrosive. Diesel oil is available commercially as diesel fuel oil. It varies in aromatic content depending on degree of refinement. Usually it is an effective contact herbicide. Low-grade oils are available only from local refineries in some oil-producing regions; only limited amounts of oil extracts are available.

(b) Light oils not toxic to all plants and used for selective weed control: stove oil, kerosene distillate, Stoddard solvent, and mineral spirits. They are low in aromatic content.

(c) Special oils resulting from the manufacture of gasoline and formulated especially for weed control. Many oils of this type are now available, but they are also low in aromatic content.

(d) Fortified oils, whose herbicidal properties have been increased by the addition of pentachlorophenol, dinitrocresol, dinitrobutylphenol, or octachlorocyclohexanone.

(e) Emulsifiable oils; oil solutions containing a surfactant capable of causing emulsification upon mixing with water. The oils, in general, are moderately toxic to animals, but kerosene types are highly toxic.

Oil sprays wet leaf surfaces and penetrate waxy leaf surfaces more effectively than water sprays, are less easily washed off the plant, and evaporate more slowly under high temperatures. The effect of oils on perennials is temporary. Oils are used for a quick kill of topgrowth—a chemical substitute for mowing. They penetrate the leaves of nongrass plants, but kill grasses by creeping down the stem to the crowns and roots. Repeated treatments are necessary where seasons are long and rainfall is high. The cost depends on distance from source of supply. If relatively nontoxic, large volumes are necessary especially for oil-tolerant species and aerial applications are impractical. Some of the disadvantages of the oils used alone can be overcome by fortifying them with phenol compounds or using them in conjunction with soil sterilants. The necessary volume can be reduced, the toxicity to tolerant weeds can be increased, a wider range of oils can be used, and the initial kill can be hastened, but the cost is raised.

The fortified oil sprays in low volume are effective on small weeds. When plants, especially grasses, are tall enough to protect their crowns, larger spray volumes are required. Emulsions provide larger volume although they do not increase toxicity to plants. The oil content can be varied—10 percent for easy-to-kill species and up to 25 percent for hard-to-kill species. Frequently, a fortified oil emulsion is more economical than a straight oil emulsion. Oils used as solvents or carriers may or may not be toxic to plants.

The fortified oil emulsions are well suited for killing all vegetation on roadsides, ditchbanks, and similar places and for spot treatment of shallow-rooted perennials. The staining that may result from oils carrying the dinitros when used on sidewalks and driveways is objectionable. Weed oils are preferred for such use and for oil-tolerant weeds.

As a class, oils are insoluble in water; when mixed with water in the presence of a surfactant, they form an emulsion. The common emulsion has oil dispersed in water; an invert emulsion is the reverse—water is dispersed in the oil. The fortifying chemical is dissolved in either the water or the oil or both.

Resistant weeds are: chamomile, stinking mayweed; cocklebur, common; cowparsnip; duckweed, common; fennel, common; Florida-pusley; foolsparsley; mallow, dwarf; milkweed, common; pineappleweed (*M. matricarioides*); poison-hemlock; redvine; St.-Johns-wort, Klamath-weed; and star-thistle, yellow.

MALEIC HYDRAZIDE (1,2-DIHYDROPYRIDAZINE-3,6-DIONE)

This compound is designated as MH by WSA. It is used to reduce mowing expense, since it retards the growth of some grasses. It is formulated as a sodium salt—a water-soluble powder

containing 40 percent MH equivalent and a diethanolamine salt—a water-soluble liquid containing 3 pounds per gallon of active ingredient. Both formulations are only slightly toxic to man and animals.

Johnsongrass, yellow nutgrass, and wild onion are resistant.

MIXTURES

Amitrole-simazine (III, a)

In this mixture, the simazine is added to provide residual toxicity after the quick knockdown of vegetation by the amitrole. This mixture is more effective than amitrole alone for pole yards, parking areas, gravel shoulders and center strips on highways, lumberyards, around buildings, transmission towers, guardrails, bridges, and on similar areas. It does not corrode spray equipment, is nonflammable and odorless, and does not stain.

Weeds resistant to both amitrole and simazine are resistant to the mixture.

Borate-monuron

This mixture is designated as BMM by WSA. A proprietary mixture containing 63.2 percent disodium tetraborate pentahydrate, 30.8 percent disodium tetraborate decahydrate, and 4.0 percent monuron is available. The B_2O_3 equivalent of the boron compounds in this mixture is 41.4 percent. Both constituents are only slightly toxic to mammals. The formulation is a granular product that is nonflammable and noncorrosive. The boron compounds are effective on broad-leaved plants, and monuron is an effective grasskiller. It is slow in action and is resistant to breakdown by soil micro-organisms.

Resistant weeds are: maidencane; needlegrass; purslane, common; rose, prairie; smartweed, Pennsylvania; and toadflax, yellow.

Borate-2,4-D

This mixture is designated as BDM by WSA. A proprietary mixture containing 55 percent disodium tetraborate pentahydrate, 35.5 percent disodium tetraborate decahydrate, and 7.5 percent 2,4-dichlorophenoxyacetic acid is available. It is applied dry. It is nonpoisonous when used as directed and is noncorrosive and nonflammable.

The mixture is designed to kill deep-rooted, perennial, broad-leaved weeds. It is not recommended to control grasses. It results in quicker topkills than borates alone. In semiarid regions, residual toxicity lasts 1 to 2 years at rates of 12½ to 14½ pounds per 1,000 square feet. It is resistant to attack and decomposition by soil organisms, but it is leached below the root zone in soil when exposed to heavy rains.

Chlorate-borate (I, d; III, b)

This mixture is designated as CBM by WSA. A proprietary mixture containing 73 percent disodium octaborate and 25 percent sodium chlorate, with a B_2O_3 equivalent of 49 percent is available. It may be applied dry or as a spray. It is completely soluble in water. Its oral toxicity is low. It is noncorrosive to ferrous metals, and the borate in the mixture is a fire deterrent.

This mixture combines the rapid contact action of chlorates with the more persistent toxicity of the borates. The residual toxicity may last 3 to 5 years at rates of 25 to 30 pounds per 1,000 square feet in semiarid regions, but it varies with soil type and rainfall. In spray form, the mixture acts as a contact herbicide, killing topgrowth, and is also absorbed by plant roots.

Resistant weeds are: ceanothus, Jersey-tea; daisy, English; hawksbeard, smooth; and sowthistle, annual.

Chlorate-borate-monuron (I, d; III, b)

This compound is designated as CBMM by WSA. A proprietary mixture of 40 percent sodium chlorate, 54 percent sodium metaborate, and 2.4 percent monuron is available. It is formulated as a powder for both dry and wet application and as a granular product.

The sodium chlorate and boron compounds are effective against deep-rooted, perennial broadleaved weeds, and monuron is effective against grasses. The mixture is a long-lasting soil sterilant that is nonpoisonous to mammals. The borate in the mixture is a fire retardant, but some precautions are necessary to avoid a fire hazard.

Resistant weeds are: ceanothus, Jersey-tea; daisy, English; hawksbeard, smooth; hawkweed, orange; needlegrass; nightshade, black; nutgrass, purple and yellow; panicum; and sowthistle, annual and perennial.

Chlorate-chloride (I, d)

The herbicidal properties of this mixture are similar to those of sodium chlorate (p. 19), since the chlorate is the active ingredient. The chloride is added to reduce the fire hazard of the chlorates. Although the fire hazard of the mixture is less than that of sodium chlorate alone, dry accumulations on clothing, wood, or other organic matter may be flammable. Precautions as outlined for sodium chlorate should be observed (p. 36). Rates are based on the amount of chlorate in the mixture. It may be used dry or as a spray.

Weeds resistant to sodium chlorate are also resistant to this mixture.

Dalapon-silvex (I, b; III, a)

An emulsifiable formulation containing 4 pounds dalapon plus one-half pound silvex per gallon is available commercially. The diethylene

glycol ester of dalapon and the propylene glycol butyl ether esters (low volatile) of silvex are used. The mixture is noncorrosive and nonpoisonous, but it may cause skin irritation.

It is nonselective and translocated. It is not so dependent on rain as those herbicides that are absorbed by plant roots. It is most effective when plants are growing rapidly. Re-treatment or spot treatments are usually necessary for seasonal control, since it does not have a long residual toxicity in the soil. Drift is a hazard to plants nearby.

Weeds resistant to both dalapon and silvex are resistant to the mixture.

Octachlorocyclohexenone (I)

This compound is designated as OCH by WSA. It is a mixture of isomers so has no precise physical properties. It is highly toxic. It is formulated as a 40-percent solution of petroleum oil. It is used to kill duckweed.

Pentachlorophenol (I, II, III, V)

This compound is designated as PCP by WSA. It is a contact herbicide used alone and to fortify oils. It is used for topkills of vegetation, but it is considerably less effective than the dinitros over a wide range of plants and is more difficult to handle. Effectiveness on weeds can be increased by adding ammonium sulfate, aluminum sulfate, or sodium bisulfate. The oil formulation is destructive to rubber. PCP is not compatible with calcium arsenate.

PCP is highly poisonous if swallowed, if absorbed by the skin, or if appreciable amounts of spray mist are inhaled. Since both the powder and spray mist are very irritating to the nose and throat and cause violent sneezing, and since swallowing would induce immediate vomiting, absorption through the skin is the most likely way for PCP to enter the body. The powder and water solutions are irritating to the skin, but the chemical is readily absorbed.

Phenoxy Compounds (III, A; V)

The phenoxy compounds include 2,4-D, MCPA, 2,4,5-T, and silvex. In the acid form, these herbicides are only slightly soluble in water. For commercial use, they are formulated as esters, which form milky emulsions with water and also dissolve in light oils, or as water-soluble salts. The amines are the most widely used salts. They are easily soluble in water and are commonly sold in liquid form. There are also sodium and ammonium salt formulations that are sold as water-soluble powders, but they are not so effective as the amine salts on hard-to-kill species or on weeds that are in bud stage and beyond. All of the salts are practically nonvolatile. Two general kinds of esters are commercially available: relatively high-volatile esters and relatively low-volatile esters. Although the low-volatile esters vaporize less rapidly than the volatile esters, both types are volatile at high temperatures. Drift can occur with any of the formulations if the spray is in very fine droplets or mist and there is a wind.

The phenoxy formulations are moderately toxic. The hazard to livestock and wildlife is negligible on treated vegetation, but toxic amounts could be eaten if animals had access to undiluted concentrates or large amounts of spray mixtures. As ordinarily handled, these materials are not likely to cause irritation to skin or eyes. They are not absorbed through the skin to any appreciable extent, and, in the amounts likely to be inhaled, are not hazardous. Neither is the ingestion of harmful amounts likely. At dosages used for weed control, they may harm fish in still, shallow water. They are noncorrosive and nonflammable.

2,4-D (2,4-dichlorophenoxyacetic acid)

2,4-D is formulated as water-soluble sodium, ammonium, or amine salts and volatile or low-volatile esters. Sodium salts and esters are also available as dusts. A new formulation is the diamine salt. It is an oil-soluble amine that has the weedkilling properties of an ester and the nonvolatile features of amine salts. It is formulated in a concentrate containing 2 pounds, acid equivalent, per gallon.

2,4-D is used for the control of herbaceous broad-leaved weeds. It can be applied at extremely low concentrations compared with the inorganic herbicides, such as borates and chlorates. It is absorbed through leaves and is readily translocated in the plant, but it is also absorbed by plant roots. It is commonly used as a selective herbicide rather than a soil sterilant. Its effect, when applied to the soil, is temporary except under very dry conditions or cool weather. It is more effective on broad-leaved weeds when applied as a foliar spray than on grasses, although in some areas it has killed grass seedlings when applied in large amounts to the soil.

2,4-D is used on many perennial broad-leaved weeds, since it is translocated to the roots and underground storage organs. It is carried with the sugars as they move out of the leaves. It is, therefore, most effective on warm sunny days when photosynthesis is active. It is a very useful herbicide to kill annual nongrass weeds that frequently re-infest an area treated with a soil sterilant after it has leached below the surface layer. It is also an inexpensive and convenient chemical to kill certain weeds that are tolerant to a soil sterilant. On roadsides and similar areas where grasses are desirable for erosion control and in

turf, 2,4-D can be used selectively to kill broadleaved plants in sod. 2,4-D is also effective on certain broad-leaved aquatic plants.

2,4-D is also used for the control of woody plants. The salt formulations are practically nonvolatile but, with the possible exception of the diamine salt, are less effective than the esters on hard-to-kill species. The low-volatile esters are equally as effective as the volatile esters and in some instances are better. Some woody species are tolerant to 2,4-D but susceptible to 2,4,5-T and vice versa. For use on mixed populations, the two herbicides are combined in a formulation sold as "brush killers." These brush killers contain one-third to one-half 2,4,5-T and two-thirds to one-half 2,4-D. Brush killers are also effective on poison-ivy, poison-oak, and poison-sumac.

The esters are used extensively in oil for basal-bark, stump, and cut-surface applications. Diesel oil, kerosene, and water are used as carriers. They are used in the fall and winter on deciduous trees when there are few active leaves present or in the summer to increase penetration of leaves, bud scales, and bark. Water is commonly used as the carrier with ester in emulsion for foliage sprays. Only small amounts of oil can be used for this latter purpose (up to 10 gallons per acre), since oil kills leaf tissue and hence prevents movement of the chemical to the roots.

2,4-D is more effective than MCPA on buckbrush, snowberry; ceanothus, wedgeleaf; chamise; chickweed, common, field, and mouse-ear; cinquefoil, common and sulfur; cocklebur; dock, broadleaf and curly; flixweed; garlic, wild; gooseweed; gromwell, corn; ground-ivy; hawkweed, orange and yellow; heal-all; Indian hemp; knapweed, diffuse; knotweed, prostrate; lupine, silvery; mallow, little; manzanita; milkvetch; nutgrass; oak, post and white; onion, wild; pineappleweed (*M. matricarioides*); poison-oak; poorjoe; puncturevine; purslane, common; rabbitbrush, grey; rose, Macartney; rush; sage, creeping; sagebrush, big; sorrel, heartwing and sour dock; speedwell; sumac, Chinese; tansy; toyon; tree-of-heaven; vetch, narrowleaf; and wormwood, annual.

Resistant species are: agrimony; algae, *Mycrocystis;* artichoke thistle; ash; aster, western and woody; barberry, Allegheny; barnyard grass; basswood; bedstraw; beech; bermudagrass; betony, Florida; blackberry; bluebell; bluestem, little; bouncing-bet; bracken; bristlegrass; bromegrass; broomsedge; buckwheat, tartary; buffalobur; bugleweed, creeping; burnet; buttercup, bulbous; calendula; campion; catchfly; chamomile, corn; cheat; cherry; chinquapin, golden; cockle, white; coriander; corncockle; cowcockle; crabgrass; cudweed; deadnettle, red; dodder; duckweed; elm; false-chamomile; fieldmadder; fir, balsam, red, and white; foxtail; fumitory; goosefoot, spear-leaved; goosegrass; gourd, buffalo; goutweed, bishops; greenbrier; gromwell, common; groundcherry, clammy and smooth; groundsel, common; gum, black; hawksbeard; hawthorn; hemlock; hempnettle; henbane; henbit; hickory; hogpotato; honeylocust; horsebrush, littleleaf; horsenettle; horsetail, field; huisache; johnsongrass; juniper; knapweed, Russian; knawel; ladysmantle; larkspur, duncecap, little, and tall; mallow, common; manzanita, greenleaf; maple; marigold, corn; mayweed, scentless; medusahead; mesquite, honey and velvet; milkweed, climbing, common, showy, western, and whorled; mint, field and water; mugwort; mulberry; mullein, common; needle-and-thread; nightshade, silverleaf; nimblewill; oak, black, blackjack, bluejack, canyon live, interior live, and scrub; oats, wild; Osage-orange; panicum; paspalum; pellitoryweed; persimmon, common; pine, jack, Jeffrey, lodgepole, red, and white; plum, chickasaw; prickly-ash; quackgrass; queensdelight; redbay; redbud; redcedar, eastern; redtop; redvine; rescuegrass; rocket, London; rose, California, multiflora, and Woods; St.-Johns-wort, Klamathweed; salmonberry; saltcedar; sandburs; sandspurry; sedge; sida, alkali; smartweed, green and swamp; smutgrass; sorrel, red; spikerush; sprangletop; spruce, white; spurge, flowering, leafy, upright, and corn; squirreltail; strawberry, wild; sweetgrass, floating; sweetgum; tanoak, scrub; thistle, wavyleaf; toadflax, yellow; violet; whitethorn, mountain; windmillgrass, tumble; woodsorrel, yellow; yarrow; yaupon; and yucca, soapweed.

MCPA (2-methyl-4-chlorophenoxyacetic acid)

MCPA contains several isomers, but the 2-methyl-4-chloro isomer is the most effective for killing weeds. Therefore, the better formulations contain a high proportion of this isomer. The most widely used formulations are the sodium and amine salts.

MCPA is very similar in use to 2,4-D. It is used for the control of herbaceous broad-leaved weeds. (See under 2,4-D, p. 15.)

MCPA is more expensive than 2,4-D. However, it is more effective than 2,4-D on artichoke thistle; buckwheat, tartary; burcucumber; buttercup; coffeebean; hempnettle; hickory; honeysuckle; horsetail, field; knapweed, spotted; pepperweed, perennial; St.-Johns-wort, Klamathweed; spurry, corn; and yarrow, common.

Resistant species are: alligatorweed; ash; aster, woody; bedstraw, cleavers and smooth; blackberry; bluemustard; bouncing-bet; bracken; buckbrush, snowberry; buffalo-bur; bugleweed; burnet; buttercup, bulbous; calendula; campion, bladder; catchfly, nightflowering; chamise; chickweed; cockle, white; comfrey, common; coriander; corncockle; cowcockle; deadnettle, red;

dodder; elm; garlic, wild; gooseweed; grape-hyacinth; greenbrier; gromwell, corn; ground-cherry, smooth; ground-ivy; groundsel, common; halogeton; hawksbeard, smooth; hawkweed, orange and yellow; hawthorn (*Crataegus* spp.); heal-all; henbit; hogpotato; horsenettle; Indian hemp; knapweed, diffuse and Russian; knawel; knotweed, prostrate; ladysmantle; larkspur, duncecap and tall; lupine, silvery; mallow, common and little; manzanita; maple; marigold, corn; mayweed, scentless; mercury, annual; mesquite, velvet; milkweed, common, showy, and western whorled; mint, water; mugwort; mullein, common; nutgrass; oak, blackjack, bluejack, interior live, post, scrub, and white; onion, wild; pellitoryweed; poison-oak; poppy; purslane, common; rabbitbrush, grey; redvine; rocket (*Franseria*); rose, Macartney and multiflora; sagebrush, big; saltcedar; sandspurry; sedge; smartweed, green; smilax; sorrel, red; speedwell; spurge, leafy; squirreltail; strawberry, wild; sumac, Chinese; tansy; thistle, wavyleaf; toadflax, yellow; tree-of-heaven; violet; and woodsorrel, yellow.

2,4,5-T (2,4,5-trichlorophenoxyacetic acid)

2,4,5-T is generally used in the ester formulation although there are sodium and triethanolamine salts. There is also a new diamine formulation containing 2 pounds, acid equivalent, per gallon; 2,4-D and 2,4,5-T are also combined in a formulation called "brush killer." The diamine salt brush killer contains 1 pound, acid equivalent, of 2,4-D plus 1 pound, acid equivalent, of 2,4,5-T; other brush killers contain the esters in combinations of one-third to one-half 2,4,5-T to two-thirds to one-half 2,4-D.

2,4,5-T can be used for the selective control of broad-leaved weeds in turf and for some emersed aquatics of nongrass species, but it is used principally for the control of woody plants. Like 2,4-D, it is a growth-regulator type of herbicide that can injure nearby broad-leaved plants through drift. Handling precautions are the same as for 2,4-D. The salt formulations are practically nonvolatile but, with the possible exception of the diamine salt, are less effective than the esters on woody plants. The low-volatile esters are equally as effective as the volatile esters and in some instances are better.

Some woody species are tolerant to 2,4,5-T but susceptible to 2,4-D and vice versa. Brush killers are used on mixed populations.

Resistant species are: arrowhead (*S. longiloba*); artichoke thistle; ash; aster, western and woody; barnyard grass; bedstraw; beech; bermudagrass; betony, Florida; bluestem, little; bouncing-bet; bristlegrass; bromegrass; broomsedge; buckbrush, snowberry; buckeye, California; buffalo-bur; campion; carpetweed; catchfly, nightflowering; cheat; chinquapin, golden; cockle, white; comfrey, common; corncockle; cowcockle; crabgrass; dodder; duckweed; foxtail; garlic, wild; goosegrass; greenbrier; groundcherry, smooth; groundsel, common; halogeton; hawkbit; hawksbeard; hawkweed, orange and yellow; heal-all; hemlock; hogpotato; horsebrush, littleleaf; horsetail, field; huisache; Indian hemp; iris, Rocky Mountain; johnsongrass; juniper; knapweed, diffuse and Russian; knawel; larkspur, little and tall; mallow, common; manzanita, greenleaf; medusahead; mercury, annual; milkweed, common, showy, and western whorled; mountain-mahogany; mugwort; mulberry; needle-and-thread; nightshade, silverleaf; nimblewill; nutgrass; oak, canyon live, interior live, and turbinella; oats, wild; onion, wild; paspalum; pine, jack, Jeffrey, red, and white; pentstemon; pineappleweed (*M. matricarioides*); quackgrass; rabbitbrush, grey; redbud; redcedar, eastern; redtop; redvine; rescuegrass; rocket (*Franseria*); sandburs; smutgrass; sorrel, red; speedwell; spikerush, creeping; sprangletop; spruce, white; spurge, leafy, upright, and corn; squawberry; squirreltail; strawberry, wild; tanoak, scrub; toadflax, yellow; umbrella-sedge; Virginia-creeper; yaupon; and yucca, soapweed.

Silvex (2-(2,4,5-trichlorophenoxy)propionic acid)

Silvex is an organic acid that is formulated as a low-volatile ester, a liquid potassium salt, and a granular product.

When emulsified with water or an oil-water carrier, the ester formulation is used as a selective translocated foliar spray to control many broad-leaved weeds and some woody plants. Commercial products are formulated of mixed propylene glycol butyl ether esters, a butoxyethanol ester, or an iso-octyl ester of silvex to contain 4 pounds, acid equivalent, per gallon. Undiluted, the esters are very painful to the eyes and irritating to the skin; but in diluted spray mixtures, they are only mildly irritating. In acute oral toxicity, they are similar to esters of 2,4-D and 2,4,5-T.

Ester formulations of silvex are used in much the same way as esters of 2,4,5-T except that (1) they are safer where drift onto cotton is a hazard, (2) they are more effective as a foliage spray on maple, redbud, Cherokee rose, saltcedar, and trumpetcreeper, (3) they are not so effective for basal-bark and cut-surface applications, and (4) they are more effective on mouse-ear chickweed, henbit, and yucca.

Resistant species are: ash; aster, western and woody; bluestem, little; blueweed, Texas; bracken; broomsedge; buckbrush, snowberry and coralberry; buckeye, California; buffalo-bur; calendula; campion, bladder; caraway; carpetweed; catchfly, nightflowering; chamise; chinquapin, golden; corncockle; cowcockle; deathcamus,

grassy; dock, curly; dodder; duckweed; elm; garlic, wild; gooseweed; greenbrier; groundcherry, smooth; groundsel, common; halogeton; hawksbeard, smooth; hawthorn; heal-all; hogpotato; horsetail, field; iris, Rocky Mountain; juniper; knapweed, diffuse and Russian; larkspur, little; mallow, common; medusahead; needle-and-thread; nightshade, silverleaf; nutgrass; oak, interior live; pineappleweed (*M. matricarioides*); plum, chickasaw; rabbitbrush, grey; redbay; redvine; rocket (*Franseria*); rose, Woods; sandburs; smartweed, green; smilax; snakeroot, white; snakeweed, broom; snowbrush; speedwell; spikerush, creeping; sprangletop; squawberry; sweetgrass, floating; tanoak (*L. densiflora*); toadflax, yellow; umbrella-sedge; and water-chestnut.

The liquid salt formulation is a solution of the potassium salt of silvex containing 6 pounds, acid equivalent, per gallon. It is used to control aquatic weeds. This formulation is less toxic than the ester formulations to fish except brown trout. It does not injure land plants growing adjacent to treated areas. It is similar to 2,4-D in its effect on many species of submersed aquatic weeds and is more effective on some. Handling precautions are similar to those for the ester formulations.

The granular product contains 20 percent acid equivalent. It is used to control the same aquatic weeds as the liquid salt. Handling precautions are similar to those for the liquid salt and esters except that there is more danger of inhaling dust and less danger of skin irritation. Toxicity to fish is the same as for the liquid salt.

Aquatic weeds susceptible to silvex are: arrowhead, coontail, fanwort, parrotfeather, pickerelweed, primrose-willow, spatterdock, water-hyacinth, waterlilies, watermilfoil, waterplantain, watershield, water-stargrass, and water-starwort.

Phenylurea Compounds (I, B, C; III, B, C)

The substituted phenylureas used for soil sterilants include monuron, diuron, and fenuron. They are only slightly soluble in water; low in volatility; noncorrosive; and nonflammable. They are formulated as water-dispersible powders, granular products, liquids, and pellets. With the exception of the pelleted and granular materials, all forms are applied as suspensions in relatively large volumes of water and require agitation in the spray tank.

Although these chemicals do not move far laterally in the soil, they may be washed down the surface of slopes to kill vegetation below and they leach deeply enough to reach the roots of trees, shrubs, and other deep-rooted plants growing under the treated area. All three chemicals can irritate eyes, nose, throat, and skin.

Monuron (3-(*p*-chlorophenyl)-1,1-dimethylurea)

Monuron is formulated as a water-dispersible powder containing 80 percent active ingredient. It is also formulated as a granular material.

The effects of monuron on all weeds are slow to appear. Monuron is more effective in light sandy soils than in heavy types at equivalent rates and is more active in mineral soils than those high in organic-matter content. It is much more soluble in water than diuron, so it is better adapted to areas of less than 25 inches of rainfall a year except along irrigation and drainage ditches. It is also preferred to diuron for soils containing considerable amounts of clay, especially bentonite, or of organic matter. At high rates, it leaches readily from sandy soils and moves downward twice as fast as diuron in both clay and sandy soils. It is somewhat more effective on grasses than nongrasses and gives better control than sodium chlorate. Heavy rainfall and standing or running water; conditions favoring microbial activity such as warm soils of high organic-matter content and moisture; and soil cultivation shorten its persistence in the soil. Sterility of the soil may last 1 to 3 years; this depends on rates applied, soil type, and rainfall.

Resistant weeds are: bracken; burdock, great; carrot, wild; cocklebur; coltsfoot; dandelion; horsetail; nimblewill; nutgrass, purple; paspalum; plantain; and yucca (*Y. smalliana*).

Diuron (3-(3,4-dichlorophenyl)-1,1-dimethylurea)

Diuron is even less soluble in water than monuron. It is formulated as a water-dispersible powder containing 80 percent active ingredient. There is also a liquid suspension, containing 2.8 pounds per gallon, active ingredient.

The effects of diuron on all weeds are slow to appear. Diuron is more effective than monuron where rainfall is over 25 inches a year and especially on sandy soils. It is not recommended for areas of low rainfall, especially to control deep-rooted plants. Larger amounts of diuron than monuron are adsorbed by all soils; consequently, it is more persistent.

Resistant weeds are: bracken; burdock, great; carrot, wild; cocklebur, common; coltsfoot; dandelion; dock, veiny; elderberry; horsetail, field; nimblewill; paspalum; and yucca (*Y. smalliana*).

Fenuron (3-phenyl-1,1-dimethylurea)

Fenuron is more soluble in water than monuron or diuron, but still only small amounts can be dissolved (0.02 lb. per gal. water). It is formulated as a 25-percent pelleted product. It is inactivated more rapidly than monuron or diuron and is adapted as a soil sterilant only for dry areas.

PHENYLMERCURIC ACETATE (I)

This compound is designated as PMA by WSA. It is a solid only slightly soluble in water. It is used both as a herbicide for the control of crabgrass in turf and as a fungicide to control some turf diseases. The most common formulation is a liquid containing 10 percent PMA. It is extremely poisonous if taken internally and can cause severe burns on the skin.

SODIUM CHLORATE (I, D)

When unmixed with other chemicals, sodium chlorate is readily soluble in water. Because it strongly supports fire, it is frequently mixed with soluble borates or calcium chloride to reduce this hazard. The solubility of the mixtures is considerably less than sodium chlorate alone. Sodium chlorate is relatively nontoxic to man and animals unless consumed in large quantities. Because of its salty taste, sodium chlorate may increase the palatability of poisonous plants that would not otherwise be eaten by livestock.

Sodium chlorate is an inexpensive, long-lasting soil sterilant in dry areas and a relatively temporary one in humid areas. The rate of decomposition is hastened by high temperatures and adequate moisture, which are favorable to microbial action; it is readily leached in coarse-textured soils; it is not readily absorbed by plants in soils high in nitrates or salts. It is absorbed by active roots in moist soil but not by dormant roots in dry soil. With adequate rain, chlorate is distributed throughout the soil profile, but in dry soils the chlorate is confined to the upper layers. Nitrates, which prevent absorption of the chlorate by plant roots, are also accumulated in these layers. The effectiveness of sodium chlorate is also reduced by a high organic-matter content and a high pH of the soil. It is generally applied to the soil, but it can be used as a foliar spray for a quick topkill. It may be translocated when applied as a foliar spray. It is highly toxic to many plants, but there are resistant species.

Resistant weeds are: bracken; camels-thorn; gorse; heliotrope, wild; kochia; poison-oak; rescuegrass; sida, alkali; and sweetgrass, floating.

The most important disadvantage of sodium chlorate is its flammability when in contact with organic matter, sulfur, sulfides, phosphorus, powdered metals, strong acids, or ammonium salts. When stored in paper or cloth sacks or when dry on clothing or vegetation after spraying, it may be ignited by friction, a spark, or even the heat of the sun. It burns so rapidly that the operator can be injured severely or buildings destroyed before the fire can be extinguished. In spite of the danger of handling sodium chlorate, large quantities are used safely by following the proper precautions.

TRIAZINES (III, B, C)

The triazines include simazine and atrazine. These are soil sterilants when applied at high rates. They are noncorrosive, nonflammable, and present no electrical or conductivity problem around utilities, power plants, transformers, signal blocks, or other electrical installations.

Simazine (2-chloro-4,6-bis(ethylamino)-s-triazine)

Simazine is practically insoluble in water. It is formulated as an 80-percent water-dispersible powder and as a 4-percent granular product. Both formulations are used for the nonselective control of vegetation on areas where any plant growth is undesirable. The granular product is also effective against rooted aquatic plants such as coontail, fanwort, horned pondweed, and watermilfoil.

Simazine is adsorbed by soil colloids. High cation-exchange capacity, high organic-matter content and, to a less extent, high clay content of soils reduce its toxicity to plants. It is probably also deactivated by soil micro-organisms. Simazine has little or no contact action on foliage, so there is no drift hazard. It cannot penetrate an unbroken leaf cuticle and is absorbed only through the roots. Simazine is ineffective until water carries it to the root zone, and its action is slow. It is easily removed from equipment by washing. It forms a suspension in water that requires agitation to keep the chemical from separating out.

Resistant weeds are: barberry; bindweed, field; blackberry; buttercup, creeping; dock, veiny; dogwood; golden-aster, false; hemlock; johnsongrass; knapweed, Russian; milkweed, common; nutgrass, purple and yellow; pine, white; rose, multiflora; spurge, leafy; thistle, Canada; vaseygrass; and white-cedar.

Atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) (III, a)

Atrazine is formulated as an 80-percent water-dispersible powder and a 4-percent granular product. It is more soluble than simazine, so that it is more effective in dry areas. Weeds better controlled with atrazine than simazine are: horsetail; Indian hemp; lettuce, prickly; nutgrass, yellow; rush; sedge; and thistle, Canada.

Atrazine, unlike simazine, is absorbed through plant leaves; hence, there is a drift hazard. It is slightly more toxic than simazine to mammals and remains toxic in the soil for a slightly shorter time.

TRICHLOROACETIC ACID (I, B, C; IV)

This compound is designated as TCA by WSA. It is readily soluble in water. It is formulated as the sodium salt containing 94 percent active in-

gredient and 82.8 percent acid equivalent and as a liquid containing 5 pounds per gallon, acid equivalent. In the liquid form it tends to decompose and liberate chloroform. In warm storage it may expand to the extent of damaging the containers. Solutions of 10 percent or more may burn skin and eyes unless washed off immediately. There is no practical hazard to livestock from eating or contacting sprayed foliage. In concentrations of 10 percent or more, TCA corrodes low-quality steel, galvanized iron, zinc, aluminum, and brass.

TCA is used to control grasses. It is not so effective as dalapon in foliar applications, but it is somewhat more persistent in the soil. It disappears through leaching and microbial activity. It is so soluble that it is quickly leached by heavy rainfall and in well-drained soils. It is also adsorbed in clay and organic soils and disappears more slowly from muck than sandy soils. For mixed populations of broad-leaved and grass plants, some broad-leaved weedkiller is added. The effectiveness of TCA is greatly increased by tillage; rates of application can be reduced from one-half to two-thirds by tillage.

Most of the broad-leaved weeds, including bitterweed, false golden-aster, purple nutgrass, pagodatree, and vaseygrass, are resistant.

HERBICIDES AND MIXING OF SPRAY MATERIALS

Some herbicides can be used as they come from the manufacturer. Such chemicals as sodium arsenite or sodium chlorate can be applied dry or need only to be dissolved in water. Others, however, are practically useless in their original form and require formulation before they can be used for weed control.

Formulations of Herbicides

A formulation contains the herbicide in a form that can be (1) dissolved or suspended in a carrier and distributed in solution or suspension by sprayers, (2) distributed dry by dusters or spreaders, or (3) easily vaporized for fumigation. Often an emulsifier, spreader, sticker, or other surfactant is added to facilitate dilution or increase wetting capacity. Frequently formulations contain an inactive filler that serves as a diluent only. For example, there may be only 2, 3, 4, or 6 pounds of active weedkiller in a herbicide formulation that weighs 10 pounds per gallon. There are several types of formulations.

Water-Soluble Concentrates

Water-soluble concentrates are readily dissolved in water to make a spray. They are often sold as solids. TCA, dalapon, sodium salt of 2,4-D, and amitrole are examples. They are also formulated as liquids—amine salts of 2,4-D or MCPA and the sodium salts of PCP and endothall. These liquid formulations are prepared because some water-soluble chemicals cannot be handled conveniently unless they are diluted. For example, the alkanol amine salt of 2,4-D is soluble in water, but at room temperature it is a heavy viscous liquid that would be difficult to measure or mix with water and when cool it becomes stiff and unpourable. It is formulated into a free-flowing liquid that can easily be diluted with water and is convenient to handle. Water-soluble concentrates are also available as pastes and slurries—sodium salts of DNC, PCP, and 2,4-D. They may or may not include wetting agents.

Emulsifiable Concentrates

Emulsifiable concentrates are usually liquids in which the chemical is dissolved in one or more water-insoluble solvents such as oil or benzene and to which an emulsifier is added. When the emulsifiable concentrate is added to water and agitated, the mixture is broken into fine droplets. The emulsifying agent causes the fine droplets of oil to be suspended in the water to form an emulsion. The esters of 2,4-D, 2,4,5-T, and silvex are examples. The formulation should be clear, homogeneous, and free from sediment or crystalline solids. It should not corrode equipment, and the flash point should not be lower than 140° F. Since emulsions are frequently used in cold weather, the concentrate should have a maximum pour point of −10° F.

The emulsifiable concentrate should disperse readily. A concentrate having poor dispersibility emulsifies only with vigorous agitation and free oil usually separates from the emulsion on standing a short time. A good emulsion has globules that are barely visible; one with globules so fine they cannot be seen with the naked eye is better. Such an emulsion is called tight.

The breaking time of an emulsion is also important. Some formulations produce emulsions that break in a few minutes after application, others remain stable for 24 hours. The fast-breaking emulsion requires constant agitation and does not wet leaves adequately. Where constant agitation is impracticable, such an emulsion settles in the tank. Very stable emulsions may not break soon enough, especially in brush spraying, and they tend to drain off the leaf. A good emulsion should contain the solvents and emulsifying agents necessary to keep it stable with hard or soft water during the mixing and application period but to allow it to break soon after reaching the plant surface. As an average, the hardness of water is 322 p.p.m. in terms of calcium carbonate for hard water, 115 p.p.m. for water

in municipal systems, and 35 p.p.m. for rainwater.

Emulsifiable concentrates should be stable under both hot and cold storage.

Invert emulsions are water-in-oil mixtures in which every spray droplet is surrounded by oil instead of water. This results in a viscous material difficult to apply but less likely to drift.

Oil-Soluble Concentrates

Oil-soluble concentrates are similar to emulsifiable concentrates, but they do not contain an emulsifier. They do not mix with water, but they can be diluted with fuel oil or kerosene or applied without dilution. PCP and DNBP are examples.

Powders and Pastes

Wettable powders or water-dispersible powders are generally formulated from chemicals that are insoluble or soluble with difficulty in oil or water. They are finely ground with or without a powdered diluent. A wetting agent is added to keep the particles from floating, and a dispersing agent is added to keep the material in suspension. Monuron, diuron, and simazine are examples. 2,4-D, 2,4,5-T, and MCPA have been formulated as powders and pastes.

Dusts

Dusts are dry herbicides plus a filler. The sodium salt of 2,4-D is formulated as a dust.

Granules and Pellets

Granules and pellets are forms of herbicides in which the chemical is impregnated upon vermiculite, attaclay, or similar carriers. They can be prepared by spraying the herbicide on the carrier or by adding the core material, such as vermiculite, to the original dry powder. Then a pill-rolling technique with binders is used to produce pellets, or the powder plus binders and water is extruded, chopped, and dried to produce grains or pellets. Fenuron, simazine, 2,4-D, and an increasing number of herbicides are formulated as pellets. No water and no mixing are required, application equipment is less expensive than sprayers, there is no drift hazard, and they can be applied in areas awkward for spray equipment. If the chemical is effective only by root absorption, a spray intercepted by leaves is wasteful; grains or pellets that drop to the ground are more effective. However, their cost is higher, they are not adapted for foliar applications but must be applied to the soil, they are generally less effective than sprays where moisture is limited, and distribution of small amounts is difficult except by hand.

Fumigants

Fumigants contain the base chemical and sometimes a lachrymal additive that serves as a warning that poisonous vapors are present. Methyl bromide, DMTT, and SMDC are examples.

Surfactants

Surfactant is a general term for wetting agents, spreader-stickers, and other materials that alter the physical and chemical characteristics of a spray solution. A surfactant may serve as an emulsifier, improve suspension and dispersion of insoluble powders in water, or improve wetting through the reduction of surface tension. A realization of the importance of these additives is increasing. The interaction between surfactant and herbicide appears to be more important than the effect of the surfactant on surface tension in some instances.

A good emulsifier must be soluble in both oil and water or the emulsion will settle out. Wetting agents may increase greatly the entry of a spray into the leaf. They also prevent precipitation of calcium, magnesium, and iron salts of 2,4-D in hard water. Common concentration is about 0.1 percent of the spray. Spreader-stickers help sprays to stick, spread, and cover. Household detergents have similar effects.

Purchase of Herbicides

Adequate specifications for the purchase of some herbicide materials are now being developed.[1] They are difficult to write. Basically, the economic value of a herbicide depends upon the relative amounts of active chemical toxic to plants that are contained per pound or gallon. This is expressed in percent of active ingredient, acid equivalent, or phenol equivalent for solids and pounds per gallon for liquids. Thus, a solid containing 74 percent of the weedkilling ingredient is worth more than a 20-percent granular product pound for pound, and an amine salt formulation of 2,4-D containing 4 pounds per gallon, acid equivalent, is of more value than the same formulation containing 2 pounds per gallon. Actually, since mixing charges and cost of containers, freight, and handling have to be paid on twice as much material for a 2-pound-per-gallon formulation as a 4-pound formulation, the cost per pound of active material is less in the 4-pound formulation than in the 2-pound formulation although the cost per gallon of product is more.

[1] Federal specifications for use by Federal agencies in procuring amitrole, dalapon, 2,4-D, simazine, and 2,4,5-T have been approved.

But this relationship is affected by other factors: Under some circumstances 1 pound of 2,4-D in the ester formulation is twice as effective as 1 pound of the amine salt. This could be true on hard-to-kill species, on many brush species, and in arid climates. Equivalent amounts of the sodium salt are less effective than the amine salts. The amount of chemical that can be packed into a formulation is limited both for physical and chemical reasons and from an economic standpoint.

Some herbicides are mixtures of several isomers. Often one is more effective than the others. Although it may not be economically practicable to purify a formulation for the effective isomer, there may be larger proportions of it in one formulation than another. For example, the 2-methyl-4-chlorophenoxyacetic acid isomer of MCPA is more toxic to plants than the 2-methyl-6-chloro isomer, and, among the polychlorobenzoics, the 2,3,6-trichlorobenzoic acid is more effective on most species than the 2,3,4-; 2,3,5-; 2,4,5,-; 2,4,6-; or 3,4,5-trichlorobenzoic acids.

Additives, such as wetting agents, spreader-stickers, cosolvents, and emulsifiers, influence the effectiveness of a chemical. Their precise role and comparative values, however, are not too well understood and purchase at present must depend largely on empirical information. Carriers of the chemical also vary in cost and in toxicity to plants. Some can reduce the effectiveness of the chemical.

The proprietary mixture of two or more chemicals may be less effective than the constituents applied separately. Because better timing of application can be made of each constituent applied separately than applied together, the effectiveness of the mixture may be less than the sum of individual effects.

The purchase of herbicide formulations at present depends on the relative amounts of active chemical per unit, packaging, freedom from foaming and precipitation problems, and stability under storage. Sometimes the superiority of a formulation can be demonstrated because of these factors. When Federal specifications become available, purchase can be made on the basis of the requirements stated in the specification.

Mixing of Spray Materials

Mixing spray materials correctly involves calculations of the proper amounts of herbicide and diluent and procedures for mixing.

Calculations

Rates of application are expressed in terms of acid equivalent for certain herbicides such as 2,4-D, 2,4,5-T, 2,3,6-TBA, TCA, dalapon, and silvex; phenol equivalent for the dinitros; and active ingredient for others, such as amitrole and simazine. They are recommended in ounces or pounds per square foot, square rod, or acre where the area to be treated can be measured.

Where spot spraying of individuals or small clumps of plants is necessary or where dense foliage, as in brush or trees, is to be thoroughly wet, the concentration of the spray is recommended in pounds of active ingredient or acid equivalent per 100 gallons. Also, in the control of aquatic weeds, concentration of the herbicide is often referred to in terms of parts per million of water. This means the number of parts (by weight or volume) of the chemical in 1 million parts of water or other diluent.

1 acre-foot of water weighs 2,722,500 lb.; that is, 43,560 sq. ft.$\times$1 ft.=43,560 cu. ft.$\times$62 lb. =2,722,500 lb.

Therefore, 1 p.p.m.=2.7 lb. chemical in 2,722,500 lb. water (1 acre-ft.).

To determine number of pounds chemical required, use the following:

$$X \text{ (pounds chemical)} = \text{p.p.m.} \times \text{acre-ft.} \times 2.7$$

Example: Rate, 5 p.p.m.; volume, 1 acre 2 ft. deep, then $X=5\times2\times2.7=27$.

Therefore, 27 lb. of chemical would be required for 5 p.p.m.$\times$2 acre-ft.

Usually the pounds of active ingredient or acid equivalent per gallon are given on the label of liquid herbicide. The percent is given on labels of powders, granules, and other dry materials.

To calculate the amount of liquid herbicide required when the rate is expressed in pounds per acre use the following formula:

$$\frac{\text{Rate in pounds per acre}}{\text{pounds of herbicide per gallon}} = \text{gallons per acre}$$

Example: If the rate is 1½ pounds per acre and the herbicide contains 4 pounds per gallon, then $\frac{1.5}{4.0}=0.37$ gallon, or 8 pints$\times$0.37=3 pints.

Use the same formula to calculate gallons of herbicide per 100 gallons of spray.

Example: If the rate is 2.5 pounds per 100 gallons and the herbicide contains 2 pounds per gallon, then $\frac{2.5}{2.0}=1.25$ or 1¼ gallons.

To calculate the amount of dry product required when the rate per acre is given, use the following:

$$\frac{100}{\text{percent active ingredient}} \times \text{rate per acre} = \text{pounds product}$$

Example: If the rate is 15 pounds, active ingredient, per acre, and the percent of active ingredient is 75, then $\frac{100}{75} \times 15 = 20$.

Amounts of liquid herbicide or of dry material to use per acre in various concentrations and for various rates of application are given (table 2). A list of equivalents in measures, weights, and rate of speed is given (Appendix, p. 83) for convenience. Equivalent temperatures on Centigrade and Fahrenheit scales are given in the "Appendix," p. 83.

TABLE 2.—*Amounts of liquid concentrate or of wettable powder to use per acre in various concentrations and for various rates of application*

Concentration of herbicide	Concentrate to use per acre at the rate of—							
	2 oz.	4 oz.	8 oz.	12 oz.	1 lb.	2 lb.	3 lb.	4 lb.
Pounds per gallon of water:[1]	*Pints*	*Pints*	*Pints*	*Pints*	*Pints*	*Pints*	*Pints*	*Pints*
1	1.0	2.0	4.0	6.0	8.0	16.0	24.0	32.0
1½	.67	1.3	2.6	4.0	5.3	10.6	16.0	21.3
2	.50	1.0	2.0	3.0	4.0	8.0	12.0	16.0
3	.34	.67	1.3	2.0	2.7	5.3	8.0	10.7
4	.25	.50	1.0	1.5	2.0	4.0	6.0	8.0
5	.20	.40	.80	1.2	1.6	3.2	4.8	6.4
6	.17	.34	.67	1.0	1.3	2.6	4.0	5.3
7	.14	.30	.60	.90	1.1	2.3	3.4	4.6
8	.125	.25	.50	.75	1.0	2.0	3.0	4.0
9	.11	.22	.45	.67	.9	1.8	2.7	3.6
10	.10	.20	.40	.60	.8	1.6	2.4	3.2
Percentage of dry material:	*Pounds*[2]	*Pounds*[2]	*Pounds*[2]	*Pounds*[2]	*Pounds*[2]	*Pounds*[2]	*Pounds*[2]	*Pounds*[2]
10	1¼	2½	5	7	10	20	30	40
20	10 oz.	1¼	2½	3½	5	10	15	20
25	8¾ oz.	17½ oz.	2	3	4⅙	8⅓	12½	16⅔
30	7½ oz.	15 oz.	1⅔	2⅓	3⅓	6⅔	10	13⅓
40	5 oz.	10 oz.	1¼	1¾	2½	5	7½	10
50	4 oz.	8 oz.	1	1⅖	2	4	6	8
75	3 oz.	6 oz.	11 oz.	1	1⅓	2⅔	4	5⅓
90	2¼ oz.	4½ oz.	9 oz.	12½ oz.	1⅑	2¼	3⅓	4⅔

[1] In active ingredient, acid equivalent, or phenol equivalent.
[2] To be added to the water or other liquid to be sprayed on 1 acre.

Procedure

To calculate capacity of the sprayer tank (all measurements in inches):

Cylindrical tanks: Multiply length×square of diameter×0.0034=capacity in gallons.

Tanks with elliptical cross section: Multiply length×short diameter×longer diameter×0.0034=capacity in gallons.

Rectangular tanks with square or oblong cross section: Multiply length×width×depth×0.004329=capacity in gallons.

Never pour the concentrate into an empty tank. Either fill the tank half full, add the chemical, agitate, and complete the filling or start filling and add the chemical as the filling is continued. Operate the sprayer with the nozzles shut off bypassing the spray through the tank for several minutes (at least six times) to insure a thorough mixing.

Water Sprays

When using a soluble powder or crystals, fill the tank half full of water. Add the chemical slowly, and stir to dissolve it completely. If a detergent is recommended, add one-quarter to one-half pound of household detergent per 100 gallons spray. If a solid grasskiller is to be used with 2,4-D or 2,4,5-T, mix it with water first and then add the 2,4-D or 2,4,5-T. Use the spray solution within 1 or 2 days after mixing, since some chemicals lose strength on standing.

If an amine salt of DNBP is used in very hard water, add 1 pound softener per 100 gallons spray.

Emulsions

Since emulsions are suspensions and not solutions, they require constant agitation. If no additional oil is to be used, start running water into the empty tank and slowly add the herbicide formulation with continuous agitation. The

chemical should all be added by the time the tank is one-third full.

If oil is to be used, premix the herbicide and the oil in a separate container. Do not allow any water to get into this mixture or it may jell. Fill tank one-third full of water, add premixed oil and herbicide, and continue filling. Agitate constantly. The water should be clean and low in carbonates and sulfates. (If ordinary hand soap lathers well, the water is satisfactory.) Circulate the mixture until it is uniformly white. If the emulsion stands for several hours, stir until uniformly white before using. Take samples of the emulsion from various sections of the tank at intervals to determine if separation has taken place.

When an invert emulsion is used, add water slowly to the premixed herbicide-oil solution under constant mechanical agitation; circulating with bypass is insufficient. Invert emulsions may separate readily on standing. After 24 hours of separation, most invert emulsions cannot be restored.

Oil Sprays

Add esters of 2,4,5-T, 2,4-D, or silvex, or other oil-soluble herbicides to the required amount of oil and mix thoroughly in the tank. This can be done at any time before spraying, since the spray does not separate. Do not let any water or any oil-water mixture get into the chemical formulation or the herbicide-oil mixture or it may jell.

Suspensions

Water-dispersible powders mix readily with water but do not dissolve. There are two methods of mixing: (1) add the powder slowly to water, with agitation—it should not be added to an empty tank—or (2) make a thin water slurry of the required amount of material before it is added to the water in the tank. A thorough job of mixing will help the agitator do its job more efficiently.

When esters of 2,4-D are used with monuron or diuron, add one-half pound of a caseinate conditioning agent to the suspension before adding the 2,4-D ester.

When a water-soluble chemical is to be mixed with a water-dispersible powder, dissolve the water-soluble chemical in the water before adding the powder.

Storage of Herbicides

A chemical with a low flash point (140° F. or less) is dangerous in storage.

Deterioration of chemicals in storage can be prevented by observing the following precautions.

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

Liquid formulations should be stored on pallets or duckboards to avoid rusting of the metal containers. The containers should be kept tightly closed. Where air vents have been punched in cans to facilitate pouring, they should be plugged. Even small amounts of water introduced into emulsion concentrates or oil solutions can cause them to jell and cause deterioration of the container.

Chemicals may crystallize out of solution at temperatures below 32° F. If this happens, warm the products to 40° F. or higher and roll drums or shake containers. If the crystals return to solution, no harm has been done. The following formulations do not freeze if stored in unheated rooms: Low-volatile esters of 2,4-D, 2,4,5-T, 2,4-D plus 2,4,5-T (brush killer), and silvex and the alkanol amine salt of DNBP. The following formulations may freeze if stored at temperatures below those indicated:

	° F.
2,4-D, alkanol amine salt	15
2,4-D, dimethylamine salt	20
2,4-D, butyl ester	23
2,4-D, isopropyl ester	32
2,4,5-T, butyl ester	47
2,4,5-T, amine salt	34
2,4-D plus 2,4,5-T, butyl ester	18
2,4-D plus 2,4,5-T, amine salt	43
MCPA, amine salt	14
DNBP, emulsifiable oil concentrate	20
DNBP, ammonium salt	32

At high temperatures, chemicals may expand and cause bulging of drumheads and leaks in the containers. They may deteriorate at temperatures over 95° F. High temperatures may reduce the effectiveness of emulsifiers and hasten the corrosion of containers.

APPLICATION EQUIPMENT

The results that follow the use of a herbicide depend largely on how well or how poorly it is applied, and this in turn depends on the operator and his equipment. Equipment is designed to apply herbicides (1) wet, in sprays or mists, (2) dry, in dusts or granules, and (3) in readily vaporized form for fumigation.

DESCRIPTION

Ground Sprayers

Hand Sprayers

Hand sprayers are suitable for treating small patches, inaccessible areas, and fence rows; for spot spraying; and for situations where the spray is to be applied close to susceptible plants. They include sprinkling cans, compressed-air sprayers of 1- to 5-gallon capacity carried by a strap over the shoulder, and knapsack sprayers with hand-operated pump. In the ordinary compressed-air sprayer, the pressure is reduced as the tank is emptied; but there are constant-pressure types. Some models, useful on trails, have cylinders of CO_2 gas to provide pressure. Knapsack sprayers are more expensive than compressed-air sprayers, but they have an agitator attached to the pump that makes them more suitable for suspensions.

Trombone-type sprayers are very versatile. They are especially adaptable for spraying tall trees.

Water-dispersible powders that form suspensions of high concentration in water tend to clog flat spray tip nozzles; a cone type gives less trouble. Compressed-air and knapsack sprayers are well adapted for herbicide concentrates to be used along highways. The cone oil-burner type nozzle that delivers 2.5 to 6 gallons per hour at 20 to 30 p.s.i. is very suitable. The solution or emulsion at 20 times usual concentration is applied at the rate of 5 to 6 gallons per acre for low-growing vegetation or 12 gallons per acre for heavier brush. A hood around the wand or boom prevents drift onto sensitive plants nearby.

Boomless Sprayers

Boomless sprayers—nozzle-cluster type—are well adapted for spraying roadsides and ditchbanks, under utility lines, and along fence rows. They are less expensive, simpler to operate, and have less nozzle trouble than boom sprayers. They can pass between trees and shrubbery, they can be maneuvered close to other obstacles, and they are practical for rough ground. They spray a broadcast swath of 20 to 30 feet with large volumes that provide moderately good coverage.

For foliage sprays, the conventional equipment consists of a piston-type hydraulic sprayer, such as the Hardie, Bean, Iron Age, or Myers, equipped with ¾-inch high-pressure hose and 15 g.p.m. (gallon per minute) pumps for a 3/16-inch nozzle opening or 35 to 60 g.p.m. pumps for ¼-inch, 5/16-inch, and 15/16-inch nozzle openings. The equipment is mounted on a four-wheel-drive power wagon or caterpillar-type tractor. The chief disadvantage of the boomless sprayers is that the spray stream is greatly affected by the wind. They should not be used when the wind may cause drift to sensitive vegetation nearby.

Boom Sprayers

Boom sprayers are adapted for large areas where complete coverage is necessary or for turf areas adjacent to a road where the entire application can be made from a tractor or truck-mounted boom.

For roadside or ditchbank spraying, arm booms are available. One end of a shaft is fastened to the truck and the other end terminates in a boomless sprayer nozzle. A two-nozzle arm boom is used for ditchbanks. A larger boom can be set at right angles to the truck for roadside or ditch spraying or vertically to spray above tall weeds. For roadside spraying, two or more nozzles are grouped together and mounted on an arm that reaches over mailboxes, highway signs, etc. A boom mounted on a truck designed to spray under guide rails reaches over them and sprays from the outside toward the pavement. Nozzles mounted off center enable the operator to spray 15 to 20 feet on one side.

Hand booms and adjustable spray guns are operated from truck-mounted power spray equipment and are used for application of basal sprays and stump treatments, for brush control and spot treatments, and for spraying around structures of various kinds. Handguns are used with pressures of about 100 p.s.i. Increased pressures result in a larger proportion of fine droplets and drift is increased. Handguns can vary delivery from a broad mist to a narrow coarse stream. Instead of a single nozzle, a bank of three to eight can be used. Sometimes the conveyor truck is stationary and long lines of hoses and side hoses are used to reach the area to be treated.

Mist Blowers

Mist blowers are power-driven machines that disperse highly concentrated sprays in finely atomized form at low volumes per acre. The herbicide is carried principally in an airstream instead of a liquid. These sprayers are free from boom and nozzle troubles and are very useful to spray herbaceous weeds and woody plants in swamps, under fences, around stone piles, along roadsides, in drainage ditches, and under powerlines. Mist blowers require minimum amounts of water, they cover vegetation rapidly, and they can be used for areas inaccessible to power equipment. The equipment is cheaper

than the conventional hydraulic power equipment. Use of mist blowers for weed spraying, however, is limited by the serious hazard of drift. Mist blowers in 5- to 12-h.p. (horse power) sizes are useful for brush spraying, if drift is not a problem. A 2-h.p. knapsack mist blower is useful for brush up to 30 feet tall, for spot spraying, and for re-treating.

Special Equipment

For spraying berm and adjacent weeds and brush: A right-hand drive truck with four nozzles mounted on a 6-foot sturdy vertical beam. A low-position, solid-stream nozzle with a 3/16-inch opening sprays berm to 24 feet from the machine and three fan-type boomless nozzles spray brush and weeds close to the machine. The pump delivers up to 20 g.p.m. at 800 p.s.i. from a three-speed power takeoff. The whole operation is controlled by the driver of the truck. The sprayer delivers from 25 to 50 gallons semiconcentrated material per mile of road.

For spraying around guard rails and posts: A truck-mounted tank with power sprayers and a boom mounted on the right side of the truck. The boom is controlled by an operator sitting next to the driver. The control valve is hand-operated. There are two nozzles, one sprays on each side of the guard rail or post.

For treating shoulders or fireguards: A boom operated hydraulically or electrically makes it possible to raise or lower it over obstructions, posts, and slopes. The boom for shoulder applications is about 8 feet long and for fireguards, 12 feet.

For basal-stem treatment: A 4-h.p. gas engine and 1/2-inch gear pump, and two lines of light hose with suitable nozzles, gun, and shutoff valve attached to each line of hose. The spray is five times the concentration of dilute sprays. A simple device is a 2-gallon can—called a "trickler"—carried on the operator's back, that allows the chemical to flow by gravity through a flexible tube to a light wand. The discharge is controlled by a leakproof valve.

For brush, briers, and small trees in fence lines and on ditchbanks: A tractor-powered, high-pressure sprayer for spraying foliage. It may be equipped with nylon-roller or other high-pressure pump, 25 feet of high-pressure hose, and an adjustable spray pattern handgun.

Individual Parts

Pumps.—The capacity of the pump should be about twice the nozzle delivery rate to provide for an overflow that is bypassed back to the tank for agitation of the spray. The several types are as follows:

1. A rubber-impeller pump is cheap, is not injured by abrasive suspensions, develops about 35 p.s.i., but is not adapted for oils.
2. A rotary gear pump has positive action. The discharge rate depends on the speed of rotations. Suspensions are hard on the gears. Plastic gear pumps can be replaced more cheaply than repairing permanent equipment.
3. A centrifugal pump is a single-rotating impeller type. It pumps a large volume of spray but does not develop a high pressure—40 p.s.i. to 70 p.s.i. It can handle all spray materials with minimum wear. It is not self-priming so must be mounted lower than the tank. Unlike most pumps, it pushes the liquid in one direction only.
4. A piston pump is designed for large quantities of spray and high pressures—up to 1,000 p.s.i. It has one or more plungers connected to a crankshaft. The plungers or pistons work inside smooth cylinders. The piston pump can be used for any type of sprayer, stands rough treatment, and is long lasting but expensive.
5. A nylon-roller pump gives good service, but it is expensive and is not well adapted for suspensions. It pumps only after reaching a high speed.
6. A diaphragm pump is similar to a piston pump except that one side of the chamber is made of a flexible fabric that creates the vacuum. This pump handles abrasives well, but the fabric does not always last long under the pressure normally required for spraying. The diaphragm, however, can be replaced easily and economically.

Tanks.—Tanks should be easy to clean and rustproof. Other desirable features are: a wide mouth with 12- to 16-mesh removable strainer; a round or trough-shaped bottom with a drain in the lowest part; a paddle-type agitator that moves slowly, sweeps the bottom, and can be disengaged; and an auxiliary 1- to 3-gallon graduated flush tank for quick flushing of the spray line and that can also be used for small quantities of spray. The tank should be calibrated in 5-gallon increments with an unpainted and unvarnished measuring stick. A shutoff valve should be placed immediately below the tank to prevent spray material from settling in the spray line, strainers, and nozzles.

Pressure regulators.—Bypass regulators are necessary for gear, nylon-roller, diaphragm, and reciprocating piston pumps; diaphragm regulators, for centrifugal or impeller pumps. The bypass regulator allows excess liquid to flow back to the tank; with proper adjustment it can maintain a constant pressure at the nozzles. Neither a spring-loaded ball-type high-pressure relief valve nor a hand-operated bypass valve functions correctly as a pressure regulator. The

regulator should be a sensitive spring-loaded type for high pressures and a disk or diaphragm type for pressures up to 175 p.s.i.

Valves, pressure gage, and strainers.—The shutoff valves should be fast, easily accessible, and of the same diameter as the main boom line. Dripping may be reduced or prevented by (1) special spring-activated valves that automatically close with reduced pressure, installed between each nozzle and the boom, or (2) venturi tubes and shutoff valves, arranged to cause a suction from the nozzles into the boom when the supply is cut off.

The pressure gage should be mounted where it is easily seen by the operator and should be large enough to be read easily.

Strainers in the boom line should be placed so as to intercept solid particles before they reach pump, pressure regulator, or nozzle. A 50- to 80-mesh screen should be installed in the suction line to the pump. A strainer of 100- to 150-mesh and about 100 square inches in area should be placed between pressure regulator and boom when emulsions or solutions are used. Nozzles require individual screens; a 50-mesh for tips of greater capacity than 0.1 gallon per minute and 100-mesh for smaller tips. Nozzle screens should have mesh openings only slightly smaller than the nozzle opening, so fine particles may pass through.

Hoses and fittings.—Hoses should be strong enough to withstand the pressure to be used and of a material not deteriorated by spray solutions and oil. Ordinary garden hose stands about 70 p.s.i. The hose on the intake side of the pump should be at least one-half inch in diameter. The discharge hose from pump to pressure regulator should be of the same size. The discharge hose from the pressure regulator to the nozzles can be smaller, but it must be large enough to feed at least twice the number of nozzles being used. Too small a hose results in reduced pressure at the distant nozzles. Pipe fittings should be resistant to corrosion. Eyelet fittings are more desirable than welded.

Booms.—Booms should be adjustable for height, and the tube that carries the spray should be noncorrosive. In booms with large diameters, the spray liquid does not flow so rapidly as in those with smaller diameter. When a suspension is used, the powder may settle in the boom if the flow is too slow. Valves at the outer ends facilitate cleaning. Dry booms are supports for a separate hose or tube that carries the spray liquid to the nozzles. Small booms can be used for hand sprayers instead of a wand. A funnel slipped over the nozzle on the end of a wand confines the spray to a small area and prevents contact with nearby plants.

Nozzles.—Nozzles are of two general types—those with removable tips and those whose tips are an integral part of the nozzle. Removable tips are convenient. Tips are designed to produce a flat, fan-shaped spray or a cone-shaped spray. The fan-shaped is the more accurate in volume delivery and produces a spray that covers more uniformly than the hollow-cone type on the average boom sprayer. The fan-type with tapered edges sprays more uniformly on a boom than the preemergence or band-spray type with squared edges. Cone-shaped nozzles do not clog so easily as flat spray types, especially when the spray is a suspension.

Broadcast nozzles spray a wide swath. They are used singly and in clusters to cover a width of 20 to 30 feet and, under some conditions, up to 60 feet. Uniform spray patterns are difficult to obtain, especially if there is a wind.

The most widely used fan-type nozzles are the flat atomizing group of which Tee-Jet is an example. They come in spray angles of 110° to 15° or even in a solid stream. Spacing on a boom is usually 20 inches. On the nozzles of some companies, the first two digits of the number on a flat-spray tip indicate the spray angle, the latter two indicate the capacity in gallons per minute at 40 p.s.i. Numbers on cone-spray tips designate the capacity only at 10-, 40-, or 60-pound pressure and depend on the tip design. The spray angle is directly associated with design and the line pressure and is stated in the manufacturer's specifications.

Flooding types of flat-fan nozzles deliver a spray whose droplets are about one-half larger in diameter than those delivered by the conventional flat-fan nozzles. The conventional flat-fan nozzles produce a spray pattern of larger droplets than those produced by the hollow-cone or full-cone types.

The smaller the opening, the finer the droplets if the nozzle design and pressure are the same. Larger openings can be used for any method of application by (1) widening the nozzle spacing on the boom, (2) increasing the spray volume per acre, (3) increasing the rate of travel, or (4) decreasing the pressure.

Use flat-spray offcenter ¾-inch tips for ditchbank weeds. Use ¼-inch offcenter tips for directed basal sprays. Use two small fan-type tips in a double swiveled nozzle for hard-to-wet foliage instead of one larger sized tip; e.g., two 8002's instead of one 8004.

Aerial Sprayers

The obvious advantages of aerial spraying are offset to some degree by the hazards to the pilot and the damage from drift. A complete discussion of aerial equipment may be found in Concentrated Spray Equipment, Mixtures and Application Methods, by Samuel F. Potts, Caldwell, N.J.,

1958. A summary of pertinent information follows.

A helicopter needs no runway and can fly better in low visibility than light fixed-wing aircraft, but it is more expensive.

Drift can be reduced by: (a) flying in calm weather, (b) using low-volatile chemicals, (c) using nozzles with large openings, (d) using water or emulsions instead of pure oils, and (e) using low pressures. A positive shutoff valve for each nozzle will avoid damage from dribble.

Tanks.—Tanks are made of stainless steel, aluminum, galvanized iron, or molded plastic. Removable tank liners of synthetic rubber or plastic shorten cleaning time and avoid contamination when different chemicals are used. Tanks should have large filler necks to eliminate need for a funnel and to facilitate cleaning. Use a removable fine-mesh screen to catch sediment.

Pumps.—Centrifugal pumps handle all kinds of spray chemicals with least wear, but they push the liquid in one direction only. They must be mounted below the tank or some priming arrangement must be provided. Turbine types develop higher pressures and move the spray in either direction, but they have to be mounted lower than the tank or be primed by hand.

Gravity feeds are satisfactory for herbicides applied as coarse sprays or atomized by devices other than standard nozzles. The pressure and rate of flow decrease as the tank is emptied.

Pump materials must be rust resistant. Operate the pump from wind-driven propellers, hydraulic motors, electric motors, or the accessory drive pad of the engine.

Pipes, fittings, and valves.—Pipes are made of aluminum, stainless steel, or plastic. Hoses must be resistant to aromatic fuels; fittings should be dural or brass-flare type. Main-line valves should be quick closing; nozzles require nondribble shutoff valves.

Dusters and Spreaders

The use of dry materials, especially granular formulations, instead of sprays is increasing. Where water is not readily available, dusts are substituted for sprays and applied with various kinds of dusters from hand-operated to power-driven machines. Dusters are simple to operate, can be filled rapidly, and travel at faster speeds than sprayers, but drift is a serious problem and application of herbicidal dusts is prohibited by law in some States.

Granular products are more practical than dusts in most situations. Application is made by hand, with broadcast seedsowers, with fertilizer spreaders both small and tractor-drawn, or with air-gun applicators. A typical hand spreader has a rotating plate powered by a handcrank for spreading the granules. It is carried by a shoulder sling strap, weighs 6 pounds, has a capacity of 25 pounds, and is adjustable for various rates. The rotary type of spreader handles heavy formulations effectively, but it is not so satisfactory for formulations based on lighter materials such as vermiculite.

Granular herbicides such as fenuron are applied to brush by hand. Typical equipment consists of a 10-quart pail and plastic spoon for each member of a crew and a 2-ton crawler tractor that pulls a "scoot" (a sled-type carrier with steel runners 6 inches wide and 24 inches clearance) equipped with a 7½- x 4-foot box in which to haul bags of chemical. The tractor and "scoot" are driven along the highway, the crew (10 men) spread out across 70 feet and, as they walk, throw a teaspoon of fenuron beside each brush cluster. Where brush is thick, the crew uses the grid system throwing a teaspoon of chemical every 3 feet.

Applicators for Soil Fumigants

Applications of soil fumigants are made with sprinkling cans, spreaders, hose proportioners, soil injectors, and inexpensive applicators that puncture the can of such fumigants as methyl bromide and gasket the openings. Saran tubing, evaporating pans, and a gasproof cover are necessary for those chemicals requiring cover. Applicators and other equipment are available from distributors and dealers.

Requirements for Different Types of Sprays

Oils

All hose connections should be made of neoprene-type rubber. The tank need not be heavy walled or equipped to operate under pressure. The pump should be milled with very close tolerances; it should not require lubrication. Pumps that depend upon packing and repacking to prevent leakage are not satisfactory for application of oil.

Emulsions

The pump described for oils is satisfactory for emulsions. Internal rotary gear pumps, diaphragm, piston, and nylon-roller types are adaptable to oil-water emulsions for spraying ditchbank weeds.

Suspensions

For small areas, use lawn sprinkling cans or knapsack sprayers. Keep spray mixture well agitated. With knapsack sprayers, use either cone-type or fan-type nozzles. Often small booms with

two to four nozzles spaced 20 inches apart are useful. Skips or unnecessary overlapping can be avoided by marking off small areas to be covered at a time.

For large areas, use power equipment. Agitate the spray mixture continuously so that the chemical does not settle out. Mechanical agitation is usually adequate, but it is ineffectual if the power unit is idled or operated at reduced speeds. Check the effectiveness of the agitation by watching for any powder left in the corners of the empty tank. Effective suspension of water-dispersible powders can be obtained with hydraulic agitation provided from bypassed spray materials if the pump has sufficient capacity.

To construct a jet agitator, install a pipe to the output side of the pump and extend it to and along the bottom of the tank to reduce foaming. One pint of kerosene per 100 gallons spray is an effective antifoaming agent. Fit the pipe with sufficient jet-agitator nozzles or drill holes in the pipe to maintain turbulence. Recirculate the solution through this pipe at about 10 percent of the tank capacity per minute. Use no finer than a 50-mesh screen or strainer when powders are used.

Gear pumps wear out quickly when used for suspensions of wettable powders. A piston pump, driven by a separate engine or a diaphragm pump, is more dependable. The most portable units use a roller pump. Where tractors or trucks with power takeoff are to be used, a good roller pump or diaphragm pump is satisfactory.

Pumps for power-takeoff mounting deliver volumes roughly in proportion to the speed of the shaft. Standard maximum power-takeoff speed is about 540 r.p.m. If the speed of the power-takeoff shaft is not maintained near maximum, pump volume drops off. Since large pump capacities are necessary if the volume for both adequate spraying and agitation is to be maintained, it is important to spray with the vehicle throttle set as near maximum as possible. If the pump does not have enough capacity to supply both the agitator and the desired number of nozzles, reduce the ground speed of the vehicle by changing to a lower gear and use smaller nozzles demanding less volume.

Maintain a pressure range of 30 to 60 pounds when a boom attachment is used. For hand-operated spray guns with larger nozzles, increase the pressure. Since some small pumps have maximum outputs of 4 to 5 gallons per minute, it is impossible for them to recirculate 10 percent of a 55-gallon tank per minute and furnish additional capacity for spraying. Use a pump with capacity sufficient to furnish 4 to 5 gallons per minute to the boom in addition to the volume needed for the agitator if hydraulic agitation is to be used.

A spray boom mounted on a tractor or some other vehicle provides one of the most accurate and rapid methods of application. A large area can be covered quickly, and the spray equipment can be calibrated accurately. In booms with large diameters, the spray liquid does not flow so rapidly as in small-diameter booms and the powder may come out of suspension and settle in the boom. For average equipment, use booms $\frac{3}{8}$ to 1 inch in diameter; the size depends on the length of the boom, the screen, and the size of the nozzles. For blanket spraying with nozzles at 20-inch spacing along the boom, the tips should be about 18 inches above the ground or tops of the weeds for 80° nozzles and 21 inches for 70° nozzles. These nozzle heights provide for a little overlap of the spray pattern between nozzles; this assures a uniform and continuous swath.

Use a 50-mesh, or coarser, filter screen for the suction strainer and the line strainer. For the individual nozzles, use screens with only slightly smaller openings than the nozzle opening. Do not use flannel or cloth filters.

Operation

To a large extent the proper adjustment and calibration of spray equipment determine the success of a spraying operation. Keep the nozzles clean, and keep the volume per acre constant. Never use a metal object to clean nozzles; an old toothbrush cleans without injuring the orifice. The volume can be varied by changing the pressure, the speed of travel, or the nozzle size.

Regulating Volume

A change in pressure results in only small changes in volume. To double volume, it is necessary to increase the pressure four times. The more convenient ways to change volume are to change the speed of travel or to change the nozzle tip. Doubling the speed reduces volume one-half. The amount of spray delivered by a nozzle is directly proportional to the square of the diameter of the opening. Thus, doubling the diameter of the opening increases the volume four times. Charts are available from spray-equipment companies showing capacities of nozzle size in gallons per minute at different pressures. Some charts give gallons per acre at designated speeds.

Even after selecting the proper nozzle, calibration is necessary. Nozzle output may vary considerably from the charted capacity. Calibration is not necessary where rates of application are given in pounds herbicide per 100 gallons spray and the amount applied depends on density of foliage or stems as in brush spraying with handguns.

Regulating Droplet Size

The smaller the droplets, the longer they remain suspended in the air and the greater the chance of drift. The lower the pressure, the larger the average size of droplet. With a typical flat-fan nozzle, a decrease in pressure from 60 to 20 pounds per square inch can double the size of the average droplet. It can also decrease by four or five times the number of fine droplets.

To reduce the drift hazard: Never use less than 10 gallons per acre. Use 20 to 30 pounds' pressure for broad-leaved weeds. Keep nozzles as close to the top of vegetation or the ground as possible while maintaining a complete coverage within the swath. The boom may be lowered by rotating its axis so that nozzles spray backward or forward at an angle onto the foliage rather than straight down. A high ground speed allows use of larger nozzles for a given volume per acre. A high ground speed plus high gallonage plus low pressure permits the use of nozzles with large openings; hence, the droplets will be coarser and there will be less drift. Use a flooding type of nozzle if susceptible plants are nearby. Never increase output of the sprayer by raising the pressure; change to a larger size nozzle. Use smoke trails to determine wind direction.

Calibration of Equipment

Both hand and power equipment require calibration for the conditions under which they are to be used. The calibration by the manufacturer is made in the laboratory or factory and may not apply to field conditions. Furthermore, the delivery of spray changes as the machine becomes older, because parts become worn and strainers and screens become partially clogged.

Hand Equipment

The volume of spray per square rod or per 1,000 square feet in which the chemical can be applied depends on the size of the nozzle and the speed at which the operator walks. To calibrate the sprayer, measure out a plot 1 square rod or 1,000 square feet in area. Spray the plot with water in the equipment to be used and at the normal walking rate of the operator. Measure the water used. Convenient volumes for calculations are 1 pint per square rod (20 gallons per acre), or 1 quart per square rod (40 gallons per acre), or 2 quarts per 1,000 square feet (22 gallons per acre). The amount of chemical recommended for treatment is then mixed or dissolved in the volume of liquid thus determined.

Power Sprayers—Boom Type

Before proceeding to calibrate a sprayer you should do the following: Run water through the sprayer to see that all nozzles are clean. Check to see if they discharge at a uniform rate by running water through them at uniform pressure and catching the discharge from each nozzle in a separate container such as a calibrated nursing or baby bottle. If the discharge varies widely, replace nozzle tips.

Determine the amount of herbicide to put in the tank by one of the following methods.

1. Determine the amount of liquid a sprayer applies per acre as follows:

   a. Start with a tank filled to the brim with clean water. Adjust the pressure as you will use it in the field.

   b. Drive exactly one-eighth mile (40 rods, or 660 ft.) in a field or along a road, ditchbank, or other area to be sprayed at the speed you will use when spraying—usually 3 to 5 miles an hour. Measure from where the spray begins, not where the tractor started. Mark the notch in which the throttle is set and keep it there when spraying.

   c. Shut off the spray, return to the original filling position on level ground, and refill the tank. Measure the amount of liquid required.

   d. Calculate the application rate as follows:

$$\frac{\text{Number of quarts used} \times 16.5}{\text{width of spray swath, in feet}} = \text{gallons per acre}$$

Example: If 6 quarts of water were used in one-eighth mile and the spray width is 20 feet, multiply 6 by 16.5 and divide by 20. The result is 4.95, or about 5 gallons per acre.

$$\frac{6 \times 16.5}{20} = \frac{99}{20} = 4.95 \text{ gal. per acre}$$

Divide the number of gallons the tank holds by the number of gallons your sprayer applies per acre. This gives you the number of acres one filling will spray. Multiply the number of acres one tankful will spray by the amount of herbicide to be used per acre. This gives the amount of herbicide to be used for each tankful.

Example: If the tank holds 55 gallons and the sprayer applies 5 gallons per acre, one tankful will spray 11 acres (55 divided by 5). If 1 pint of spray material is required per acre, 11 pints would be required for each tankful.

2. Catch the discharge from one nozzle in a pint jar as the sprayer is being operated at the speed and pressure that it will be used for spraying. Measure the distance, in feet, traveled while collecting 1 pint. Then determine the rate of application per acre from table 3.

TABLE 3.—*Calibration of sprayer by collecting the discharge from 1 nozzle*

Distance traveled to collect 1 pint	Gallons to be applied per acre when discharge equals 1 pint and nozzles are spaced at intervals of—			
	20 inches	18 inches	15 inches	12 inches
Feet	*Gallons*	*Gallons*	*Gallons*	*Gallons*
40	82	91	109	136
50	65	73	87	110
60	54	60	73	91
70	47	52	62	80
80	41	45	55	68
90	36	40	49	62
100	33	36	44	55
110	30	33	40	50
120	27	30	37	46
130	25	28	34	42
140	23	26	31	39
150	22	24	29	36
160	20	22	28	34
180	18	20	24	31
200	17	18	22	28
220	15	16	20	25
240	14	15	18	23
260	13	14	17	21
280	12	13	16	20
300	11	12	15	18
400	5	6	7	9

Example: If it takes 120 feet to collect 1 pint of spray and the nozzle spacing on the boom is 20 inches, 27 gallons per acre would be required (table 3).

3. A variation of method 2 is to measure the time required to collect nozzle discharge. Partially fill the tank with water, turn on the sprayer and set to the desired pressure.

Catch the total amount of spray discharged in a given number of minutes. Divide the number of gallons by the number of minutes. This equals the output in gallons per minute. It may be more convenient to weigh than to measure the water collected. A gallon of water weighs 8.34 pounds.

Calculate the speed of travel as follows:

$$\frac{495 \times \text{gallons per minute}}{\text{gallons per acre} \times \text{spray width, in feet}} = \text{miles per hour}$$

Example: The nozzle output is 2 gallons per minute, the volume of application desired is 50 gallons per acre, and the spray width is 3 feet.

$$\frac{495 \times 2}{50 \times 3} = 6.6 \text{ or } 7 \text{ miles per hour}$$

If the calculated speed of travel is not practical, adjust the pressure, and calculate again.

Power Sprayers—Boomless Type

Calculated application data rather than calibration are used for boomless sprayers. These data are available from the manufacturers of nozzles.

Aerial Sprayers

Determine the flow rate in gallons per minute as follows:

Put a measured amount of spray in the tank or fill the tank to a definite level. Instruct the pilot to turn on the spray for a timed interval (30 or 60 seconds) while flying level and straight at the speed to be used for spraying. When the plane lands, drain and measure the liquid remaining in the tank or, with the plane in the location where the tank was filled, measure the amount required to refill the tank to the same level. Compute the flow rate in gallons per minute. Compute the flow rate required as follows:

$$\frac{SWD}{F} = 495$$

S = speed of plane in m.p.h.

W = width of effective swath (not total swath), in feet

D = dosage to be applied in gallons per acre

F = flow rate, in gallons per minute

$$\frac{60 \times 43{,}560}{5{,}280} = 495$$

Example: $S = 80$ m.p.h.; $W = 40$ ft.; $D = 2$ gallons per acre.

$$\frac{80 \times 40 \times 2}{495} = 12.9 \text{ gal. spray required per minute.}$$

CLEANING AND PREPARATION FOR STORAGE

Cleaning After Each Use

All spraying equipment should be cleaned after use. If the chemical is soluble in water, a thorough flushing and rinsing with water is sufficient. Equipment that has been used for phenoxy herbicides such as 2,4-D, 2,4,5-T, silvex, erbon, or MCPA is very difficult to clean. Use one of the following methods for hand sprayers or field equipment.

1. Remove nozzles and scrub with kerosene.
2. Ammonia rinse.
   (a) Add a box of nonsudsing detergent to 30 to 40 gallons of water, run through pump, and bypass for 5 minutes and then out through the boom.
   (b) Partly fill tank with a solution of 1-percent to 2-percent household ammonia (1 to 2 quarts in 25 gallons water, or 2 teaspoons per quart water).

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

(d) Rinse thoroughly with clean water.

3. Charcoal rinse.

(a) Use at least one-third of a tank of water. For each 10 gallons of water add one-quarter pound of activated charcoal and one-eighth to one-quarter pound of laundry detergent. Agitate this mixture vigorously to distribute the charcoal through the water.

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

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

Preparation for Storage

Scrub the sprayer with a stiff bristle brush. Coat all iron parts exposed to the chemical with a rust inhibitor or light oil. Remove nozzles, take apart, clean, and store in light oil—before using the next year, wash in kerosene or gasoline to remove oil.

Fill pump with a rust preventive.

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

If the sprayer is powered with a gas engine, drain fuel tank and carburetor, and pour a tablespoon of engine oil through a spark plug hole. Turn motor over by hand to distribute oil on cylinder walls.

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

Thoroughly clean dusters and spreaders before storage.

APPLICATION OF HERBICIDES

In the following pages, rates of application are given in minimum and maximum amounts. This spread in amounts to apply is necessary to take care of differences in the response of species, the stage of growth when treatment is made, the period of residual toxicity desired, the amount and distribution of rainfall, soil textures and composition, and other environmental conditions. In general, the proper rate for a specific situation can be determined from table 4. Extremes are given; rates for intermediate conditions can be approximated.

Many rates are given in units of chemical per 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 at the beginning of each season for the volume of spray delivered per unit of area. If the amount of chemical per unit of volume is known, the rate per unit of area is easily determined (p. 22).

Volume of spray needed varies with density of foliage. For applications to the soil, it can be as low as the sprayer can distribute uniformly, except that it should be increased where trash or vegetation is present.

The lists of hard-to-kill weeds for each herbicide are not complete; they include only those whose response to a herbicide has been determined. Since available information varies widely among chemicals and among regions, the longer list for one chemical compared with others does not necessarily indicate that it is less generally effective. It may result from wider investigation of plant response to this chemical.

TABLE 4.—*Situations where light and heavy rates of herbicides are needed*

Light rates	Heavy 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	
Short period	Several years
Arid regions	Humid regions
SOIL TYPE	
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
FOLIAR-ABSORBED CHEMICAL	
Light growth	Heavy growth

All Vegetation

There is no one herbicide available that meets all requirements for complete control of vegetation. At practical rates of application, even the soil sterilants do not always kill all vegetation. There are two major reasons. First, there are certain weed species that are resistant to each of the soil sterilants listed in this handbook, and, second, these herbicides do not behave equally well under all environmental conditions. To be effective, a soil sterilant must be soluble enough to be carried into the root zone by soil water but also it must remain long enough for a lethal dose to be absorbed by the plant. Aside from the relative solubility of the chemical, its movement and persistence in the soil are influenced by (1) the rainfall pattern of the area, (2) the physical and chemical properties of the soil, such as texture, structure, and pH, and (3) the micro-organisms in the soil that are able to deactivate the chemical.

Failure to get expected control may result from an incomplete distribution of the herbicide in the soil or from amounts in the soil solution inadequate 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 was made at the wrong time. A soluble chemical may leach out of the soil before plant roots absorb a lethal dose. This occurs most commonly in sandy soils with excessive underdrainage and where rainfall is high, in seasons of heavy showers, and under irrigation. It may also result from improper timing of the treatment. 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.

The rates of application and the optimum time for treatment also vary with the soil, the 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. Non-grass species are usually the first vegetation to re-infest sterilized areas. Relatively inexpensive treatments with esters of 2,4-D at 1 pound per acre will maintain areas free of vegetation for several additional years. Where species difficult to control are present, spot treat such plants by hand rather than use a general spray treatment at rates high enough to kill the tolerant weeds.

On areas where the perennial weeds are susceptible to the phenoxy herbicides, it is economical to use a relatively insoluble soil sterilant such as simazine or diuron to control annual weeds and 2,4-D, MCPA, or silvex to kill the perennials. The soil sterilant is applied preemergence to moist soil at 4 pounds in 100 gallons water per acre. The phenoxy compound is applied to perennials at 1 pound per acre when they are in full leaf and growing rapidly to induce the maximum translocation to their roots. For this method to be successful, the soil sterilant must remain near the surface and there must be enough rain to activate it. Heavy rain will leach the herbicide and shorten the period of control. Incorporation of the chemical with the soil helps activate it in dry seasons, but this does not substitute for rain.

The application of herbicides useful on areas where bare ground is necessary for accessibility, visibility, and prevention of fire is discussed under two groupings: (1) relatively permanent soil sterilants and (2) foliage-applied nonselective herbicides.

Relatively Permanent Soil Sterilants

Soil sterilants, when present in the soil, prevent the growth of green plants. The soil may or may not be sterile. These chemicals are used in storage areas, lumberyards, and parking lots; on tennis courts and racetracks; under pipelines and transformer cages; under guardrails and surrounding signposts on highways and lights on runways; near fire hydrants, trestles, and bridges; on public utility rights-of-way; on gravel blanket areas; around buildings, grain elevators, utility poles, and tank farms; along fence rows; for firebreaks; and in similar areas where any plant growth is undesirable. There are two major problems in maintaining bare ground: (1) no herbicide kills all species at reasonable rates of application and (2) re-infestation results from weed seeds in the soil after the herbicide has been leached below the surface. Meet these problems by using a combination of chemicals effective against the weed species to be killed and by repeated applications of the proper herbicide to kill seedlings.

Single-Chemical Soil Sterilants

Single-chemical herbicides are satisfactory where the weed population is restricted to a few susceptible species or where hard-to-kill species can be controlled easily and economically by a second treatment. For example, dandelions or plantain that are tolerant to monuron and diuron can be killed with an application of 2,4-D.

Arsenicals

Rates of application vary widely, depending on soil texture, rainfall, and species of plant. For general application, where no adjustment for

these factors is made, use 14½ pounds As_2O_3 per 1,000 square feet, 4 pounds per square rod, or 640 pounds per acre and repeat as necessary. For light soils, apply 8 to 15 pounds per 1,000 square feet, 2¼ to 4 pounds per square rod, or 360 to 640 pounds per acre; for loam soils, 15 to 22 pounds per 1,000 square feet, 4 to 6 pounds per square rod, or 640 to 960 pounds per acre; and for clay soils, 28 to 44 pounds per 1,000 square feet, 7½ to 12 pounds per square rod, or 1,200 to 1,920 pounds per acre. Use the heavier rates on all soil types for seashore saltgrass and other grasses. The higher rates also provide longer periods of sterility in dry regions. For adobe and red soils derived from basic igneous rocks, double the rate for each soil texture.

Caution.—Inorganic arsenicals are very poisonous and caustic. Avoid contact with the skin and eyes, contamination of clothes, and inhaling spray fumes. For skin protection, use an arsenic-resistant cream such as Kerodex No. 71 (water repellent). Sodium arsenite is dangerous to livestock because they eat treated plants. Prevent access to treated vegetation until the chemical has been washed from the plants.

If the chemical is swallowed, induce vomiting. When vomit fluid is clear take raw eggs, milk, limewater, flour and water, or sweet oil to absorb the poison and soothe irritated membranes. If the chemical is spilled on the skin, wash immediately and rinse with boric acid.

Water with more than 0.05 p.p.m. (parts per million) is not safe for drinking. Wait 2 days after treating water before using it to water lawns, for bathing, to water livestock, or for other similar purposes. Keep pets away for 2 days. There are no reports of widespread damage to birds from arsenicals used as soil sterilants.

Benzoic acid compounds

Apply 20 to 30 pounds, acid equivalent, in 50 to 100 gallons water per acre for broad-leaved weeds. Use the heavier rates when weeds are in full leaf and for longer control. Wet the foliage thoroughly. For spot treatment, dissolve 2 oz., acid equivalent, per gallon water and apply 3½ gallons per 1,000 square feet, 1 gallon per square rod, or 20 pounds per acre.

Among the broad-leaved weeds camels-thorn; milkweed, climbing; povertyweed; rubberweed, Colorado; smartweed, swamp; and sweetfern are hard to kill.

Caution.—Do not use on walks, driveways, tennis courts or other areas where desirable vegetation can be affected by leaching or washing. Do not drain or flush out equipment used for applying this chemical near desirable plants or on areas where roots may have extended below the surface or where the chemical may be washed into contact with the roots. Do not apply to areas where nearby fields are to be used for susceptible crops. Clean equipment thoroughly after use. Avoid contact with skin, eyes, and clothing; it is a mild skin irritant.

Erbon

Apply 3 to 4 pounds erbon per 1,000 square feet, ¾ to 1 pound per square rod, or 120 to 160 pounds per acre. Use the higher rates in areas of high rainfall. Mix with water in proportion of 1 part of a 4-pound formulation to 6 parts water, and cover vegetation thoroughly. For bare ground use enough volume for uniform distribution. Apply in late spring or early summer in northern areas and in early to midwinter in California and other areas of medium to light rainfall. For spot treatment, mix 1 part of a 4-pound formulation with 4 parts water, and wet all vegetation and exposed bare ground. Spray an extra 5 feet beyond the weed patches.

Hard-to-kill weeds are: cattail; heliotrope, wild; horsetail, field; johnsongrass; sida, alkali; milkweed, climbing; quackgrass; saltgrass, seashore; and sedge.

Caution.—Erbon is irritating to the skin and eyes. If contact is made, wash skin thoroughly with water and soap or wash eyes with water for 15 minutes. Prevent drift to susceptible plants.

Fenac

Early preemergence treatments are more practical than postemergence since fenac is slow to act. It is readily adsorbed in heavy soils and those high in organic matter; hence, larger rates are required than for light sandy soils.

Apply 4 to 6 pounds, acid equivalent, per acre for puncturevine or Russian-thistle. In areas of more than 10 inches of rainfall, apply to puncturevine in late winter or early spring. In drier areas, apply in the fall. In areas of seasonal rainfall, apply in late fall or early winter for Russian-thistle before it germinates. In other areas apply in the spring before germination.

Apply 18 to 20 pounds per acre for field bindweed, leafy spurge, Russian knapweed, and Canada thistle. Apply any time during the growing season, preferably before the rainy season. Thoroughly wet the foliage and soil around the weeds. If topgrowth is heavy, remove before application or disk it into the soil.

Apply 15 pounds per acre for annuals and burfranseria and alkali sida (perennial broad-leaved weeds). Apply preemergence in early spring for annuals but not to frozen ground. Apply in fall or spring for perennials to permit leaching of chemical to the roots.

Caution.—Do not swallow. Wash thoroughly with soap and water if chemical is spilled on the skin.

Monuron and diuron

In areas of low rainfall, apply monuron in late fall or early spring but not to frozen ground. In areas of high rainfall, apply in late spring or early summer. Apply diuron in fall or early spring only in areas of high rainfall, especially on sandy soils or when heavy rains can be expected to follow application. Apply at or below the waterline of ditches and ponds. If a quick topkill of weeds in addition to soil sterilization is wanted, use weed oil as the carrier or an oil-water emulsion. Add 8 pounds monuron or diuron to 100 gallons aromatic weed oil and apply per acre. If an emulsion is used, add ½ pound calcium caseinate conditioner to each 100 gallons spray. Add the monuron or diuron and the conditioner to the tank when the water is just above the agitator, and add the oil before the tank is over one-third full. Good agitation is essential.

Rates vary from 20 to 80 pounds, active ingredient, per acre. Water is the carrier most frequently used. Remove topgrowth before treatment if it is heavy; translocation from leaves to roots does not occur. Use only enough water to make a uniform application. The heavier rates of chemical increase the rapidity and depth of penetration and lengthen the period of residual effects. Use them on the heavier soils, organic soils, and for the control of perennials. Increase the effectiveness of monuron alone by adding sodium chlorate—8 pounds monuron to 100 pounds chlorate; increase the effectiveness of diuron by adding 2,3,6-TBA—8 pounds 2,3,6-TBA to 25 pounds diuron. For spot treatment, use 1½ to 2 pounds per 1,000 square feet, one-half pound per square rod, or 65 to 87 pounds per acre; for small areas, use 5 cups per 1,000 square feet or 50 pounds per acre and apply in at least 2 gallons water. Stir frequently. Results may be poor on soils impregnated with wood charcoal as around lumber mills.

Hard-to-kill weeds, requiring 30 to 40 pounds per acre, are: bermudagrass; bindweed, field; dallisgrass; houndstongue; ragwort, golden; saltgrass, seashore; seamyrtle; smartweed, water; sowthistle, perennial; tansy-ragwort; thistle, Canada; and whitetop.

For the broad-leaved perennials, include 2,3,6-TBA at 20 to 30 pounds, acid equivalent, per acre.

Caution.—If spread on the surface and exposed to intense and extended sunlight, these chemicals may be decomposed before they are carried into the soil. Under such conditions work them into the surface soil.

Do not use on walks, driveways, tennis courts, and other areas where desirable vegetation can be affected by leaching or washing. Monuron and diuron do not move far laterally in the soil, but they may be washed down slopes to kill vegetation below and they leach deeply enough to reach the roots of trees, shrubs, and other deep-rooted plants growing under the treated area. Apply a light coating of road oil to hold the herbicide in place. Fill treated excavations with a layer of crushed rock to reduce erosion. Do not drain or flush out equipment used for applying these chemicals near desirable plants or on areas where roots may have extended below the surface or where the chemicals may be washed into contact with the roots. Both monuron and diuron can irritate eyes, nose, throat, and skin.

MonuronTCA

Apply dry at 150 to 200 pounds per acre of product containing 22 percent monuronTCA for most weeds; 300 pounds for hard-to-kill species.

Apply as a spray at 21 to 42 pounds monuronTCA per acre for most weeds; 42 to 66 pounds for hard-to-kill species. Dilute with enough kerosene, fuel oil, or aromatic weed oil to cover well. The amount depends on density of vegetation—75 to 150 gallons per acre. The carrier can also be water. Mix in the proportion of 1 gallon of 3-pound concentrate in 19 gallons of water. Add the liquid formulation to the water with constant agitation, and apply within a few hours after mixing.

For spot treatment, use one-quarter to one-half cup liquid in 2½ to 5 gallons oil.

Apply just before or just after growth begins in the spring. Later applications are more slowly effective. Mow tall plants before treatment. In semiarid areas, apply before rainy season ends. Both the dry and spray applications are absorbed through roots and must be carried to the root zone by rain. Apply the liquid formulation in the fall for deep-rooted perennials.

Species that require the heavier rates are: bracken; carrot, wild; cocklebur, common; dock, curly; houndstongue; johnsongrass; mugwort; quackgrass; ragwort, golden; sowthistle, perennial; spurge, leafy; thistle, Canada; vaseygrass; and whitetop.

Caution.—In areas south and east of region 1 (fig. 1, p. 42) toxicity is short unless high rates are used.

Do not drain or flush equipment near desirable plants or on areas where roots of such plants may extend. Prevent drift. Clean application equipment with water and a detergent to prevent corrosion. The herbicide is harmful if swallowed and is irritating to skin and eyes.

Simazine and atrazine

Apply as a suspension in water or dry in granules. Apply before or during emergence of weeds at 3 to 4 ounces per 1,000 square feet, 1 ounce per square rod, or 10 pounds per acre, active ingredient, for 1-year control, 15 to 25 pounds per acre

for longer residual effects. Remove vegetation before treatment. Use the higher rates for clay soils or soils high in organic matter. If spraying is delayed, mix sodium chlorate with simazine at the rate of 2½ pounds per 1,000 square feet, 10 ounces per square rod, or 100 pounds per acre.

Weeds requiring the heavier rates of simazine are: bermudagrass; bullnettle; canarygrass, Reed; euonymus; honeysuckle; horsenettle, Carolina; juniper; maple; mockorange; panicum; St.-Johns-wort, spotted; spikerush, creeping; and willow.

Those requiring heavier rates of atrazine are: horsenettle, Carolina; nutgrass, yellow; panicum; and St.-Johns-wort, spotted.

Add the chemical to the spray tank during or after filling with the required amount of water (20 to 40 gallons per acre). Provide adequate agitation to keep the chemical in suspension. Use Tee-Jet 8002, 8003, or 8004 fan-type or similar nozzles with openings of equal or larger size. Use screens no finer than 50 mesh. Set pressure at 20 to 40 pounds per square inch.

Caution.—Use the same precautions against washing and leaching as for monuron and diuron. Prevent drift of atrazine.

Sodium chlorate

In dry climates, apply in the fall so that winter rains may carry the chemical into the soil. In areas of heavy winter rains, apply dry in late winter. In humid areas, apply in the fall for perennial weed control and in the spring for annuals. Avoid applications just before a long rainy period. Rates vary widely to meet differences in soil texture and fertility, rainfall, and response of weed species. An average application is 11 pounds per 1,000 square feet, 3 pounds per square rod, or 480 pounds per acre. In semiarid regions, rates vary from 11 to 22 pounds and in humid areas or on soils high in nitrates from 22 to 44 pounds per 1,000 square feet. Use the lighter rates for susceptible species under optimum conditions and heavy applications for tolerant species and unfavorable conditions. For a quick kill of topgrowth, apply sodium chlorate in 100 to 500 gallons water per acre; otherwise, apply dry, since the fire hazard is less. If used in mixtures that reduce the fire hazard, base rates on the amount of sodium chlorate contained.

Hard-to-kill species are: blackberry; dock, curly; horsetail, field; kikuyugrass; morningglory; saltgrass, seashore; and whitetop.

Caution.—Store and handle only in metal containers. Store away from wooden buildings and out of reach of children and livestock. Clothing or other organic material on which sodium chlorate has dried is extremely flammable. Do not smoke when handling or spraying. Do not spray around wooden buildings or on other flammable organic matter near buildings. Do not drive or walk through treated areas, and keep livestock away until a rain has washed off the chlorate. Wear rubber boots when spraying. Remove clothing wet with spray and wash before using again. Thoroughly drain and flush equipment with water. The toxicity is quite low in usual concentrations, but it is hazardous to stock in large doses. It is toxic to fish.

Trichloroacetic acid (WSA designation, TCA)

Apply to soil when rain can be expected to carry it to plant roots. If there is considerable vegetation or trash on the area, remove it or disk it in before treatment. Rate of application depends on whether or not tillage can be combined with treatment. Where tillage is impossible, use 1.8 to 2.75 pounds per 1,000 square feet, one-half to three-quarter pound per square rod, or 80 to 100 pounds per acre, acid equivalent. If bermudagrass, cutgrass, tall larkspur, panicum, or paragrass are present, remove topgrowth, increase the rate to 125 to 150 pounds per acre, and apply preemergence. Where tillage is possible, 30 to 40 pounds are adequate. For spot treatment, dissolve 1 pound in 1 gallon water; wet all foliage and exposed roots thoroughly. Uniform distribution of TCA spray is important. Use enough water for uniform distribution on bare ground and up to 300 gallons per acre where trash or vegetation is heavy.

Caution.—The solid formulations or strong aqueous solutions of sodium TCA (50 percent or more) may cause burns if skin is exposed to them for an hour or more and they may be painful to the eyes. Wash affected parts with water if contact is made. Flush equipment with water immediately after use.

Soil Sterilant Mixtures

For some situations, mixtures of two or more chemicals are more effective than single-chemical herbicides. Proprietary mixtures are combinations of chemicals that (1) provide a quick knockdown of vegetation plus a residual toxicity in the soil, (2) consist of one best adapted to kill broadleaved weeds plus one best adapted for grassy weeds, or (3) consist of a dangerous fire hazard plus a fire deterrent.

Caution.—Observe the precautions as given for each chemical in the mixture.

Borate-monuron (WSA designation, BMM)

Apply dry in fall, winter, or early spring. Make summer applications only in areas where there is sufficient rain to carry the herbicide to

the plant roots. Apply 5 to 10 pounds product per 1,000 square feet, 1½ to 3 pounds per square rod, or 220 to 440 pounds per acre to annuals and up to 900 pounds per acre to perennials. In the Eastern States, use up to 1,700 pounds per acre.

Weeds requiring the heavier rates are: bermudagrass; bracken; dandelion; golden-aster, false; horsetail, field; horseweed, marestail; knapweed, Russian; nutgrass, purple; panicum; sedge; spurge, upright; thistle, Canada; and vaseygrass.

Borate-2,4-D (WSA designation, BDM)

Apply dry to control broad-leaved plants only. Apply 10 pounds product per 1,000 square feet, 2.75 pounds per square rod, or 440 pounds per acre to annuals in the spring when they are emerging. Apply up to 30 pounds per 1,000 square feet to perennials in the fall when nearing maturity. Do not use in late spring and summer unless there is sufficient rain to carry the chemical to the root zone.

Bracken and Russian knapweed are hard to kill.

Chlorate-borate (WSA designation, CBM)

Apply as a spray for quick topkill. For annuals, use 10 pounds product in 5 gallons water per 1,000 square feet, 2.75 pounds per square rod, or 440 pounds per acre; thoroughly wet the foliage. For deep-rooted perennials, use 20 to 40 pounds dry product per 1,000 square feet, 5½ to 11 pounds per square rod, or 870 to 1,740 pounds per acre or dissolve 2 pounds product per gallon water and use 10 to 20 gallons of the solution per 1,000 square feet. In California and similar areas, use 1,600 to 2,000 pounds dry product per acre. For hard-to-kill weeds, apply the heavier of the rates given.

Bermudagrass; bindweed, field; quackgrass; and whitetop are hard to kill.

Caution.—Do not apply to tall vegetation or in hot dry weather, because of the fire hazard. Do not use on slopes where the chemical can wash onto desirable plants. Wash clothing and equipment after application. The fire hazard from sodium chlorate is greatly reduced in this mixture, but precautions are advisable.

Chlorate-borate-monuron (WSA designation, CBMM)

Apply dry or as a spray at following rates of product: annuals and shallow-rooted plants, 10 pounds per 1,000 square feet, 2.75 pounds per square rod, or 436 pounds per acre; perennials and deep-rooted plants, 15 pounds per 1,000 square feet; 20 pounds for hard-to-kill grasses.

Apply to annuals in the spring when they are small and to perennials in areas of over 20 inches rainfall. In semiarid areas, apply to perennials in fall or early winter.

Bermudagrass; bindweed, field; dandelion; johnsongrass; knapweed, Russian; licorice, wild; quackgrass; seamyrtle; spurge, upright; and vaseygrass are hard to kill.

Caution.—Observe the same precautions as for chlorate-borate.

Foliage-Applied Nonselective Herbicides

The foliage-applied nonselectives are used primarily to kill weeds on land later to be cropped; but they also are useful on land where long residuals are not required, where quick kills are needed, and where weeds have survived or escaped treatment with a long-lasting soil sterilant. Some of the selectives, like the phenoxy compounds, remove broad-leaved weeds from grass sods, while others, like dalapon, control grasses without severe injury to most broad-leaved plants. These herbicides are used where the killing of vegetation for long periods is undesirable because erosion is a problem or for esthetic reasons.

Single-Chemical Herbicides

Amitrole and amitrole-T

For annual broad-leaved weeds and annual grasses, use a solution of 2 pounds, active ingredient, in 100 gallons water. Wet thoroughly. For perennial broad-leaved weeds, use a solution of 4 pounds, active ingredient, in 100 gallons water; apply in bud to bloom stage. Wet thoroughly. When using a spray boom, apply at the rate of 4 pounds, active ingredient, in 40 to 50 gallons water per acre. The perennial grasses are more difficult to kill. For these use amitrole-T at double the rates for perennial broad-leaved weeds or use a mixture of amitrole with monuron, with simazine, with TCA, or with dalapon.

Dalapon

For temporary control of mixed broad-leaved and grassy annuals, apply 10 pounds dalapon, acid equivalent, plus 1 to 2 pounds low-volatile ester of 2,4-D, acid equivalent, per acre. Increase rates for longer control. For hard-to-kill grasses, such as kikuyugrass, panicum, quackgrass, and redtop, apply 30 to 50 pounds dalapon in 100 gallons water per acre with a boom sprayer or, if using a handgun, dissolve 10 to 20 pounds dalapon in 100 gallons water and apply 200 to 400 gallons per acre and wet the foliage thoroughly. For spot treatment, dissolve 1 pound dalapon in 5 to 20 gallons water; add one-quarter to one-half pound detergent, such as Tide or Dreft, if the foliage is hard to wet. Several applications of any of these sprays are usually necessary to maintain weed control. Apply when grasses are

leafy and growing vigorously. Do not apply during droughts.

Most broad-leaved weeds are hard-to-kill or resistant.

Caution.—Do not allow spray solutions to stand more than 2 days after they are mixed. In combination sprays with 2,4-D, do not use a solution more concentrated than 6 pounds dalapon, acid equivalent, to 10 gallons water. Fill spray tank at least half full of water before adding the chemical and stir until completely dissolved. Prevent drift. Avoid contact of undiluted dalapon or dust with eyes, skin, or clothing. Wash affected parts with water if contact is made. Flush equipment with water immediately after use.

Herbicide Mixtures

A mixture of amitrole with dalapon, amitrole with other chemicals, or of dalapon and silvex is often more effective for the complete control of vegetation than amitrole or dalapon alone. This is true where the plant population includes annuals and perennials, grasses and nongrasses, herbaceous and woody plants, or species tolerant to one of the constituents but susceptible to another. Some combinations are available as proprietary mixtures, others have been tried as homemade mixtures.

Amitrole-dalapon; amitrole-monuron; amitrole-simazine; amitrole-TCA

For annual grasses and perennial broad-leaved weeds: use 4 pounds amitrole and 10 pounds dalapon, acid equivalent, per acre (5 oz. of the mixture per 1,000 sq. ft. or 1½ oz. per sq. rd.); 4 pounds amitrole and 20 pounds monuron per acre (8.8 oz. of the mixture per 1,000 sq. ft. or 2.4 oz. per sq. rd.); or 4 pounds amitrole and 10 pounds simazine per acre (5 oz. of the mixture per 1,000 sq. ft. or 1½ oz. per sq. rd.). For annual weeds: apply 2 pounds amitrole and 10 pounds monuron per acre (4½ oz. of the mixture per 1,000 sq. ft. or 1⅕ oz. per sq. rd.) or 2 pounds amitrole and 5 pounds simazine per acre (2½ oz. of the mixture per 1,000 sq. ft. or 0.7 oz. per sq. rd.). Rates for amitrole, monuron, and simazine are in active ingredients.

If amitrole and TCA is used, apply 5 pounds amitrole, active ingredient, and 50 pounds TCA, acid equivalent, per acre (1¼ lb. of the mixture per 1,000 sq. ft. or 5½ oz. per sq. rd.) for most weeds. For johnson and bermuda grasses and for heavy stands of other grasses, double the rate of TCA.

Time and methods of application are the same as for the single ingredients of the mixtures.

Caution.—Refer to precautions for handling as follows: dalapon, p. 37; monuron, p. 35; simazine, p. 36; and TCA, p. 36.

Dalapon-silvex

For areas of mixed grasses and nongrasses, use a liquid formulation containing 4 pounds dalapon, acid equivalent, and one-half pound silvex, acid equivalent, per gallon at the rate of 3 gallons in 97 gallons water. Apply in large enough volume to wet the foliage thoroughly (200 to 300 gallons per acre). Apply at least 6 gallons of the herbicide per acre. For spot treatment, use 1 pint of the herbicide in 3 gallons water per 1,000 square feet. Apply when plants are young and growing vigorously. Re-treat or spot treat for seasonal control.

Quackgrass and spurge are hard to kill.

Caution.—Prevent drift. Avoid contact with eyes, skin, and clothing.

Contact Herbicides

Contact herbicides are often more practical than soil sterilants in areas where leaching is rapid and where mowing or cultivation of unwanted vegetation is difficult. They are also well adapted for spot treatment of shallow-rooted perennials and weeds that come up through cracks in pavement, ditch lining, or gravel drives. Contact herbicides kill only the topgrowth of herbaceous vegetation wet by the spray, so that complete coverage is essential. They usually kill annual broad-leaved weeds, but they may not kill the roots and underground storage organs of perennials and they may not always kill annual grasses. To kill grasses, the spray must creep down the stems to the crowns. Oil sprays are most effective for this use. Contact sprays do not prevent reinfestation by seedlings nor do they always prevent recovery of perennial plants from crown or root buds. For these reasons, repeated applications are usually required to keep an area free from vegetation. Although some contact herbicides kill quickly, the heavy fuel oils and aromatic oils act slowly.

Herbicidal oils

Use sufficient volume to wet plants thoroughly and cover to as near the ground line as possible. For grasses, wet the plant until excess spray creeps down the stems. Use 80 to 160 gallons oil per acre. Maintain 60 p.s.i. at the nozzles. On boom sprayers, space the nozzles so that the spray fans meet just above the tops of the vegetation and adjust height of boom to 18 inches or less above the plants. For dense growth, provide double coverage from different angles. When spot spraying, travel slowly and wet thoroughly. Repeat treatments where seasons are long and rainfall is high.

For oil-tolerant species, use 2,4-D on broad-leaved plants or TCA or dalapon on grasses before spraying with oil.

Caution.—Highly volatile oils with low flash points ignite easily and may be explosive. All of the oils are flammable. All hose connections should be of neoprene-type rubber.

Dinitros

Apply sufficient volume to wet the vegetation thoroughly, since these compounds are not translocated. The parent compounds are more effective than their salts. Add a wetting agent if grasses are present. Apply in warm weather; these herbicides are most toxic at temperatures above 80° F. and at a high humidity; below 60° F., they are not very effective.

For general weed control, use 2 to 3 pints DNBP or DNAP in 5 to 30 gallons oil in enough water to make 100 gallons spray. Use the lower amounts of chemical and oil for young, succulent growth; larger amounts for older, coarser, and hard-to-kill species. Unless an activator has been added, add 6 to 9 pints DNC to the same amount of oil and water. Since these compounds kill vegetation quickly, spray a trial strip to determine proper amounts of chemical and oil for best results.

Caution.—Keep the dinitros from contact with eyes, skin, and clothing. Avoid breathing spray drift; do not swallow any; wear synthetic rubber gloves, a respirator, and goggles; and wash clothing before using again. Keep the oil solutions away from heat and open flame. Dinitros are yellow dyes that will stain sidewalks, driveways, skin, and clothing. They are toxic to game and fish.

If any chemical is swallowed, send for a physician, induce vomiting, and when vomit fluid is clear, take 2 tablespoons of baking soda in a glass of water.

Pentachlorophenol (WSA designation, PCP)

Apply sufficient volume to wet the vegetation thoroughly, since PCP is not translocated. The parent compound is more effective than its salts. Add a wetting agent if grasses are present. Apply in warm weather; PCP is most toxic at temperatures above 80° F. and at a high humidity; below 60° F., it is not very effective.

Caution.—Avoid breathing PCP dust, and avoid contact with skin and clothing. Do not swallow any. PCP is considered moderately toxic, but experience in the tropics indicates it is more dangerous than thought. Skin absorption is the primary danger.

If the chemical is swallowed, send for a physician, induce vomiting, and when vomit fluid is clear, take 2 tablespoons of baking soda in a glass of water.

Emulsions

The following formulas are satisfactory for broad-leaved weeds and grasses growing in sheltered locations.

1. Pentachlorophenol, 4 pounds, or DNBP, 1⅓ pounds
   Aromatic oil, 8 gallons
   Oil-soluble wetting agent, 4 pounds
   Water, 92 gallons

Add the pentachlorophenol to the oil and agitate until it is all dissolved, then add the oil-soluble wetting agent and agitate until a uniform solution is obtained. This makes a stable concentate that may be stored. To prepare the spray solution, mix equal volumes of concentrate and water, agitate vigorously until a stable emulsion is formed, then add the remaining water with agitation.

2. Dinitro concentrate, 1 quart
   Diesel oil, 15 gallons
   Water, 85 gallons

For old, tough weeds use:

3. Dinitro concentrate, 1 quart
   Diesel oil, 40 gallons
   Water, 60 gallons

For more vigorous grasses, increase the percentage of oil or decrease the volume of water. If more oil is required, mix it with the fortified oil in No. 3 and emulsify the entire mixture. For the supplementary oil, use any kind with a viscosity (p. 13) not over 50 seconds. Use up to 50 percent oil if necessary. Maintain at least 100 p.s.i. at the nozzles and keep the emulsion agitated.

Weeds in Specific Areas

For precautions in handling the chemicals recommended in this section, refer to:

Amitrole-dalapon mixture, p. 38
Amitrole-TCA mixture, p. 38
Chlorate-borate mixture, p. 37
Dalapon, p. 37
Dalapon-silvex mixture, p. 38
Dinitros and PCP, p. 39
Diuron, p. 35
Erbon, p. 34
Monuron, p. 35
Monuron TCA, p. 35
TCA, p. 36

Paved Highways

Vegetation that encroaches from the edges of asphalt pavement or grows up through cracks and holes causes premature breakdown of the pavement. Control with presurface and postsur-

face applications of herbicides. Shoulders immediately adjacent to the trafficway, medians separating divided highways, and islands at highway intersections are often surfaced with asphalt. On such areas, apply the herbicide to the gravel base just before it is "shot" with asphalt. A standard highway watering truck can be adapted for this use by equipping it with a loading pump to circulate the spray material and standard asphalt nozzles that deliver a fan spray.

Several herbicides prevent the emergence of plants through the pavement, but they vary in cost and in injury to vegetation adjacent to the paving. The plant growth on the unpaved area, particularly on fill slopes, may be desirable to prevent erosion. The following products control vegetation at the accompanying rates per foot-mile. (Rates per foot-mile×8.25=rate per acre.)

Chlorate-borate, 200 pounds
(25 percent sodium chlorate)
Dalapon, 10 pounds
Dalapon-silvex, 2.5 gallons
(4 lb. dalapon + ½ lb. silvex per gallon)
Diuron, 5 pounds
Erbon, 5 gallons
(4 lb. per gal.)
Monuron, 5 pounds
MonuronTCA, 0.9 gallon
(3 lb. per gal.)
TCA, 25 pounds

Postpaving treatments will be necessary later to prevent encroachment from unpaved areas and to control vegetation growing up through cracks in old pavements. Use repeated spray treatments with dalapon-silvex mixture or use dalapon on grasses and 2,4-D or amitrole on broad-leaved weeds.

Caution.—Erbon, monuron, and chlorate-borate mixture may injure vegetation some distance from the edge of the pavements, and monuron, diuron, and monuronTCA may injure trees adjacent to the treated area.

Railroads

There are three rather distinct areas on railways on which weed control is necessary: the ballast, the roadbed, and the right-of-way. The ballast is a strip 12 to 16 feet wide, made up of coarse material, such as cinders or gravel, that should be kept free from weeds. Because it is so porous, it does not retain chemicals well. Insoluble herbicides, those absorbed through leaves, and contact herbicides are most suitable. The roadbed (berm) beyond the ballast requires weed control, but elimination of vegetation increases erosion. The rest of the area to the right-of-way fence is similar to roadsides. If control is effected during the first 2 years by heavy rates of application, it can be maintained with reduced rates thereafter. The effectiveness of some soil sterilants like diuron and simazine may not show up until the second or third year of use, especially in dry areas or with deep-rooted weeds.

Apply 5 to 8 gallons dalapon-silvex mixture, in 150 to 300 gallons water per acre-mile on ballast and berm areas or 5 to 6 quarts DNAP and 300 gallons diesel oil per mile on roadbed. For heavy growth, add 300 gallons water.

Specific treatments adapted to different regions of the United States (fig. 1) follow. Rates are in pounds per acre in terms of acid equivalent for dalapon, silvex, 2,4-D, and TCA. All others are pounds per acre of active ingredients except oil-PCP, which is in gallons per acre of product.

Region 1.—Dalapon, 40 pounds, plus silvex, 4 pounds; or oil-PCP, 20 gal., plus 2,4-D, 4 pounds, plus monuron, 8 pounds.

Region 2.—Dalapon, 16 pounds, plus erbon, 20 pounds, plus 2,4-D amine, 4 pounds; or dalapon, 20 pounds, plus simazine, 4 pounds, plus 2,4-D, 4 pounds; or dalapon, 20 pounds, plus monuron, 8 pounds, plus 2,4-D, 4 pounds.

Region 3.—Dalapon, 10 pounds, plus 2,4-D, 2 pounds; or dalapon, 10 pounds, plus amitrole, 5 pounds; or oil-PCP, 48 gal., plus monuron-TCA, 21 pounds. Apply twice a season. Add 10 pounds diuron or simazine to these sprays to increase amount and length of control. One application of amitrole, 5 pounds, plus TCA, 20 pounds, plus diuron, 20 pounds, often provides control for an entire season.

Region 4.—Dalapon, 20 pounds, plus 2,4-D, 4 pounds, applied three times; or oil-PCP, 100 gallons, applied twice.

Region 5.—Dalapon, 40 pounds, plus 2,4-D, 6 pounds.

Region 7.—Oil-PCP, 20 gal., plus 2,4-D, 4 pounds, plus monuron, 15 pounds.

Reinfested Areas

To kill annual weeds and seedlings of biennials and perennials that reinfest an area, use 2 pounds 2,4-D and 20 to 30 pounds dalapon and 1 cup wetting agent in 50 gallons water per acre. For species resistant to 2,4-D, use amitrole at 4 pounds, active ingredient, in 100 gallons water per acre. Repeat applications as necessary.

For use of soil sterilants to prevent reinfestation refer to page 33.

Woody Plants

Both selective and nonselective kills of woody plants can be accomplished with chemicals. Where a selective kill of certain species is desired, 2,4-D, 2,4,5-T, silvex, and amitrole are most com-

monly used. Ammonium sulfamate, monuron, diuron, and fenuron kill nonselectively. There are several methods of treating woody plants: foliage applications, basal-bark applications, stump applications, cut-surface applications, tree injections, and soil applications.

Foliage Applications

Make foliage applications in the active growing season after the leaves are full size. Soil moisture adequate for good growth and complete coverage are essential for satisfactory kills. Use a boom sprayer for large areas; spray individual plants or small groups with a hand boom from a power sprayer or a truck. Airplanes and helicopters are also used for control. Repeated annual treatments are required if eradication is wanted. Reduce the drift hazard in aerial spraying by using a 1:4 oil-water emulsion instead of oil alone. Foliage applications are the cheapest method, but often they are objectionable because of drift hazards and the unsightliness of defoliated or dead trees. They are most practical for controlling plants that can be covered thoroughly from the ground. A variation of this treatment is the stem-foliage application, in which both stems and leaves are wet to the point of runoff. It is sometimes more effective than basal sprays on root-suckering species. The important consideration is to wet all the leaves thoroughly. Wetting of the stems is incidental. The spray volume depends on the height and density of the brush and varies from 100 to 400 gallons per acre.

2,4-D and 2,4,5-T

Species tolerant to 2,4-D and requiring heavy rates or repeated annual treatments are: birch; buckbrush, snowberry; buckeye, California; ceanothus, varnishleaf; chamise; chaparrel; chinquapin; creosotebush; dogwood; elderberry; gorse; greasewood; hawthorn, fleshy; honeysuckle; ivy, English; locust, black; madrone; manzanita; oak, Oregon, post, shinnery, Turkey, and white; poison-ivy; poison-oak; rabbitbrush, grey and yellow; redwood; rose, Cherokee, Macartney, and prairie; sagebrush, fringed and silver; snowbrush; sumac, Chinese; tamarack; thimbleberry; tree-of-heaven; trumpetcreeper; Virginia-creeper; and whitethorn.

Species tolerant to 2,4,5-T and requiring heavy rates or repeated annual treatments are: basswood; bearberry; buckbrush; coralberry; cactus, pricklypear; catclaw, mimosa; chamise; chapparel; cherry; chestnut; chinquapin; coffeetree; cottonwood; coyotebrush; creosotebush; dogwood; elm; gallberry; gorse; groundcherry, clammy; gum, black; hawthorn, fleshy; hazel; hickory; honeylocust; honeysuckle; hophornbeam; larch; madrone; manzanita; maple; mesquite, honey and velvet; oak, black, blackjack, bluejack, gambel, live, Oregon, red, scrub, and Turkey; palmetto, saw; persimmon, common; pine, lodgepole; plum, chickasaw; prickly-ash; rose, California, Cherokee, Macartney, multiflora, and Woods; saltcedar; skunkbrush; tamarack; tarbush; toyon; trumpetcreeper; and whitethorn, mountain.

Spray with 2,4-D if the species are susceptible to this herbicide, since it is cheaper than 2,4,5-T. Most hardwood species, however, are more susceptible to 2,4,5-T. For mixed species, use a mixture of 2,4-D and 2,4,5-T (brush killer). Spray when plants are in full leaf and growing. If the browning of trees and brush is not objectionable and if drift damage is unimportant, spray in early summer. If these objections are important, spray in late summer and add oil, especially if oaks are present. Dead brush can be knocked down by equipment.

In general, esters are the most effective formulations for brush control. The diamine salt formulation, however, appears to be equally effective. Apply 3 to 4 pounds 2,4-D, 2,4,5-T, or 2,4-D and 2,4,5-T mixture per 100 gallons water for susceptible species and brush. (See Weed Species and Herbicides for Control, p. 58.) Repeated annual treatments are necessary for hard-to-kill species. Aerial sprays of 2 to 3 pounds per acre 2,4,5-T in a total volume of 5 gallons per acre are satisfactory if drift hazard to crops can be avoided.

All rates of 2,4-D and 2,4,5-T are in terms of acid equivalent.

Specific recommendations for the seven regions of the United States follow. (See fig. 1, p. 42.)

Regions 1 and 2.—For most brush, use 2,4,5-T; but, for buckbrush and hazel, use 2,4-D in mid-June. Hazel starts regrowth the year after treatment, but there is a release period of 5 to 8 years. For hard-to-kill species, use a stem-foliage spray—3 to 6 pounds 2,4-D and 2,4,5-T mixture in 10 to 25 gallons oil and enough water to make 100 gallons of spray. Wet leaves and stems thoroughly. For elderberry, elm, eastern redcedar, sassafras, sumac, sweetgum, sycamore, walnut, wild plum, and a topkill of honeysuckle, use up to 8 pounds per acre.

Region 3.—For late summer spray, use 3 to 4 pounds 2,4,5-T in 25 gallons oil plus 75 gallons water for the carrier. 2,4,5-T is more effective than 2,4-D on blackberries and other brambles, common persimmon, and prairie rose. 2,4-D is more effective on buckbrush and skunkbrush. Aerial sprays are satisfactory, but cotton is especially susceptible to drift damage so that extreme precautions must be used.

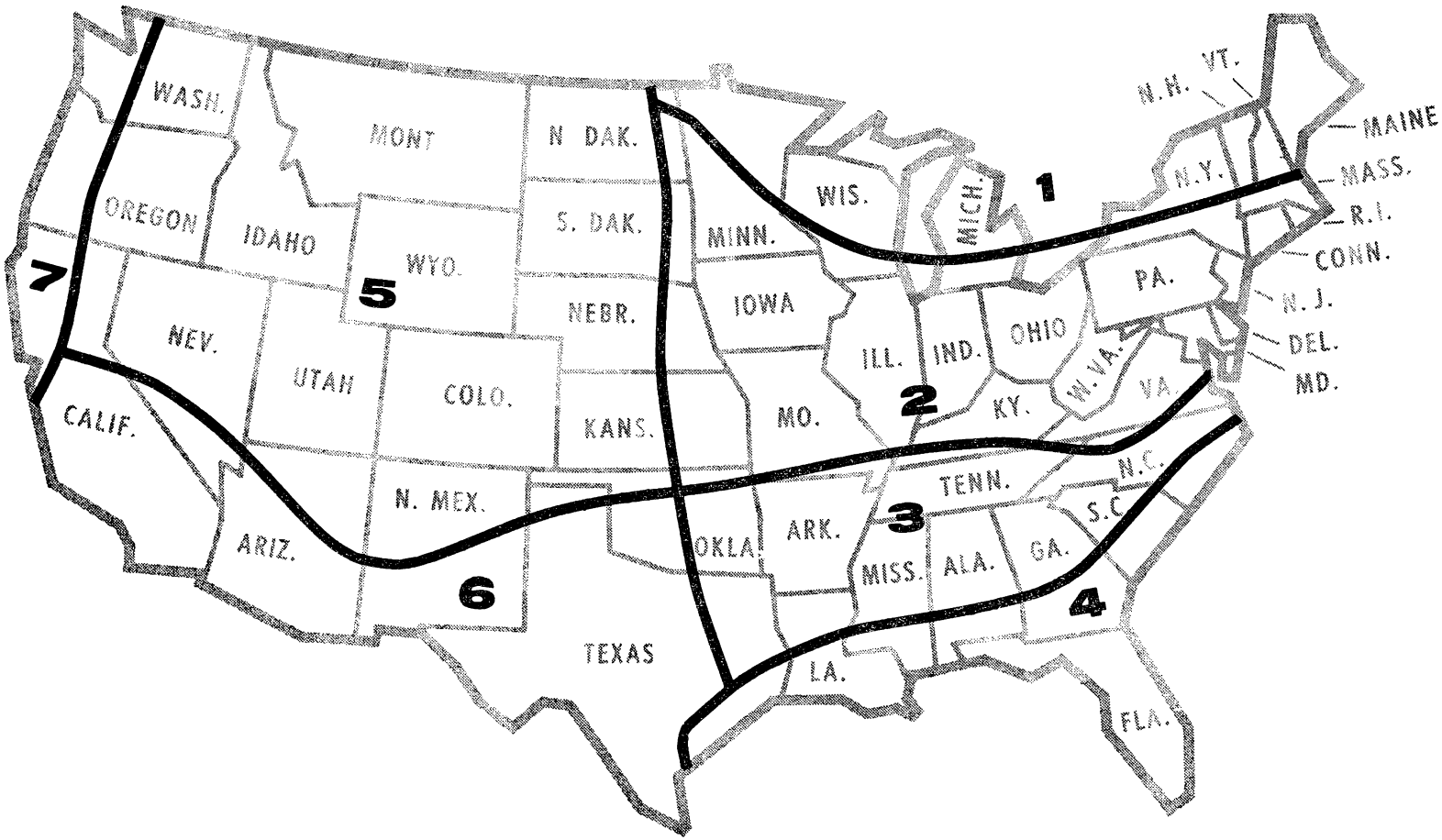

Figure 1.—Regions of somewhat similar soil types, climate, vegetation, and growing season.

Region 4.—Use 2,4,5-T at 2 pounds per 100 gallons water for alder; bluejack, post, and Turkey oak; and persimmon. Apply on Turkey oak in May or June and on persimmon and post oak in July or August. Use 1½ to 2 pounds 2,4,5-T in 5 to 6 gallons of oil-water emulsion per acre for most deciduous upland hardwoods but not pines. For resistant species, use 8 to 10 gallons per acre.

Region 5.—Apply 2,4-D and 2,4,5-T mixture at 3 to 4 pounds per 100 gallons water to brush for control of willows and cottonwood; apply 2,4,5-T at the same rate for chokecherries and wild rose. Use 2,4-D at 2 pounds per acre to control sagebrush.

Region 6.—Apply one-third pound 2,4,5-T per acre in oil-water emulsion to original growth of mesquite; use one-half pound per acre on regrowth. These treatments completely defoliate the plant and kill up to 35 percent of the roots. For dense stands, use three-quarter pound 2,4,5-T in 2 gallons diesel oil plus 8 gallons water per acre. Use one-half pound 2,4,5-T in oil-water emulsion for shinnery oak, and apply annually for 3 years. Use 2,4,5-T in oil-water emulsion on post oak, and apply 2 successive years. Use 1 pound 2,4-D for sand sagebrush.

Region 7.—For general spraying, apply 2 pounds 2,4,5-T and 2,4-D mixture in 1 gallon diesel oil plus enough water to make 40 gallons per acre. For coyotebrush, 10 gallons spray per acre is enough. For willow, use 100 gallons. For aerial spraying in California, use 10 gallons spray per acre. Dissolve 2 to 4 pounds 2,4,5-T and 2,4-D mixture in 1 gallon diesel fuel oil and mix with enough water to make 10 gallons spray. For individual plants use 4 pounds 2,4,5-T and 2,4-D mixture in 1 gallon diesel oil plus 98 gallons water. For dormant spray, use 8 pounds 2,4-D and 2,4,5-T mixture in 98 gallons diesel oil for deciduous trees and 4 pounds per gallon diesel oil in 90 gallons water for evergreens. Cover well.

Amitrole

In general, spray the foliage of susceptible species with 3 to 6 pounds, active ingredient, per acre in water. The volume required varies from 100 gallons (average) to 500 gallons (for solid stands) per acre.

Hard-to-kill species are: aspen, blackberry, hickory, common persimmon, and sumac.

Caution.—Although the danger from drift is less with amitrole than with 2,4-D and 2,4,5-T, follow directions for reducing drift (pp. 30 and 46).

Ammonium sulfamate (WSA designation, AMS)

Apply 60 to 80 pounds 95-percent product per 100 gallons water for foliage spray when brush or trees are in full leaf. Add 4 ounces spreader-sticker per 100 gallons to increase wetting and retention of spray. Wet leaves and stems thoroughly. In dense brush, 400 to 450 gallons spray per acre may be needed. In South Carolina, Missouri, and Mississippi, use 1 pound per gallon. For re-treatments of surviving growth and seedlings, use only one-fourth to one-third the original amounts. Ammonium sulfamate can be applied successfully with a mist blower; use 360 pounds ammonium sulfamate plus 1 quart spreader-sticker plus 5 gallons No. 2 fuel oil plus 1 pint emulsifying agent plus enough water to make 100 gallons. Typical species controlled are: cherry; hickory; maple, bush; oak, red and white; poison-ivy; sassafras; and willow.

Hard-to-kill species are: ash; basswood; buckeye; caragana; euonymus; fir, balsam; hawthorn; honeylocust; juniper; locust, black; sumac, Chinese; and tree-of-heaven.

Caution.—Avoid long contact with strong solutions. Do not use near metal pipes and tanks. Coat exposed metal parts of spray equipment with acid-resistant paint or rubberized undercoating used on automobiles. Wash truck and spray rig with spray gun when refilling the tank and at end of day. Cover metal surfaces with light oil on weekends. At end of season, wash inside and out and cover metal surfaces with light coating of oil. Whenever possible, use copper, stainless steel, bronze, or aluminum, but not brass, for sprayer parts.

Ammonium sulfamate is not hazardous to wild life. Drift from mist blowers is very dangerous.

Silvex

Use at about the same rates, acid equivalent, as 2,4-D and 2,4,5-T. In Florida, use 3 pounds per acre, and apply annually, for bluejack and Turkey oak and persimmon. In Oklahoma, use the low-volatile ester for chittam, elm, oaks, and redbud.

Hard-to-kill species are: blackberry; cactus, pricklypear; cherry; creosotebush; dogwood; groundcherry, clammy and purple-flower; gum, black; hickory; manzanita; mesquite, honey and velvet; mulberry; oak, blackjack, bluejack, scrub, and white; Osage-orange; persimmon; rose, Macartney and multiflora; sagebrush, big; sweetgum; tarbush; toyon; whitethorn (*Acacia constricta*); yerba-santa; and yucca, soapweed.

Caution.—Avoid drift (pp. 30 and 46).

Dalapon and trichloroacetic acid (TCA)

Use either dalapon or TCA for control of conifers. Jack pine, white pine, and white-cedar are

most susceptible. Spruce is harder to kill. Species tolerant to both chemicals are: goldenchaintree, Norway maple, pagodatree, and virginal mockorange. Euonymus is tolerant to TCA.

Use 15 to 25 pounds, acid equivalent, per 100 gallons water. Applications are effective only during the growing season. For information on handling, see pages 36 and 37.

Trichloroacetic acid (TCA) and 2,4-D or 2,4,5-T

Combine 2,4-D or 2,4,5-T with TCA to kill tag alder, quaking aspen, and willow. Applications are effective only during the growing season. For information on handling, see pages 23 and 36.

Basal-Bark Applications

Basal-bark applications are made to the base of tree trunks and brush stems 6 inches or less in diameter. They are effective on either dormant or growing plants. Treatments are most successful if applied in warm weather. Basal treatments are well suited for uncut brush and regrowth from cut brush or trees and particularly for selective control. The method is slightly more expensive than foliage applications and in dense stands is more difficult. It is more effective on hard-to-kill species than foliage applications, but it may be less effective on root-suckering species like willows, sumac, and sassafras.

In general, 2,4,5-T is better than 2,4-D or a mixture of 2,4,5-T and 2,4-D for control of most hardwood species, but there are some exceptions. The esters of 2,4-D are satisfactory for cottonwood and willow. For most situations, apply 2,4,5-T at 12 to 16 pounds in 96 gallons diesel fuel oil or kerosene. Cover all exposed bark just above the ground line, and apply enough volume to permit the spray to run down the bark to the bud zone. Old or rough bark requires a larger volume than young or smooth bark.

Specific recommendations for regions 2, 3, 4, and 7 follow.

Region 2.—In the northeast, make basal-bark applications with a solution of 16 pounds of 2,4,5-T in 100 gallons diesel fuel oil at any time of the year for practically all trees except those that produce root suckers. These are most easily eliminated by late-summer applications.

Regions 3 and 4.—Use basal sprays of 16 pounds 2,4,5-T in 100 gallons diesel fuel oil for oaks, gums, elms, and other hardwood brush species. In Oklahoma use frill applications for elm. Apply to trees less than 6 inches in diameter.

Region 7.—In California, use the cut-surface method for trees over 2 inches in diameter. For small trees, use 16 pounds 2,4,5-T in 100 gallons diesel fuel oil and apply 2 to 3 fluid ounces per inch of stem diameter.

Stump Applications

Stump applications are made to freshly cut stumps. The top and all sides of the stump to the ground line and any exposed roots must be wet thoroughly. In general, use the same spray solution of 2,4,5-T or 2,4-D for stump applications as for basal-bark treatment. Use 1 pint spray per 6 inches of stem diameter. Treatments are most successful if applied in warm weather.

For stump treatment of ash, boxelder, cottonwood, maple, plum, and willow, use crystals or a concentrated solution of 4 to 6 pounds ammonium sulfamate per gallon of water. Use crystals for small stumps under 2 inches; cover the freshly cut surface with 1 tablespoon per 2 inches of diameter. Spray or paint larger stumps with the solution; wet the entire surface thoroughly.

Sodium arsenite is used to a limited extent on stumps. Wet the tops thoroughly. Eucalyptus and willow are hard to kill.

Caution.—For precautions in handling ammonium sulfamate and sodium arsenite, refer to pages 43 and 33, respectively.

Cut-Surface Applications

Cut-surface applications are made in frills, or girdles, or in cups or notches.

The frills, or girdles, are made with an ax through the bark and well into the wood; space them so that the ax cuts overlap and completely encircle the tree. This method is used on individual trees too large—usually over 6 inches in diameter—or too thick-barked to be killed by basal-bark treatments. It prevents sprouting of standing trees more effectively than the cut-stump method.

Rates of application and preference of formulation varies among the regions. In general, use 16 pounds 2,4,5-T or 2,4,5-T and 2,4-D mixture per 100 gallons diesel fuel oil. In Minnesota, use the low-volatile esters of 2,4-D for cottonwood and willow. In Oklahoma, use frill applications rather than basal-bark treatments on elm. In California, use the frill method for trees over 2 inches in diameter. Treatments can be made at any time of the year.

For cups or notches, use crystals of ammonium sulfamate. Space cups or notches about 6 inches apart around the base of stems or trunks and apply one-half ounce crystals per notch to trees not over 10 inches in diameter. Treat at any time of the year. Use a water-soluble dye to mark trees that have been treated.

For frill applications to ash, quaking aspen, hickory, maple, pecan, common persimmon, blackjack oak, post oak, red oak, and sweetgum, use 4 pounds ammonium sulfamate per gallon water.

Caution.—For information in handling ammonium sulfamate, see page 43.

Sodium arsenite is used to a limited extent in frills. Apply with a pump oiler. Eucalyptus and willow are tolerant.

Caution.—Sodium arsenite is poisonous to humans and other warm-blooded animals and must be handled with extreme care. For information on handling, see page 34.

Tree Injections

Tree injections are simply an improved method of making cut-surface applications; they are made into the outer sapwood with a tree injector. They work best on old trees; young trees sprout from the bud zone. For most hardwoods, inject a solution of 33 pounds 2,4,5-T in 100 gallons diesel fuel oil or kerosene from February to August in the Southern States. Use 44 pounds 2,4,5-T and 2,4-D mixture from August to February. Make injections in the base of the stems not more than 2 inches apart.

Soil Applications

Chemicals that are absorbed by the roots are applied around the base of trees and brush.

Fenuron

Apply to heavy soils at any time except when the ground is frozen. Apply to sandy soils in spring, early summer, or just before the rainy season in arid regions. Use either spot or broadcast method.

Spot applications are most easily made when plants are dormant. Spread 1 to 2 tablespoons of pellets on the ground at the base of each clump of brush. Use 2 tablespoons for large clumps of trees; apply to opposite sides. For black locust, sassafras, sumac, and other species with wide-spreading root systems, spread the chemical over 2 to 4 square feet at the base of each tree. For species with less root spread, cover ½ to 1 square foot. On sloping ground, apply to the upside slope of the clump.

For broadcast applications, spread 12 to 18 pounds, active ingredient, per acre (50 to 75 lb. per acre of the 25-percent pellets) evenly over the area to be treated with a hand or power spreader or by plane. Use the lighter rates on sandy soils. The heavier rates are required on heavy soils, on limestone soils, on poorly drained soils, and for the hard-to-kill species.

Black gum, hawthorn, hazel, hickory, maple, Turkey oak, Osage-orange, redbud, seamyrtle, and smilax are hard to kill.

Specific recommendations for regions 1, 2, and 6 follow. (See fig. 1, p. 42.)

Regions 1 and 2.—Use fenuron instead of monuron for aspen, quaking; birch; cherry; dogwood; hackberry; hawthorn; hazel; hickory; locust, black; maple; mulberry; oak, bluejack, post, and Turkey; Osage-orange; poison-ivy; redbud; redcedar, eastern; sassafras; and shadbush. Among these species, those that are hard-to-kill and require the heavy rates of application are: hawthorn; hazel; hickory; maple; oak, Turkey; Osage-orange; and redbud. Fenuron pellets control conifers at less cost than 2,4,5-T, and applications can be made much faster.

Region 6.—Use fenuron instead of monuron. Apply broadcast or by air on winged elm, blackjack oak, and post oak growing on sandy loams. Other susceptible species are: blackberry, boxelder, chestnut, dogwood, hawthorn, and sweetgum. Apply the pellets broadcast at 6 to 10 pounds per acre or at 2 to 3 tablespoons per tree to defoliate mesquite.

Caution.—Follow the usual precautions about breathing the dust and undue contact with skin, eyes, and clothing. Do not clean equipment near desirable plants or where the chemical may be washed into contact with their roots.

Monuron

Apply 10 to 20 pounds, active ingredient, per acre at any time of year except when the ground is frozen. The light rate is adequate for most species including Turkey oak. Use 20 pounds for 2-year control. Encircle the base of the plant. Use 2 teaspoons per plant for multiflora rose in Northeastern United States. In Alabama, use 7 to 8 pounds per acre for Cherokee rose. In Virginia, apply 1 teaspoon monuron in pellets or slurry per clump of brush on such species as hickory, red and white oak, sassafras, and sourwood. Use 2 teaspoons for dewberry, black locust, persimmon, and seamyrtle. The slurry is made of equal parts of monuron and water. In Massachusetts, use the slurry for groundjuniper.

Caution.—For precautions in handling, see page 35.

FenuronTCA

Apply 80 to 120 pounds, granular formulation, per acre broadcast for brush and other weeds or 6 to 9 gallons liquid in enough water or oil to cover well—75 to 150 gallons per acre. For small areas, use one-quarter to one-half pound per square foot or 2½ to 5 cups liquid in 2½ to 5 gallons water or oil per 1,000 square feet. For

spot or basal application to brush, use 1 to 3 ounces per clump or 2 to 3 tablespoons undiluted liquid fenuronTCA per clump. Apply in a circle halfway between the trunk or center of the clump and the drip area. Or dilute liquid fenuronTCA in the proportion of 1 quart formulation to 2½ gallons water or oil and apply to the base and root area of the plant. About 75 to 150 gallons oil per acre are required—amount depends on density of vegetation. The liquid formulation is generally preferable in the Southeast; but, where a rapid knockdown of weeds is unnecessary, the granular product is better for brush control.

Caution.—Do not drain or flush equipment on or near croplands, lawns, trees, or other desirable plants or on areas where roots of desirable plants may extend. Prevent drift. Thoroughly clean application equipment with water and a detergent to prevent corrosion. FenuronTCA is harmful if swallowed and is irritating to skin and eyes.

Applications Along Roadsides and Utility Lines

Herbicides are useful in the maintenance of roadsides and utility lines if properly applied. The greatest dangers come from drift, runoff, improper application, and leaching to roots of desirable species under the treated area.

Before spraying, make a survey of the area, spotting slopes subject to erosion, location of desirable vegetation, and density and height of brush.

Caution.—Drift hazards are greatest when growth-regulating herbicides such as 2,4-D, 2,4,5-T, and silvex or contact herbicides are used as sprays, but damage often results from careless application. Drift occurs not only with volatile herbicides, such as the esters of 2,4-D and 2,4,5-T, but also with any spray that has been atomized into a mist by high pressure and small nozzle opening. The volume of spray per unit area also influences drift. Where there are adjacent susceptible plants, use at least 10 gallons per acre and move sprayer at slow speed. It is especially important to reduce mist when spraying with a handgun. Operate at low pressure (30 to 60 p.s.i.). Direct spray downward as much as possible, and do not spray when windy. When treating edges of roads, spray from the outside toward the pavement. Runoff is an important hazard on slopes, bare ground, and pavements. Cut-back asphalt, applied with a soil sterilant, helps to hold the chemical in place. Use 39 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 and shrubs some distance from soil treated with soil sterilants may be killed if their roots extend below this area.

Stump, basal-bark, and foliage applications are most suitable for the control of brush and trees along roadsides and utility lines.

Stump applications are most satisfactory for killing trees along roadsides and controlling brush over 3 feet tall. Considerable labor is required, but the danger from falling branches is removed and there are no standing dead trees. Use esters of 2,4,5-T or 2,4-D plus 2,4,5-T at any time of year or ammonium sulfamate during the growing season. For rates of application, see page 44. Sodium arsenite can be used where the hazards of poisoning are not important.

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. Use esters of 2,4,5-T or 2,4-D plus 2,4,5-T. For rates of application, see page 44.

Applications made in frills or girdles are more effective than basal treatments on large or thick-barked trees, and they prevent sprouting more effectively than stump treatments. Use 2,4,5-T or 2,4-D plus 2,4,5-T. For rates of application, see pages 44 and 45. Apply ammonium sulfamate and sodium arsenite in the same manner as for stump treatments.

Roadsides

For brush after an initial clearance:

Oaks and maples.—(1) Use basal spray on clumps for maximum kill and minimum regrowth. Follow with basal sprays on nonsuckering species or stem-foliage sprays on suckering species. Or, (2) use large volumes of stem-foliage spray. Follow in 2 to 3 years with a basal spray.

Suckering species.—Use overall stem-foliage spray. On susceptible species, repeat the following year; on resistant species, use basal sprays as followup.

For dense brush after hand cutting or light foliage spray:

Oaks and maples.—Drench the base of stems and stumps. Thoroughly wet the base of saplings that are not cut. Follow in 2 to 3 years with a basal spray in summer.

Suckering species.—Use overall stem-foliage spray. On susceptible species, repeat the following year; on resistant species, use basal sprays as followup.

For foliage applications, use esters of 2,4,5-T and 2,4-D on most species. (See p. 41.) Silvex is better on some oaks and locust. (See p. 43.) Use amitrole for white ash, black locust, poison-oak, and poison-ivy. (See pp. 43 and 48.) Use ammonium sulfamate in areas where drift from 2,4-D or 2,4,5-T is too hazardous. It can be used successfully in a mist blower in areas where ordinary application methods are difficult. (See p. 43.)

Fenuron or 2,3,6-TBA in dry form controls lateral root-sprouting species such as sumac, black locust, sassafras, and persimmon more effectively than foliage applications of 2,4-D and 2,4,5-T. Desirable trees adjacent to the right-of-way may be injured. (See p. 45.)

Utility Lines

Make two complete sprayings of all transmission lines at 2-year intervals—the first to kill as much growth as possible and the second to kill escapes and resistant species. Spray only those species that grow tall enough to interfere with the lines. If they are over 6 feet tall, cut and spray the stump.

Fenuron pellets at 12½ pounds per acre, active ingredient, kill alder, blackberries, and sumac; elderberry, elm, hawthorn, maple, or willow are not killed, but all species are defoliated.

TCA and dalapon are moderately effective on conifers.

Foliage sprays of 2,4,5-T at 2½ pounds per 100 gallons water control many species of hardwood brush throughout the season. They are most effective when applied soon after leaves are fully expanded and when the plants are growing actively. Esters of 2,4-D plus 2,4,5-T in equal proportions (brush killer) kill alder, smooth and staghorn sumac, and willow.

Weeds in Woody Plantings

When shrubs or trees are to be planted along a highway, in ornamental nurseries, for a windbreak, or other functional use, weeds can be controlled with chemicals until the plantings become established. There are three methods of application.

Preemergence.—Apply before weeds emerge or after they have been destroyed by cultivation. Apply as a spray or in dry form around the base of well-rooted 1-year-old shrubs or trees. Do not spray foliage, and apply granular materials to foliage only when dry. Except in areas of low rainfall, use diuron at 1 to 2 pounds or simazine at 2 to 4 pounds. Use DNBP at 9 to 12 pounds.

Postemergence.—Apply to young weeds at the base of established shrubs or trees. Wet thoroughly, but keep spray off the plantings. Use 5 to 10 pounds dalapon or 4 to 6 pounds amitrole in 40 to 50 gallons water per acre. Dalapon kills grasses; amitrole kills both grasses and broadleaved weeds.

Preemergence and postemergence.—Apply to weeds when young. Wet thoroughly with combinations of chemicals given above. Examples are: 2 to 4 pounds amitrole plus 2 to 4 pounds simazine per acre or 5 to 10 pounds dalapon plus 3 to 6 pounds DNBP per acre.

Use knapsack sprayers, hand-boom off-power sprayers, or hand dusters. Granular formulations are safer than sprays, but they are not used postemergence.

All woody species are tolerant of DNBP, but the period of weed control is short. Those known to be uninjured by recommended rates of diuron or simazine are:

Broom (*Genista tinctoria*)
Burning-bush, European (*Euonymus europaea*)
Honeysuckle, common (*Lonicera tartarica*)
Honeysuckle, Zabel (*L. korolkowii*)
Maple, English hedge (*Acer campestre*)
Mockorange, Lemoines (*Philadelphus lemoines*)
Pea-tree, Siberian (*Caragana arborescens*)
Spurge, Japanese (*Pachysandra terminalis*)
Willow, arctic (*Salix pupurea 'nana'*)

Ninebark (*Physocarpus opulifolius*), Korean spiraea (*Spiraea trichocarpa*), *Spiraea media*, and Preston hybrid lilac (*Syringa prestoniae*) are injured by both diuron and simazine. Diuron injures newly planted evergreens.

Species in which simazine can be used safely when the plants are a year or more old are:

Arborvitae (*Thuja occidentalis*)
Barberry (*Berberis* spp.)
Boxwood (*Buxus* spp.)
Chamaecyparis (*Chamaecyparis* spp.)
Cotoneaster (*Cotoneaster* spp.)
Dogwood (*Cornus* spp.)
Douglas-fir (*Pseudotsuga*)
Fir, balsam (*Abies balsamea*)
Fir, Fraser (*A. fraseri*)
Hemlock (*Tsuga* spp.)
Juniper (*Juniperus* spp.)
Pine, mugho (*Pinus mugho*)
Pine, red (*P. resinosa*)
Pine, Scotch (*P. sylvestris*)
Pine, white (*P. strobus*)
Privet (*Ligustrum* spp.)
Rose, multiflora (*Rosa multiflora*)
Spruce, blue (*Picea pungens*)
Spruce, Norway (*P. abies*)
Spruce, red (*P. rubra*)
Spruce, white (*P. glauca*)
Yew (*Taxus* spp.)

Poison-Ivy, Poison-Oak, and Poison-Sumac

There are four satisfactory herbicides for killing poison-ivy, poison-oak, and poison-sumac—amitrole, ammonium sulfamate, brush killer, and 2,4,5-T. Apply when leaves are fully expanded, and wet the foliage to the point of runoff. Drench the stems as high as possible when the plants are growing on a wall, and allow the ex-

cess spray to run down to the roots. Plants growing in the shade require more amitrole or brush mixture than those in the sun.

Amitrole

Use 2 to 4 pounds, active ingredient, per 100 gallons water. Amitrole does not vaporize readily, but spray drift can damage nearby plants. If ivy is growing on a desirable tree, cut ivy stem at ground level in winter and treat the sprouts after leaves come out in the spring. If ivy is intertwined with desirable plants, paint the ivy leaves with a long-handled brush. Mix 2 tablespoons of the 50-percent product in 1 quart water for the paint. Cover at least one-half of the leaves. Amitrole can also be applied dry.

Where brush is to be killed along with the ivy, oak, or sumac, brush killer is effective on more species than amitrole.

Caution.—Amitrole kills most lawn grasses. It is slow in action; effects may not show up for 2 or 3 weeks.

Ammonium sulfamate

Use 2 to 2½ pounds, 95-percent product, in 3 gallons water and add a spreader-sticker. Ammonium sulfamate does not evaporate, but spray drift can damage nearby plants.

Caution.—Ammonium sulfamate sterilizes the soil for several months. For precautions in handling, see page 43.

2,4-D and 2,4,5-T mixture (brush killer) and 2,4,5-T

Use 2 to 3 pounds, acid equivalent, per 90 gallons water plus 10 gallons diesel oil. If any regrowth occurs, repeat the application. Brush killer in diesel oil is also effective when applied in late winter or early spring. Use 12 pounds 2,4,5-T per 100 gallons oil for dormant spray. Treat poison-sumac in the dormant stage to avoid skin poisoning.

Caution.—Prevent drift by applying on calm days and at least 100 feet from sensitive plants. Treat in winter if sensitive plants are to be grown nearby.

Turf Weeds

Weeds in lawns, athletic fields, golf grounds, parade grounds, the turf portions of roadsides and railroad rights-of-way, and similar areas are controlled by good maintenance practices supplemented with chemical herbicides. It is important to prevent the encroachment of weeds by maintaining competition from vigorously growing turf grasses. The principal factors in maintenance are soil, grass, water, mowing, and pests.

Turf Management

Both the physical and chemical properties of the soil are important. Adequate organic-matter content, drainage, and aeration are as essential as proper fertility. The selection of the grass or grasses to be seeded is also important. Each type has its requirements for optimum adaptation. Water not only keeps plants from wilting, it is itself a nutrient and it acts as a solvent and carrier of nutrients and food. The frequency and height of mowing are important. The height is determined by the kind of grass, and the frequency depends on rate of growth. Pests include insects, diseases, and weeds. These often require treatment beyond good maintenance practices. Insecticides, fungicides, and herbicides are supplementary controls.

Chemical Control

Chemicals are useful for killing weeds (1) in preparation for seeding, (2) where weeds have become established in disturbance areas, or (3) where, for other reasons, there is an incomplete cover of desirable grasses.

Preplanting Weed Control

Nonselective control of weeds in turf areas is possible only in preparation for seeding. Fumigants and the nonvolatile temporary soil sterilants dalapon and TCA are used.

FUMIGANTS

Some fumigants can be mixed with the surface soil and sealed in with water. Others require a gasproof cover to confine the vapor until it has penetrated the soil. Polyethylene covers are commonly used. Certain fumigants are injected into the soil. Injectors may be hand operated or power driven. The hand type consists of a sharp-pointed tube that is thrust into the ground. It has an attached funnel at the top through which the chemical is fed. Power-driven injectors operate by gravity feed with subsequent coverage of the gas by plowing or by gear pumps that force the liquid into the ground just behind furrow openers.

Sodium-N-methyldithiocarbamate (WSA designation, SMDC)

SMDC is most effective when a gasproof cover is used in addition to a water seal, but it can be used without the cover. Prepare the soil as for a seedbed, and keep wet for 5 days before treatment. Application can be made by hand (sprinkling can or hose proportioner), by a sprinkler system, or by injection. Directions for each method accompany the product. Use 1 quart of a 4-pound solution per 100 square feet.

SMDC can also be sprayed in the plow sole ahead of covering. If plantings or seedings are to be made, cultivate the soil a week after treatment to permit escape of gas. Wait another week before planting or sowing. If prolonged rains follow treatment or if the SMDC has penetrated deeply, make test plantings to determine if the soil is toxic. In irrigated areas, meter the chemical into irrigation water continuously during check flooding.

Turf and lawn renovation.—Treat old weedy turfs and lawns by the hand or sprinkler method. Rake off dead vegetation 2 weeks after treatment, reseed area, rake lightly, and water. Bermudagrass is a special problem since a few surface runners may survive. For this weed start treatment early enough in the summer to allow retreatment of survivors. If soil is compacted and impermeable where bermudagrass or other perennial grass occurs, cultivate the soil before applying SMDC.

New lawns.—Cultivate soil, add manures and fertilizers, keep damp for a week, and then add 1 quart SMDC per 100 square feet by the hand or sprinkler methods.

Caution.—Do not apply SMDC within 3 feet of small shrubs or within the drip line of large shrubs or trees. If the treated area slopes toward desirable plants, prevent runoff into the root zones. Fumes of SMDC may burn the leaves of established plants. If applied near trees and shrubs, apply during a breeze as it is less hazardous than when there is little air movement. Do not apply when the temperature is over 90° F.

SMDC and its decomposition products are irritating to eyes, skin, and mucous membranes. Avoid inhaling mist or fumes. Use rubber boots and rubber gloves. Wash any affected parts of the body immediately with large amounts of water, and remove contaminated shoes and clothing. Keep container tightly closed and away from children, food, and feedstuffs. Wash all equipment thoroughly with water immediately after use. Avoid splashing SMDC on painted surfaces.

3,5-dimethyltetrahydro-1,3,5,2H-thiadiazine-2-thione (WSA designation, DMTT)

Apply dry or as a spray at 7 pounds per 1,000 square feet or 300 pounds per acre when soil temperatures are 50° F. or higher. Heavier rates are required for nutgrass. After application, mix with soil to a depth of 6 inches and irrigate with 1 inch of water. Improved control results from use of a polyethylene cover in addition to the water. Plant or sow 2 weeks after application, if the soil has been exposed to the air for at least a week and if there have been no heavy rains or watering; otherwise, wait 3 weeks.

Caution.—Use large nozzles and screens to prevent clogging. Keep suspension agitated. Do not inhale the dust, avoid prolonged or repeated contact with skin, and do not swallow. Do not let DMTT wash within 4 feet of growing plants or closer than the drip line of trees or large shrubs.

Methyl bromide

Work heavy soils into seedbed condition to aid penetration of the gas. Open a furrow or trench around the margins of the area to be treated so that the edges of the cover can be anchored. Place supports at intervals over the area to prevent the cover from hugging the ground and to insure free circulation of the gas. Apply the fumigant with an applicator as directed by the manufacturer at the rate of 1½ pounds per 100 cubic feet of piled soil or per 100 square feet of an area. Apply when the soil temperature is 65° F. or above. Remove cover in 24 hours. Seed in 48 to 72 hours after removal of cover.

Caution.—Handle with care. Methyl bromide is poisonous to humans and can cause serious burns.

Chloropicrin

Apply chloropicrin with injector at 9½ pounds per 1,000 square feet or 400 pounds per acre; inject at a depth of 6 inches in holes 12 to 15 inches apart. To kill surface seeds, use a gasproof cover after injection. Apply when the soil is moist and at 65° F. or above. Expose for 3 days. For soil in piles, inject 7 cc. per cubic foot (1 pint per 64 cubic feet) and cover with a gasproof material.

Caution.—Chloropicrin is poisonous, but it is so irritating to nose and throat that it is its own warning.

Carbon disulfide

Carbon disulfide gas kills on contact; hence, thorough distribution in the soil is essential. High soil moisture, hardpans, and tight layers of clay interfere with its movement and distribution. Inject the liquid into holes; apply 2 ounces per hole and space holes 24 inches apart each way for light soils, 18 inches apart for medium soils, and 12 to 15 inches apart for heavy soils. For deep-rooted plants, place the chemical 8 to 18 inches deep in the soil with either a hand or power injector. Apply in warm weather. Seal after injection by rolling or by wetting.

Caution.—Carbon disulfide is poisonous, flammable, and explosive. Ground the barrel through a metal bar buried in the soil.

NONVOLATILE TEMPORARY SOIL STERILANTS

Dalapon and TCA are used as nonvolatile temporary soil sterilants.

Dalapon

Apply dalapon at 4½ to 5½ ounces per 1,000 square feet or 12 to 15 pounds, acid equivalent, per acre in July to rid an area of perennial grasses growing in moist fertile soil. Dalapon is effective when sprayed on growing vegetation. Usually, followup treatments are necessary in August to kill surviving plants. Apply long enough ahead of seeding turf grasses so that toxic residues have disappeared. Dalapon disappears fastest in warm humid areas and persists in dry cool soils where the environment is unfavorable for microbial activity. If there is adequate moisture and temperatures are warm for 3 to 4 weeks after the last treatment, lawn grasses can then be seeded. Dalapon injures or kills all grasses in the area treated, and reseeding such areas will be necessary. In semiarid regions with cold winters, early-fall applications have usually disappeared by late spring.

Caution.—Avoid contact with skin and eyes and avoid inhaling spray mist. Wash affected parts with water if contact is made. Flush equipment with water immediately after use. Do not allow spray solutions to stand more than 2 days after mixing.

Trichloroacetic acid (WSA designation, TCA)

Apply TCA at 9 to 11 ounces per 1,000 square feet or 25 to 30 pounds, acid equivalent, per acre to land that has been plowed or can be plowed after treatment. Remove trash before application. TCA is leached rapidly from well-drained soils after heavy rainfall. Substantial amounts are adsorbed on organic colloids so that it disappears more slowly from muck soils than sandy or clay soils.

Caution.—Same precautions apply to TCA as for dalapon.

Selective Weed Control

Turf weeds comprise (1) broad-leaved species that can be killed with one group of herbicides without seriously injuring turf grasses and (2) undesirable grasses that can be controlled by a second group of chemicals. The morphological and physiological differences between broad-leaved weeds (dicotyledons) and grasses (monocotyledons) make selective control possible. Where weedy grasses are to be removed from turf grasses, selectivity is accomplished usually if the weed is an annual and the turf grass is a perennial.

BROAD-LEAVED WEEDS

Broad-leaved weeds that are common in turf include curly dock, common or mouse-ear chickweed, dandelion, field bindweed, heal-all, henbit, knotweed, plantain, shepherds-purse, speedwell, wild carrot, wild garlic, wild onion, woodsorrel, and yarrow.

2,4-D; MCPA; 2,4,5-T; and silvex

The four most commonly used herbicides for control of broad-leaved weeds in turf are 2,4-D, MCPA, 2,4,5-T, and silvex. Unless a species is more susceptible to silvex, 2,4,5-T, or MCPA, use 2,4-D because it is less expensive. (See Weed Species and Herbicides for Control, p. 57.) At recommended rates none of these herbicides injures established grasses other than bents, but they may reduce the stand of legumes. All are growth-regulator type herbicides that may injure susceptible plants adjacent to the area sprayed. There is no danger of injury from vapors from the salt formulations. The low-volatile esters are less hazardous than the methyl, ethyl, isopropyl, butyl, or amyl esters, but they also vaporize at temperatures above 90° F. Drift, however, may occur with any spray if droplets are small enough to remain suspended in the air. Therefore, spray with low pressures (30 p.s.i. or less) and a coarse nozzle to reduce number of fine droplets.

A classification of weeds based on control by 2,4-D, MCPA, 2,4,5-T, and silvex follows.

1. Weeds equally well controlled by 2,4-D, MCPA, 2,4,5-T, and silvex: Field bindweed, creeping buttercup, dandelion, lawn pennywort, broad-leaved plantain, buckhorn plantain, blackseed plantain, Canada thistle, and common yarrow.

Apply 2,4-D, MCPA, or 2,4,5-T at 0.3 to 0.4 ounces, acid equivalent, per 1,000 square feet or about 1 pound per acre. For smaller areas, use 2 tablespoons of a 4-pound-per-gallon formulation in 1 gallon water or follow instructions on the label of the container. Spray when weeds are growing rapidly and wet the foliage completely. Apply 1 to 1½ pounds silvex per acre in Northern States and 2 to 3 pounds in the Southern States. Yarrow is hard to kill. Repeat treatments.

2. Weeds better controlled by 2,4-D or 2,4,5-T than by MCPA or silvex: Sulfur cinquefoil, curly dock, and purslane speedwell.

Tops of curly dock are easily killed if sprayed before stalks or stems appear but repeated treatments are required for root kills. Repeat treatments for speedwell.

3. Weeds better controlled by 2,4-D than by 2,4,5-T, MCPA, or silvex: Wild carrot, common cinquefoil, wild garlic or onion, heal-all, moneywort, puncturevine, and shepherds-purse.

Wild onion and wild garlic are satisfactorily controlled by repeated annual treatments with esters of 2,4-D applied early in the spring. Rates vary from 1 to 3 pounds, acid equivalent, per acre—in Minnesota, Indiana, and Northeastern

United States, use 1 pound per acre; in Virginia, Tennessee, Mississippi, Alabama, and Oregon, use 1½ to 2 pounds; and in North Carolina, use 3 pounds in a single application or in three treatments each year—mid-January, mid-February, and mid-March—and apply for 3 years. If the amine salts are used, add a detergent (¼ lb. per 50 gal. spray). Make successive applications in the spring, the next fall, and the following spring on new growth. Bentgrasses and some fescues are injured at these rates.

4. Weeds better controlled by silvex than by 2,4-D, 2,4,5-T, or MCPA: Chickweed, groundivy, henbit, annual knawel, black medic, upright spurge, wild strawberry, violet, and yellow woodsorrel.

Except in the South, repeated applications of silvex or 2,4,5-T control common chickweed (annual), and silvex has been effective on mouse-ear chickweed (perennial). (See also DNBP, below.)

5. Weeds better controlled by silvex or 2,4,5-T then by MCPA or 2,4-D: The clovers and ponyfoot (*Dichondra repens*).

Where these species are undesirable, use 1 to 1½ pounds silvex or 2,4,5-T, acid equivalent, per acre in the Northern States and 2 or 3 pounds in the Southern States. For putting greens, use ½ pound in 25 to 30 gallons water per acre. Bentgrasses and fescues are more susceptible to injury than bluegrass. To remove burclover and whiteclover from bermudagrass and St. Augustinegrass turf in Texas, use ¾ to 1½ pounds per acre silvex.

Caution.—Use light rates of 2,4-D or silvex on St. Augustinegrass. Use one-fourth to one-half the usual rate of 2,4-D, MCPA, or silvex on bentgrasses and new seedlings of other turf grasses. Normal rates can be used after the second mowing. If clover is to be maintained, use one-fourth to one-half the normal rate of 2,4-D, MCPA, or silvex.

Dicamba

Apply dicamba at ½ to 1½ pounds per acre to control prostrate knotweed. Use as a foliar spray in fall or spring. Use at 2 pounds per acre for wild garlic or wild onion.

Caution.—Avoid drift. (See pp. 30 and 46.)

DNBP

In the South, use DNBP for control of chickweed. Apply amine DNBP at 1 to 2 pounds per acre in 40 gallons water. Apply when temperatures are above 60° F.

Caution.—See precautions for application, page 39.

Methyl bromide

Methyl bromide is effective against wild garlic and wild onion; but application is laborious, since the area to be treated has to be covered with a gasproof cover. All vegetation is killed so that reseeding is necessary.

WEEDY GRASSES

Weedy grasses common in turf include annual bluegrass, barnyard grass, crabgrass, foxtail, goosegrass, nimblewill, nutgrass (a sedge), fall panicum, stinkgrass, Texas millet, wild paspalum, and witchgrass. All except nimblewill, nutgrass, and paspalum are annuals and can be controlled selectively by treating the entire area. Both preemergence and postemergence treatments can be used. The perennial grasses are controlled by treating individual plants.

Preemergence control.—For preemergence control of annual species, use lead or calcium arsenate (or products containing these chemicals), dimethyl ester of tetrachloroterephthalic acid (DCPA), O-(2,4-dichlorophenyl)-O-methyl isopropylphosphoramidothioate (DMPA), or chlordane.

Calcium arsenate and lead arsenate

Apply 8 to 12 pounds calcium arsenate per 1,000 square feet or 12 to 20 pounds lead arsenate for crabgrass on low-fertility or sandy soils; 12 to 16 pounds calcium arsenate or 20 to 32 pounds lead arsenate on fertile or clay soils. Apply 50 percent more of either for annual bluegrass. These treatments may reduce the vigor of lawn grass, and overtreatment may reduce stands. If proper rates are used, the grass maintains a green color. The effectiveness of arsenicals is greatly reduced by phosphate in the soil. Apply only to soils low in this nutrient, and do not spread phosphate fertilizer until the arsenic has controlled the weeds.

Caution.—The arsenates are poisonous and must be handled with care. Arsenic compounds persist in the soil.

DCPA

Apply DCPA before weed seed germinates. Mix thoroughly with enough water to provide at least 40 gallons spray per acre. Keep the spray suspension agitated to avoid settling. For susceptible weeds, apply 3¾ ounces, active ingredient, per 1,000 square feet or 10 pounds per acre. For barnyard grass, redroot pigweed, and upright spurge, use 5 ounces per 1,000 square feet or 14 pounds per acre.

Caution.—DCPA prevents growth of turf grasses if seeded soon after treatment; wait at least 3 months. It is harmful if swallowed. Avoid contact with eyes, skin, and clothing.

DMPA

Apply DMPA before weed seed germinates. Use the emulsifiable liquid formulation for the

control of crabgrass, prostrate knotweed, and nimblewill in established bluegrass turf. The granular formulation does not control nimblewill. It is less liable than the liquid formulation to cause foliage burn of turf grasses. It can be used on established turf of blue, St. Augustine, centipede, bermuda, and zoysia grasses.

For control of crabgrass, use 5½ ounces, active ingredient, per 1,000 square feet or 15 pounds per acre of either the liquid or granular product. The granular product can be applied in the fall, but it controls only the crabgrass. For control of nimblewill, apply the liquid in May or June and repeat the treatment about 1 month later. Use at the rate of 1 pint (3-lb. formulation) per 1,000 square feet with enough water to wet the foliage thoroughly (about 5 to 6 gal.) but without excessive runoff. To prepare the spray, add one-half the required amount of water to the tank, add the proper amount of liquid concentrate, add the rest of the water, and stir. Do not sprinkle after treatment.

Caution.—DMPA prevents growth of turf grasses if seeded soon after treatment; wait at least 3 months. It is harmful if swallowed. Avoid contact with eyes, skin, and clothing. Keep DMPA away from heat and open flame.

Chlordane

Results with chlordane have been erratic. It is most successful under dry conditions and low soil fertility. Apply 2 pounds per 1,000 square feet preemergence.

Postemergence control.—For postemergence control of annual species, except annual bluegrass (pp. 51 and 52), use amine methylarsonate (AMA), disodium monomethylarsonate (DMA), or phenylmercuric acetate (PMA). Make first application soon after emergence of the weed. Repeat treatments at 7- to 10-day intervals until satisfactory control is achieved. Usually three treatments are required.

AMA

If temperature is not over 80° F., apply AMA to moist soil at one-half pint of 16-percent formulation in 6 gallons water per 1,000 square feet. Wet foliage lightly. If temperature is over 80° F., use 1 pint in 12 gallons water per 2,500 square feet. Sprinkle 2 days after treatment.

Caution.—Do not treat newly seeded areas with AMA before the third mowing. Do not use on centipede or St. Augustine grasses.

Avoid contact with eyes or skin. Do not inhale spray mist. Do not take internally. Do not allow livestock to graze treated vegetation.

DMA

Apply DMA to moist soil at 2 to 3 ounces, active ingredient, per 1,000 square feet or 5 to 8 pounds per acre to Kentucky or Merion bluegrass and zoysiagrass sods. For fine-leaved fescues and bentgrass, use 2 ounces and apply only in the spring before hot weather arrives.

Caution.—Do not use DMA on St. Augustinegrass. Avoid inhaling spray mist. Keep livestock from grazing treated vegetation. Avoid drift. Store in glass bottles or metal cans.

PMA

Apply PMA at one-fifth ounce, active ingredient, per 1,000 square feet or 5.4 pounds per acre. Use half this rate on putting greens and other areas where the grass is cut short.

Caution.—Merion bluegrass is sensitive to PMA. PMA is poisonous when taken internally. Wash immediately with soap and warm water if skin is irritated through contact.

Sodium arsenite

Sodium arsenite controls annual bluegrass. In addition it also controls angleworms and white grubs. Sodium arsenite can severely burn the turf if applied in hot weather. On golf ground fairways, use 2 pounds per acre in 75 gallons water when temperatures are 40° to 50° F., 1½ pounds at 50° to 65°, 1.0 pound at 65° to 75°, and do not treat when temperatures are above 75°. For putting greens, use three-quarter ounce per 1,000 square feet at temperatures of 40° to 50° F., one-half ounce at 50° to 65°, and one-third ounce at 65° to 75°.

Caution.—Sodium arsenite is very poisonous to man and animals. (See p. 33.)

Treatment of individual plants.—For treatment of individual perennial grass plants, use dalapon or petroleum naptha (for treatment of bermudagrass, see p. 49). Dissolve one-quarter pound dalapon in 1 gallon water. Apply the solution to grasses at ground level. Use a cane-type applicator, a syringe, or a wad of cotton fastened to the end of a stick.

Petroleum naptha is effective on both broadleaved and grassy weeds. Use full strength with same types of applicators as recommended for dalapon.

Bermudagrass can be killed with methyl bromide (p. 49), SMDC (p. 48), or DMTT (p. 49). Only one application of methyl bromide is required, and the area treated can be reseeded in 2 or 3 days.

Aquatic Weeds

The major groups of aquatic weeds are (1) floating, (2) submersed, and (3) emersed. All three groups may occur in agricultural water-control systems, ponds, and lakes.

Floating Weeds

Floating weeds germinate in the bottom of ditch or pond, then become separated and float. Water-hyacinth, waterlettuce, waterfern, pennywort, and rooted submersed weeds with floating leaves such as waterlilies and watershield (in ponds and lakes) can be controlled with 2,4-D. Apply the amine salt formulation or low-volatile esters at 2 to 4 pounds, acid equivalent, per 100 gallons water, except for waterfern and waterlettuce (below). Use sufficient volume to cover foliage uniformly. Use the esters in seasons of frequent rain. Spray during the growing season and when the weather is warm; use low pressure and large nozzles. Re-treat surviving plants in 2 or 3 weeks. Where drift is no problem, spray by aircraft; use 60 to 80 pounds ester per 100 gallons #2 diesel fuel oil, and apply at 3 to 4 pounds, acid equivalent, per acre. The ester formulation of silvex is also effective on waterlilies at 2.5 p.p.m.

The foliage of waterlettuce and waterfern is hard to wet; water sprays are ineffective and even esters in oil are not dependable. For waterlettuce, use invert emulsions (see p. 24) of 2,4-D or 2,4,5-T; a mixture of 2,4-D and 2,4,5-T emulsified with 10 to 15 percent (by volume) diesel fuel oil in water; diesel fuel oil at 20 gallons per acre; or simazine at 10 pounds per 100 gallons water. For waterfern, use an invert emulsion of 2,4-D and 2,4,5-T at 3 to 4 pounds per 100 gallons and completely cover the foliage. Amitrole-T at 2 to 5 pounds per acre is promising on water-hyacinth and waterlettuce.

Duckweed can be controlled with copper sulfate or 1 percent octachlorocyclohexenone (OCH) in oil; apply twice at an interval of 2 weeks.

Submersed Weeds

Submersed weeds include (a) rooted species such as pondweeds, naiad, watermilfoil, watercrowfoot, waterweed, and water-stargrass, and (b) nonrooted species such as algae.

In Ponds and Lakes

For control of rooted submersed species in still water use one of the following chemicals.

Sodium arsenite

Apply sodium arsenite at 2 to 10 p.p.m. Use the light rate for soft water, 4 p.p.m. for hard water, and 8 to 10 p.p.m. for cold water. Dilute the solution concentrate to spraying consistency with water and spray weed beds or entire pond. Treat shoreline areas first. Apply when weed growth is active but before shoots have reached the surface. Repeat applications if needed. Do not treat ponds fed by large streams—the chemical is diluted before it can become effective. Apply to the entire water volume when weeds are scattered throughout the pond. If rooted weeds or algae are concentrated near the shore, calculate the volume of water in the weed strip. To determine the volume of water in a pond and the amount of chemical needed, use the following:

Average depth of water, in feet, ×surface acreage×43,560=volume water, in cubic feet, or

Average depth water, in feet, ×surface area, in square feet=volume water, in cubic feet.

1 p.p.m.=2.7 lb. per acre-foot (43,560 cu. ft.)

Pounds chemical=p.p.m.×acre-foot×2.7

Apply 1 gallon 4-pound liquid per 16,000 cubic feet water in the pond. If there are heavy masses of summer algae, use 1 gallon per 10,000 cubic feet. For a strip of underwater weeds or floating summer algae near the shore, use 1 gallon 4-pound liquid per 6,500 cubic feet if pond is large and unprotected from wind and waves or per 8,500 cubic feet if the pond is small and protected. For application, dilute sodium arsenite with water in proportion of 1:3 or 1:4. Spray only one-half of area; treat the rest 7 to 10 days later. At rates effective on most underwater species, sodium arsenite is not toxic to fish, but they may be killed if an excess of weed decay removes oxygen from the water.

Water-hyacinth, algae growing below the surface, and other aquatic plants that have a waxy leaf covering are not killed by sodium arsenite at these concentrations.

Caution.—Inorganic arsenical compounds are caustic poisons and must be handled with extreme care to avoid injury or death to human beings, livestock, or game animals. See page 33 for handling. Do not use water for bathing, sprinkling of lawns and gardens, or watering of animals for 3 days after treatment. Treated water must be quarantined 2 weeks before it is safe for drinking. Do not use the arsenical treatment in any waters intended for rice culture. Carefully observe all State laws on applications of arsenicals.

Where the danger of poisoning from sodium arsenite is too great, the following herbicides can be used.

2,4-D

2,4-D in pellet or granular form can be used in still water for broad-leaved submersed and emersed aquatic plants. Apply 150 pounds of the pellets containing 20 percent, acid equivalent, per acre for young, susceptible species and 200 pounds for more resistant kinds or in extremely acid or alkaline water.

Coontail, fanwort, and watermilfoil are easily controlled; wavy-leafed pondweed, some other

pondweeds, bladderwort, and waterweed (*Elodea*) are more difficult.

Silvex

Use the granular potassium salt of silvex at 2 to 3 p.p.m.; the liquid at 4 p.p.m.; and low-volatile ester at 2.5 p.p.m. for arrowhead, coontail, fanwort, some pondweeds, some buttercups, and watermilfoil.

Endothall

For most *Potamogeton* pondweeds, horned pondweed, and coontail, use at 1 to 2 p.p.m. in large areas and 2 to 3 p.p.m. for spot or lake-margin treatment. Use 2 to 3 p.p.m. in large areas and 3 to 4 p.p.m. for spot treatment for watermilfoil. Use 3 to 4 p.p.m. and 4 to 5 p.p.m., respectively, for burreed. Use 25 p.p.m. for arrowhead in large areas and for spot treatment.

Caution.—Avoid contact with skin and eyes. Avoid breathing spray mist. Bathe and change clothing at least daily while using. In case of contact with the skin, immediately flush exposed areas with plenty of water for at least 15 minutes; get immediate medical attention if eyes are affected. If chemical is swallowed, take cold milk and Amphogel (1 oz.) instead of an emetic. Call a doctor immediately.

Prevent drift. Wash equipment thoroughly with water after each application. Do not use treated water for irrigation, agricultural sprays, or domestic purposes within 7 days after treatment. Do not use fish from treated water for food or feed within 3 days after treatment. Obtain necessary approval and permits for use in States or areas where required.

Dichlone

For control of rooted species such as coontail, naiad, parrotfeather, pondweeds, and watermilfoil, use dichlone at 10 to 20 pounds per surface acre. At these rates, concentrations of the chemical range from 2.7 to 10.8 p.p.m. in water 5 to 10 feet deep. Toxicity of dichlone to fish has been variable, and safe concentrations have not definitely been determined.

For control of blue-green and filamentous green algae, use dichlone at 1 pound per surface acre water (0.01 p.p.m.). Repeat applications to maintain control.

Caution.—It may be dangerous to trout at 0.05 p.p.m. Consult Federal or State Fish and Wildlife Service for information relative to fish.

Diuron, fenuron, monuron, simazine, fenuronTCA, and monuronTCA

Use these chemicals preemergence at 20 to 40 pounds per acre, or 1 to 5 p.p.m., on coontail and naiad and pondweeds (*Najas* spp. and *Potamogeton* spp.).

Diquat

Use diquat at 5 p.p.m. for most algae (*Anabaena*, *Chara* spp., *Cladophora*, *Hydrodictyon*, and *Oscillatoria*). Use 8 pounds, active ingredient, per gallon water for diapedium or dianthera (*Justicia* spp.). Use 1 p.p.m. for sago pondweed (*Potamogeton pectinatus*) and leafy pondweed (*P. foliosus*). Use 3 to 4 p.p.m. for buttercup (*Ranunculus* spp.) and waterweed (*Elodea canadensis*). Use 10 pounds, active ingredient, per 100 gallons water for arrowhead.

Caution.—Diquat is highly toxic if swallowed.

Copper sulfate

For control of filamentous green algae, use copper sulfate at ½ to 1 p.p.m. in soft water or 1 to 2 p.p.m. in hard water. For branched filamentous algae (*Hydrodictyon*) make three to five treatments of copper sulfate at the same rate as above on consecutive days. Apply during early-development stages of algae.

There are four methods of application: (1) Drag a burlap bag of crystals across the pond or lake behind a boat. Use a definite pattern to distribute the required quantity evenly. (2) Dissolve crystals or powder in water and sprinkle or spray this solution on the water. (3) Release solution underneath the surface from either shore or from a boat. (4) Broadcast crystals from shore or boat. If temporary relief rather than elimination of the algae is adequate, spray a lane parallel to the shore 200 to 400 feet wide and spray all protected bays. This frees the treated area of algae, but reinfestation will occur.

Caution.—Copper sulfate is safe for most fish at the recommended concentrations, but do not use in trout waters since trout are susceptible to very low concentrations. Continuous or frequently repeated applications may also control rooted species, but they tend to be detrimental to fish. Copper sulfate is highly corrosive to iron and galvanized metal. Use equipment made of red brass, commercial bronze, copper, stainless steel, enameled ware, or wood. Do not apply on a windy day, and avoid contact with eyes, nose, and mouth.

In Irrigation and Drainage Systems

For control of weeds growing in the bottoms and on lower slopes of ditches that carry water only occasionally, apply diuron or monuron at 10 to 40 pounds, active ingredient, per acre; simazine at 15 pounds, active ingredient; erbon at 100 to 160 pounds, active ingredient; sodium arsenite at 300 to 600 pounds, product; chlorate-borate-monuron mixture at 500 to 1,000 pounds, product; or borate-monuron mixture at 300 to 500 pounds, product. Treatments are effective for 1 to 3 years.

For control at the waterline and in the bottom

of ditches carrying water constantly or frequently, apply diuron at 20 to 80 pounds, simazine at 15 to 40 pounds, or sodium arsenite at 600 to 1,000 pounds when there is no waterflow. Repeat treatments every 3 to 12 months. Frequency of re-treatment depends on the rate of herbicide applied, the amount of rainfall, and the amount of water that flows through the ditch after treatment. These treatments control most aquatic weeds rooted at the waterline.

Caution.—Whenever possible spray when the ditch is empty to avoid contamination of the water. When water is present, spray upstream to reduce the concentration of chemical in the water.

For ditchbank weeds, use herbicides that do not have long residual toxicity in the soil. For annual and perennial broad-leaved weeds, where few or no weedy grasses are present and where desirable grasses should be preserved, apply amine salts or low-volatile esters of 2,4-D at 1 to 2 pounds per acre during early growth of weeds. Repeat as necessary to maintain control.

For weedy grasses, apply dalapon at 10 to 30 pounds, acid equivalent, per acre; amitrole at 5 to 10 pounds, active ingredient, per acre; or aromatic oil or fortified fuel oil at 80 to 160 gallons per acre. Amitrole and dalapon treatments are also effective on cattails, cutgrass, and sedges. Use the lower rates where only annual species are present and when re-treatments are to be made. Oil treatments must be repeated every 3 or 4 weeks to eliminate the weeds in one or two growing seasons. Usually, one or two applications of amitrole or two to four applications of dalapon per year will maintain adequate control. After perennial grasses have been eliminated, add 2,4-D at 1 to 2 pounds per acre to amitrole or dalapon to control invading broad-leaved weeds.

For general weed control in areas where proximity to cotton, grapes, tomatoes, and other sensitive crops or ornamentals prevents the use of 2,4-D, use aromatic oil or fortified oil at 80 to 160 gallons per acre as often as necessary.

For johnsongrass, use:

(1) *Dalapon.*—Thoroughly wet the foliage with a solution of 1 pound, product, to 5 gallons water. Re-treat whenever the grass becomes 12 to 15 inches tall; two or three treatments are usually required.

(2) *Undiluted aromatic oil.*—Apply before grass is 12 inches tall. Re-treat whenever grass becomes 12 inches. The number of applications needed depends on vigor of the grass—usually four to nine. Apply about 160 gallons oil per acre for the first application; decrease the volume as the stand of grass is thinned.

(3) *TCA.*—Apply to regrowth 10 to 12 inches tall in the fall. Use 120 pounds, product, in 160 gallons water per acre.

For weedy ditchbanks where desirable grasses are to be sown, eliminate weeds by preceding methods. Delay sowing grass seed 1 month after the final chemical treatment. Apply 2,4-D amine at 1 pound per acre to grass 1 month after emergence. Re-treat until the grass stand is established if it is necessary to control invading broad-leaved weeds.

Caution.—Whenever possible, spray when the ditch is dry to avoid contamination of the water. When water is present, spray upstream to reduce the concentration of chemical in the water.

For control of rooted submersed species such as pondweeds and waterweed and for algae in Western and Great Plains irrigated areas, use one of the following chemicals.

Emulsifiable aromatic solvents (methylated benzenes such as xylene)

Apply these solvents in the canal at 5.4 to 10 gallons per c.f.s of waterflow during 30 to 60 minutes for pondweeds and waterweed. This gives 400 to 740 p.p.m. for 30 minutes, or 200 to 370 p.p.m. for 60 minutes. Add nonionic or anionic-nonionic blend emulsifiers to solvents at a concentration of 1 percent for waters over 70° F., 1.5 percent for waters between 60° and 70°, and 2 percent for waters below 60° F. Repeat treatments in regions with long growing seasons. Some of the pondweeds require up to 925 p.p.m. (12.5 gal. per c.f.s.). The water level in the ditch must cover weeds so that the herbicide contacts all plants.

For steady flowing water, spray under the surface or feed into the irrigation pump intake causing the flow. Use booster treatments of 5 gallons per c.f.s. along the ditch at intervals of 2 to 3 miles to strengthen the emulsion as it passes. One treatment gives control for 6 to 8 weeks.

For still water or dead-end ditches, spray under water. Apply continuously along the ditch from equipment mounted on a boat, an airboat, or truck. Use low and medium boiling solvents with enough chlorinated benzenes in them to make the specific gravity of the solvent mixture 1.01 to 1.03. They are effective on southern naiad and other submersed species in Southeastern United States. For the first treatment, use 40 p.p.m.; for later treatments, 20 p.p.m. every 20 to 24 months. In sandy soils, use 80 p.p.m. for the first treatment and 40 p.p.m. every 6 to 9 months. If ditches are inaccessible, drain and refill with treated water.

Use the following formula to compute the amount of herbicide required for a still-water ditch:

$$V = A \times L \times C \times \frac{7.5}{1{,}000{,}000}$$

where V = gallons of herbicide; A = cross-section

area of ditch, in square feet; L=length of ditch, in feet; and C=desired concentration of the solvent, in p.p.m.

An application of 100 p.p.m. is equivalent to 4 gallons herbicide per square foot of cross-section area for every mile of ditch.

The warmer and more quiet waters prevalent in water-control canals of Southeastern States permit much longer exposure times to treatment and make possible control of waterweeds with much lower concentrations of herbicides than are necessary in colder and rapidly flowing water in canals of Western and Great Plains States. For control of rooted submersed species such as southern naiad, coontail, and bladderwort, use emulsifiable aromatic solvents at 20 to 200 p.p.m. during a continuous treatment period of 24 to 48 hours. Gasoline mixtures with polychlorobenzenes at similar concentrations and exposure times give good control in Florida.

Caution.—These solvents kill fish and may kill all aquatic life. They are irritating to the skin. Keep all fire away; the low-boiling type flashes as easily as gasoline; the medium-boiling types also ignite readily. Use hose and fittings that are resistant to oil and solvent. Do not inhale solvent vapors. Naptha fumes are toxic to fish and waterfowl.

Aromatic solvents

Apply aromatic solvents at 100 to 150 p.p.m. during a 15-minute period for control of filamentous green algae in western irrigation canals. Aromatic solvents usually are more economical than mechanical methods of weed control in canals up to 70 c.f.s., and frequently they are used in canals of 100 to 200 c.f.s where water is used for sprinkler irrigation.

Caution.—See precautions for applying emulsifiable aromatic solvents.

Copper sulfate

Use copper sulfate for control of filamentous green algae in water flowing at one-half foot or more per second and apply at three-quarters to 2 pounds per c.f.s. Repeat treatments at intervals of 2 to 6 weeks.

Caution.—See precautions on page 54.

Acrolein

Apply acrolein at 1 to 2½ gallons per c.f.s. during 1 to 4 hours. This treatment has proved even more effective than aromatic solvents. Each application usually gives control for 4 to 8 weeks.

Caution.—Because of difficulty in handling and its severe irritation to eyes and respiratory passages, a safe application procedure has been designed for use only by skilled operators with specialized equipment.

Pentachlorophenol

Apply pentachlorophenol at 1-percent to 2-percent concentration for weeds protected from sun and wind, as in deep drainage ditches. Use 2 percent to 5 percent for hard-to-kill species.

Caution.—See precautions on page 39.

In Reservoirs and Large Canals Carrying Water for Potable or Industrial Uses

For control of algae or rooted submersed aquatic species in slowly moving water, use copper sulfate and apply continuously. Use enough to maintain 0.6 to 1.0 p.p.m. concentration in the water throughout the growing season. The amount of copper that dissolves is influenced by the hardness of the water. Provide a concentration of 1.0 p.p.m. early in the season, and reduce it gradually after midsummer to as low as 0.6 p.p.m. late in the growing season. These rates give adequate control and are well below the maximum permitted concentration of 3.0 p.p.m. copper ion or 7.5 p.p.m. copper sulfate in potable water supplies, as established by the U.S. Public Health Service.

Concentrations of 0.1 to 4 p.p.m. can be lethal, but are tolerated in hard alkaline water by resistant fish such as large-mouthed bass.

Emersed and Marginal Weeds

Emersed and marginal weeds are rooted beneath the surface but rise above the waterline. The more common emersed species in regions of their adaptation are alligatorweed, arrowhead, bulrushes (or tules), burreed, cattails, emergent parrotfeather, grasses, lotus, pickerelweed, primrose-willow, reeds, rushes, sedges, smartweeds, spatterdock, spikerushes, swamp-loosestrife, waterchestnut, watercress, waterlilies, waterprimrose, and watershield. Alligatorweed, reeds, and smartweeds frequently grow entirely emersed from water on ditchbanks and wetlands with their roots extended into saturated soil. In general, control the emersed aquatic weeds with the same herbicides that are effective on ditchbank weeds. (See pp. 38 and 55.)

Broad-Leaved Species

For most broad-leaved emersed species, spray the foliage with 2,4-D, 2,4,5-T, or silvex at 2 pounds, acid equivalent, in 100 gallons water per acre. Add 6 ounces wetting agent for plants with waxy leaves or mix the 2,4-D with 100 gallons diesel oil. Repeat application in 2 or 3 months. Cover all leaves and stems thoroughly. Do not spray when vegetation is wet with dew or rain.

For control of arrowhead, lotus, pickerelweed, Pennsylvania and water smartweed, spatterdock,

waterlilies, and waterprimrose, use low-volatile esters of 2,4-D at 1 to 4 pounds per acre and apply in oil or oil-water emulsion in sufficient volume to cover foliage thoroughly. Of these weeds, arrowhead and spatterdock are hardest to kill.

Caution.—For 2,4-D in oil-water emulsions, mix 2,4-D and oil before adding water. Keep the emulsion agitated while spraying.

Grass and Grasslike Species

For most grass or grasslike species use amitrole or dalapon. (See pp. 6, 10, and 55.) Usually the emersed aquatic weeds, especially in ditches with running water, are less susceptible to soil-sterilant herbicides than are ditchbank weeds.

Cattails and Bulrushes

Use the low-volatile ester formulation of 2,4-D at 4 to 6 pounds in a 1 to 20 oil-water emulsion and apply as a foliage spray. Use 150 to 300 gallons per acre. Make the first treatment just before heading stage of the weeds and repeat as necessary on regrowth. About three applications over a 2-year period are necessary for complete control.

Apply dalapon at 15 to 30 pounds, acid equivalent, per acre in late summer or early autumn at least 2 weeks before the first frost. Add oil at the rate of 5 to 10 gallons per acre or add a good wetting agent to the spray solution to improve results. Repeat applications as necessary. For spot spraying with spray gun, dissolve 10 pounds in 100 gallons water and wet all foliage thoroughly.

Caution.—See precautions on pages 30, 37, and 46.

Apply amitrole at 6 to 12 pounds, active ingredient, per acre at the same time and in the same way as dalapon.

The treatments with dalapon and amitrole are more expensive than the 2,4-D treatment, but are safer to use near crops extremely sensitive to 2,4-D. Use reasonable care, however, to prevent herbicide treatments from drifting.

Dalapon-silvex mixture at 5 to 6 gallons per acre, erbon at 40 pounds per acre, and fenuron-TCA, emulsifiable, at 3 gallons (9 lb.) per acre are promising for control of cattails.

WEED SPECIES AND HERBICIDES FOR CONTROL

This section consists of a table in which the response of weeds to herbicides is given.

The weeds are listed in alphabetical order by common names. Genus, species, and, in some instances, variety are given where response to herbicides is specific and information is available.

In the "Response to herbicides" column, S means susceptible, I means intermediate, and R means resistant. S and I represent ranges in response. The response of a plant to an application of herbicide depends not only on the species but also on the age of the plant, the rate of herbicide used, 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 described as S to a herbicide may vary from a susceptible reaction if treated at the optimum time, with the optimum rate, and under the optimum environment to a more tolerant reaction under conditions less favorable for control. A weed described as I may vary from tolerant to resistant; its response depends on age when treated, rate of herbicide used, and environmental conditions.

When a weed is susceptible (S), it can be killed with moderate rates of a herbicide. If it is intermediate in reaction (I), it is severely injured or partially controlled by higher rates. If it is resistant (R), control with the herbicide is not feasible.

The list of chemicals to which the response of a weed species is listed as S or I or R is not complete. The absence of any chemical from the list does not imply that it could not be used or that it should not be used. Its absence means only that it has not been tried sufficiently or in direct comparison with other chemicals by impartial investigators at this time (1963). Additions to the list can be made when such information becomes available.

TABLE 5.—*Weed species and herbicides for control*

[A, annual; Aq, aquatic; B, biennial; P, perennial; W, woody; S, susceptible; I, intermediate; R, resistant; pagination includes only those pages on which additional information is given]

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Absinthe (*Artemisia absinthium*)	A		S	Amitrole; 2,4-D; 2,3,6-TBA
	A		R	Erbon
African-rue (*Peganum harmala*)	P		I	Silvex; 2,4,5-T
Agrimony (*Agrimonia gryposepala*)	P		R	2,4-D
Alder:				
(*Alnus* spp.)	W		S	AMS; fenuron; MCPA; silvex; 2,4-D; 2,4,5-T
black	W		S	Brush killer
speckled	W		S	Do.
tag	W		S	2,4-D + TCA; 2,4,5-T + TCA
Alfilaria (*Erodium cicutarium*)	A or B		S	DCPA
Algae	Aq	53, 55		
(*Anabaena*)	Aq	54, 56	S	Copper sulfate; dichlone; diquat
(*Aphanizomenon*)	Aq	54, 56	S	Copper sulfate; dichlone
(*Chara* spp.)	Aq	54, 56	S	Copper sulfate; diquat
	Aq		R	Dichlone; endothall
(*Cladophora*)	Aq	11, 54, 56	S	Copper sulfate; diquat; endothall; simazine; sodium arsenite
	Aq		R	Dichlone; monuron
(*Hydrodictyon*)	Aq	54, 56	S	Copper sulfate; diquat; endothall; simazine; sodium arsenite
	Aq		R	Dichlone, monuron
(*Lemna minor*). (*See* Duckweed, common.)				
(*Mycrocystis*)	Aq	54, 56	S	Copper sulfate; dichlone
	Aq		R	2,4-D
(*Mougeotia*)	Aq	54, 56	S	Copper sulfate; sodium arsenite
(*Oedogonium*)	Aq	54, 56	S	Do.
(*Oscillatoria*)	Aq	54	S	Diquat
	Aq		R	Dalapon
(*Pithophora*)	Aq	11, 54	S	Endothall; silvex; simazine; sodium arsenite
	Aq		R	Copper sulfate
(*Spirogyra*)	Aq	11, 54, 56	S	Copper sulfate; endothall; sodium arsenite
(*Zygnema*)	Aq	54, 56	S	Copper sulfate; sodium arsenite
	Aq		R	Dichlone
Alligatorweed (*Alternanthera philoxeroides*).	Aq	56	I	Silvex; 2,4-D
	Aq		R	Amitrole; MCPA
Alyssum, hoary (*Beteroa incana*)	B or P		S	Amitrole; 2,4,5-T
	B or P		I	MCPA, 2,4-D
Amaranth:				
green (*Amaranthus hybridus*)	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
Palmer (*A. palmeri*)	A		S	Do.
Ammannia (*Ammannia coccinea*)	A		S	Do.
Arrowgrass, seaside (*Triglochin maritima*).	P		I	2,4-D; 2,4,5-T
Arrowhead:				
(*Sagittaria calycina*)	Aq	54, 56	S	Diquat; MCPA; silvex; 2,4-D; 2,4,5-T
	Aq		I	Endothall
(*S. longiloba*)	Aq		S	Diquat; silvex
	Aq		I	MCPA; 2,4-D
	Aq		R	2,4,5-T
Artichoke thistle (*Cynara scolymus*)	P		S	Fortified oil
	P		I	MCPA
	P		R	2,4-D; 2,4,5-T
Ash (*Fraxinus* spp.)	W	7, 44, 45	S	Amitrole; fenac
	W		I	AMS
	W		R	Fenuron; MCPA; silvex; 2,4-D; 2,4,5-T
Aspen (*Populus* spp.)	W	45	S	AMS; fenuron; 2,4-D; 2,4,5-T
	W		I	Amitrole; 2,3,6-TBA
quaking (*P. tremuloides*)	W		S	AMS; fenuron; 2,4-D; 2,4,5-T; 2,4-D + TCA; 2,4,5-T + TCA
	W		I	Amitrole; 2,3,6-TBA
Aster:				
many-flowered (*Aster ericoides*)	P		S	2,4-D
western (*A. occidentalis*)	P		R	2,4-D; 2,4,5-T
white heath (*A. pilosus*)	P		I	Silvex; 2,4-D; 2,4,5-T
woody (*Xylorrhiza parryi*)	P		R	MCPA; silvex; 2,4-D; 2,4,5-T

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Baccharis. (*See* Coyotebrush.)				
Bachelors-button (*Centaurea cyanus*)	A		S	2,4-D
Baileya, desert (*Baileya multiradiata*)	P		S	2,4-D; 2,4,5-T
Ballmustard (*Neslia paniculata*)	A		S	2,4-D
Barberry:				
Allegheny (*Berberis canadensis*)	W		S	2,4,5-T
	W		R	Simazine; 2,4-D
Colorado (*B. fendleri*)	W		S	2,4-D
	W		R	Simazine
Barley, wild (*Hordeum jubatum*)	A		S	Dalapon
Barnyard grass (*Echinochloa crus-galli*).	A	51, 52, 55	S	Calcium and lead arsenate; chlordane; dalapon; DCPA; DMPA; TCA
	A		R	MCPA; silvex; 2,4-D; 2,4,5-T
Bassia, fivehook (*Bassia hyssopifolia*)	A		I	2,4-D
Basswood (*Tilia americana*)	W		S	Fenac
	W		I	AMS; 2,4,5-T
	W		R	2,4-D
Bearberry (*Arctostaphylos uva-ursi*)	W		I	2,4,5-T
Bedstraw:				
cleavers (*Galium aparine*)	A		S	DNBP; monuron; silvex
	A		R	MCPA; sodium arsenite; 2,4-D; 2,4,5-T
smooth (*G. mollugo*)	P		S	Silvex
	P		R	MCPA; 2,4-D; 2,4,5-T
Beech (*Fagus* spp.)	W		S	AMS
	W		R	2,4-D; 2,4,5-T
Beeplant, Rocky Mountain (*Cleome serrulata*).	A		I	2,4-D
Beggarticks (*Bidens frondosa* and *B. vulgata*).	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
Bellflower, creeping (*Campanula rapunculoides*).	P		S	2,3,6-TBA
Bellwort (*Colchicum autumnale*)	P		I	MCPA; 2,4-D
Bermudagrass (*Cynodon dactylon*)	P	35–38,	S	Dalapon; herbicidal oils and fumigants
	P	49, 55	I	Amitrole; BMM; CBM; CBMM; diuron; monuron; simazine; TCA
	P		R	MCPA; silvex; 2,4-D; 2,4,5-T
Betony, Florida (*Stachys floridana*)	P		R	2,4-D; 2,4,5-T
Bindweed:				
field (*Convolvulus arvensis*)	P	34, 35, 50	S	Dicamba; fenac; PBA; sodium chlorate; 2,3,6-TBA
	P		I	CBM; CBMM; diuron; MCPA; monuron; silvex; 2,4-D; 2,4,5-T
	P		R	Amitrole; amitrole-T; erbon; simazine
hedge (*C. sepium*)	P		S	MCPA; 2,4-D; 2,4,5-T
Birch (*Betula* spp.)	W		S	AMS; fenuron; 2,4,5-T
	W		I	2,4-D
Birdrape (*Brassica rapa*)	B		S	MCPA; silvex; 2,4-D; 2,4,5-T
Biscuitroot (*Lomatium leptocarpum*)	P		S	2,4,5-T
	P		I	2,4-D
Bistort, American (*Polygonum bistortoides*).	P		I	2,4-D; 2,4,5-T
Bittercress (*Cardamine* spp.)	Aq		S	MCPA; 2,4-D
Bitterweed or bitter sneezeweed (*Helenium tenuifolium*).	A		S	AMS; MCPA; silvex; 2,4-D; 2,4,5-T
	A		R	TCA
Blackberry (*Rubus* spp.)	W	36, 41,	S	AMS; fenuron; 2,4,5-T; 2,3,6-TBA
	W	45	I	Amitrole; monuron; silvex; sodium chlorate
	W		R	MCPA; simazine; 2,4-D
Black-eyed-susan (*Rudbeckia serotina*)	P		S	Silvex; 2,4-D; 2,4,5-T
Bladderwort (*Utricularia* spp.)	Aq	56	S	Aromatic solvents; erbon; silvex; sodium arsenite; 2,4,5-T
	Aq		I	2,4-D
Blessedthistle (*Cnicus benedictus*)	A		S	Do.
Bloodweed (*Ambrosia aptera*)	A		S	2,4-D; 2,4,5-T
Bluebells (*Campanula rotundifolia*)	P		S	2,3,6-TBA
	P		R	2,4-D

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Bluebur. (*See* Stickseed, or sticktight, European.)				
Bluegrass, annual (*Poa annua*)	A	51, 52	S	Calcium and lead arsenate; chlordane; DCPA; DMPA; sodium arsenite
Bluemustard (*Chorispora tenella*)	A		S	Silvex; 2,4,5-T
	A		I	2,4-D
	A		R	MCPA
Bluestem, little (*Andropogon scoparius*).	P		I	Fenuron; 2,3,6-TBA
	P		R	Silvex; 2,4-D; 2,4,5-T
Bluethistle (*Echium vulgare*)	B		I	MCPA; 2,4-D; 2,4,5-T
Blueweed, Texas (*Helianthus ciliaris*)	P		S	AMS; amitrole; fenuron; 2,3,6-TBA
	P		I	2,4-D
	P		R	Silvex
Bouncing-bet (*Saponaria officinalis*)	P		R	MCPA; silvex; 2,4-D; 2,4,5-T
Boxelder (*Acer negundo*)	W	44	S	Fenuron; silvex; 2,4-D; 2,4,5-T
Bracken (*Pteridium aquilinum*)	P	35–37	S	CBM; amitrole and AMS kill fronds
	P		I	BDM; BMM; monuronTCA
	P		R	Dalapon; diuron; erbon; MCPA; monuron; silvex; sodium arsenite; sodium chlorate; 2,4-D
Brambles. (*See* Blackberry.)				
Briers. (*See* Smilax.)				
Bristlegrass:				
bur (*Setaria verticillata*)	A	55	S	Amitrole; dalapon; diuron; monuron; TCA
	A		R	Silvex; 2,4-D; 2,4,5-T
knotroot (*S. geniculata*)	P	55	S	Amitrole; dalapon; diuron; monuron; TCA
	P		R	Silvex; 2,4-D; 2,4,5-T
Bromegrass, downy (*Bromus tectorum*).	P	55	S	Amitrole; dalapon; diuron; endothall; monuron; simazine; TCA
	P		R	DCPA; silvex; 2,4-D; 2,4,5-T
Broomsedge (*Andropogon virginicus*)	P		I	Dalapon
	P		R	Silvex; 2,4-D; 2,4,5-T; 2,3,6-TBA
Broomweed:				
common (*Gutierrezia dracunculoides*).	A		S	Silvex; 2,4-D; 2,4,5-T
threadleaf (*G. microcephala*)	P		S	Do.
Buckbrush:				
coralberry (*Symphoricarpos orbiculatus*).	W	41	S	AMS; fenuron; 2,4-D
	W		I	2,4,5-T; 2,3,6-TBA
	W		R	Silvex
snowberry (*S. occidentalis*)	W	41	S	AMS; fenuron
	W		I	2,4-D; 2,3,6-TBA
	W		R	MCPA; silvex; 2,4,5-T
Buckeye:				
(*Aesculus arguta*)	W		I	AMS; MCPA
	W		R	Silvex
California (*A. californica*)	W		I	2,4-D
	W		R	Silvex; 2,4,5-T
Buckhorn, Carolina (*Rhamnus caroliniana*).	W		R	Fenuron
Buckwheat:				
tartary (*Fagopyrum tartaricum*)	A		S	Dicamba; endothall; MCPA
	A		I	Silvex; 2,4,5-T
	A		R	DMPA; 2,4-D
wild. (*See* Wildbuckwheat.)				
Buffalo-bur (*Solanum rostratum*)	A		R	MCPA; silvex; 2,4-D; 2,4,5-T
Bugleweed, creeping (*Ajuga reptans*)	P		R	MCPA; 2,4-D
Bullnettle (*Cnidoscolus stimulosus*)	P	36	S	2,4-D; 2,4,5-T
	P		I	MCPA; simazine
Bullthistle (*Cirsium vulgare*)	B		S	MCPA; silvex; 2,4-D; 2,4,5-T
Bulrush (*Scirpus* spp.)	Aq	7, 56, 57	I	Amitrole; dalapon; MCPA; silvex; 2,4-D; 2,4,5-T
	Aq		R	Copper sulfate
Burclover (*Medicago hispida*)	A	51	S	Endothall; silvex
Burcucumber (*Sicyos angulatus*)	A		S	MCPA; 2,4,5-T
	A		I	2,4-D

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Burdock:				
common (*Arctium minus*)	B		S	MCPA; silvex; 2,4-D; 2,4,5-T
	B		R	MonuronTCA
great (*A. lappa*)	B		I	MCPA; 2,4-D
	B		R	Diuron; monuron; monuronTCA
Bur-franseria (*Franseria discolor*)	P	34	S	Amitrole; fenac; PBA; 2,3,6-TBA
	P		I	MCPA; silvex; 2,4-D; 2,4,5-T
Burhead (*Echinodorus cordifolius*)	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
Burnet (*Poterium sanguisorba*)	P		R	MCPA; 2,4-D
Burning-bush. (*See* Kochia.)				
Burreed (*Sparganium americanum*)	Aq	54, 56	S	Endothall; diuron; monuron; 2,4-D
	Aq		I	Dalapon; silvex
Burroweed (*Haplopappus tenuisectus*)	P		S	2,4-D; 2,4,5-T
Bush-honeysuckle (*Diervilla lonicera*)	W		S	2,4-D
Buttercup	A, B, or P	54		
bulbous (*Ranunculus bulbous*)	P		R	MCPA; 2,4-D
celeryleaf (*R. sceleratus*)	A		I	2,4-D
corn (*R. arvensis*)	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
creeping (*R. repens*)	P	50	S	Monuron; MCPA; silvex; sodium chlorate; 2,4-D; 2,4,5-T
	P		R	Simazine
small-flower (*R. abortivus*)	A or B		S	2,4-D
tall (*R. acris*)	P		S	MCPA; silvex; 2,4-D; 2,4,5-T
Butterweed (*Senecio triangularis*)	P		I	2,4-D; 2,4,5-T
Buttonbush or buttonball (*Cephalanthus occidentalis*).	W		S	AMS; 2,4-D; 2,4,5-T
Cactus, pricklypear (*Opuntia* spp.)	W		I	Silvex; 2,4,5-T; 2,3,6-TBA
Calendula (*Calendula arvensis*)	A		R	DNC; MCPA; silvex; 2,4-D
Camels-thorn (*Alhagi camelorum*)	P		I	PBA; 2,3,6-TBA; 2,4,5-T
	P		R	Sodium chlorate
Camphorweed (*Heterotheca subaxillaris*).	A or B		I	2,4-D
Campion:				
bladder (*Silene cucubalus*)	P		R	MCPA; silvex; 2,4-D; 2,4,5-T
red (*Lychnis dioica*)	B or P		R	2,4-D; 2,4,5-T
Canarygrass, Reed (*Phalaris arundinacea*).	P	7, 36, 55	S	Amitrole-T; dalapon
	P		I	Monuron; simazine
Caragana or pea-tree (*Caragana arborescens*).	W		S	Monuron; 2,4,5-T
	W		I	AMS; diuron; simazine
Caraway (*Carum carvi*)	B		I	MCPA; 2,4-D; 2,4,5-T
	B		R	Amitrole; silvex
Carelessweed. (*See* Amaranth, Palmer.)				
Carpetgrass (*Axonopus affinus*)	P	55	S	Amitrole
Carpetweed (*Mollugo verticillata*)	A		S	DCPA; 2,4-D
	A		R	Silvex; 2,4,5-T
Carrot, wild (*Daucus carota*)	B	35	S	AMS
	B		I	MCPA; monuronTCA; silvex; 2,4-D; 2,4,5-T
	B		R	Diuron; DNBP; monuron
Catbrier. (*See* Smilax.)				
Catchfly:				
hairy (*Silene dichotoma*)	A		R	2,4-D
nightflowering (*S. noctiflora*)	A		R	Dicamba; DMPA; endothall; MCPA; silvex; 2,4-D; 2,4,5-T
sleepy (*S. antirrhina*)	A		R	2,4-D
Catclaw, mimosa (*Mimosa biuncifera*)	W		I	2,4,5-T
Catnip (*Nepeta cataria*)	P		S	2,4-D; 2,4,5-T
Cats-ear, spotted (*Hypochaeris radicata*).	P		S	MCPA; silvex; 2,4-D; 2,4,5-T
Cattail, broadleaf or common (*Typha latifolia*) and narrowleaf (*T. angustifolia*).	Aq	7, 56, 57	S	Amitrole; dalapon; 2,4-D esters
	Aq		I	Amitrole-T; erbon; silvex; 2,4,5-T
Ceanothus:				
Jersey-tea (*Ceanothus Americanus*).	W		R	CBM; CBMM
varnishleaf (*C. velutinus* var. *laevigatus*).	W		S	2,4,5-T
	W		I	2,4-D
wedgeleaf (*C. cuneatus*)	W		S	2,4-D; 2,4,5-T
	W		I	MCPA

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Centipedegrass (*Eremochloa ophiuroides*).	P	55	S	TCA
Chamise (*Adenostoma fasciculatum*)	W		I	2,4-D; 2,4,5-T
	W		R	MCPA; silvex
Chamomile:				
corn (*Anthemis arvensis*)	A or B		R	2,4-D
stinking mayweed (*A. cotula*)	A		I	MCPA; silvex; 2,4-D; 2,4,5-T
	A		R	DNBP; herbicidal oils
Chaparrel (*Ceanothus* spp.)	W		I	MCPA; 2,4-D; 2,4,5-T
Charlock. (*See* Mustard, wild.)				
Cheat or chess (*Bromus secalinus*)	A		R	DCPA; silvex; 2,4-D; 2,4,5-T
Cherry (*Prunus* spp.)	W	41, 43	S	AMS; fenuron
	W		I	Silvex; 2,4,5-T; 2,3,6-TBA
	W		R	Amitrole; 2,4-D
Chestnut (*Castanea* spp.)	W		S	AMS; fenuron
	W		I	2,4,5-T
Chickweed:				
common (*Stellaria media*)	A	2, 51	S	DCPA; dicamba; DNBP; monuron; silvex; sodium chlorate; 2,4,5-T
	A		I	2,4-D
	A		R	Endothall; MCPA
field (*Cerastium arvense*)	P		S	Silvex; 2,4,5-T
	P		I	2,4-D
	P		R	MCPA
mouse-ear (*C. vulgatum*)	P	51	S	Dicamba; silvex
	P		I	2,4-D; 2,4,5-T
	P		R	DNBP; endothall; MCPA
Chicory (*Cichorium intybus*)	P		S	MCPA; silvex; 2,4-D; 2,4,5-T
Chinaberry (*Sapindus drummondi*)	W		R	Fenuron
Chinquapin:				
(*Castanopsis sempervirens*)	W		I	2,4-D; 2,4,5-T
golden (*C. chrysophylla*)	W		R	Amitrole; silvex; 2,4-D; 2,4,5-T
Chittam (*Bumelia lanuginosa*)	W	43	S	Silvex; 2,4,5-T
Chokecherry. (*See* Cherry.)				
Cholla, jumping (*Opuntia fulgida*)	W		S	Silvex; TCA
	W		I	2,4,5-T
	W		R	2,3,6-TBA
Cinquefoil:				
blueleaf (*Potentilla diversifolia*)	P		I	2,4-D; 2,4,5-T
common (*P. canadensis*)	P		S	2,4-D
	P		I	MCPA; silvex; 2,4,5-T
rough (*P. norvegica*)	A or B		S	2,4-D
sulfur (*P. recta*)	P		S	2,4-D; 2,4,5-T
	P		I	MCPA; silvex
Cleavers. (*See* Bedstraw, cleavers.)				
Cockle, white (*Lychnis alba*)	P		S	Dicamba; PBA; 2,3,6-TBA
	P		R	MCPA; 2,4-D; 2,4,5-T
Cocklebur, common (*Xanthium pennsylvanicum*).	A	35	S	2,4-D; 2,4,5-T
	A		I	MCPA; monuronTCA
	A		R	Diuron; herbicidal oils; monuron
Coffeebean (*Sesbania exaltata*)	A		S	MCPA; silvex; 2,4,5-T
	A		I	2,4-D
Coffeeberry (*Rhamnus californica*)	W		I	Do.
Coffeetree (*Gymnocladus dioica*)	W		S	AMS
	W		I	2,4,5-T
Coffeeweed:				
(*Cassia tora*)	A		S	MCPA; 2,4-D
(*Daubentonia texana*)	A		S	Silvex; 2,4-D; 2,4,5-T
Coltsfoot (*Tussilago farfara*)	P		S	Sodium chlorate
	P		I	MCPA; 2,4-D
	P		R	Diuron; monuron
Comfrey, common (*Symphytum officinale*).	P		R	MCPA; 2,4-D
Coneflower, tall (*Rudbeckia laciniata*)	P		S	Silvex; 2,4-D; 2,4,5-T
Coontail, common (*Ceratophyllum demersum*).	Aq	54, 56	S	Aromatic solvents; dichlone; endothall; silvex; simazine; sodium arsenite; 2,4-D; 2,4,5-T; 2,3,6-TBA
	Aq		R	Copper sulfate

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Coralberry. (*See* Buckbrush, coralberry.)				
Coreopsis. (*See* Tickseed.)				
Coriander (*Bifora* spp.)	A		I	DNC
	A		R	MCPA; 2,4-D
Corncockle (*Agrostemma githago*)	A or B	2	R	MCPA; silvex; 2,4-D; 2,4,5-T
Cornflower. (*See* Bachelors-button.)				
Cotton, wild (*Hibiscus moscheutos*)	W		R	MonuronTCA
Cottonwood (*Populus deltoides*)	W	43, 44	S	AMS; 2,4-D
	W		I	2,4,5-T
	W		R	Amitrole
Cowcockle (*Saponaria vaccaria*)	A		R	Dicamba; MCPA; silvex; 2,4-D; 2,4,5-T
Cowparsnip (*Heracleum sphondylium*)	P		R	Herbicidal oil
Cowslip (*Caltha palustris*)	P		I	MCPA; 2,4-D
Coyotebrush (*Baccharis pilularis*)	W	43	S	2,4-D
	W		I	2,4,5-T
Coyotillo (*Karwinskia humboldtiana*)	P		S	Fenuron; silvex; 2,4,5-T
Crabgrass (*Digitaria* spp.)	A	51, 52	S	AMA; calcium and lead arsenate; chlordane; DCPA; DMA; DMPA; PMA; TCA
	A		R	Silvex; 2,4-D; 2,4,5-T
Cranesbill. (*See* Geranium, Carolina.)				
Creeping-charlie. (*See* Ground-ivy.)				
Creosotebush (*Larrea tridentata*)	W		S	Fenuron; fenuronTCA
	W		I	Monuron; silvex; 2,4-D; 2,4,5-T; 2,3,6-TBA
Crotolaria, showy (*Crotolaria spectabilis*).	A		I	2,4-D
Croton:				
Lindheimer (*Croton lindheimeri*)	A		S	Do.
	A		I	Silvex; 2,4,5-T
Texas (*C. texensis*)	A		S	Silvex; 2,4-D; 2,4,5-T
woolly (*C. capitatus*)	A		S	Do.
Cudweed (*Gnaphalium* spp.)	A		R	2,4-D
Currants (*Ribes* spp.)	W		S	AMS; 2,4-D; 2,4,5-T
Cutgrass (*Leersia* spp.)	P	36, 55	S	Amitrole; dalapon
	P		I	Silvex; TCA
Daisy:				
English (*Bellis perennis*)	P		I	MCPA; 2,4-D
	P		R	CBM; CBMM
oxeye (*Chrysanthemum leucanthemum*).	P		S	2,4,5-T
	P		I	MCPA; silvex; 2,4-D
Dallisgrass (*Paspalum dilatatum*)	P	35, 55	S	AMA; dalapon
	P		I	Diuron; monuron
	P		R	DMPA
Dandelion (*Taraxacum officinale*)	P	33, 37, 50	S	MCPA; silvex; sodium chlorate; 2,4-D; 2,4,5-T; 2,3,6-TBA
	P		I	BMM; CBMM
	P		R	Amitrole; DCPA; diuron; DMPA; erbon
Dayflower (*Commelina communis*)	A		S	2,4-D
Deadnettle, red (*Lamium purpureum*)	A or B		R	MCPA; 2,4-D
Deathcamas:				
foothill (*Zigadenus paniculatus*)	P		S	2,4-D
	P		I	2,4,5-T
grassy (*Z. gramineus*)	P		I	2,4-D
	P		R	Silvex
Deerbrush (*Ceanothus integerrimus*)	W		S	2,4-D
Deerweed (*Lotus scoparius*)	W		S	2,4-D; 2,4,5-T
Desert-baileya. (*See* Baileya, desert.)				
Desertparsley (*Lomatium grayi*)	P		S	MCPA; silvex; 2,4-D
Devilsclaw (*Proboscidea louisianica*)	A		S	2,4-D
Dewberry. (*See* Blackberry.)				
Diapedium ordianthera (*Justicia* spp.)	A		I	Diquat

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Dock:				
broadleaf (*Rumex obtusifolius*)	P		S	Silvex; 2,4-D; 2,4,5-T
	P		I	MCPA
curly (*R. crispus*)	P	35, 36,	S	2,4-D; 2,4,5-T
	P	50	I	MCPA; monuronTCA; sodium chlorate
	P		R	Silvex
fiddle (*R. pulcher*)	P		S	2,4-D
smooth, or pale (*R. altissimus*)	P		S	MCPA; silvex; 2,4-D; 2,4,5-T
veiny (*R. venosus*)	P		I	2,4-D
	P		R	Diuron; monuron; simazine
Dodder (*Cuscuta* spp.)	A		S	Herbicidal oils
	A		R	MCPA; silvex; 2,4-D; 2,4,5-T
Dogbane. (*See* Indian hemp.)				
spreading (*Apocynum androsaemifolium*).	P		S	2,4-D
Dogfennel:				
(*Eupatorium capillifolium*)	A		S	Dicamba; silvex; 2,4-D; 2,4,5-T
yellow. (*See* Bitterweed or bitter sneezeweed.)				
Dogmustard (*Erucastrum gallicum*)	A		S	MCPA; 2,4,-D
Dogwood:				
(*Cornus* spp.)	W		S	Fenuron
	W		I	Silvex; 2,4-D; 2,4,5-T
	W		R	Amitrole; simazine
flowering (*C. florida*)	W		S	2,4,5-T
Dokewood. (*See* Oak, post.)				
Ducksalad (*Heteranthera limosa*)	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
Duckweed, common (*Lemna minor*)	A	53	S	Copper sulfate; diquat; OCH; sodium arsenite
	A		R	Dichlone; herbicidal oils; silvex; 2,4-D; 2,4,5-T
Eelgrass. (*See* Wildcelery.)				
Elderberry (*Sambucus* spp.)	W	41, 47	S	AMS; 2,4,5-T
	W		I	2,4-D
	W		R	Amitrole; diuron; fenuron; monuron
Elm:				
(*Ulmus* spp.)	W	41, 43,	S	AMS; monuron
	W	47	I	Silvex; 2,4,5-T
	W		R	Amitrole; fenuron; MCPA; 2,4-D
winged (*U. alata*)	W	45	S	Fenuron
Elodea. (*See* Waterweed.)				
Eucalyptus (*Eucalyptus* spp.)	W		S	AMS
	W		I	Sodium arsenite
Euonymus (*Euonymus fortune* var. *vegetus*).	W	36	I	AMS; diuron; DNBP; simazine; TCA
	W		R	Dalapon
Evening-primrose, common (*Oenothera biennis*).	B		S	Silvex; 2,4-D; 2,4,5-T
False-chamomile. (*See also* Mayweed, scentless.)	A		R	2,4-D
Falseflax (*Camelina* spp.)	A		S	Amitrole; 2,4-D
	A		R	Dicamba; DMPA
False-hellebore, California (*Veratrum californicum*).	P		S	2,4-D
Fanweed. (*See* Pennycress, field.)				
Fanwort (*Cabomba caroliniana*)	Aq	54	S	Silvex; simazine; sodium arsenite; 2,4-D
	Aq		R	Dichlone; diquat; endothall
Fennel, common or sweet (*Foeniculum vulgare*).	P		R	DNBP; herbicidal oils
Fiddleneck, coast (*Amsinckia intermedia*).	A		S	Silvex; 2,4-D; 2,4,5-T
	A		I	MCPA
	A		R	Sodium arsenite
Fieldcress, Austrian (*Rorippa austriaca*).	P		I	2,4-D
Fieldmadder (*Sherardia arvensis*)	A		R	Do.
Filaree, redstem (*Erodium cicutarium*)	A or B		S	DCPA; 2,4-D
Fir:				
balsam (*Abies balsamea*)	W	47	I	AMS
	W		R	Amitrole; 2,4-D
red (*A. magnifica*)	W		R	2,4-D
white (*A. concolor*)	W		R	Do.

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Fleabane:				
annual (*Erigeron annuus*)	A		S	Silvex; 2,4,5-T
	A		I	MCPA; 2,4-D
Oregon (*E. speciosus*)	P		I	2,4-D
rough or daisy (*E. strigosus*)	A or B		S	Silvex; 2,4-D; 2,4,5-T
Flixweed (*Descurainia sophia*)	A or B		S	2,4-D
	A or B		I	MCPA
Florida-pusley (*Richardia scabra*)	A		S	DCPA; 2,4-D
	A		R	Herbicidal oils
Flower-of-an-hour (*Hibiscus trionum*)	A		S	MCPA; 2,4-D; 2,4,5-T
Foolsparsley (*Aethusa cynapium*)	A		R	Herbicidal oils
Four-o'clock, wild (*Mirabilis nyctaginea.*)	P		S	2,4-D
	P		R	Erbon
Foxtail (*Setaria* spp.)	A	51, 52, 55	S	AMA; atrazine; calcium and lead arsenate; chlordane; dalapon; DCPA; simazine; TCA
	A		R	Silvex; 2,4-D; 2,4,5-T
Franseria, woollyleaf (*Franseria tomentosa*).	P		S	Amitrole; fenac; 2,3,6-TBA
	P		I	MCPA; silvex; 2,4-D; 2,4,5-T
Frenchweed. (*See* Pennycress, field.)				
Fumitory, common (*Fumaria officinalis*).	A		S	DNC
	A		R	2,4-D
Galinsoga, hairy (*Galinsoga ciliata*)	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
and smallflower (*G. parviflora*).	A		R	DCPA
Gallberry (*Ilex glabra*)	W		I	2,4,5-T
Garlic, wild (*Allium vineale*)	P	50, 51	S	Dicamba; methyl bromide; SMDC; 2,3,6-TBA
	P		I	Dalapon; fenac; MH; 2,4-D
	P		R	Amitrole; MCPA; silvex; 2,4,5-T
Geranium, Carolina (*Geranium carolinianum*).	A or B		S	MCPA; silvex; 2,4-D; 2,4,5-T
Goatsbeard:				
(*Tragopogon dubius*)	B or P		S	MCPA; 2,4-D
(*T. pratensis*)	B		S	2,4-D
common (*T. porrifolius*)	B or P		S	Do.
Goatsrue (*Galega officinalis*)	P		I	2,4-D; 2,4,5-T
Goatweed. (*See* Croton, Lindheimer.)				
Golden-aster, false (*Chrysopsis* spp.)	P	37	I	BMM
	P		R	Simazine; TCA
Goldenchain-tree (*Laburnum anagyroides*).	W		I	Dalapon; TCA
Goldenfleece (*Haplopappus arborescens*).	W		I	2,4-D
Goldenrod (*Solidago* spp.)	P		S	AMS
	P		I	2,4-D
Gooseberries:				
(*Ribes oxyacanthoides* and *R. roezlii*).	W		S	Do.
most other *Ribes* spp.	W		S	2,4,5-T
Goosefoot:				
Jerusalem (*Chenopodium botrys*)	A		I	2,4-D
nettleleaf (*C. murale*)	A		S	MCPA; 2,4-D; 2,4,5-T
	A		R	Endothall
oakleaf (*C. glaucum*)	A		S	MCPA; 2,4-D; 2,4,5-T
	A		I	Silvex
	A		R	Endothall
spear-leaved (*Monolepis nuttalliana*).	A		R	MCPA; 2,4-D
Goosegrass (*Eleusine indica*)	A	51, 52	S	Calcium and lead arsenate; chlordane; DCPA; DMPA
	A		R	Silvex; 2,4-D; 2,4,5-T
Gooseweed (*Sphenoclea zeylanica*)	A		I	2,4-D; 2,4,5-T
	A		R	MCPA; silvex
Gorse (*Ulex europaeus*)	W		I	2,4-D; 2,4,5-T
	W		R	Sodium chlorate
Gourd, buffalo or wild (*Cucurbita foetidissima*).	P		S	Do.
	P		R	2,4-D
Goutweed, bishops (*Aegopodium podograria*).	P		R	Do.

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Grape-hyacinth (*Muscari botryoides*)	P		R	MCPA
Greasewood (*Sarcobatus vermiculatus*)	W		I	2,4-D
Greenbrier (*Smilax bona-nox*)	W		S	AMS
	W		I	FenuronTCA
	W		R	Amitrole; MCPA; monuron TCA; silvex; 2,4-D; 2,4,5-T; 2,3,6-TBA
Gromwell:				
common (*Lithospermum officinale*).	P		R	2,4-D
corn (*L. arvense*)	A		S	DNC
	A		I	2,4-D
	A		R	MCPA
Groundcherry:				
clammy (*Physalis heterophylla*)	W		I	Silvex; 2,4,5-T
and purple-flower (*P. lobata*).	W		R	2,4-D
smooth (*P. subglabrata*)	W		R	MCPA; silvex; 2,4-D; 2,4,5-T
Wrights (*P. wrightii*)	A		S	Silvex; 2,4-D; 2,4,5-T
Ground-ivy (*Glechoma hederacea*)	P		S	Monuron; silvex
	P		I	2,4-D; 2,4,5-T
	P		R	MCPA
Groundsel:				
arrowleaf (*Senecio triangularis*)	P		I	2,4-D; 2,4,5-T
common (*S. vulgaris*)	A		S	Monuron; sodium chlorate
	A		R	MCPA; silvex; 2,4-D; 2,4,5-T
cressleaf (*S. glabellus*)	A		S	Do.
riddell (*S. riddellii*)	P		S	2,4-D
tansy-ragwort. (*See* Tansy-ragwort.)				
threadleaf (*S. longilobus*)	P		I	2,4-D
Guava, common (*Psidium guajava*)	W		S	Fenuron; 2,4,5-T
Gum, black (*Nyssa sylvatica*)	W	44	S	AMS
	W		I	Fenuron; silvex; 2,4,5-T
	W		R	Amitrole; 2,4-D
Gumweed (*Grindelia squarrosa*) and (*G. perennis*).	P		S	MCPA; 2,4-D
Hackberry (*Celtis occidentalis*)	W		S	AMS; fenuron; 2,4,5-T
	W		R	Amitrole
Halogeton (*Halogeton glomeratus*)	A		S	PBA; 2,3,6-TBA
	A		I	2,4-D
	A		R	MCPA; silvex; 2,4,5-T
Hares-ear-mustard (*Coringia orientalis*).	A		S	MCPA; 2,4-D
Hawkbit:				
fall (*Leontodon autumnalis*)	P		I	2,4-D
rough (*L. nudicaulis*)	P		I	Do.
Hawksbeard, smooth (*Crepis capillaris*)	A or B		R	CBM; CBMM; MCPA; silvex; 2,4-D; 2,4,5-T
Hawkweed:				
mouse-ear (*Hieracium pilosella*)	P		S	MCPA; 2,4-D
orange (*H. aurantiacum*)	P		I	2,4-D
	P		R	CBMM; MCPA; 2,4,5-T
yellow (*H. pratense*)	P		I	2,4-D
	P		R	MCPA; 2,4,5-T
Hawthorn:				
(*Crataegus* spp.)	W	47	I	AMS; fenuron; 2,4,5-T
	W		R	Amitrole; MCPA; monuron; monuronTCA; silvex; 2,4-D
fleshy (*C. succulenta*)	W		I	2,4-D; 2,4,5-T
Hazel (*Corylus* spp.)	W	41	I	Fenuron; 2,4-D; 2,4,5-T
	W		R	Amitrole
Heal-all (*Prunella vulgaris*)	P		S	2,4-D
	P		R	MCPA; silvex; 2,4,5-T
Hedgemustard (*Sisymbrium officinale*)	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
Heliotrope, wild (*Heliotropium* spp.)	W		I	Erbon
	W		R	Sodium chlorate
Hemlock (*Tsuga canadensis*)	W		R	Simazine; 2,4-D; 2,4,5-T
Hemp, wild (*Cannabis sativa*)	A		S	2,4-D; 2,4,5-T
Hempnettle (*Galeopsis tetrahit*)	A		S	Amitrole
	A		I	MCPA
	A		R	2,4-D

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Henbane, black (*Hyoscyamus niger*)	A		R	2,4-D
Henbit (*Lamium amplexicaule*)	A		S	Silvex
	A		I	2,4,5-T
	A		R	MCPA; 2,4-D
Hickory (*Carya* spp.)	W	45	S	AMS
	W		I	Amitrole; fenuron; fenuronTCA; MCPA; monuron; silvex; 2,4,5-T
	W		R	2,4-D; 2,3,6-TBA
Hoarycress. (*See* Whitetop.)				
Hogpeanut (*Amphicarpa bracteata*)	P		S	2,4-D
Hogpotato (*Hoffmanseggia densiflora*)	P		S	Fenac; 2,3,6-TBA
	P		R	MCPA; silvex; 2,4-D; 2,4,5-T
Honeylocust (*Gleditsia triacanthos*)	W		I	AMS; 2,4,5-T
	W		R	2,4-D
Honeysuckle (*Lonicera* spp.)	W	36, 41	S	AMS; amitrole; fenac; MCPA; silvex; TCA
	W		I	Diuron; DNBP; simazine; 2,4-D; 2,4,5-T
Hophornbeam (*Ostrya virginiana*)	W		S	AMS
	W		I	2,4,5-T
	W		R	Fenuron
Hornwort. (*See* Coontail, common.)				
Horsebrush, littleleaf (*Tetradymia glabrata*).	W		R	2,4-D; 2,4,5-T
Horsenettle, Carolina (*Solanum carolinense*).	P	36	S	Amitrole
	P		I	Atrazine; simazine; 2,4,5-T
	P		R	MCPA; 2,4-D; 2,3,6-TBA
Horsetail, field (*Equisetum arvense*)	P	36, 37	S	Atrazine; 2,3,6-TBA
	P		I	Amitrole; BMM; erbon; MCPA; sodium chlorate
	P		R	Diuron; monuron; monuronTCA; silvex; 2,4-D; 2,4,5-T
Horseweed, marestail (*Erigeron canadensis*).	A	37	S	Silvex; 2,4,5-T
	A		I	BMM; MCPA; 2,4-D
Houndstongue (*Cynoglossum officinale*)	B	35	I	Diuron; monuron; monuronTCA; 2,4-D
Huisache (*Acacia farnesiana*)	W		R	2,4-D; 2,4,5-T
Hydrangea, smooth (*Hydrangea arborescens*).	W		S	2,4-D
Indian hemp (*Apocynum cannabinum*)	P		S	Atrazine
	P		I	2,4-D
	P		R	Amitrole; MCPA; 2,4,5-T
Indian mallow. (*See* Velvetleaf.)				
Indian-rushpea. (*See* Hogpotato.)				
Indian-tobacco (*Lobelia inflata*)	A		I	2,4-D
Indigo, curly (*Aeschynomene virginica*)	A		S	2,4,5-T
	A		I	MCPA; silvex; 2,4-D
Iris, Rocky Mountain (*Iris missouriensis*).	P		I	2,4-D
	P		R	Silvex; 2,4,5-T
Ironweed, western (*Vernonia baldwini*).	P		S	Amitrole; 2,4-D; 2,4,5-T
	P		R	Silvex
Ironwood. (*See* Hophornbeam.)				
Ivy, English (*Hedera helix*)	P		S	2,4,5-T
	P		I	2,4-D
Jerusalem-artichoke (*Helianthus tuberosus*).	P		S	2,4-D; 2,4,5-T
Jewelweed (*Impatiens pallida*)	A		S	2,4-D
Jimmyweed (*Haplopappus pluriflorus*)	P		I	2,4-D; 2,4,5-T
Jimson-weed (*Datura stramonium*)	A		S	MCPA; 2,4-D; 2,4,5-T
	A		R	DCPA
Johnsongrass (*Sorghum halepense*)	P	35, 38, 55	S	BMM; CBM; dalapon; herbicidal oils; sodium chlorate; TCA
	P		I	CBMM; erbon; fenac; monuron; monuronTCA; 2,3,6-TBA
	P		R	Amitrole; amitrole-T; MH; silvex; simazine; 2,4-D; 2,4,5-T
Jointvetch, northern. (*See* Indigo, curly.)				

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Juniper:				
(*Juniperus* spp.) (*See also* Redcedar, eastern.)	W	36, 45	S	Amitrole; diuron; fenuron; monuron; 2,3,6-TBA
	W		I	AMS; simazine
	W		R	Silvex; 2,4-D; 2,4,5-T
(*J. horizontalis 'plumosa'*)	W		S	Simazine
Kidneywort baccharis. (*See* Coyotebrush.)				
Kikuyugrass (*Pennisetum clandestinum*).	P	36, 37,	S	CBM; erbon
	P	55	I	Dalapon; sodium chlorate; TCA
	P		R	Amitrole
Kinghead. (*See* Ragweed, giant.)				
Klamath-weed. (*See* St.-Johns-wort.)				
Knapweed:				
black (*Centaurea nigra*)	P		S	2,4-D
brown (*C. jacea*)	P		I	Do.
diffuse (*C. diffusa*)	B		S	Do.
	B		R	MCPA; silvex; 2,4,5-T
Russian (*C. repens*)	P	34, 37	S	AMS; BDM; CBM; erbon; fenac; PBA; sodium chlorate; 2,3,6-TBA
	P		I	BMM; CBMM
	P		R	Amitrole; amitrole-T; MCPA; silvex; simazine; 2,4-D; 2,4,5-T
spotted (*C. maculosa*)	B		S	MCPA; silvex
	B		I	2,4-D; 2,4,5-T
squarrose (*C. squarrosa*)	P		I	2,4-D
Knawel, annual (*Scleranthus annuus*)	A		S	Silvex
	A		R	MCPA; 2,4-D; 2,4,5-T
Knotweed:				
Japanese. (*See* Smartweed, Japanese.)				
prostrate (*Polygonum aviculare*)	A	51	S	Dicamba; DMPA; DNBP; monuron; sodium chlorate
	A		I	Silvex; 2,4-D; 2,4,5-T
	A		R	MCPA; sodium arsenite
Sakhalin (*P. sachalinense*)	P		S	2,4-D
silversheath (*P. argyrocoleon*)	A		I	Do.
Kochia (*Kochia scoparia*)	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
	A		R	Erbon; sodium chlorate
Kudzu (*Pueraria lobata*)	P		I	MCPA; silvex; 2,4-D; 2,4,5-T
Ladysmantle (*Alchemilla arvensis*)	P		S	DNC
	P		R	MCPA; 2,4-D
Ladysthumb. (*See* Smartweed, ladysthumb.)				
Lambsquarters, common (*Chenopodium album.*)	A		S	DCPA; MCPA; silvex; 2,4-D; 2,4,5-T
	A		R	Endothall
Lantana (*Lantana camara*)	W		S	BMM; CBMM; fenuron
	W		R	MonuronTCA
Larch (*Larix* spp.)	W		I	2,4-D; 2,4,5-T
Larkspur:				
duncecap (*Delphinium occidentale*).	P		I	Silvex; 2,4,5-T
	P		R	MCPA; 2,4-D
little (*D. bicolor*)	P		R	Silvex; 2,4-D; 2,4,5-T
menziesii (*D. menziesii*)	P		I	2,4-D; 2,4,5-T
tall (*D. barbeyi*)	P	36	S	Silvex plus 2,4,5-T
	P		I	Fenuron; silvex; TCA
	P		R	Amitrole; MCPA; 2,4-D; 2,4,5-T
Leatherwood (*Dirca palustris*)	W		S	2,4-D
Leptotaenia, carrotleaf (*Leptotaenia multifida*).	P		S	2,4,5-T
	P		I	2,4-D
Lettuce:				
blue (*Lactuca pulchella*)	P		I	MCPA; silvex; 2,4-D; 2,4,5-T
prickly or wild (*L. scariola*)	A		S	Atrazine; BMM; MCPA; 2,4-D
Licorice, wild (*Glycyrrhiza lepidota*)	P		I	CBMM; 2,4-D
Lilac (*Syringa vulgaris*)	W		S	2,4,5-T
Linden. (*See* Basswood.)				

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Locoweed:				
bigbend (*Astragalus earlei*)	A or P		S	2,4-D
white. (*See* White-locoweed.)				
Locust, black (*Robinia pseudoacacia*)	W	7,	S	Amitrole; fenuron; silvex; 2,3,6-TBA; 2,4,5-T
	W	45–47	I	AMS; monuron; 2,4-D
Loosestrife:				
purple or spiked (*Lythrum salicaria*).	Aq		S	Silvex
	Aq		I	2,4-D
swamp. (*See* Swamp-loosestrife.)				
Lotebush or lotewood (*Condalia obtusifolia*).	W		S	2,4-D; 2,4,5-T
Lotus, American (*Nelumbo lutea*)	Aq	56	S	AMS; silvex; 2,4-D; 2,4,5-T
	Aq		R	Dalapon
Lupine:				
(*Lupinus rivularis*)	W		S	2,4-D; 2,4,5-T
silvery (*L. argenteus*)	P		S	Silvex; 2,4,5-T
	P		I	2,4-D
	P		R	MCPA
tailcup (*L. caudatus*)	P		S	2,4-D
Madrone (*Arbutus menziesii*)	W		I	2,4-D; 2,4,5-T
Magnolia (*Magnolia* spp.)	W		S	2,4,5-T
Maidencane (*Panicum hemitomon*)	Aq		S	Dalapon
	Aq		I	Monuron; TCA
	Aq		R	Amitrole; BMM; 2,3,6-TBA
Mallow:				
alkali. (*See* Sida, alkali.)				
common or cheese (*Malva neglecta*).	A or B		R	MCPA; silvex; 2,4-D; 2,4,5-T
dwarf or roundleaf (*M. rotundifolia*).	P		I	2,4-D
	P		R	DNBP; herbicidal oils
Indian. (*See* Velvetleaf.)				
little (*M. parviflora*)	A		I	2,4-D
	A		R	MCPA
Venice. (*See* Flower-of-an-hour.)				
Mannagrass, water. (*See* Sweetgrass, floating.)				
Manzanita:				
(*Arctostaphylos* spp.)	W		I	Silvex; 2,4-D; 2,4,5-T
	W		R	MCPA
greenleaf (*A. columbiana*)	W		R	2,4-D; 2,4,5-T
Maple:				
(*Acer* spp.)	W	36,	S	AMS; fenac; silvex
	W	44–47	I	Diuron; DNBP; fenuron; simazine; 2,4,5-T
	W		R	Amitrole; MCPA; 2,4-D
Norway (*A. plantanoides*)	W		I	Dalapon; TCA
Marestail. (*See* Horseweed, marestail.)				
Marigold, corn (*Chrysanthemum segetum*).	A		S	DNC
	A		R	MCPA; 2,4-D
Marsh-elder (*Iva xanthifolia*)	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
Mayweed:				
scentless (*Matricaria maritima inodora*).	A		S	Amitrole; sodium chlorate
	A		R	MCPA; 2,4-D
stinking. (*See* Chamomile, stinking mayweed.)				
Meadowsweet. (*See* Spirea.)				
Medic, black (*Medicago lupulina*)	A		S	Silvex
	A		I	MCPA; 2,4-D; 2,4,5-T
Medusahead (*Elymus caput-medusae*)	A		S	Dalapon; simazine
	A		R	Silvex; 2,4-D; 2,4,5-T
Mercury, annual (*Mercurialis annua*)	A		S	DNC
	A		R	MCPA; 2,4-D
Mescalbean. (*See* Norcalbean.)				

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Mesquite	W	43, 45		
honey (*Prosopis juliflora* var. *glandulosa*).	W		S	Fenuron
	W		I	Silvex; 2,4,5-T
	W		R	Amitrole; 2,4-D; 2,3,6-TBA
velvet (*P. juliflora* var. *velutina*)	W		S	Fenuron
	W		I	Silvex; 2,4,5-T
	W		R	MCPA; 2,4-D
Mexican-fireweed. (*See* Kochia.)				
Mexican-tea (*Chenopodium ambrosioides*).	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
Mexican-weed (*Caperonia castaneaefolia*).	A		S	Silvex; 2,4,5-T
	A		I	MCPA; 2,4-D
Milkvetch:				
(*Astralagus* spp.)	P		S	Silvex; 2,4-D; 2,4,5-T
	P		I	MCPA
narrowleaf (*A. pectinatus*)	P		S	Silvex
	P		I	2,4-D; 2,4,5-T
two-grooved (*A. bisulcatus*)	P		S	2,4-D
Milkweed:				
bloodflower (*Asclepias curassavica*).	P		S	2,4-D; 2,4,5-T
	P		I	Amitrole
broad-leaved (*A. latifolia*)	P		I	Amitrole; silvex; 2,4-D
climbing (*Ampelanus albidus*)	P		I	Erbon; PBA; 2,3,6-TBA
	P		R	2,4-D
common (*Asclepias syriaca*)	P		I	Amitrole; silvex
	P		R	Erbon; herbicidal oils; MCPA; simazine; 2,4-D; 2,4,5-T
showy (*A. speciosa*)	P		S	Silvex
	P		I	Amitrole
	P	51, 52	R	MCPA; 2,4-D; 2,4,5-T
western whorled (*A. verticillata*)	P		I	Amitrole
	P		R	MCPA; 2,4-D; 2,4,5-T
Millet, Texas (*Panicum texanum*)	A		S	Chlordane; DCPA; DMPA; lead and calcium arsenate
Mint:				
field (*Mentha arvensis*)	P		R	2,4-D
water (*M. aquatica*)	Aq		R	MCPA; 2,4-D
Mockorange (*Philadelphus virginalis*)	W	36	I	Dalapon; diuron; DNBP; simazine; TCA
Moneywort (*Lysimachia nummularia*)	P		S	2,4-D
Monolepis. (*See* Goosefoot, spear-leaved.)				
Morning-glory (*Ipomoea* spp.)	A	36	S	Silvex; 2,4-D; 2,4,5-T
	A		I	Sodium chlorate
Mountain-mahogany (*Cercocarpus montanus*).	W		R	2,4,5-T
Mountain-misery (*Chamaebatia foliolosa*).	W		S	2,4-D; 2,4,5-T
Mugwort (*Artemisia vulgaris*)	P	35	I	Monuron; monuronTCA
	P		R	MCPA; 2,4-D; 2,4,5-T
Mulberry (*Morus* spp.)	W		S	Fenuron
	W		I	Silvex
	W		R	Amitrole; 2,4-D; 2,4,5-T
Mulesears (*Wyethia amplexicaulis*)	P		S	Silvex; 2,4-D; 2,4,5-T
Mullein:				
common (*Verbascum thapsus*)	B		I	2,4,5-T
	B		R	MCPA; 2,4-D
moth (*V. blattaria*)	P		I	2,4-D; 2,4,5-T
Muskgrass. (*See* Algae, *Chara* spp.)				
Mustard:				
black (*Brassica nigra*)	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
	A		R	DCPA
Indian (*B. juncea*)	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
white (*B. hirta*)	A		S	2,4-D
wild (*B. kaber*)	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
	A		R	DCPA; endothall

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Naiad:				
(*Najas gracillima*)	Aq	53, 54	R	Diquat; endothall
southern (*N. guadalupensis*)	Aq	55, 56	S	Acrolein; aromatic solvents; dichlone; diquat; sodium arsenite
Natalgrass (*Tricholaena rosea*)	P		R	BMM; CBMM
Needle-and-thread (*Stipa comata*)	P		R	Silvex; 2,4-D; 2,4,5-T
Needlerush (*Juncus roemerianus*)	Aq		S	Diuron; monuron; silvex; 2,4-D
	Aq		I	Dalapon
	Aq		R	Erbon
Nettle:				
burning (*Urtica urens*)	A		S	2,4-D
stinging (*U. dioica*)	P		S	MCPA; monuron; 2,4-D; sodium chlorate
tall (*U. procera*)	A		S	Monuron; 2,4-D
Niggerhead (*Rudbeckia occidentalis*)	P		S	2,4-D
Nightshade:				
black or purple (*Solanum nigrum*)	A		S	Silvex
	A		I	MCPA; 2,4-D; 2,4,5-T
	A		R	CBMM
cutleaf (*S. triflorum*)	A		I	2,4-D
silverleaf (*S. elaeagnifolium*)	P		R	Fenac; silvex; 2,4-D; 2,4,5-T; 2,3,6-TBA
Nimblewill (*Muhlenbergia schreberi*)	P	51, 52	S	Calcium and lead arsenate; chlordane; DCPA; DMPA
	P		R	Amitrole; diuron; monuron; monuronTCA; 2,4-D; 2,4,5-T
Norcalbean (*Sophora secundiflora*)	W		S	Silvex; 2,4,5-T
Nutgrass, or nutsedge:				
purple (*Cyperus rotundus*)	P	37, 49,	S	Chloropicrin; methyl bromide
	P	51	I	BMM; 2,4-D
	P		R	Amitrole; CBMM; DMTT; erbon; MCPA; monuron; silvex; simazine; TCA; 2,4,5-T
yellow (*C. esculentus*)	P	36, 49,	S	Chloropicrin; methyl bromide; TCA
	P	51	I	Atrazine; 2,4-D
	P		R	CBMM; MCPA; MH; silvex; simazine; 2,4,5-T
Oak:				
black (*Quercus velutina*)	W		I	2,4,5-T
	W		R	2,4-D
blackjack (*Q. marilandica*)	W		I	Silvex; 2,4,5-T
	W		R	MCPA; 2,4-D
bluejack (*Q. douglasii*)	W	43, 45	S	Fenuron
	W		I	Silvex; 2,4,5-T
	W		R	MCPA; 2,4-D; 2,3,6-TBA
canyon live (*Q. chrysolenpis*)	W		R	2,4-D; 2,4,5-T
gambel (*Q. gambelii*)	W		I	2,4,5-T
interior live (*Q. wislizenii*)	W		R	MCPA; silvex; 2,4-D; 2,4,5-T; 2,3,6-TBA
live (*Q. virginiana*)	W		I	2,4,5-T
Oregon (*Q. garryana*)	W		I	2,4-D; 2,4,5-T
post (*Q. stellata*)	W	43, 45	S	AMS; fenuron; silvex; 2,4,5-T
	W		I	2,4-D
	W		R	MCPA; 2,3,6-TBA
red (*Q. rubra, Q. coccinea, Q. ellipsoidalis*).	W	43, 45	S	AMS; monuron
	W		I	2,4,5-T
	W		R	Amitrole
scrub (*Q. dumosa*)	W	43	I	Silvex; 2,4,5-T
	W		R	MCPA; 2,4-D
shinnery (*Q. havardii*)	W	43	S	Silvex; 2,4,5-T
	W		I	2,4-D
	W		R	Amitrole; 2,3,6-TBA
turbinella (*Q. turbinella*)	W		R	2,4,5-T
Turkey (*Q. laevis*)	W	43, 45	S	Diuron; monuron; silvex
	W		I	Fenuron; 2,4-D; 2,4,5-T
	W		R	Amitrole; AMS; 2,3,6-TBA
white (*Q. alba*)	W	43, 45	S	AMS; monuron; 2,4,5-T
	W		I	Silvex; 2,4-D
	W		R	Amitrole; MCPA

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Oats, wild (*Avena fatua* and *A. ludoviciana*).	A		S	Atrazine; dalapon; diuron; monuron; simazine; sodium arsenite
	A		R	DCPA; silvex; 2,4-D; 2,4,5-T
Onion:				
tapertip (*Allium acuminatum*)	P		I	2,4-D
wild (*A. canadense*)	P	50, 51	S	Dicamba; methyl bromide; SMDC; 2,3,6-TBA
	P		I	2,4-D
	P		R	Amitrole; dalapon; MCPA; MH; 2,4,5-T
Orache (*Atriplex patula* var. *hastata*)	A		S	2,4-D; 2,4,5-T
	A		R	Endothall; sodium arsenite
Osage-orange (*Maclura pomifera*)	W		S	AMS; 2,4,5-T
	W		I	Fenuron; silvex
	W		R	2,4-D
Oxalis. (*See* Woodsorrel, yellow.)				
Pagodatree (*Sophora japonica*)	W		R	Dalapon; TCA
Palmetto, saw (*Serenoa repens*)	W		S	Silvex
	W		I	2,4,5-T
	W		R	Monuron
Panicum (*Panicum* spp.)	P	36, 37, 51, 55	S	Calcium and lead arsenate; chlordane; DCPA; DMPA
	P		I	Atrazine; BMM; dalapon; monuron; simazine; TCA
	P		R	CBMM; 2,4-D; 2,3,6-TBA
fall (*P. dichotomiflorum*)	P	51, 52	S	Calcium and lead arsenate; chlordane; DCPA; DMPA
Paragrass (*Panicum purpurascens*)	Aq	36, 55	S	Dalapon; monuron; simazine
	Aq		I	TCA
Parrotfeather (*Myriophyllum brasilense*).	Aq	54, 56	S	Dichlone; emulsifiable solvents; endothall; monuron; silvex; 2,3,6-TBA
	Aq		I	2,4-D
Parsnip, wild (*Pastinaca sativa*)	B		S	2,4-D; 2,4,5-T
Partridgepea (*Cassia fasciculata*)	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
Paspalum (*Paspalum* spp.)	P	51, 52,	S	Amitrole; dalapon; DMA
	P	55	I	Fenuron; 2,3,6-TBA
	P		R	Diuron; monuron; monuronTCA; silvex; sodium arsenite; 2,4-D; 2,4,5-T
Passionflower, maypop (*Passiflora incarnata*).	P		S	Silvex
	P		I	2,4-D
Pea, wild (*Lathyrus aphaca*)	P		S	DNC; MCPA; 2,4-D
Pea-tree. (*See* Caragana or pea-tree.)				
Peavine (*Astragalus emoryanus*)	A		S	2,4-D; 2,4,5-T
Pecan (*Carya illinoensis*)	W	45	S	AMS
	W		R	Fenuron
Pellitoryweed (*Parietaria floridana*)	A		S	2,4,5-T
	A		R	MCPA; 2,4-D
Pennycress, field (*Thlaspi arvense*)	A	2	S	MCPA; silvex; 2,4-D; 2,4,5-T
Pennywort:				
lawn (*Hydrocotyle sibthorpioides*)	P	50, 53	S	Silvex; MCPA; 2,4-D; 2,4,5-T
water (*H. umbellata*)	Aq		S	2,4-D
Pentstemon, Rydberg (*Pentstemon rydbergii*).	P		I	Do.
	P		R	2,4,5-T
Pepperweed, or peppergrass:				
clasping (*Lepidium perfoliatum*)	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
field (*L. campestre*)	A		S	Calcium and lead arsenate; MCPA; 2,4-D; 2,4,5-T
	A		I	Silvex
greenflower (*L. densiflorum*)	A		S	2,4-D
perennial (*L. latifolium*)	P		S	MCPA
	P		I	2,4-D; 2,4,5-T
Virginia (*L. virginicum*)	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
yellowflower (*L. perfoliatum*)	A		S	Do.

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Persimmon:				
common (*Diospyros virginiana*)	W	41, 43,	S	AMS; fenuron; 2,3,6-TBA
	W	45, 47	I	Amitrole; monuron; silvex; 2,4,5-T
	W		R	2,4-D
Texas (*D. texana*)	W		S	Silvex; monuron; 2,4-D
Phragmites (*Phragmites communis*)	Aq	56	S	Amitrole; dalapon
	Aq		I	Amitrole-T; monuron
Pickerelweed (*Pontederia cordata*)	Aq	56	S	Silvex; 2,4-D; 2,4,5-T
Pigweed:				
prostrate (*Amaranthus graecizans*)	A		S	Atrazine; silvex; 2,4-D; 2,4,5-T
redroot or rough (*A. retroflexus*)	A	51	S	Atrazine; MCPA; silvex; 2,4-D; 2,4,5-T
smooth (*A. hybridus*)	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
spiny (*A. spinosus*)	A		S	Silvex; 2,4-D; 2,4,5-T
tumble (*A. albus*)	A		S	Atrazine; dicamba; MCPA; silvex; 2,4-D; 2,4,5-T
Pimpernel, scarlet (*Anagallis arvense*)	A		S	DNC
	A		I	MCPA; 2,4-D
Pincherry (*Prunus pennsylvanicum*)	W		S	2,4-D
Pine:				
jack (*Pinus banksiana*)	W	43	S	Dalapon; TCA
	W		R	2,4-D; 2,4,5-T
Jeffrey (*P. jeffreyi*)	W		R	Do.
lodgepole (*P. contorta*)	W		I	2,4,5-T
	W		R	2,4-D
red (*P. resinosa*)	W	47	S	Amitrole
	W		R	2,4-D; 2,4,5-T
white (*P. strobus*)	W	43	S	Dalapon; TCA
	W		I	2,3,6-TBA
	W		R	Amitrole; simazine; 2,4-D; 2,4,5-T
Pineappleweed:				
(*Matricaria chamomilla*)	A		R	DNBP; MCPA; 2,4-D
(*M. matricarioides*)	A		I	2,4-D
	A		R	DNBP; herbicidal oils; MCPA; silvex; 2,4,5-T
Pingue. (*See* Rubberweed, Colorado.)				
Plantain	A or P	33		
blackseed (*Plantago rugelii*)	P	50	S	MCPA; silvex; 2,4-D; 2,4,5-T
bracted (*P. aristata*)	A		S	2,4-D
common or broad-leaved (*P. major*).	P	50	S	MCPA; silvex; 2,4-D; 2,4,5-T
English or buckhorn (*P. lanceolata*).	P	50	S	Do.
slender (*P. pusilla*)	A		S	2,4-D
woolly (*P. purshii*)	A		S	Do.
Plum	W	44		
chickasaw (*Prunus angustifolia*)	W		S	AMS; fenuron
	W		I	2,4,5-T; 2,3,6-TBA
	W		R	Amitrole; silvex; 2,4-D
wild. (*See* Cherry.)				
Poison-hemlock (*Conium maculatum*)	B		S	MCPA; silvex; 2,4-D
	B		I	2,4,5-T
	B		R	Herbicidal oils
Poison-ivy (*Rhus radicans*)	W	7, 47, 48	S	Amitrole; AMS; brush killer; fenuron; silvex; 2,4,5-T
	W		I	MCPA; 2,4-D
Poison-oak (*Rhus diversiloba*)	W	7, 47,	S	Amitrole; AMS; brush killer; silvex; 2,4,5-T
	W	48	I	2,4-D
	W		R	MCPA; monuronTCA; sodium chlorate
Poison-sumac (*Rhus vernix*)	W	7, 47, 48	S	Amitrole; AMS; brush killer; 2,4,5-T
Pokeweed (*Phytolocca americana*)	P		S	Silvex; 2,4,5-T
	P		I	MCPA; 2,4-D

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Pondweed:				
(*Potamogeton* spp.)	Aq	53–55	S	Acrolein; aromatic solvents; dichlone; endothall; silvex; sodium arsenite
	Aq		I	2,4-D
horned (*Zannichellia palustris*)	Aq	54	S	Aromatic solvents; dichlone; endothall; monuron; simazine; sodium arsenite
	Aq		R	Copper sulfate
leafy (*Potamogeton foliosus*)	Aq	54	S	Diquat
sago (*P. pectinatus*)	Aq	54	S	Acrolein; diquat; simazine; sodium arsenite
	Aq		I	2,4-D
	Aq		R	Copper sulfate
Ponyfoot (*Dichondra repens*)	P	51	S	MCPA; silvex; 2,4-D; 2,4,5-T
Poolmat, common. (*See* Pondweed, horned.)				
Poorjoe (*Diodia teres*)	A		S	2,4-D; 2,4,5-T
	A		I	MCPA; silvex
Poplar, or popple:				
(*Populus tremuloides*). (*See* Aspen, quaking.)				
balsam (*P. balsamifera*)	W		S	2,4-D
Poppy:				
(*Papaver* spp.)	A		S	DNC
	A		R	MCPA; 2,4-D
Roemer (*Roemeria refracta*)	A		S	2,4-D
Povertyweed (*Iva axillaris*)	P		S	2,4-D
	P		I	PBA; 2,3,6-TBA
Prairiegrass. (*See* Rescuegrass.)				
Pricklepoppy (*Argemone intermedia*)	A		S	2,4-D
Prickly-ash, northern (*Zanthoxylum americanum*).	W		I	2,4,5-T
	W		R	2,4-D
Primrose-willow (*Jussiaea peruviana*)	Aq	56	S	Diuron; monuron; silvex; 2,4-D; 2,4,5-T
Punctureviné (*Tribulus terrestris*)	A	34	S	Fenac; 2,4-D
	A		I	MCPA; silvex; 2,4,5-T
Purslane, common (*Portulaca oleracea*)	A		S	DCPA; silvex; 2,4,5-T
	A		I	Dicamba; 2,4-D
	A		R	BMM; DMPA; endothall; erbon; MCPA
Quackgrass (*Agropyron repens*)	P	7, 35, 37, 55	S	Atrazine; amitrole-T; monuron; simazine; sodium chlorate; TCA
	P		I	Amitrole; CBM; CBMM; dalapon; erbon; fenac; MH; monuronTCA
	P		R	BDM; DMPA; silvex; 2,4-D; 2,4,5-T
Queensdelight (*Stillingia sylvatica*)	P		R	2,4-D
Rabbitbrush, grey (*Chrysothamnus nauseosus*) and yellow (*C. viscidiflorus*).	W		I	Do.
	W		R	MCPA; silvex; 2,4,5-T
Radish, wild (*Raphanus raphanistrum*)	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
	A		R	Endothall
Ragweed:				
common (*Ambrosia artemisiifolia*)	A		S	BMM; MCPA; silvex; 2,4-D; 2,4,5-T
	A		R	DCPA
giant (*A. trifida*)	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
western (*A. psilostachya*)	P		S	AMS; silvex; 2,4-D; 2,4,5-T
Ragwort, golden (*Senecio aureus*)	P	35	I	Diuron; monuron; monuronTCA
Rape, wild (*Rapistrum rugosum*)	A or B		S	DNC; MCPA; 2,4-D
Raspberry, wild black or red. (*See* Blackberry.)				
Redbay (*Persea borbonia*)	W		S	2,4,5-T
	W		R	Silvex; 2,4-D
Redbud (*Cercis canadensis* and *C. occidentalis*).	W	43	S	AMS; silvex
	W		I	Fenuron
	W		R	2,4-D; 2,4,5-T
Redcedar, eastern (*Juniperus virginiana*).	W	41	S	Diuron; fenuron; monuron
	W		R	AMS; amitrole; 2,4-D; 2,4,5-T; 2,3,6-TBA
Redstem (*Ammannia coccinea*)	A		S	MCPA; silvex; 2,4-D; 2,4,5-T

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Redtop (*Agrostis* spp.)	A or P	37, 55	S	Amitrole; diuron; methyl bromide; monuron
	A or P		I	Dalapon
	A or P		R	2,4-D; 2,4,5-T
Redvine (*Brunnichia cirrhosa*)	P		R	Herbicidal oils; MCPA; silvex; 2,4-D; 2,4,5-T
Redwood (*Sequoia sempervirens*)	W		I	2,4-D
Reed, common or giant. (*See* Phragmites.)				
Rescuegrass (*Bromus catharticus*)	A or B		S	Monuron
	A or B		R	Sodium chlorate; 2,4-D; 2,4,5-T
Rocket:				
London (*Franseria confertiflora*)	P		R	MCPA; silvex; 2,4-D; 2,4,5-T
London (*Sisymbrium irio*)	A		S	Do.
Rose	W	43		
California (*Rosa californica*)	W		I	2,4,5-T
	W		R	2,4-D
Cherokee (*R. laevigata*)	W	45	S	Monuron; silvex
	W		I	2,4-D; 2,4,5-T
Macartney (*R. bracteata*)	W		I	Silvex; 2,4-D; 2,4,5-T
	W		R	MCPA
multiflora (*R. multiflora*)	W	45	S	Monuron; 2,3,6-TBA
	W		I	Silvex; 2,4,5-T
	W		R	MCPA; simazine; 2,4-D
prairie (*R. pratincola*)	W	41	S	2,4,5-T
	W		I	2,4-D
	W		R	BMM
Woods (*R. woodsii*)	W		I	2,4,5-T
	W		R	Silvex; 2,4-D
Rubberweed:				
bitter (*Hymenoxys odorata*)	A		S	2,4-D
Colorado (*H. richardsonii*)	P		S	Do.
	P		I	PBA; 2,4,5-T; 2,3,6-TBA
Rush:				
(*Juncus* spp.)	Aq	56	S	Amitrole; atrazine; dalapon; diuron; monuron; silvex; sodium chlorate; 2,4-D
	Aq		I	Amitrole-T; MCPA
slender (*J. tenuis*)	P		S	2,4-D
Russian-pigweed (*Axyris amaranthoides*).	A		S	Do.
Russian-thistle (*Salsola kali*)	A	34	S	Dicamba; fenac; MCPA; silvex; 2,4-D; 2,4,5-T
Ryegrass (*Lolium* spp.)	A or P		S	Dalapon
Sage:				
creeping (*Salvia sonomensis*)	P		S	2,4-D; 2,4,5-T
	P		I	MCPA; silvex
meadow (*S. pratensis*)	P		I	MCPA; 2,4-D
purple (*S. leucophylla*)	P		S	2,4-D
white (*S. apiana*)	P		S	Do.
Sagebrush	W	43		
big (*Artemisia tridentata*)	W		S	2,4-D; 2,4,5-T
	W		I	Silvex
	W		R	MCPA
California (*A. californica*)	W		S	2,4-D; 2,4,5-T
fringed (*A. frigida*)	W		I	2,4-D
sand (*A. filifolia*)	W	43	S	MCPA; silvex; 2,4-D; 2,4,5-T
silver (*A. cana*)	W		I	2,4-D
St.-Johns-wort:				
Klamath-weed (*Hypericum perforatum*).	P		S	Monuron; sodium chlorate
	P		I	MCPA
	P		R	Herbicidal oils; 2,4-D
spotted (*H. punctatum*)	P	36	I	Atrazine; simazine; 2,4-D; 2,4,5-T
Salmonberry (*Rubus spectabilis*)	W		S	Amitrole; silvex; 2,4,5-T
	W		R	2,4-D; 2,3,6-TBA

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Salsify:				
common. (*See* Goatsbeard, common.)				
meadow. (*See* Goatsbeard (*T. pratensis*).)				
western (*Tragopogon major*)	B		S	2,4-D
Saltbush. (*See* Orache.)				
Saltcedar (*Tamarix gallica*)	W		S	Silvex
	W		I	2,4,5-T
	W		R	MCPA; 2,4-D
Saltgrass, seashore (*Distichlis spicata*)	P	34–36	I	Diuron; erbon; monuron; sodium arsenite; sodium chlorate
Saltwort, common. (*See* Russian-thistle.)				
Sandburs (*Cenchrus* spp.)	A	55	S	Dalapon; fortified oils; TCA
	A		R	Silvex; 2,4-D; 2,4,5-T
Sandspurry (*Spergularia segetalis*)	A or B		S	DNC
	A or B		R	MCPA; 2,4-D
Sandwort, thymeleaf (*Arenaria serpyllifolia*).	A		S	2,4-D
Saskatoon (*Amelanchier alnifolia*)	W		S	Do.
Sassafras (*Sassafras varifolium* and *S. albidum*).	W	41, 44, 45, 47	S	AMS; fenac; fenuron; fenuronTCA; monuron; 2,4-D; 2,4,5-T; 2,3,6-TBA
	W		R	Amitrole
Scotch-broom (*Cytisus scoparius*)	W		S	2,4-D; 2,4,5-T
Seamyrtle (*Baccharis halimifolia*)	W	35, 45	S	Do.
	W		I	CBMM; diuron; fenuron; monuron
Sedge (*Carex* spp.)	P	37, 56	S	Amitrole; AMA; atrazine; dalapon; herbicidal oil + DNBP
	P		I	BMM; erbon; monuron
	P		R	MCPA; 2,4-D
Sesbania. (*See* Coffeebean.)				
Shadbush or serviceberry (*Amelanchier canadensis*).	W		S	Fenuron; 2,4-D
	W		R	Amitrole
Shepherds-purse (*Capsella bursa-pastoris*).	A	2	S	MCPA; silvex; 2,4-D; 2,4,5-T
Sicklepod. (*See* Coffeeweed (*Cassia tora*).)				
Sida, alkali or mallow (*Sida hederacea*)	P	34	S	Fenac; 2,3,6-TBA
	P		I	Erbon
	P		R	Sodium chlorate; 2,4-D
Silverberry. (*See* Wolfwillow.)				
Silverweed (*Potentilla anserina*)	P		I	2,4-D
Skeletonweed (*Lygodesmia juncea*)	P		S	Do.
Skunkbrush (*Schmaltzia trilobata*)	W	41	S	Do.
	W		I	2,4,5-T
Skunkcabbage (*Symplocarpus foetidus*).	P		S	2,4-D; 2,4,5-T
	P		I	Silvex
Skunkweed. (*See* Croton, Texas.)				
Smartweed	A or P	56		
green (*Polygonum scabrum*)	A		S	Dicamba
	A		R	DMPA; endothall; MCPA; silvex; 2,4-D
Japanese (*P. cuspidatum*)	P		S	AMS; BMM; erbon; monuron; silvex; TCA
	P		I	2,4-D; 2,4,5-T
ladysthumb (*P. persicaria*)	A		S	Silvex; 2,4,5-T; 2,3,6-TBA
	A		I	MCPA
	A		R	DCPA
Pennsylvania (*P. pennsylvanicum*)	A		S	MCPA; 2,4-D; 2,4,5-T; 2,3,6-TBA
	A		I	Silvex
	A		R	BMM; DCPA
swamp (*P. coccineum*)	A		S	Diuron; monuron
	A		I	PBA; 2,3,6-TBA
	A		R	Amitrole; 2,4-D
water (*P. amphibium*)	Aq		S	2,4-D
water (*P. hydropiper*)	Aq	35	I	Amitrole; diuron; monuron

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Smilax (*Smilax* spp.)	W		S	AMS
	W		I	Fenuron
	W		R	Amitrole; MCPA; monuronTCA; silvex
Smutgrass (*Sporobolus poiretii*)	A or P	55	S	Amitrole
	A or P		R	Silvex; 2,4-D; 2,4,5-T
Snakeroot, white (*Eupatorium rugosum*).	P		I	2,4-D; 2,4,5-T
	P		R	Silvex
Snakeweed:				
broom (*Gutierrezia sarothrae*)	P		I	MCPA; 2,4-D; 2,4,5-T
	P		R	Silvex
threadleaf. (*See* Broomweed, threadleaf.)				
Sneezeweed, bitter. (*See* Bitterweed.)				
Snowberry, western. (*See* Buckbrush.)				
Snowbrush (*Ceanothus velutinus*)	W		S	2,4,5-T
	W		I	2,4-D
	W		R	Amitrole; AMS; silvex
Snow-on-the-mountain (*Euphorbia marginata*).	A		S	2,4,5-T
	A		I	2,4-D
Sorrel:				
heartwing (*Rumex hastatulus*)	P		S	Do.
red or sheep (*R. acetosella*)	P		S	Dicamba; 2,3,6-TBA
	P		I	Silvex
	P		R	Amitrole; erbon; MCPA; 2,4-D; 2,4,5-T
sour dock (*R. acetosa*)	P		S	2,4-D; 2,4,5-T
	P		I	MCPA; silvex
Sourwood (*Oxydendrum arboreum*)	W	45	S	Monuron; 2,4-D
Sowthistle:				
annual (*Sonchus oleraceus*)	A		S	MCPA; 2,4-D; 2,4,5-T
	A		R	CBM; CBMM
perennial (*S. arvensis*)	P	35	S	Dicamba; fenac; simazine; sodium chlorate; 2,3,6-TBA
	P		I	Amitrole; diuron; MCPA; monuron; monuron TCA; silvex; 2,4-D; 2,4,5-T
	P		R	CBMM
spiny (*S. asper*)	A		S	2,4-D; 2,4,5-T
Spanish-needles (*Bidens bipinnata*)	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
Spatterdock (*Nuphar advena*)	Aq	56, 57	S	Silvex
	Aq		I	2,4-D
Speedwell:				
(*Veronica* spp.)	P	50	S	Monuron; sodium chlorate
	P		I	2,4-D
	P		R	MCPA; silvex; 2,4,5-T
purslane (*V. peregrina*)	P		S	MCPA; silvex; 2,4-D; 2,4,5-T
Spicebush (*Lindera benzoin*)	W		S	AMS; 2,4-D; 2,4,5-T
	W		R	Amitrole
Spikegrass. (*See* Saltgrass, seashore.)				
Spikerush:				
(*Eleocharis* spp.)	P		I	Silvex; 2,4-D; 2,4,5-T
creeping (*E. parvula*)	Aq	36, 56	I	MCPA; simazine; 2,4-D
	Aq		R	Silvex; 2,4,5-T
Spirea (*Spiraea* spp.)	W		S	Diuron; simazine; 2,4,5-T
Sprangletop:				
Mexican (*Leptochloa univervia*)	A		R	Silvex; 2,4-D; 2,4,5-T
red (*L. filiformis*)	A		R	Do.
Spruce:				
(*Picea* spp.)	W		S	AMS; 2,3,6-TBA
	W		I	Dalapon; TCA
black (*P. mariana*)	W		R	Amitrole
white (*P. glauca*)	W		R	2,4-D; 2,4,5-T

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Spurge:				
flowering (*Euphorbia corollata*)	P		S	2,4,5-T
	P		R	2,4-D
leafy (*E. esula*)	P	34, 35	S	AMS; erbon; fenac; PBA; 2,3,6-TBA
	P		I	MonuronTCA; silvex
	P		R	Amitrole-T; MCPA; simazine; 2,4-D; 2,4,5-T
upright or spotted (*E. maculata*)	A	37, 51	I	BMM; CBMM; DCPA; silvex
	A		R	2,4-D; 2,4,5-T
Spurry, corn (*Spergula arvensis*)	A		S	Dicamba
	A		I	MCPA; silvex
	A		R	2,4-D; 2,4,5-T
Squawberry (*Rhus trilobata*)	W		R	Silvex; 2,4,5-T
Squirreltail (*Sitanion bystrix*)	P		R	MCPA; 2,4-D; 2,4,5-T
Star-of-Bethlehem (*Ornithogalum umbellatum*).	P		S	2,3,6-TBA
	P		I	2,4-D
Star-thistle:				
meadow (*Centaurea pratensis*)	A or B		I	MCPA; 2,4-D
yellow (*C. solstitialis*)	A		I	2,4-D
	A		R	Herbicidal oils; sodium arsenite
Stickseed, or sticktight, European (*Lappula echinata*).	A		S	2,4-D
Stinkgrass (*Eragrostis cilianensis*)	A	51, 52	S	Calcium and lead arsenate; chlordane; DCPA; DMPA
Stinking-willie. (*See* Tansy-ragwort.)				
Stinkweed. (*See* Pennycress, field.)				
Stinkwort (*Inula graveolens*)	P		S	2,4-D
Stonewort (*Chara* spp.)	Aq		S	Copper sulfate
	Aq		R	Sodium arsenite
Strawberry, wild (*Fragaria* spp.)	P		I	Silvex
	P		R	MCPA; 2,4-D; 2,4,5-T
Sumac (*Rhus* spp.)	W	7, 41,	S	AMS; fenuron; 2,4-D; 2,4,5-T; 2,3,6-TBA
	W	44, 45, 47	I	Amitrole; fenuronTCA
Chinese (*Ailanthus* spp.)	W		S	Silvex; 2,4,5-T
	W		I	AMS; 2,4-D
	W		R	MCPA
smooth (*Rhus glabra*)	W		S	Brush killer
staghorn (*R. typhina*)	W	7	S	Amitrole; brush killer
Sumpweed, rough (*Iva ciliata*)	A		S	2,4-D
Sunflower:				
common (*Helianthus annuus*)	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
prairie (*H. petiolaris*)	A		S	2,4-D
Swamp-loosestrife (*Decodon verticillatus*).	Aq	56	S	Silvex
Sweetclover, yellow annual (*Melilotus indica*).	A		S	MCPA; 2,4-D
Sweetfern (*Comptonia peregrina*)	W		I	PBA; 2,4-D; 2,3,6-TBA
Sweetgrass, floating (*Glyceria fluitans*)	Aq		S	Dalapon; diuron; monuron
	Aq		R	Copper sulfate; silvex; sodium chlorate; 2,4-D
Sweetgum (*Liquidambar styraciflua*)	W	41, 45	S	AMS; fenuron; 2,4,5-T
	W		I	Silvex
	W		R	2,4-D
Swinecress (*Coronopus didymus*)	A		S	Do.
Sycamore (*Platanus occidentalis*)	W	41	S	AMS; fenuron; 2,4-D; 2,4,5-T
Tamarack (*Larix laricina*)	W		I	2,4-D; 2,4,5-T
Tanoak:				
(*Lithocarpus densiflora*)	W		R	Silvex; 2,4-D; 2,4,5-T
scrub (*L. densiflora* var. *montanus*).	W		R	2,4-D; 2,4,5-T
Tansy (*Tanacetum vulgare*)	P		I	Do.
	P		R	MCPA
Tansymustard (*Descurainia pinnata*)	A		S	2,4-D
Tansy-ragwort (*Senecio jacobaea*)	P	35	S	Sodium chlorate; 2,4-D
	P		I	Diuron; MCPA; monuron; silvex; 2,4,5-T

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Tanweed. (*See* Smartweed, swamp.)				
Tarbush (*Flourensia cernua*)	W		S	Fenuron; fenuronTCA; monuron; 2,4-D
	W		I	Silvex; 2,4,5-T
	W		R	2,3,6-TBA
Tarweed, fiddleneck. (*See* Fiddleneck, coast.)				
Thimbleberry (*Rubus parviflorus*)	W		S	2,4,5-T
	W		I	2,4-D
Thistle:				
bristly (*Cirsium horridulum*)	B and P		I	Do.
bull. (*See* Bullthistle.)				
Canada (*C. arvense*)	P	34, 35, 37, 50	S	Amitrole; AMS; atrazine; BDM; CBM; dicamba; fenac; PBA; sodium chlorate; 2,3,6-TBA
	P		I	BMM; diuron; MCPA; monuron; monuronTCA; silvex; 2,4-D; 2,4,5-T
	P		R	Amitrole-T; erbon; simazine; sodium arsenite
wavyleaf (*C. undulatum*)	P		R	MCPA; 2,4-D
Thornapple. (*See* Hawthorn (*Crataegus* spp.).)				
Tickseed (*Coreopsis tinctoria*)	A		S	2,4-D; 2,4,5-T
Tievine (*Jacquemontia tamnifolia*)	A		S	Silvex
Toadflax, yellow (*Linaria vulgaris*)	P		S	Diuron; monuron
	P		R	Amitrole; BMM; MCPA; monuronTCA; silvex; 2,4-D; 2,4,5-T
Torpedograss (*Panicum repens*)	P	55	S	Amitrole
	P		R	MonuronTCA
Toyon (*Heteromeles arbutifolia*)	W		S	2,4-D
	W		I	MCPA; silvex; 2,4,5-T
Tree-of-heaven (*Ailanthus altissima*)	W		S	Silvex; 2,4,5-T
	W		I	AMS; 2,4-D
	W		R	MCPA
Trumpetcreeper or trumpetvine (*Campsis radicans*).	W		S	AMS; silvex
	W		I	2,4-D; 2,4,5-T
	W		R	Amitrole
Tule. (*See* Bulrush.)				
Tuliptree (*Liriodendron tulipifera*)	W		S	AMS; 2,4,5-T
	W		R	Amitrole; fenuron
Tumblemustard (*Sisymbrium altissimum*).	A		S	MCPA; 2,4-D; 2,4,5-T
Tumbleweed. (*See* Pigweed, tumble.)				
Tupelo. (*See* Gum, black.)				
Turks-rug (*Chorizanthe staticoides*)	A		R	Sodium arsenite
Umbrella-sedge (*Cyperus difformis*)	A		I	MCPA; 2,4-D
	A		R	Silvex; 2,4,5-T
Vaseygrass (*Paspalum urvillei*)	A or P	35, 37	I	BMM; CBMM; diuron; monuronTCA
	A or P		R	Simazine; TCA
Velvetleaf (*Abutilon theophrasti*)	A		S	MCPA; 2,4-D; 2,4,5-T
	A		R	DCPA
Venus-lookingglass (*Specularia perfoliata*).	A		I	2,4-D
Vervain (*Verbena* spp.)	P		S	Do.
Vetch:				
narrowleaf (*Vicia angustifolia*)	A		S	2,4-D; 2,4,5-T
	A		I	MCPA
wild (*Vicia* spp.)	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
Viburnum, maple-leaf (*Viburnum* spp.).	W		S	2,4-D; 2,4,5-T
Violet (*Viola* spp.)	P		I	Silvex
	P		R	MCPA; 2,4-D
Virginia-creeper (*Parthenocissus quinquefolia*).	W		I	2,4-D; 2,4,5-T
Walnut, black (*Juglans nigra*)	W	41	S	Do.
Waterchestnut (*Trapa natans*)	Aq	56	S	MCPA; 2,4-D
	Aq		R	Monuron; silvex; 2,3,6-TBA
Watercress (*Nasturtium officinale*)	Aq	56	S	Monuron; 2,4-D

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Watercrowfoot (*Ranunculus aquatilis*).	Aq	53	S	Acrolein; aromatic solvents; diuron; monuron; sodium arsenite
	Aq		I	Silvex
Waterfern (*Azolla* spp.)	Aq	53	S	Invert emulsion of 2,4-D and 2,4,5-T
Waterhemlock:				
(*Cicuta douglasii*)	P		I	2,4-D
spotted (*C. maculata*)	P		S	Silvex; 2,4-D; 2,4,5-T
Water-horehound (*Lycopus americanus*).	P		S	2,4-D
Water-hyacinth (*Eichornia crassipes*)	Aq	7, 53	S	Amitrole-T; silvex; 2,4-D; 2,4,5-T
Waterlettuce (*Pistia stratiotes*)	Aq	53	S	Herbicidal oils; invert emulsion of 2,4-D and 2,4,5-T; simazine
Waterlily (*Nymphaea* spp.)	Aq	53, 56,	S	Erbon; silvex; 2,4-D
	Aq	57	R	Dalapon; sodium arsenite
Watermilfoil (*Myriophyllum heterophyllum*).	Aq	53, 54	S	Acrolein; aromatic solvents; dichlone; endothall; silvex; simazine; 2,4-D; 2,4,5-T
Waterplantain, common (*Alisma triviale*).	Aq		S	MCPA; silvex; sodium arsenite; 2,4-D; 2,4,5-T
	Aq		R	Copper sulfate
Waterprimrose (*Jussiaea* spp.)	Aq	56, 57	S	Acrolein; diuron; fenuron; monuron; silvex; 2,4-D; 2,4,5-T
Waterpurslane (*Ludwigia palustris*)	Aq		S	Monuron; sodium arsenite
Watershield (*Brasenia schreberi*)	Aq	53, 56	S	Silvex
	Aq		I	2,4-D; 2,4,5-T
	Aq		R	Copper sulfate; monuron; sodium arsenite
Water-stargrass (*Heterantha dubia*)	Aq	53	S	Acrolein; aromatic solvents; silvex; sodium arsenite; 2,3,6-TBA
Water-starwort (*Callitriche verna*)	Aq		S	Silvex
	Aq		R	Copper sulfate
Waterweed, Canada (*Elodea canadensis*).	Aq	53–55	S	Acrolein; aromatic solvents; diquat; diuron; sodium arsenite
	Aq		I	Copper sulfate; MCPA; 2,4-D
Wedgeleaf. (*See* Ceanothus, wedgeleaf.)				
Whitebrush (*Aloysia lycioides*)	W		I	MCPA
White-cedar (*Thuja occidentalis*)	W	43	S	Dalapon; TCA
	W		R	Amitrole; simazine
Whiteclover (*Trifolium repens*)	P	51	S	Endothall; silvex; 2,4-D; 2,4,5-T
White-locoweed (*Oxytropis lambertii*)	P		I	Silvex; 2,4-D; 2,4,5-T
Whitethorn:				
(*Acacia constricta*)	W		S	Fenuron; fenuronTCA; monuron
	W		I	Silvex; 2,4-D
	W		R	2,3,6-TBA
mountain (*Ceanothus cordulatus*)	W		I	2,4,5-T
	W		R	Amitrole; 2,4-D
Whitetop (*Cardaria draba*)	P	35, 36	S	Amitrole
	P		I	CBM; diuron; MCPA; monuron; monuronTCA; silvex; sodium chlorate; 2,4-D; 2,4,5-T
Wildbuckwheat (*Polygonum convolvulus*).	A		S	Dicamba; fenac; monuron; sodium chlorate; 2,4,5-T; 2,3,6-TBA
	A		I	MCPA; silvex; 2,4-D
	A		R	Amitrole
Wildcelery (*Vallisneria* spp.)	Aq		S	Silvex; sodium arsenite
Wildcucumber. (*See* Burcucumber.)				
Wildflax. (*See* Tickseed.)				
Wild-indigo (*Baptisia tinctoria*)	P		S	2,4,5-T
	P		I	2,4-D
Willow (*Salix* spp.)	W	36, 43, 44, 47	S	AMS; MCPA; monuron; silvex; 2,4-D; 2,4,5-T; 2,4-D + TCA; 2,4,5-T + TCA
	W		I	Diuron; DNBP; simazine; 2,3,6-TBA
	W		R	Amitrole; fenuron
Willowweed or willow-herb (*Epilobium* spp.).	W		S	Silvex; 2,4-D; 2,4,5-T
Windmillgrass, tumble (*Chloris verticillata*).	P		R	2,4-D
Wintercress. (*See* Yellow-rocket.)				
Witchgrass. (*See* Panicum.)				
Witch-hazel (*Betula lutea* var. *macrolepsis*).	W		S	AMS; 2,4,5-T

TABLE 5.—*Weed species and herbicides for control*—Continued

Weed species	Growth habit	Page	Response to herbicide	Herbicide
Witchweed (*Striga asiatica*)	A		S	Fenac; MCPA; silvex; 2,4-D; 2,4,5-T
Wolfberry. (*See* Buckbrush, snowberry.)				
Wolfwillow (*Elaeagnus commutata*)	W		S	2,4-D
Woodsorrel, yellow (*Oxalis stricta*)	A or P		S	Silvex
	A or P		R	MCPA; 2,4-D
Woolgrass. (*See* Bulrush.)				
Wormseed-mustard (*Erysimum cheiranthoides*).	A		S	MCPA; silvex; 2,4-D; 2,4,5-T
Wormwood:				
absinthe. (*See* Absinthe.)				
annual (*Artemesia annua*)	A		S	2,4-D; 2,4,5-T
	A		I	MCPA
biennial (*A. biennis*)	B		S	MCPA; 2,4-D
Yankeeweed (*Eupatorium compositifolium*).	P		I	2,4-D; 2,4,5-T
Yarrow:				
common (*Achillea millefolium*)	P	50	I	MCPA; silvex; 2,4,5-T
	P		R	2,4-D
western (*A. lanulosa*)	P		I	2,4-D; 2,4,5-T
Yaupon (*Ilex vomitoria*)	W		R	2,4-D; 2,4,5-T; 2,3,6-TBA
Yellow-rattle (*Rhinanthus* spp.)	A		S	MCPA; 2,4-D
Yellow-rocket (*Barbarea vulgaris*)	B or P	2	S	MCPA; 2,4-D; 2,4,5-T
	B or P		I	Silvex
Yerba-santa (*Eriodictyon californicum*)	W		S	MCPA; 2,4-D; 2,4,5-T
	W		I	Silvex
Yucca:				
(*Yucca smalliana*)	W		S	Do.
	W		R	Amitrole; diuron; monuron; monuronTCA
soapweed (*Y. glauca*)	W		I	Silvex
	W		R	2,4-D; 2,4,5-T

APPENDIX

List of Equivalents

Linear measure

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

Square measure

1 square foot=144 square inches
1 square yard=9 square feet
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 16½ feet (1 rod) × ½ mile
1 hectare=2.47 acres
1 square mile=640 acres=259 hectares

Capacity measure (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=28.316 liters
1 cubic yard=27 cubic feet

Capacity measure (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 measure (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

Weight

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
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 gram water=15.432 grains=0.0353 ounces

Rate of speed

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

Table 6.—*Relation of Centigrade and Fahrenheit scales* [1]

°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	15	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		

[1] 1° C.=1.80° F.; 1° F.=0.56° C. To convert C. to F.: Multiply C. by 9/5 and add 32. To convert F. to C.: Subtract 32 from F. and multiply by 5/9.

GLOSSARY

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

Acid equivalent—The theoretical yield of parent acid from an active ingredient. It is used instead of or in addition to the active ingredient for certain herbicides.

Active ingredient—The chemical compound in a product that is responsible for the herbicidal effects.

Adsorbed—Held so tightly that the herbicide is rendered inactive or only slowly effective. The principal adsorbing agents of the soil are its inorganic (clay) and organic (humus) colloids.

Aliphatic materials—Chemically, those that have an open-chain molecular structure. As herbicides, they are less toxic to plants than aromatic compounds.

Anionic surfactant—One that has a negative charge and performs best in cold water and soft water. Most wetting agents and detergents and some emulsifiers are anionic.

Annual—A plant that completes its life cycle from seed in 1 year.

API Gravity—Gravity of oils determined by the American Petroleum Institute and expressed in degrees API.

Aquatic weeds—Undesirable plants that grow in water.

Aromatic oils and solvents—Chemically, those that have a ring molecular structure. As herbicides, they are generally more toxic to plants than aliphatic materials.

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

Basal-bark applications—Herbicide treatments applied to the stems of woody plants at or just above the ground.

Berm—A narrow band along a bank; along the pavement on a highway; along the ballast on a railroad.

Biennial—A plant that completes its life cycle in 2 years. The first year it produces leaves and stores food. The second year it produces fruits and seeds.

Botanical plant name—A scientific name made up of the genus and species. Sometimes the variety or subspecies is included. It is more reliable and more universal than common names.

Broadcast application—Uniform distribution of a herbicide over an entire area.

Broad-leaved plants—Botanically, those classified as dicotyledons. Morphologically, those that have broad, usually compound leaves.

Carrier—The liquid or solid material added to a chemical compound to facilitate its application in the field.

Cation exchange—The exchange of positive ions (H, Ca, Mg, Na, NH_4) from clay particles for other cations. Soils are able to filter out salts in much the same way a water softener removes them. Some soils have a larger capacity than others for doing this. Such soils can adsorb or filter out and hold large amounts of a herbicide so that it is not immediately effective. The cation exchange capacity of a soil can be learned from the State agricultural experiment station.

c.f.s.—Cubic feet of water flow per second.

Chemical name—One that indicates the chemical composition of the compound and also the structure of the molecule in organic compounds.

Common plant name—An English name in common use. A plant may be known by several different common names, and one common name may be used for different plants in different parts of the country. Many common names are local.

Compatible pesticides—Compounds or formulations that can be mixed and applied together without undesirably altering their separate effects.

Concentration—The amount of active ingredient or acid equivalent in a given volume of liquid or in a given weight of dry material.

Contact herbicide—One that kills primarily by contact with plant tissue rather than as a result of translocation.

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

Deciduous trees—Those that lose their leaves during winter.

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

Diluent—Any liquid or solid material that dilutes an active ingredient in the preparation of a formulation.

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

Emulsifiable concentrates—Usually liquids in which the chemical is dissolved in one or more water-insoluble solvents such as oil or benzene to which an emulsifier is added.

Emulsifier—A surface active material that facilitates the suspension of one liquid in another.

Emulsion—The suspension of one liquid as minute globules in another liquid; for example, oil dispersed in water.

Escape—A plant in a treated area that has missed treatment. For example, an annual or shallow-rooted perennial that re-infests an area after the chemical has been leached below the surface; a perennial, part of whose root system is below the treated layers of soil; or a plant that was missed at the time of application.

Extruded—A process in which a powdered carrier mixed with the herbicide is moistened until it becomes plastic and then is forced or expelled as rods. These rods are dried, ground, and screened to the required screen mesh for a granular formulation. This process increases internal pore volume and surface area. The product is frequently referred to as AA in contrast to A materials, which have not been subjected to an extrusion process.

Formulation—A term used synonymously with product. It contains the herbicide in a form that can be (1) dissolved or suspended in a carrier and distributed in solution or suspension by sprayers, (2) distributed dry by dusters or spreaders, or (3) easily vaporized for fumigation.

Fortified—Herbicidal properties increased by addition of PCP, DNC, DNBP, or OCH.

g.p.m.—Gallons per minute.

Granular products—Formulations in which the chemical is impregnated on or in vermiculite, attaclay, or other suitable carrier and then formed into granules or pellets.

Grass—Botanically, any plant of the Gramineae family. Grasses are characterized by narrow leaves with parallel veins; by leaves composed of blade, sheath, and ligule; by jointed stems and fibrous roots; and by inconspicuous flowers usually arranged in spikelets.

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

Hard water—Water that contains certain minerals, usually calcium and magnesium sulfates, chlorides, or carbonates, in solution in amounts that cause a curd or precipitate instead of a lather when soap is added. Generally defined as containing 322 p.p.m. in terms of calcium carbonate. Very hard water may cause precipitates in some herbicidal sprays.

Herbaceous plant—A vascular plant that does not develop woody tissue. It dies down each year.

Herbicide—A phytotoxic chemical used for killing or inhibiting the growth of plants.

h.p.—Horsepower.

Intermediate species—One whose response to a herbicide is in between the response of a susceptible and a resistant species. It is severely injured or partially controlled by higher than moderate rates.

Invert emulsion—One in which oil is the continuous phase and water is dispersed in it.

Ionic surfactant—One that ionizes or dissociates in water.

Isomers—Two or more substances having the same chemical composition but different properties.

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

L.D.$_{50}$—Lethal dose in milligrams per kilogram of body weight for 50 percent of the animals tested.

Low-volatile ester—Chemically, an ester with a heavy molecular weight such as the butoxyethanol, iso-octyl, or propylene glycol butyl ether esters. Low-volatile esters do not include the methyl, ethyl, propyl, isopropyl, butyl, amyl, and pentyl esters. Biologically, an ester that is less liable than the high-volatile esters to injure plants by vapor activity.

Nonionic surfactant—Chemically inert.

Nonselective herbicide—A chemical that is toxic to plants generally without regard to species.

Organic matter—Plant or animal remains in the soil.

Perennial—A plant that lives more than 2 years.

pH—The chemist's measure of acidity and alkalinity. It is a scale in which the figure 7 indicates neutral, figures below 7 indicate acidity, and figures above 7 indicate an alkaline reaction.

Photosynthesis—The process by which carbohydrates are manufactured by the chlorophyll-bearing cell granules (chloroplasts) from carbon dioxide and water by exposure to the energy of sunlight.

Phytotoxic—Poisonous to plants.

Plow sole—Compact layer just below plow depth.

Postemergence—After emergence of specified weed.

p.p.m.—Parts per million.

Preemergence—Prior to emergence of specified weed.

Preplanting—Any time before the crop is planted.

Product—The herbicide as it is sold commercially. It contains not only the active ingredients but also various solvents, cosolvents, surfactants,

carriers, and other adjuvants that are designated as inert ingredients.

Proprietary mixture—One that is commercially available.

p.s.i.—Pounds per square inch.

Rate—The amount of active ingredient or acid equivalent of a herbicide applied to a unit area.

Resistant species—One that is difficult to kill; the use of the herbicide is not recommended.

r.p.m.—Revolutions per minute.

Selective herbicide—A chemical that is more toxic to some plant species than to others.

Slurry—A watery mixture or suspension of an insoluble herbicide.

Soil application—Application of herbicide made primarily to the soil surface rather than to vegetation.

Soil colloid—Extremely small particles of clay or organic matter that expose a very large surface area on which some herbicides are adsorbed.

Soil sterilant—A herbicide that prevents the growth of green plants when present in the soil. Soil sterilization effects may be temporary or relatively permanent. It does not necessarily kill all life in the soil such as fungi, bacteria, and other micro-organisms.

Soil structure—Arrangement of soil particles into separate grains or granules.

Soil texture—Proportion of sand, silt, and clay in the soil; size of soil particles.

Solvent—The component of a solution that dissolves the other components.

Species—A subdivision of a genus. A group of closely related individuals descendant from the same stock.

Spot treatment—Application of a herbicide to individual plants or small clumps of plants.

Spray drift—The movement of airborne spray particles from the intended area of application.

Spreader-sticker—A surfactant closely related to wetting agents that facilitates spreading and increases sticking of a herbicide on vegetation.

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

Surfactant—A material that improves the emulsifying, dispersing, spreading, wetting, and other surface-modifying properties of herbicide formulations.

Susceptible species—One that can be killed with moderate rates of a herbicide.

Suspension—A system consisting of very finely divided solid particles dispersed in a liquid.

Translocated herbicide—One that is moved within the plant from the point of entry.

Vapor drift—The movement of herbicidal vapors from the area of application.

Viscosity of oil—Expressed in time (seconds) required for 60 c.c. of heated oil to flow through a Saybolt Universal Viscosimeter.

Volatile—A compound is volatile when it evaporates or vaporizes (changes from a liquid to a gas) at ordinary temperatures on exposure to the air.

Water-dispersible powder—A finely ground powder plus a wetting agent plus a dispersing agent to keep the material in suspension.

Weed—A plant growing where it is not desired.

Weed eradication—The complete elimination of all live plants, plant parts, and seeds of a weed infestation from an area.

Wettable powder—A finely ground powder plus a wetting agent to keep the particles from floating when added to water.

Wetting agent—A compound that when added to a spray solution causes it to contact plant surfaces more thoroughly.

WSA—Weed Society of America.

HERBICIDE INDEX

Herbicides are listed by approved common name, chemical name, and WSA designation. Group names, based on use or mode of action, and chemical family names are also listed.

GENERAL INDEX

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